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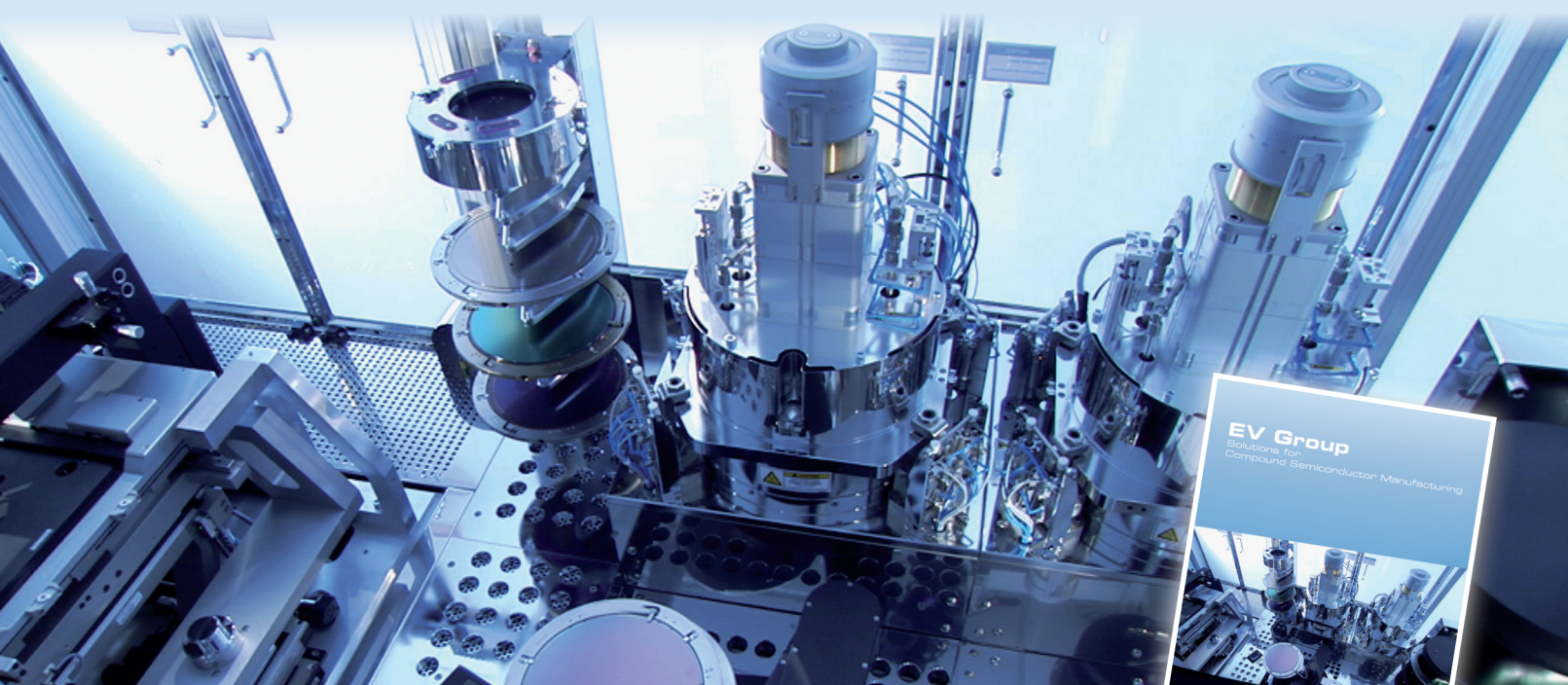
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Vol. 10 • Issue 4 • May/June 2015

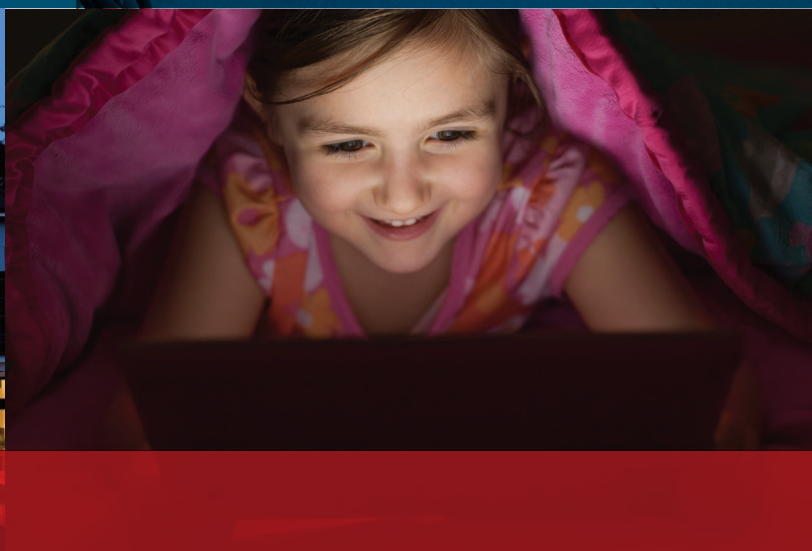
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III-V nanoscale devices on silicon wafers

1 μm

500 nm

NXP selling RF Power business • Cree files for Power & RF IPO
Cree restructuring LED Products • Soitec divests solar systems



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

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Veeco's New TurboDisc EPIK700 GaN MOCVD System

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semiconductor**TODAY** COMPOUNDS & ADVANCED SILICON

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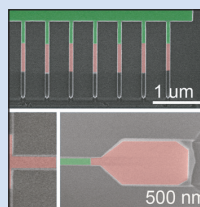
p42 UCLA professor Diana Huffaker is to lead a new research lab as part of the Compound Semiconductor Research Foundation JV between Cardiff University and IQE.



p43 SemiTEq has launched an improved version of its STE35 MBE system.



p68 Cassette carrying IBM's silicon photonics chips for 100G transceivers.



Cover: IBM has developed a new technique for the co-planar integration of III-V nanoscale devices on silicon. The SEM images show single-crystal nanostructures fabricated using template-assisted selective epitaxy — silicon is colored in green and III-V material in red. (Images: H Schmid/IBM.) **p16**

Trends in power/RF & lighting

Recent months have seen a spate of consolidations announced in the wider semiconductor industry, including Intel acquiring Altera, and Avago acquiring Broadcom (following its acquisition of LSI Logic in late 2013) — see page 18. Meanwhile, NXP Semiconductors is acquiring Freescale.

A consequence of the latter is that, to raise funds for its acquisition of Freescale, NXP has agreed to sell its RF Power business for \$1.8bn to a subsidiary of China state-owned investment firm JIC Capital — see page 20.

Another sign of the growing interest in the commercial prospects for gallium nitride and silicon carbide wide-bandgap semiconductor electronics — in addition to the number of new devices launched at the International Microwave Symposium (IMS) and PCIM (Power Conversion Intelligent Motion) Europe events (see page 29) — is that Cree has filed with the SEC for an initial public offering of stock for its Power & RF subsidiary (page 28). The objective is to raise capital to invest directly in the Power & RF business in order to support targeted future growth. Meanwhile, the IPO is expected to enable Cree to focus on the firm's LED and Lighting businesses.

This is especially needed since Cree has just announced a restructuring of its LED Products business driven by recent market trends that have resulted in greater LED average selling price (ASP) erosion than previously forecast (see page 60). However, this is indicative of the added-value in the LED industry moving down the supply chain, to the module/array level, driven by the ongoing adoption of LEDs by the lighting market, as well as temporary under-utilization of the firm's LED factory as Cree reduces internal LED consumption while it rebalances Lighting inventory. After a slight dip in the March quarter, Cree's Lighting Product revenue is expected to rebound slightly this quarter, while LED Product sales stabilize.

Indeed, according to market research firm Strategies Unlimited, lighting will be the fastest-growing sector of the packaged LED market (with a compound annual growth rate of 14.3), rising from 34% of total revenue in 2014 (equal to display backlighting and mobile applications combined) to 45% of total revenues by 2019 — see page 7. Market research firm IHS says that, regarding the packaged LED market for lighting in particular, Cree, Lumileds and Osram comprised 65% of the high-power sector in 2014. However, chip-on-board (COB) LEDs took 8% share, despite being offered by only a small number of firms starting just a few years ago. Also, the mid- to low-power sector (led by Nichia, Seoul Semiconductor and Samsung, and followed by Chinese firm, MLS) comprises 70% of the market, and mid-power LEDs could compete with high power LEDs in the future (for indoor lighting), reckons IHS (see page 6).

Trends in LED production are reflected by the main MOCVD reactor makers Aixtron and Veeco. In first-quarter 2015, both suffered dips in revenue, but this was due to deferring revenue reporting while LED makers qualified their new-generation, higher-throughput MOCVD systems (see pages 44 and 46). Veeco's actual shipments were the firm's highest since Q4/2011, while Aixtron's order backlog is its highest since Q3/2013. With China's Changelight just ordering multiple Veeco EPIK 700 systems and Taiwan's Epileds now having qualified Aixtron's AIX R6 system (for which Aixtron has also just received a further multi-tool order, for shipment through into 2016 — see pages 48–49), the signs are that the lean period is coming to an end.

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

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

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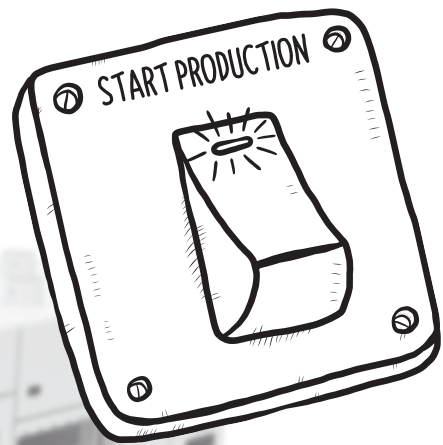
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IR LED market for surveillance applications to grow from \$94m in 2014 to \$120m in 2015

3535-type packages to replace traditional lamp-type packages

The infrared (IR) LED market for surveillance applications will grow from \$94m in 2014 to \$120m in 2015, reckons LEDinside's '2Q15 Gold Member Report - 2015 Global LED Supply and Demand Market'.

Surveillance systems have become ubiquitous, and governments in developed countries have set aside bigger budgets for upgrading their security-related infrastructures, notes assistant research manager Joanne Wu. Demand has become even stronger in areas with political turmoil and social problems, such as Central and South America, the Middle East, and the Indian sub-continent, adds the report.

Major IR LED makers have hence profited greatly by supplying components to surveillance products. These firms include Japan's EPITEX and Germany's Osram Opto Semiconductors. Taiwan-based firms

that also benefited from IR LED market growth include Epistar, Epileds and High Power Lighting.

With its main wavelength range of 750–1400nm, near-infrared (NIR) LED is primarily used for imaging, as in the case of surveillance cameras. Cameras with night-vision ability are typically equipped with digital image sensors based on one of the following two technologies: CCD or CMOS. These sensors come with IR LEDs emitting at a wavelength of 850nm or 940nm.

Due to its high cost, CCD has difficulty making inroads into the security application market. Standard surveillance cameras therefore use CMOS sensors paired with 850nm IR LEDs in order to get the best price-performance ratio.

However, some high-end surveillance cameras carry the more costly 940nm IR LEDs, since they

are less likely to create a visible red dot than 850nm IR LEDs. Note that this red-dot effect that sometimes occurs with IR LEDs does not mean that the LEDs are of poor quality. On the whole, both vendors and consumers choose between 850nm and 940nm IR LED products based on their respective needs.

In her survey of the IR LED's development, Wu believes that the 3535 package will eventually replace the traditional lamp-type package. Currently, the packaging of IR LEDs is divided into three types – lamp, SMD and high-power LED packages. Adopting high-power LEDs will reduce the number of LEDs needed as well as simplify circuit and heat dissipation design, thus increasing convenience for system manufacturers, concludes the report.

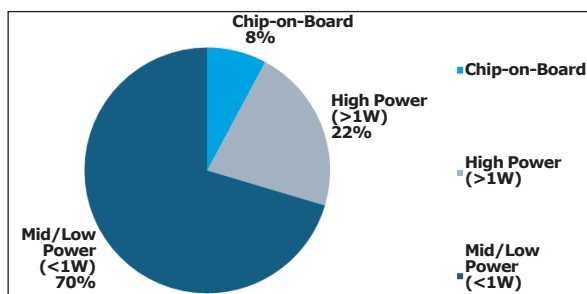
www.ledinside.com

Packaged LED lighting revenue reached \$6.6bn in 2014, with mid- to low-power LEDs comprising 70%

Cree, Lumileds and Osram comprise 65% of high-power sector

Packaged LED lighting revenue reached \$6.6bn in 2014, with about 70% of that generated by sales of mid- to low-power LEDs, according to the latest data in the 'Packaged LED Report 2015' (part of IHS LED Intelligence Service).

The share taken by chip-on-board (COB) was 8%, despite the fact that only a small number of companies began promoting COB products just a few years ago. Citizen was the largest provider in 2014 with about 20% market share, followed by Cree with 15%. The COB market is forecast to increase at a compound annual growth rate (CAGR) of 20% from 2014 to 2020, as they are used to replace high-power LEDs in out-



door lighting applications. The high-end commercial market also shows potential for COB, adds the report.

The high-power LED market is still dominated by several international companies, including Cree, Lumileds and Osram. In fact, the top three suppliers collectively comprised 65% of the LED market in 2014.

In the mid- to low-power LED market, Nichia led, followed by Seoul Semiconductor and Samsung.

This market sector is much more fragmented due to the number of Chinese companies competing.

The largest Chinese packaged LED firm, MLS, had a 5% share of the market in 2014, following Samsung. Mid-power LEDs are more cost effective for indoor lighting and, with technology improvements, this category might also compete with high power LEDs in the future, reckons IHS.

<https://technology.ihs.com/520194/packaged-leds-2015>

Data-center transceiver market to grow from \$1.4bn in 2014 to \$2.1bn by 2019

40G QSFP transceivers driving market, but 100GbE to be huge in 2016

Revenue from 10, 40 and 100 Gigabit optical transceivers sold into the enterprise and data-center markets grew 21% to \$1.4bn in 2014, almost entirely due to increased 40G QSFP (quad small-form-factor pluggable) spending, according to the biannual report '10G/40G/100G Data Center Optics' from market research firm IHS Infonetics.

Data-center transceivers account for 65% of the overall (telecom and datacom) 10G/40G/100G optical transceiver market. But specifically, total 40G transceiver revenue grew 81% in second-half 2014 over second-half 2013.

"40G transceivers are ramping up hard as data centers deploy 40 Gigabit Ethernet (40GbE), particularly as a high-density 10G interface via breakout cables," says Andrew Schmitt, research director for carrier transport networking at IHS Infonetics. "40G QSFP demand growth over single-mode fiber is primarily a result of large shipments to internet content providers Microsoft and Google," he adds.

Although 10G shipments in the data center continue to grow at healthy rates, they are being impacted by the growth of 40G interfaces used as high-density 10G interfaces. Meanwhile,

worldwide revenue for client 10G modules was flat on year-over-year in 2014.

"The market for 100G data-center optics is accelerating, but it has yet to be turbocharged by widespread data-center deployment in the way 40G QSFP optics have," notes Schmitt. "This will change dramatically in 2016 as cheap 100G silicon reaches production and QSFP28 shipments surge as a result," he adds. "Next year is going to be huge for 100GbE."

IHS Infonetics expects that the datacom optical transceiver market will grow to over \$2.1bn by 2019.

www.infonetics.com

Packaged LED market to grow from \$15.6bn in 2014 to \$22bn in 2019

Lighting to grow from 34% to 45% of market

In 2014 the global packaged LED market grew 7.6% to \$15.6bn, according to Strategies Unlimited's report 'The Worldwide Market for LEDs: Market Review and Forecast 2015', which analyzes the market for packaged LEDs used in display backlighting, automotive lighting, mobile applications, signs, lighting and other applications.

Lighting made up 34% of total revenues, which was almost the same as display backlighting and mobile applications combined at 35%. The lighting share is expected to reach 45% of total revenues by 2019, with the largest growth of any sector at a five-year compound annual growth rate (CAGR) of 14.3%. "Lighting is the largest sector and will remain the largest sector throughout the forecast," says senior research analyst Stephanie Pruitt.

"Within lighting applications, the general lighting categories make up nearly 75% of the total lighting revenues," says Pruitt. However,

the lighting applications that will see the largest growth are replacement lamps, commercial luminaires, and outdoor luminaires.

"The replacement lamps market and luminaire market are very large and, as LED adoption grows, packaged LED revenues in these segments will also grow," adds Pruitt.

Prices for packaged LEDs in lighting saw some steep declines from 2013 to 2014. Most suppliers were seeing price declines of about 20%, while some were reporting declines as steep as 25-30%, especially for chip-on-board packages (COBs). However, despite these price declines, the continued adoption of LED lighting in homes and commercial applications has allowed for the largest growth of any sector, notes Strategies Unlimited.

"LED lighting has yet to reach its tipping point," says Pruitt. "Prices continue to drop, rebates continue to incentivize, and manufacturers continue to come up with new and

exciting ways to make LED lighting relevant and desirable. With LEDs, customers are able to install lighting where they never would have thought before, opening up new opportunities," he adds. "Smart, controllable lighting will also have an impact on adoption rates, as this creates huge possibilities for the consumer — think energy savings, labor/maintenance savings, indoor navigation, and improved security. As a result, packaged LEDs in lighting will continue to be a growth segment."

Lighting will not be the only sector to see healthy growth over the forecast, says Strategies Unlimited. Automotive is also poised for strong growth as LEDs in headlamps and daytime running lights (DRLs) continue to be an option in cars, and not just high-end cars. LED revenues in exterior automotive lighting applications are forecast to grow at a CAGR of 15%, concludes the market research firm.

www.strategies-u.com

Innovations to sustain silicon's 87% share of power electronics market versus wide-bandgap materials

SiC and GaN are making gains, but silicon will comprise \$20bn of market in 2024 through advances in circuits, controls and packaging

Driven by technology innovations, silicon-based power electronics will continue their domination of the fastest-growing and largest markets, allowing silicon to maintain an 87% market share, worth \$20bn by 2024, and constraining wide-bandgap semiconductor (WBG) materials to a smaller market share, according to Lux Research.

Innovations in circuit design, control methods and module packaging will help silicon to hold off the adoption of WBG materials in many applications, particularly in the near-term, on account of silicon's high availability and volumes, reckons the market analyst firm.

"Circuit design innovation will have its biggest impact on space and efficiency improvements in IT and consumer electronics, while control method innovation impacts size reduction across all applications," says Lux Research associate Tiffany

Huang, the lead author of the report 'Sorting Through the Maze of Silicon Innovations in Power Electronics'.

"Innovations in module packing can not only reduce size, but increase the efficiency to be on par with current WBG innovations in transportation markets," she adds.

Lux analysts reviewed the ongoing innovations in silicon technology and ranked the leading companies on the Lux Innovation Grid on the basis of their technical and business execution scores. Their findings include:

● **TI, Maxim, Qualcomm dominate circuit design**

On the strength of their partnerships and customers in multiple market segments, Texas Instruments, Maxim, Power Integrations and Qualcomm are the 'Dominant' circuit design firms on the Lux Innovation Grid. The start-ups Ineda, Arctic Sand, Ambiq Micro, Brusa and Alpitronic are ranked 'High-potential'.

● **ABB, Dialog, Omron top in control methods**

With efficient products and partnerships, ABB, Dialog and Omron are the 'Dominant' companies pursuing control methods innovation.

Start-ups have attained varied degree of success, with Varentec, FINsix, Gridco and Cirasys all rated 'High-potential'.

● **Bosch, Schneider rule module packaging**

In module packaging, the 'Dominant' companies are Bosch and Schneider Electric, on account of their strengths in automotive and industrial markets, respectively. AT&S pursues novel energy-efficient packaging methods but has found little adoption in the market, while AgileSwitch's success with its digital gate driver has been limited to the USA.

https://portal.luxresearchinc.com/research/report_excerpt/19108

Telecom transceiver market fell 7% in 2014 as 100G displaced 10G and 40G shipments

Growth suppressed until 2016 when CFP2-ACO hits market

Revenue from 10, 40 and 100 Gigabit optical transceivers sold to telecom service providers fell by 7% from 2013's \$820m to \$762m in 2014, according to the biannual report '10G/40G/100G Data Center Optics' from market research firm IHS Infonetics.

Telecom 10G is beginning a long decline after an epic 15-year run, with tunable and non-tunable interfaces down on a year-on-year basis. 40G telecom module and network equipment manufacturer (NEM) shipments are vaporizing; shipments outside China are essentially over, and deployments are capped even within China.

"The decline in the telecom transceiver market is entirely a result of

vertically integrated 100G network equipment manufacturers displacing shipments of 10G and 40G telecom optical modules,"

says Andrew Schmitt, research director for carrier transport networking at IHS Infonetics. 100G WDM transceiver shipments surged in 2014, due to huge growth

The decline in the telecom transceiver market is entirely a result of vertically integrated 100G network equipment manufacturers displacing shipments of 10G and 40G telecom optical modules

from Huawei and sizable shipments from Alcatel-Lucent, Ciena, Cisco and Infinera. These five vendors control 84% of the 100G coherent market, preventing a material incursion by standalone component vendors and suppressing revenue growth for standalone optical modules.

The surge in 100G is slowing consumption of 10G WDM interfaces, something that will only accelerate once 100G shipments reach greater volume in the metro in 2016. "We don't foresee a reversal until 2016, when CFP2-ACO solutions hit the market, followed by non-coherent 80km solutions," concludes Schmitt.

www.infonetics.com

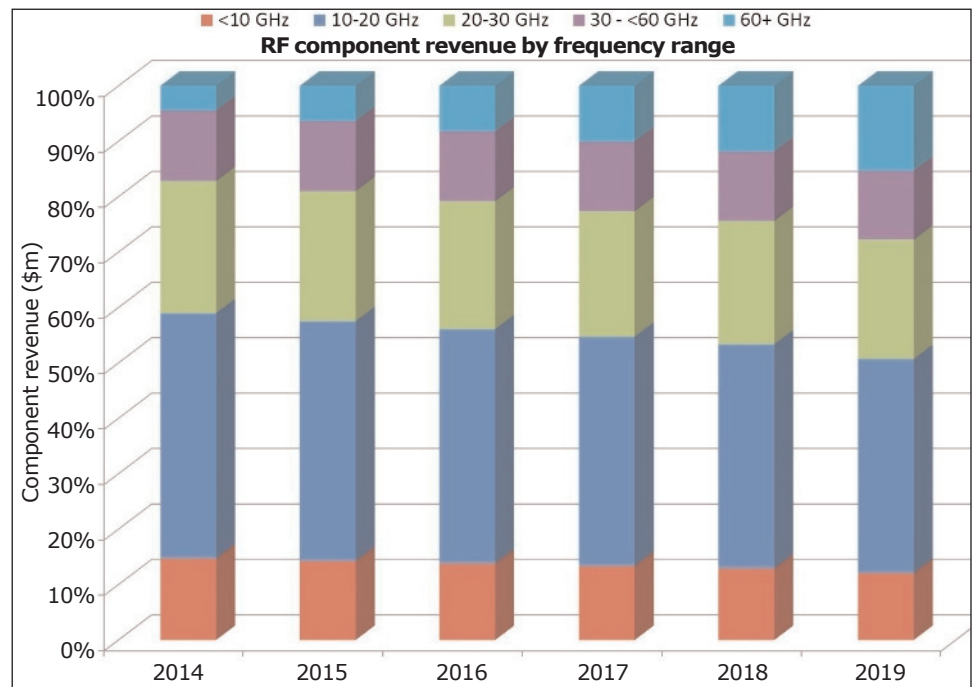
Wireless backhaul RF component revenue to fall 2% over 2014–2019, despite unit growth

33% annual growth at 60GHz to drive GaN segment to \$6m

Although wireless backhaul radio quantities will grow slowly to about 1.7 million units in 2019, price erosion will cause the corresponding RF component revenue in the segment to decline at a compound average growth rate (CAGR) of minus 2% over the forecast period, according to the Strategy Analytics Advanced Semiconductor Applications (ASA) Forecast and Outlook report 'Wireless Backhaul RF Component Demand: 2014–2019'. The slow growth reflects wireless infrastructure growth in areas that have high wireline network penetration, coupled with a lackluster deployment of the small-cell architecture.

However, the need to accommodate rapidly increasing amounts of data consumption will push equipment manufacturers and operators to higher-frequency bands, says Strategy Analytics. The frequency bands at 60GHz and above will see an annual growth rate of 33%, as enormous available bandwidth outweighs the design challenges of these higher frequencies. While this market is served primarily by gallium arsenide devices, gallium nitride technology is beginning to see use in this segment, with GaN revenue for power amplifiers forecast to grow to \$6m (about 8% of wireless backhaul RF component revenue) in 2019.

"As radio requirements continue to get tougher, we are seeing man-



ufacturers turn to GaN to solve the linearity, bandwidth, frequency and efficiency challenges," notes Asif Anwar, director in the Strategic Technologies Practice. "The low-power functions are still predominately GaAs, but there are significant development activities aimed at integrating transmit and receive functions in silicon."

"There is no question that backhaul has become a critical part of wireless network deployment and the rapid increase in wireless data consumption is forcing system designers to develop networks that provide options for future growth,"

says Eric Higham, service director, Advanced Semiconductor Applications. "This 'future-proofing' is leading to fast growth in the higher-frequency bands, but it is also creating much more interest in fiber-based front-haul and the added capabilities which that architecture provides," he adds.

So, even though the quantity of wireless backhaul radios will grow and wireless will remain the backhaul method for more than 50% of the market, fiber-based backhaul networks will capture market share, the report concludes.

www.strategyanalytics.com

China drives RF power semiconductor device sales for wireless infrastructure to over \$1bn in 2014

After a successful 2013, the market for RF power semiconductors for wireless infrastructure blew off the chart in 2014, according to a new report from market analyst firm ABI Research. The Asia-Pacific region, and China specifically, continues to be the main driver for RF power semiconductor devices

that are sold into the mobile wireless infrastructure segment.

"LTE and TD-LTE air interfaces will be the technology engines of growth for the next five years," comments research director Lance Wilson.

"Although, gallium nitride (GaN) devices had meaningful share, the 2014 story was all about

silicon LDMOS, which continues to dominate this segment by a large margin," he adds. The increasing and critical need for wireless data remains an important driver for the overall market for RF power semiconductor devices, the report concludes.

www.abiresearch.com

Anadigics' revenue falls 12% in Q1 to \$18.4m

Mobile revenue declines 42% while Infrastructure grows 23% to 65% of revenue as firm focuses on cost cutting and higher-margin products

For first-quarter 2015, broadband wireless and wireline communications component maker Anadigics Inc of Warren, NJ, USA has reported revenue of \$18.4m, down 11.7% on \$20.9m last quarter and 21% on \$23.3m a year ago.

The number of greater-than-10% customers has proliferated from just two a year ago (Samsung and Huawei) and three last quarter (adding Asia-Pacific distributor Alltek Technology Corp) to five now (including Cisco and Asia-Pacific distributor Long Trump Corp).

Mobile revenue was \$6.4m (just 35% of total revenue), down 42% on \$11.2m (53% of total revenue) last quarter and down 54% on \$14m (60.5% of total revenue) a year ago. However, this decline was partially offset by Infrastructure revenue of \$12m (a more-than-expected 65% of total revenue), up 23% on \$9.7m (47% of total revenue) last quarter and \$9.2m (39.5% of total revenue) a year ago, driven mainly by the Wi-Fi and small-cell markets.

"We are very pleased with the 23.3% sequential increase in Infrastructure revenues... enabled by our ongoing strategic shift to an Infrastructure business model [announced in June 2014]," says chairman & CEO Ron Michels.

Gross margin has risen further, from 10.9% a year ago and 18.7% last quarter to 23.2% (exceeding the forecasted 22.7%). This was driven by the Infrastructure revenue growth and a more favorable product mix, offsetting the decline in total revenue, some further inventory reduction (from \$13.9m to \$11.5m) that improved cash efficiency, and consequent slightly lower fab utilization (falling back from 35% to 32%).

Operating expenses were cut by a more-than-expected 4.4% from last quarter and by a third from a year ago, demonstrating continued

benefits of the more efficient infrastructure business model.

On a non-GAAP basis, net loss was cut for a fourth consecutive quarter, from \$9.6m (\$0.11 per share) a year ago and \$4.7m (\$0.05 per share) last quarter to \$3.8m (\$0.04 per share). Likewise, earnings before interest, taxes, depreciation and amortization (EBITDA) loss has improved further, from \$6.3m a year ago and \$2.1m last quarter to \$1.6m, "demonstrating the continued benefits of our strategic restructuring and focus on infrastructure markets," the firm says.

Capital investment was basically zero for a third consecutive quarter. During the quarter, net cash hence fell from \$14.4m to \$13m (excluding the \$4m drawn under the firm's \$10m credit facility)

For Q2/2015, Anadigics expects revenue to fall 10–15%, driven principally by a 20–25% drop in Mobile revenue, in accordance with the firm's ongoing transition to Infrastructure. Following higher-than-expected growth in Q1, Infrastructure revenue is expected to fall back by 7–9%, due to (1) some softness in forecasted demand from a key Wi-Fi infrastructure customer that is digesting some excess inventory (creating a slight headwind on new sales) and (2) a slower-than-anticipated rate of small-cell deployment (due partly to certain carriers delaying the award of hardware contracts to OEMs). "The anticipated Q2 infrastructure decline represents a temporary pause in our long-term growth infrastructure revenues," believes Michels. Due to the lower expected revenue, gross margin is expected to decline by 100–300 basis points.

"With significantly higher revenue and profitability per wafer in infrastructure, we believe that the rate of decline in Mobile wafers can be outpaced by the expected increase

in Infrastructure wafer demand while the company's financials improve over the long term," says Michels. "To achieve this, though, we must continue to align our manufacturing capacity, overall investments, and cost structure to our [leaner] Infrastructure business model," he adds.

"We are proceeding with a staff reduction, primarily in manufacturing, and implementing other cost-improvement measures that in aggregate represent a \$4–5m improvement in our annual cost structure," says executive VP & chief financial officer Terry Gallagher. "These actions are expected to enable a more streamlined operating structure that lays the foundation for Anadigics' long-term improvement," he adds.

"Based on our planned expense improvements and new leaner infrastructure business model, we expect a sequential reduction in our operating expenses of 5–7%," says Gallagher. "We expect cash usage to largely align with the anticipated EBITDA loss, adjusted for a small restructuring payout," he adds.

"We believe that Infrastructure revenue growth will return in Q3... Wi-Fi infrastructure channel inventories at our key customer will come into balance and we anticipate small-cell network deployments to resume at a pace that aligns with our customer's latest forecasts," says Michels. As the anticipated Infrastructure revenue growth returns in second-half 2015, Anadigics expects gross margin expansion to resume.

In particular, in mid-April Anadigics announced design wins for its Wi-Fi infrastructure amplifier in the high-performance TRENNet AC3200 triband wireless router (which contains six amplifiers in each). "Coupled with the continued expansion of 802.11ac, Wi-Fi infrastructure represents a tremendous

► growth opportunity for us," believes Michels.

Also, in mid-March, Anadigics announced design wins for its Wi-Fi power amplifier to be used in the video transmission system of the DJI Phantom 2 Vision Series of drones. "Our Wi-Fi products offer compelling advantages for customers not only in conventional Wi-Fi connectivity equipment, but in many adjacent applications that use Wi-Fi technologies as well," says Michels.

In early April, Anadigics expanded its small-cell wireless infrastructure power amplifier family. "Small cell is a critical market for Anadigics, and we believe that we are well-positioned to be successful in it," says Michels. "Our unique products and technology are helping carriers to solve the challenge of delivering robust service and high data rates over the cellular network in densely populated areas... our design win penetration is stronger than ever," he adds. "In spite of some slowness in the small-cell market, we still expect to double our revenue in 2015 over 2014." According to Infonetics, while some service providers are revisiting the timing for small-cell rollout, the compound annual growth rate (CAGR) of small-cell equipment is expected to be 20% through 2019.

In cable TV, product development for DOCSIS 3.0 infrastructure upgrades remains a critical focus. "In spite of recent changes in strategic activity at MSO level, CapEx spending for CATV infrastructure is continuing at a pace that can sustain our planned growth trajectory," says Michels. "In fact, our DOCSIS 3.1 products are being chosen for use in 3.0 networks, which we believe will help us hedge against potential delays in DOCSIS 3.1 deployments... We anticipate a healthy CATV revenue growth for 2015 over 2014 and that should position us for continued growth into 2016," he adds.

In machine-to-machine (M2M) and Internet-of-Things (IoT) applications, Anadigics still expects double-digit revenue growth in first-half 2015 at its largest customer in that sector. "This remains on track, and we continue to target specific applications that are a good fit for our high-performance gallium arsenide based products," notes Michels.

Regarding Anadigics' development of vertical-cavity surface-emitting laser (VCSEL) manufacturing technology, the firm reckons that its 6-inch wafer process has the necessary economic advantages over alternative 3- and 4-inch wafer processes to make the use

of VCSEL technology ubiquitous. "We are positioning VCSELs to be a significant contributor to our long-term financial growth," says Michels. "Even as we optimize our near-term manufacturing capability with the demands of our new business model, we remain well positioned to service an increasing wafer demand for VCSELs over the long term," he adds.

"We expect the Q2 headwind, offset by our planned improvements in manufacturing efficiency, to slightly delay our EBITDA breakeven goal by approximately 3–6 months," notes Michels.

"We believe that we remain on track to achieve a revenue split of at least 75:25 in favor of Infrastructure by year-end," he adds. "Our new operating model will deliver EBITDA breakeven results at a quarterly revenue level below \$19m, with utilization approximating only 25–30%," believes Gallagher.

"Our infrastructure product portfolio and design-win penetration is strong," says Michels. "Based on existing market indicators and our business outlook, we believe our net cash and our existing line of credit give us adequate capital resources to support our business and carry us through EBITDA breakeven."

www.anadigics.com

Global Technology selects surface-mount line amplifier for DOCSIS

Anadigics is shipping production volumes of its ACA1216 surface-mount line amplifier to Applied Optoelectronics Inc's China subsidiary Global Technology, an original device manufacturer (ODM) for CATV equipment, in support of new DOCSIS 3.1 CATV infrastructure equipment. DOCSIS 3.1 specifies an extended frequency range, enabling providers to offer higher data speeds and additional HDTV and video-on-demand (VOD) services.

"Global Technology's selection of our ACA1216 line amplifier for its DOCSIS 3.1 infrastructure equipment expands new growth oppor-

tunities for Anadigics in China," says James Martin, senior business development director of infrastructure products. "As MSOs embrace the advanced capabilities made possible by DOCSIS 3.1, differentiated system performance and long-term reliability are critical to enabling widespread deployment. Our newest line amplifiers leverage Anadigics' rugged process technologies, high-performance circuit designs, and proven packaging to meet the stringent specifications of this standard and support the upcoming industry upgrade cycle," he adds. "We look forward to

broadening our relationship with new designs in the near future."

Anadigics offers a complete range of surface-mount line amplifiers with high signal fidelity over extended frequencies up to 1.2GHz, in support of the newest generation of DOCSIS 3.1 downstream equipment. The surface-mount solutions offer what is claimed to be outstanding bit-error rate, composite triple-beat, composite second-order, cross-modulation and carrier-to-inter-modulation noise characteristics for optimal performance in a fully loaded spectrum.

www.anadigics.com/products/catv

Qorvo's quarterly revenue up 46% year-on-year

Operating income target approached even in seasonally weak quarter

For its fiscal fourth-quarter 2015 (ended 28 March), Qorvo Inc, a provider of core technologies and RF solutions for mobile, infrastructure and aerospace/defense applications, has reported revenue of \$633.9m, down seasonally by 14.5% on \$742m last quarter but up 46% on \$433.6m a year ago compared with the combined revenue of RF Micro Devices Inc of Greensboro, NC and TriQuint Semiconductor Inc of Hillsboro, OR, USA (following the merger of the firms on 1 January). This is also well above the guidance of \$615–625m.

There were two greater-than-10% customers (although the larger, at about 37% of revenue, represented the aggregated demand of multiple subcontractors for this end-customer).

Revenue for Infrastructure and Defense Products (IDP) was \$140m, up 10% year-on-year. However, growth was led by Mobile Products, up 61% year-on-year to \$493m (of which over 95% is 3G or 4G). "Qorvo is a leading beneficiary of the explosive demand for mobile data and the resulting growth in data traffic," says president & CEO Bob Bruggeworth.

On a non-GAAP basis (excluding about \$250m of merger-related accounting entries and costs), gross margin was a record 50.4% (well above the forecasted 46–48%). This is up on last quarter due to favorable product mix (weighted towards higher-margin IDP, in a seasonally down quarter for Mobile Products), better-than-expected manufacturing yields (through driving waste out of the manufacturing process), and synergies that are beginning to accumulate. "The sequential increase in gross margin in the seasonally down March quarter reflected crisp execution by the Qorvo team as we implemented our integration plans and captured synergies," says Bruggeworth.

Operating expenses were \$150m. Synergy-driven reductions in general & administrative (G&A) spending were offset by increased investments in R&D for masks and filter designers. Operating income was hence \$169.6m (operating margin of 26.8%), up from \$25.3m a year ago for RFMD and TriQuint combined.

Net income was \$167.2m (\$1.11 per diluted share, exceeding the guidance of \$0.80–0.90). Higher revenue and strong execution accounted for about \$0.15 of the improvement from the midpoint of guidance while lower taxes contributed \$0.09 and share count related to the timing of the merger contributed the remaining \$0.02.

Cash flow from operations was \$138m. Capital expenditure was \$120m, primarily to address continued growth in demand for premium filters. Total cash and investments was \$544.6m. Also, during the quarter Qorvo repurchased about 760,000 shares of common stock at an average price of \$65.87 (a total cost of \$50m).

During the quarter, Qorvo achieved several strategic highlights (intended to diversify and grow revenue). Specifically, the firm secured a design win with a major base-station OEM with a 3.5GHz gallium nitride (GaN) multi-mode multi-band power amplifier (MMPA) that began field trials to support major operators in China, Europe, Japan and North America. Qorvo also launched a broad family of MMPAs and duplexer modules covering major cellular bands for the small-cell base-station market. In addition, the firm was selected as the primary supplier of 802.11ac 5GHz PAs for a next-generation 802.11ac wave 2 chipset. Qorvo also saw increased design traction on leading mobile Wi-Fi reference designs, including Wi-Fi front-end solutions integrating active components and filters into a single placement.

In addition, Qorvo launched production of high-performance GPS low-noise amplifier (LNA) filter modules for a leading fitness wearable device manufacturer. It also secured its first receive diversity module design win in support of a flagship Android smartphone (due to launch in second-half 2015). Finally, Qorvo received production orders for its RF Flex solution, supporting a next-generation Octa-Core 4G chipset (with shipments starting in the June quarter). Qorvo is also supporting the launch of multiple 4G smartphones with multiple dollars of RF content (including filters, switches, antenna control solutions, discrete PAs, multi-mode multi-band PAs, and Wi-Fi solutions).

"We're leveraging our combined strengths to open new avenues of growth, many of which are coming in the form of highly integrated RF devices," says Bruggeworth. "Qorvo's Wi-Fi front-end solutions integrating active components and filters, and our receive diversity modules are both excellent examples," he adds. "In the case of our receive diversity modules, we've combined two of the fastest-growing functions in RF, premium BAW filters and high-performance, high-throw-count switches and highly integrated compact single placements. This makes them unique in our industry and are intersecting customer demand at the right time, as smartphone manufacturers increasingly migrate from SAW to BAW to solve the interference challenges of higher band count and carrier aggregation."

At its Analyst Day last November, Qorvo raised its operating model goals to 50% gross margin and 30% operating margin. "Achieving nearly 27% operating income in a seasonally weak quarter is a great start for Qorvo," comments chief financial officer Steven J. Buhaly. "Add in the substantial synergies

► yet to come and we feel we can hit these goals while making significant investments in the process technologies and great products that sustain and enhance our competitive advantage," he adds.

"We enjoy strong participation in the highest-volume and highest-value devices across the mobile, infrastructure and defense markets, and we anticipate continued strong financial performance in the June quarter," says Bruggeworth.

"We can outpace our markets this year," believes Buhaly. For the June quarter, Qorvo now expects revenue of \$660–670m (up 5% sequentially), gross margin roughly consistent

with the prior quarter, and diluted earnings per share of \$1.00–1.10. Solid operating leverage is expected to drive operating income up about 10% sequentially.

"We're making steady progress towards our goal of bringing up our second facility in China to in-source the assembly & test of legacy TriQuint products, and we expect to begin shipments in the December quarter," notes Bruggeworth. "We are confident in our ability to deliver a run rate exceeding \$75m in synergies exiting this calendar year, and we see a clear path to a run rate of greater than \$150m in synergies exiting calendar year 2016," he adds.

"From a very high level, we believe we're just beginning to demonstrate the value of bringing our two companies together, and we expect to build on that as we realize the full run rate of our cost synergies and introduce new products and technologies we could not have achieved individually," continues Bruggeworth. "Qorvo is well-positioned to win more than our share of the industry's highest-growth opportunities by leveraging our diversified product portfolio, systems-level expertise, R&D and manufacturing scale, and internal assembly & test capabilities."

www.qorvo.com

Technology Association of Oregon recognizes Qorvo as Technology Company of the Year in Enterprise category

At the annual awards ceremony of the Technology Association of Oregon (TAO) at the Portland Art Museum at the end of April, Qorvo Inc of Greensboro, NC and Hillsboro, OR, USA was recognized as winner of the 2015 Technology Company of the Year Award in the Enterprise category.

The award honors large, established companies that are leaders in both their industry and Oregon's technology community. It recognizes a variety of accomplishments over the past year, including success of new product introductions, community involvement, and



Chief financial officer Steve Buhaly accepts the TAO's Company of the Year award (photo: Naim Hasan).

impact on industry trends.

TAO award winners represent the year's top Oregon and Southwest Washington-area technology firms and products in seven categories. With an expanding network that extends beyond Oregon and SW Washington, TAO connects its members to thought leaders, executives, public officials, entrepreneurs, service providers and investors in the Pacific Northwest and beyond.

www.techoregon.org

Modelithics expands Qorvo GaN transistor model library

Modelithics Inc of Tampa, FL, USA, which provides RF and microwave active and passive simulation models for electronic design automation (EDA), is expanding the its Qorvo GaN Library of high-accuracy non-linear models for gallium nitride transistors. The existing GaN library version (v1.5) has 29 packaged and die transistor models. New plans include adding over 20 new Qorvo GaN transistor models.

"This collaboration has allowed Modelithics to apply its many years of experience with model library soft-

ware development to the benefit of Qorvo customers," says Modelithics' president & CEO Larry Dunleavy. "Qorvo's sponsorship of free distribution and support has enabled this high-accuracy non-linear library to be quickly embraced and widely utilized by the international PA design community," he adds. "Customers that also use Modelithics scalable CLR Library models for the passives in their matching and bias networks can get the best of both worlds in terms of simulation-based design success."

The non-linear GaN models feature temperature scaling, intrinsic I–V sensing capability, bias dependence, self-heat scaling factor parameter, and measurement validations including pulsed IV and load pull. Each model comes with a model datasheet, which provides detailed information about the model development, features, parameter settings and model performance plots.

The Qorvo GaN Library is available for free to approved Qorvo customers on request via Modelithics' website.

www.modelithics.com/mvpQorvo.asp

Skyworks' quarterly revenue rises by more-than-expected 58% year-on-year to \$762m

Operating income doubles year-on-year

For fiscal second-quarter 2015 (to 3 April), Skyworks Solutions Inc of Woburn, MA, USA (which manufactures analog and mixed-signal semiconductors) has reported revenue of \$762.1m, down 5.4% on last quarter's record \$805.5m but up 58% on \$481m a year ago (and exceeding the original guidance given in January of \$750m, up 56% year-on-year).

As a proportion of total revenue, compared with last quarter, integrated mobile systems have fallen back slightly from 48% to 47% as broad markets rose from 21% to 22%, while power amplifiers remain at 31%.

"Once again, integrated mobile systems was our fastest-growing category, up 139% year-over-year, highlighting the ongoing shift towards higher-margin systems solutions, which is taking place across our customer base," notes chief financial officer & executive VP Donald W. Palette. "Our broad market product lines — which serve the connected home, networking, media, automotive, and medical markets — have grown at 27% year-to-date, and that's well ahead of the analog market, helping to mitigate some of the seasonal trends in the mobile business," he adds.

"Skyworks' outperformance underscores the success of our diversification strategy, as positive momentum across our customer base, end markets and product lines helped to mitigate normal March quarter seasonality," says chairman & CEO David J. Aldrich.

Highlights during the quarter were:

- enabling Samsung's Galaxy S6 platform with SkyOne Ultra as well as switching and connectivity products;
- ramping switching and connectivity solutions for Nexus 6 smartphones;
- capturing more than 20 sockets in a next-generation small-cell LTE base-station;
- introducing 802.11ac front-end

solutions for Xiaomi's latest home router platform;

- launching an integrated Wi-Fi module for leading video monitoring provider Google;

- securing multiple design wins for the OnStar telematics platform in GM's global fleet;

- gaining high-reliability analog content in public safety radios for Harris and Sepura;

- expanding the diversity receive portfolio to support multiple device configurations;

- delivering Zigbee front-end modules for Kwikset's intelligent security products;

- powering Sierra Wireless' M2M modules for industrial applications.

"Our business continues to perform at a high level, as we capitalize on a number of powerful global trends driving the proliferation of connectivity in all of its forms," says Aldrich.

"By leveraging our architectural and integration leadership, we continue to enhance our competitive differentiation, expanding profitability and creating greater value for our customers and shareholders," he adds.

"As the market leader in complex analog and RF integration, we are the primary beneficiary of the industry's increasing adoption of systems solutions," says Palette.

"This is transforming our business model, as evidenced by our margin expansion, driving strong financial returns."

On a non-GAAP basis, gross margin was 46.7%, level with last quarter and up from 44.7% a year ago (and exceeding guidance of 46–46.5%).

"We maintained gross margins on a sequential basis in spite of the seasonal revenue impact, highlighting the strength of our underlying business fundamentals," says Palette.

Operating expenses have risen further, from \$94.4m last quarter to \$97m, driven by R&D expenses rising from \$63m to \$58.7m.

Operating income was \$258.9m

(operating margin of 34%), down on \$282m (margin of 35%) last quarter but still double the \$130.4m (margin of 27.1%) a year ago. Likewise, net income was \$224.6m (\$1.15 of diluted earnings per share), down from \$244.8m (\$1.26 per diluted share) last quarter but up from (\$0.62 per diluted share) a year ago (and exceeding the \$1.12 guidance).

Cash flow generated from operations was \$155m, down from last quarter's record \$383m but making \$538m in fiscal first-half 2015 (up from \$373m in fiscal first-half 2014). Capital expenditure remains high at \$84m, double the \$41.8m a year ago. Despite distributing \$73m to shareholders through dividend and stock repurchase activity, Skyworks maintained cash and cash equivalents at just over \$1bn (with no debt). Skyworks' board of directors has now declared a cash dividend of \$0.13 per share of common stock, payable on 4 June to stockholders of record at the close of business on 14 May.

For fiscal third-quarter 2015, Skyworks expects revenue of \$800m (up 5% quarter-to-quarter and 36% year-over-year). Gross margin should rise to 48%, driven by a combination of growing adoption of the firm's custom integrated solutions and precision analog products, increasing global scale, enhanced vertical integration and ongoing operational initiatives. "These factors have created a new baseline for our business model," says Palette. "All of this puts us on a firm path towards our target of at least 50% gross margin." Despite operating expenses rising further to about \$99.5m, diluted earnings per share are expected to rise to \$1.28. "The stage has been set for a strong 2015, giving us a high level of confidence in our near-term trajectory and accelerating our progress towards \$7 in annualized EPS," says Palette.

www.skyworksinccom

Skyworks opens design center in San Diego

Expanding capabilities to capitalize on demand for 4G/5G and Internet of Things applications

Skyworks Solutions Inc of Woburn, MA, USA (which manufactures analog and mixed-signal semiconductors) has opened a design center and laboratory facility in San Diego, California, that will focus on the development of technologies targeting 4G/5G protocols and the Internet of Things (IoT), particularly given the increasing demand for the firm's differentiated solutions.

"With the addition of Skyworks' new design center in San Diego, we are well positioned to extend our market leadership and further



Skyworks' San Diego design center.

empower ubiquitous connectivity," says chairman & CEO David J. Aldrich.

Skyworks' design center will be operational in July and is strategically

situated to enhance collaboration among the firm's design centers in Newbury Park and Irvine, California, its advanced packaging team in Irvine, its manufacturing facility in Mexicali, Mexico, as well as its filter joint venture with Panasonic in Japan (which designs and produces RF filters and duplexers). Further, the new design center supports Skyworks' long-standing relationships with its system-on-chip partners and the University of California, San Diego.

www.skyworksinc.com

Next-generation front-end modules unveiled by Skyworks for smart energy and industrial, scientific & medical markets

Skyworks has introduced next-generation front-end modules (FEMs) incorporating a complete transmit/receive chain with associated switching, filtering and logic for smart energy and industrial, scientific & medical (ISM) markets.

Given their high output power and power-added efficiency (PAE), the new family of FEMs is suitable for utility infrastructure platforms such as smart meters, which are battery powered and require fast on/off transitions.

"Our newest solutions are being leveraged by several customers to create differentiated devices and enable operational efficiencies across multiple gas and water metering applications," says John O'Neill, VP of broad markets.

Smart meters are digital meters that send energy usage information from the customer site to a utility company via radio frequency. These newer digital electronic devices are capable of tracking and recording a customer's energy usage as well as communicating with the energy supplier. Smart meters help to reduce meter reading and connection costs as well as inefficiencies in operations and billing.

According to a Business Intelligence (BI) report, smart meters have become one of the leading Internet of Things (IoT) devices and will account for 10% of IoT shipments this year. Globally, BI expects the number of smart meters to increase at a five-year compound annual growth rate

(CAGR) of 15% from an installed base of 454 million in 2015 to 930 million by 2020. Many of these devices will be enabled by Skyworks' technology, says the firm.

An example of Skyworks' next-generation smart energy solutions is the SKY65377-11, a front-end module with a complete transmit/receive chain and associated switching and filtering. The device features +30dBm output power, low leakage current shut-down and 40% PAE. It is mounted in a 28-pin, 6mm x 6mm surface-mount technology package. The SKY65377-11 and other smart energy solutions are available now for sampling and production.

www.skyworksinc.com/Product/3114/SKY65377-11

Skyworks doubles quarterly dividend

Skyworks' board of directors has declared a cash dividend of \$0.26 per share (doubling the last quarterly dividend of \$0.13 per share).

Based on the closing price of its stock on 17 June, the dividend represents roughly a 1% yield, or \$1.04 per share on an annualized basis. It is payable on 27 August to

stockholders of record as of the close of business on 6 August.

"Our quarterly dividend and share repurchases are important components of our ongoing commitment to return approximately 40% of free cash flow to shareholders — a level that we believe strikes an appropriate balance between

shareholder returns and investments in our business," says chief financial officer Donald W. Palette. "The increase in quarterly payout is supported by an expanding cash flow base and reflects our ongoing confidence in our ability to continue to consistently produce above-market growth."

IBM develops technique for co-planar integration of III-V nanoscale devices on silicon

Template-assisted selective epitaxy targets extension of Moore's Law

A team at IBM Research's Zurich Research Laboratory in Rüschlikon, Switzerland, with support from the firm's T. J. Watson Research Center in Yorktown Heights, New York, has developed what it says is a relatively simple, robust and versatile process for growing compound semiconductor crystals that will allow them to be monolithically integrated onto silicon wafers — a key step toward making chips that will allow ICs to continue shrinking in size and cost even as they increase in performance (H Schmid et al, 'Template-assisted selective epitaxy of III-V nanoscale devices for co-planar heterogeneous integration with Si', Appl. Phys. Lett. 106, 233101 (2015)).

The work could allow an extension to Moore's Law (that the number of transistors on an integrated circuit doubles about every two years). In recent years some have speculated that the ability to keep pace with Moore's Law will become exhausted eventually without new technologies. "We need better performing transistors as we continue down-scaling, and transistors based on silicon won't give us improvements anymore," says Zurich Research Laboratory's Heinz Schmid (the lead author on the paper). The new technique could also impact photonics on silicon, with active photonic components integrated seamlessly with electronics for greater functionality.

The IBM Research team fabricated single-crystal nanostructures — such as nanowires, nanostructures

containing constrictions, and cross-junctions, as well as 3D stacked nanowires — from III-V alloys of indium, gallium and arsenic (InAs, InGaAs, GaAs), which are seen as a possible future material for computer chips, but only if they can be integrated onto silicon. So far efforts at integration have not been very successful, says IBM Research.

The new crystals were grown on silicon-on-insulator (SOI) substrates by template-assisted selective epitaxy (TASE) using metal-organic chemical vapor deposition (MOCVD), which basically starts from a small area and evolves into a much larger, defect-free crystal. This approach allowed them to lithographically define oxide templates and fill them via epitaxy, making nanowires, cross-junctions, nanostructures containing constrictions and 3D stacked nanowires using the already established scaled processes of silicon technology.

IBM Research says that the benefit of TASE is exemplified by the straightforward fabrication of nanoscale Hall structures as well as multiple-gate field-effect transistors (MuG-FETs) grown co-planar to the SOI layer. Hall measurements on

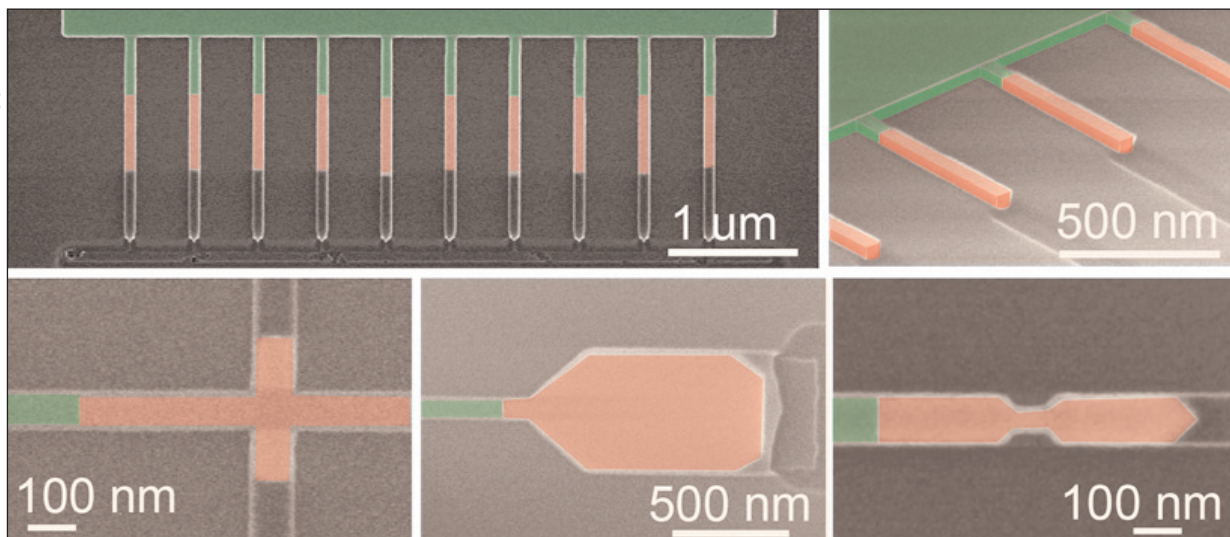
InAs nanowire cross-junctions revealed an electron mobility of $5400\text{cm}^2/\text{V}\cdot\text{s}$, while the adjacent InAs MuG-FETs with ten 55nm-wide, 23nm-thick and 390nm-long channels exhibit an on-current of $660\mu\text{A}/\mu\text{m}$ and a peak transconductance of $1.0\text{mS}/\mu\text{m}$ at $V_{\text{DS}} = 0.5\text{V}$. These results demonstrate that TASE is a promising fabrication approach for heterogeneous material integration on silicon, the researchers add.

"What sets this work apart from other methods is that the compound semiconductor does not contain detrimental defects, and that the process is fully compatible with current chip fabrication technology," says Schmid. "Importantly, the method is also economically viable."

Schmid adds that more development will be required to achieve the same control over performance in III-V devices that currently exists for silicon. However, the new method is the key to actually integrating the stacked materials on the silicon platform, Schmid says.

www.ibm.com/us/en

<http://scitation.aip.org/content/aip/journal/apl/106/23/10.1063/1.4921962>



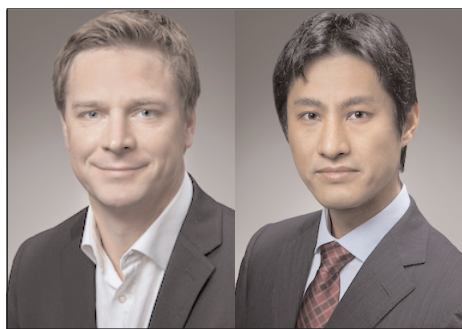
SEM images of single-crystal nanostructures fabricated using template-assisted selective epitaxy — silicon is colored in green and III-V material in red. (Images: H Schmid/IBM.)

General manager and VP of business development for Peregrine's new High Performance Analog business unit

Peregrine Semiconductor Corp of San Diego, CA, USA, a fabless provider of radio-frequency integrated circuits (RFICs) based on silicon-on-insulator (SOI), has promoted Duncan Pilgrim to VP & general manager of its newly formed high-performance analog (HPA) business unit.

"Peregrine Semiconductor was acquired by Murata last December, and they have given us the charter to continue to grow our product offerings," says Peregrine's CEO Jim Cable. "To improve alignment with Murata and better serve our customers, we have formed two separate product divisions. Duncan's strong marketing and engineering background makes him ideally suited to lead the new HPA division," he adds.

Prior to his promotion, Pilgrim was Peregrine's VP of marketing. Pilgrim, a 17-year semiconductor industry veteran, joined Peregrine in 2010. He previously served as VP of marketing for Sequoia Communications and held product, strategic and technical marketing roles at RFMD. His strong technical background comes from engineering positions at RFMD, GEC Plessey Semiconductor and Marconi. Pilgrim earned a master's degree in business administration from Wake Forest University and a bachelor's degree in electronic engineering from University of Birmingham in the UK.



HPA's Duncan Pilgrim (left) and Takaki Murata (right).

Peregrine's HPA division serves over 4000 global customers in end-markets ranging from wireless infrastructure and wired broadband to test & measurement (T&M), automotive and aerospace & defense. Products include RF switches, digital step attenuators (DSAs), digitally tunable capacitors (DTCs), tuning control switches, power limiters, phase-locked loops (PLLs), mixers, pre-scalers, DC-DC converters and monolithic phase and amplitude controllers (MPAC).

Peregrine has also appointed Takaki Murata to the role of VP of business development for the HPA business unit. Murata will be based in Peregrine's San Diego headquarters.

To improve alignment with Murata and better serve our customers, we have formed two separate product divisions

"On the heels of the Murata acquisition, I am excited to announce that Takaki Murata will be joining the Peregrine team as vice president of business development for HPA," says Duncan Pilgrim, VP & general manager of Peregrine Semiconductor's HPA business unit. "Takaki's strong technical understanding of RF technologies, coupled with his 10 years of experience at Murata, makes him the perfect support as we begin to leverage and blend our leadership position in RF with the packaging and filter dominance of Murata," he adds.

Murata was previously in charge of strategic sales planning and marketing as senior manager in the EMI filter product division of Murata Manufacturing. As part of a rotational leadership program, he worked several functions within Murata Manufacturing including cooperate accounting, product engineering of RF front-end modules and antennas and research and development of surface acoustic filters and ceramic materials. Murata earned a Ph.D. in electrical and electronic engineering from Chiba University, a master's degree in material science and engineering from Pennsylvania State University and a bachelor's degree in electrical and electronic engineering from Kyoto University.

www.psemi.com

Peregrine appoints VP of worldwide sales

Peregrine Semiconductor has promoted Colin Hunt to VP of worldwide sales, overseeing its entire sales channel (including sales offices in the USA, Europe and Asia).

"Not only does Colin bring over 20 years of sales experience, but he brings an understanding of the Murata sales organization," says CEO Jim Cable. "A former



VP of worldwide sales Colin Hunt.

employee of Murata, Colin is widely respected by their team and has been a very active participant in Peregrine's integration activities with

Murata, both prior to and after the actual deal close."

Hunt joined Peregrine in February 2013 as European sales director. He has a proven track record of growing sales and developing business opportunities in both new and emerging markets, with previous experience gained at companies including RF Micro Devices, NDK and Murata

Avago to acquire Broadcom for \$37bn

Creates \$77bn diversified communications semiconductor company

Avago Technologies Ltd of San Jose, CA, USA and Singapore (a designer and supplier of III-V-based analog components as well as digital and mixed-signal CMOS-based devices for communications, industrial and consumer applications) has entered into a definitive agreement to acquire Broadcom Corp of Irvine, CA, USA (which provides semiconductor solutions for wired and wireless communications) in a cash and stock transaction

Avago will pay \$37bn, consisting of \$17bn in cash plus the equivalent of about 140 million Avago ordinary shares worth \$20bn (as of 27 May), resulting in Broadcom shareholders owning about 32% of the combined firm. Avago intends to fund the \$17bn cash consideration with cash on hand from the combined companies plus \$9bn in new, fully committed debt financing from a consortium of banks. The transaction values the combined firm at \$77bn. Collective annual revenues should be about \$15bn. The transaction is expected to be immediately accretive to non-GAAP earnings per share (EPS) and free cash flow, while \$750m of projected annual cost synergies are expected to be achieved within 18 months.

The announcement marks "the combination of the unparalleled engineering prowess of Broadcom with Avago's heritage of technology from HP, AT&T and LSI Logic,"

comments Avago's president & CEO Hock Tan. "The combination of Avago and Broadcom creates a global diversified leader in wired and wireless communication semiconductors," he adds. "Avago has established a strong track record of successfully integrating companies onto its platform. Together with Broadcom, we intend to bring the combined company to a level of profitability consistent with Avago's long-term target model," Tan continues.

"Our customers will gain access to a greater breadth of technology and product capability," says Broadcom's president & CEO Scott McGregor. "For our shareholders, the transaction provides both compelling upfront value as well as the opportunity to participate in the future upside of the combined business," he adds.

"When Henry Nicholas and I founded Broadcom, we had a vision of creating the world leader in communications semiconductors. Today's announcement is a continuation of that vision," comments Dr Henry Samueli, co-founder, chief technical officer

Combination of Avago and Broadcom creates a global diversified leader in wired and wireless communication semiconductors

& chairman of the board at Broadcom.

"In Avago, we have found a culture and a management team that embody the best of the philosophies on which Broadcom was founded, together with a fast-paced, no-nonsense, process-driven business culture that we need to take our combined company to the next level," believes Broadcom's co-founder & ex-CEO Dr. Henry T. Nicholas.

Following completion of the transaction, Tan will continue as president & CEO of the combined company, which will adopt the name Broadcom Ltd. Samueli will join the board, as will another director from Broadcom. In addition, Samueli will be appointed chief technology officer. Nicholas will serve in a strategic advisory role within the firm, reporting to Tan.

The transaction has been unanimously approved by the boards of directors of both companies, as well as a special committee of the independent directors of Broadcom. Samueli and Nicholas have signed support agreements to vote to approve the transaction. Closing of the transaction is expected by the end of first-quarter 2016, and is subject to regulatory approvals in various jurisdictions, as well as the approval of the shareholders of Avago and Broadcom.

www.broadcom.com
www.avagotech.com

Pasternack appoints quality assurance manager

Pasternack Enterprises Inc of Irvine, CA, USA (which makes both passive and active RF, microwave and millimeter-wave products) has appointed Bruce Yolken as quality assurance manager.

Yolken has more than 30 years of QA experience in the aerospace and defense sector. Prior to joining Pasternack, he held multiple management positions with McDonnell



Bruce Yolken.

Douglas and The Boeing Company, supporting both aircraft and spacecraft programs and ranging from development and test to production activities. Yolken has

a Bachelor's Degree in Industrial Technology with a Quality Assurance Option as well as two Master's Degrees: one in Quality Assurance and one in Systems Management.

"We look forward to Bruce using his extensive experience and knowledge of quality processes and procedures," says president Brian MacDonald.

www.pasternack.com

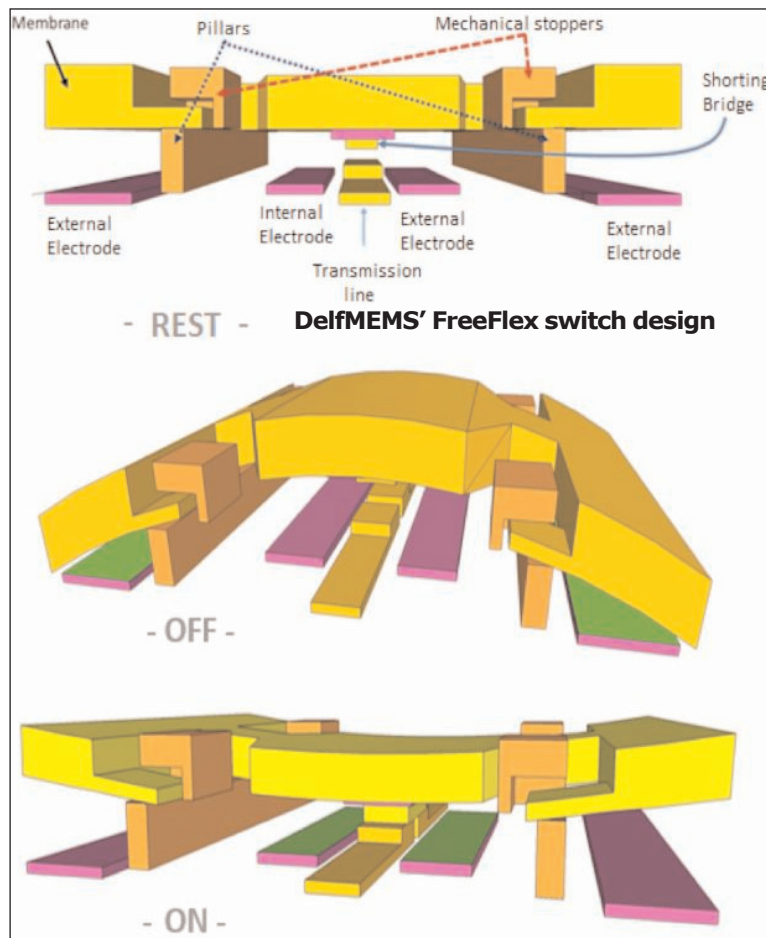
DelfMEMS' SP12T RF-MEMS ohmic switch passes 1 billion operations milestone

DelfMEMS of Villeneuve d'Ascq, France, which develops RF MEMS (micro-electro-mechanical systems) switches for radio-frequency communications (targeting next-generation multi-standard, multi-mode mobile telephony), says that its 12-throw RF-MEMS ohmic contact switch design has just passed the 1 billion test cycles milestone and is still going strong.

"This is the first time an industrialized RF-MEMS contact switch has been shown to achieve this level of performance, but this is only the beginning," says CEO Cybele Rolland. "Our second-generation production switches, which we will be shipping towards the end of 2016, are expected to achieve up to 50 billion operations," she adds. "This ensures that they will reliably deliver the performances required for the next generation of handsets, LTE-A and beyond, with ultra-low insertion loss, outstanding isolation and superior linearity, which for end-users translates to longer battery life, better call quality and massively increased data speeds."

DelfMEMS cites two key innovations helping it to achieve the milestone. First, although gold is currently used as the contact material, this will be replaced in the production switches by a metal compound that has been proven to be reliable for cold switching in excess of 50 billion cycles. Second, the firm's patented FreeFlex MEMS switch design ensures that the contact point is always changing slightly, lengthening the switch's life.

DelfMEMS says that its RF-MEMS switch structure uses a new, integrated, micro-mechanical building block that is based on a robust IP portfolio that includes seven key patents and innovations. It does not use a cantilever beam or bridge featuring a highly conductive electrode electrostatically actuated in order to create an ohmic contact resulting in a mechanical switching.



These older structures have proved to have several issues, says the firm: stress on the anchors, possible stiction, low commutation speed and possible creep of the beam.

DelfMEMS' design approach has resulted in the development of an anchorless structure for mechanical RF switching that, it is claimed, totally overcomes these historical design problems instead of trying to simply reduce them.

The FreeFlex membrane is always in a known controlled state as it is electrostatically actuated by two sets of electrodes. The electrostatically ON state is achieved by making physical contact between the membrane contact area and the transmission line, and the similarly controlled OFF state is achieved by keeping a physical distance between the membrane contact area and the transmission line. This means that the switch contact area will either be attracted to the conductive line or

repelled from it. Moving from ON state to OFF state is made through an electrostatic active actuation, which de-couples between restoring forces, contact forces and the membrane mechanical properties.

Another feature of the FreeFlex switch structure is the possibility of having a reduced gap between the membrane and the trans-

mission line, reducing the creep and mechanical stress by lowering the maximum deflection of the membrane. This results in an increased contact force in the ON state with lowered actuation voltage and therefore lower insertion losses.

DelfMEMS' RF-MEMS switches are surface micro-machined devices that use a mechanical movement to switch the RF transmission line on or off. The technology does not suffer from frequency dependency and high multi-throw switch configuration limitation, says DelfMEMS. With a figure of merit (FoM) of less than 10, it offers superior linearity, insertion loss and isolation performance compared with existing solid-state solutions, claims the firm. This first generation of DelfMEMS switches is manufactured by Honeywell/Tronics in Dallas, Texas, and will complete qualification by the end of 2015.

www.delfmems.com

NXP to sell RF Power business to China's JAC for \$1.8bn Deal to yield funds and approval for NXP's acquisition of Freescale

NXP Semiconductors N.V. of Eindhoven, The Netherlands has agreed to sell its RF Power business for \$1.8bn to Jianguang Asset Management Co Ltd (JAC Capital, a subsidiary of China state-owned investment company JIC Capital). NXP's RF Power business is said to be one of the market leaders in high-performance RF power amplifiers primarily focused on the cellular base-station market, but with potential future growth applications in industrial lighting, next-generation cooking and automotive electronic ignition systems.

"The creation of a new company focused on the RF power amplifier market is a groundbreaking transaction for JAC Capital," says NXP's CEO Richard Clemmer. "Although we would have expected a higher valuation in a regular disposal, JAC Capital's ability to support continued growth and development of the business and its ability to sign and close a transaction rapidly was a key factor in enabling the best outcome for our customers and shareholders, as well as supporting the closure of the merger with

Freescale Semiconductor [announced in March]," he adds.

"We will keep on increasing investment in R&D, manufacturing and customer service of the new company to strengthen its market position," says Brighten Li, chairman of JAC Capital Investment Evaluation Committee. "JAC Capital and its shareholders will also help the new company to maintain fast and stable growth through our network of worldwide financial institutions, industrial leaders and JAC Capital's management team with many years of experience in the semiconductor and telecom industry," he adds.

Under the agreement, the entire scope of the NXP RF Power business and about 2000 NXP staff who are primarily engaged globally in the RF Power business (including its entire management team) are to be transferred to an independent company incorporated in The Netherlands, which will be 100% acquired by JAC Capital upon closing of the transaction. Additionally, all relevant patents and intellectual property associated with the RF

Power business will be transferred in the sale, as well the NXP back-end manufacturing operation in the Philippines that is focused on advanced package, test & assembly of RF Power products.

The transaction is subject to review and approval by the US Federal Trade Commission, the European Commission, MOFCOM (China's Ministry of Commerce) and other agencies in connection with their review of NXP's proposed \$11.8bn acquisition of Freescale Semiconductor Ltd of Austin, TX, USA.

NXP and JAC Capital expect the sale to close in second-half 2015, pending required regulatory approval and employee representative consultations. NXP anticipates the sale of its RF Power business to be dilutive to earnings on a stand-alone basis in fourth-quarter 2015 and 2016. Proceeds from the sale will be used to partly to fund NXP's previously announced acquisition of Freescale Semiconductor (creating a company worth more than \$30bn).

www.nxp.com

Guerrilla RF completes \$2m Series B funding round Capital to launch additional products into mass production and generate self-sustaining cash flow

Guerrilla RF Inc of Greensboro, NC, USA, which provides monolithic microwave integrated circuits (MMICs) to wireless network infrastructure original equipment manufacturers, has closed a \$2m Series B funding round led by two angel investors Charlotte Angel Fund and Piedmont Angel Network (and joined by a growing list of individual investors).

Founded in April 2013 by Ryan Pratt, Guerrilla RF has so far raised \$3.5m in funding and introduced more than 30 products. Using patented Guerrilla Armor technology that is claimed to enable greater coverage

area and higher data rates for wireless networks, applications include enterprise/carrier-class WiFi access points, small cells, wireless backhaul, and cellular repeaters.

"Customer interest and design activity continues to blow away our expectations," says founder & CEO Ryan Pratt.

As a result of securing over 20 design wins, we are being driven to accelerate mass-production schedules for multiple products

"As a result of securing over 20 design wins, we are being driven to accelerate mass-production schedules for multiple products," he adds. "With this funding, we can ramp up our revenue much more quickly and pursue our goal of achieving self-sustaining cash flow in 2016."

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

<http://guerrillarf.com>

Infineon and Google to develop 60GHz radar technology for gesture sensing and presence detection

SiGe transceiver to be integrated with RF transceiver, antenna and control electronics in single package

Infineon Technologies AG of Munich, Germany says that it is working with Google's Advanced Technology and Projects group (ATAP) to develop a radar-based sensing solution using Infineon's 60GHz silicon germanium (SiGe) transceiver technology together with RF transceiver, antenna and control electronics integrated in a single package.

Infineon already provides solutions for wireless communications of the future to other divisions at Google.

First implementations of the new sensor, which provide gesture recognition and presence detection capability for a range of future devices, were demonstrated by Google ATAP at its Google I/O Developers Conference in San Francisco (28–29 May).

The new sensor provides Google ATAP and its developer community with a compact and low-power implementation suitable for integration and use in both mobile and fixed devices. Potential applications include wearables, the

Internet of Things and automotive applications.

"Infineon is a recognized leader in radar-based sensor ICs, providing component and system-level solutions for consumer, automotive safety, industrial and commercial sensing and machine vision applications – markets that are expected to grow significantly in the coming years," reckons Philipp Schierstaedt, VP & general manager of Infineon's RF & Sensors business line.

<https://events.google.com/io2015>
www.infineon.com

SiBEAM's single-chip CMOS transmitter captures design win in first 60GHz smartphone

SiBEAM Inc of Sunnyvale, CA, USA (a Lattice Semiconductor company that develops CMOS silicon-based millimeter-wave technologies for wireless communications) has announced a key design win for its UltraGig SiI6400 transmitter with Letv's Le Max, which is said to be the first smartphone offering 60GHz millimeter-wave wireless video technology in volume production. Announced in mid-April and available for purchase from June, Le Max is claimed to establish a new benchmark for low-power millimeter-wave design in mobile device form factors.

SiBEAM claims to be the first firm to build 60GHz chipsets using standard CMOS technology. The UltraGig SiI6400 transmitter is a single-chip solution that integrates network processor, RF transceiver and in-package antennas, offering Full HD quality with near-zero latency for immersive entertainment and gaming. The inclusion of SiBEAM's wireless technology in the device expands Letv's film, TV and gaming services to mobile consumers.



Letv's Le Max smartphone.

"SiBEAM's 60GHz millimeter-wave wireless expertise is unparalleled and their video technology gives consumers a seamless, interactive experience from the phone to the TV," comments Letv's product director Yukuan Ding. "As wireless connectivity becomes increasingly important to consumers, Letv will continue to offer products with

innovative technologies that enhance the consumer experience."

Leshi Internet Information and Technology Co is China's leading Internet content and entertainment provider, offering Internet, movie and TV content as well as Internet TVs and set-top boxes. The firm launched its first smartphone (a bezel-less device) earlier this year.

"Letv's Le Max design win is not only a key milestone for the wireless industry, but also showcases SiBEAM's leadership in millimeter-wave advancement and fulfilling the promise of gigabit wireless experience for consumers world-wide," says SiBEAM's senior director of marketing David Kuo.

SiBEAM demonstrated its millimeter-wave portfolio (including its UltraGig wireless video and data solutions as well as Snap wireless connector replacement technology) in a demo suite at the Grand Hyatt Taipei, Taiwan during the Computex Taipei trade show (2–5 June).

www.sibeaminc.com
www.lemall.com
www.computextaipei.com.tw

Anvil involved in £9.5m UK project to modernize grid SiC-on-silicon power devices to be trialled on residential network

Anvil Semiconductors Ltd of Coventry, UK is participating in a £9.5m government initiative to modernize the UK energy infrastructure to cope with the unprecedented change in energy consumption, generation and distribution. UK Government agency Innovate UK (formerly the Technology Strategy Board) is funding projects that drive innovative ways to supply and use energy to address the energy trilemma of sustainability, security of supply and affordability.

Anvil was spun off in August 2010 from the University of Warwick's School of Engineering by its technology commercialization subsidiary Warwick Ventures Ltd in order to exploit patented developments in SiC power semiconductor technology. The firm's technology enables growth of device-quality 3C-SiC epitaxy on 100mm silicon wafers to thicknesses that permit the fabrication of vertical power devices. The proprietary process is said to overcome mismatches in lattice parameter and thermal coefficient of expansion and can be readily migrated onto 150mm-diameter wafers (and potentially beyond) without modifi-

cation and is therefore suitable for large industrial-scale applications. The material has applications ranging from power devices and LEDs to medical devices and MEMS.

Trialled on Western Power Distribution's residential network, the project will utilize Anvil's SiC-on-Si power devices to look to increase the UK's energy network capacity to tackle residential and commercial needs. The team consists of Western Power Distribution, Anvil Semiconductors, Turbo Power Systems, Aston University, Exception EMS and Schneider Electric in the design and delivery of the project.

Due to multiple factors in consumption, generation and storage, the UK's energy network is set to become increasingly complex. By 2020 the UK is expected to have 10 million homes with solar panels and the number of electric vehicles sold will increase to 6.4 million by 2023. Hence the existing energy infrastructure, designed for a one-way flow of energy, will have to deal with unprecedented patterns in network load. The challenge of integrating distributed power generation with traditional larger-scale energy gen-

eration presents new risks in terms of voltage control and predicting load and demand, notes Anvil. Distribution network operators (DNOs) are facing significant challenges in modernizing existing infrastructure, and investing in smart technologies, to cope with this transformation.

The trial aims to deliver a dramatic increase in the capacity of the existing residential energy infrastructure, by increasing the local network voltage. This approach should allow the grid to simultaneously deliver different voltages for different requirements (i.e. charging an electric car and simultaneously providing a constant 240V for a residential building). The project will trial the installation of high-performance power electronic converters (PECs) into the meter-box of individual properties and a local sub-station converter for distributing at 400V. To achieve the required level of performance, efficiency, stability and sustainability at the cost demanded, these PECs will use low-cost silicon carbide switching devices built using Anvil's SiC-on-silicon technology.

www.anvil-semi.co.uk

University of Arkansas wins extra \$200,000 NSF grant to further develop high-temperature SiC ICs

The University of Arkansas has received an additional \$200,000 grant from the US National Science Foundation (NSF) to further develop silicon carbide (SiC) ICs that can survive and operate at temperatures greater than 300°C (about 600°F).

The ICs serve as the foundation for creating commercial converters in internal combustion engines, converting high-temperature sensor data to digital form for transmission to the vehicle's performance and emissions control computer. The technology should provide more robust data from the engine, enabling better control of the vehicle and greater fuel efficiency.

Led by Distinguished Professor of electrical engineering Alan Mantooth, the research team is one of just a few groups in the USA with extensive experience of designing and fabricating ICs made of silicon carbide, which is more rugged than conventional materials used in electronics, as well as being a good thermal conductor (able to withstand very high voltage and temperatures).

For this project, the University of Arkansas is collaborating with Ozark Integrated Circuits of Fayetteville, AK (which develops ICs for remote sensing and actuation under extreme environmental conditions),

which will commercialize the new circuit technology.

Together, the aim is to create a prototype of a SiC-based converter that can acquire and process data in harsh environments. They will then evaluate the prototype across temperature variations and test how the converter functions in a harsh, real-world environment by combining the system with ignition sensor technology developed by Ozark. Finally, the team will generate a commercial feasibility analysis based on projections of the manufacturing costs of a high volume of SiC.

www.engr.uark.edu

GeneSiC offers all-SiC junction transistor-rectifier co-packaged in 4-leaded mini-module

GeneSiC Semiconductor Inc of Dulles, VA, USA has announced the availability of the GA50SICP12-227 20m Ω /1200V Silicon carbide (SiC) junction transistor-diode in an isolated SOT-227 4-leaded mini-module package that enables very low turn-on energy losses while offering flexible, modular designs in high-frequency power converters.

The use of high-frequency, high-voltage and low on-resistance capable SiC transistors and rectifiers will reduce the size/weight/volume of electronics applications requiring higher power handling at high operating frequencies, says the firm. The new devices are targeted at a wide variety of applications including induction heaters, plasma generators, fast chargers, DC-DC converters, and switched-mode power supplies (SMPS).

GeneSiC says that its co-packaged SiC junction transistor (SJT)-SiC rectifiers are uniquely applicable to inductive switching applications because SJTs are the only wide-bandgap switch that offers >10 μ s repetitive short-circuit capability, even at 80% of the rated voltages



GeneSiC's 1200V/20m Ω SiC junction transistor-rectifier co-packaged in an isolated SOT-227 package providing separate gate source and sink capability.

(e.g. 960V for a 1200V device). In addition to the sub-10ns rise/falls times and a square reverse-biased safe operation area (RBSOA), the gate return terminal in the new configuration significantly improves the ability to reduce the switching energies, says GeneSiC. The new class of products offers transient energy losses and switching times that are independent of junction temperature. GeneSiC adds that its SiC junction transistors are gate-oxide free, normally-off, exhibit

positive temperature co-efficient of on-resistance, and are capable of being driven at low gate voltages (unlike other SiC switches).

The SiC Schottky rectifiers used in the mini-modules show low on-state voltage drops, good surge current ratings and the industry's lowest leakage currents at elevated temperatures, claims GeneSiC. With temperature-independent, near-zero reverse recovery switching characteristics, SiC Schottky rectifiers are suitable candidates for use in high-efficiency circuits, the firm adds.

"GeneSiC's SiC transistor and rectifier products are designed and manufactured to realize low on-state and switching losses," says president Dr Ranbir Singh. "A combination of these technologies in an innovative package promises exemplar performance in power circuits demanding wide-bandgap-based devices," he adds. "The mini-module packaging offers great design flexibility for use in a variety of power circuits like H-bridge, flyback and multi-level inverters."

www.genesicsemi.com/commercial-sic/sic-modules-copack

Toshiba launches SiC-based UPS range, enabling 98%-efficient power protection for data centers

Toshiba International Corp (TIC) has launched the G2020 Series, its latest three-phase uninterruptible power system (UPS), in which silicon carbide power modules in a three-level design enable 98%-efficient power protection with 50% load while operating in double-conversion mode.

The firm says that combining the latest in semiconductor technology with innovative circuit topology and high-performance full digital control ensures the highest level of reliable power quality to meet the demanding needs of the data-center industry. With 98.2% efficiency (said to be

the highest in the industry for double-conversion UPS), the G2020 produces less heat, noise and interference, lowers cooling costs and saves energy compared with the conventional UPS, it is claimed, and presents a solution for mission-critical infrastructure.

Available in 500 and 750kVA versions, the G2020 UPS provides a solution for demanding data-center applications that require small footprint, high efficiency, and clean uninterruptible power, says Greg Mack, VP & general manager of the TIC Power Electronics Division. "The G2020, with full digital control,

instantaneous waveform control and fast-response current control ensures the highest power quality for all UPS users," he adds.

For redundant high-reliability UPS applications, the G2020 has a footprint 17% smaller than its G9000 predecessor and up to 57% smaller than competing models, claims Jesus Penalver, product manager for the TIC Power Electronics Division. "The future of power electronics is SiC power switching technology, with >33% higher junction temperature, higher switching speed, and extremely low switching losses."

www.toshiba-components.com

Rohm starts mass producing first trench-type SiC MOSFET

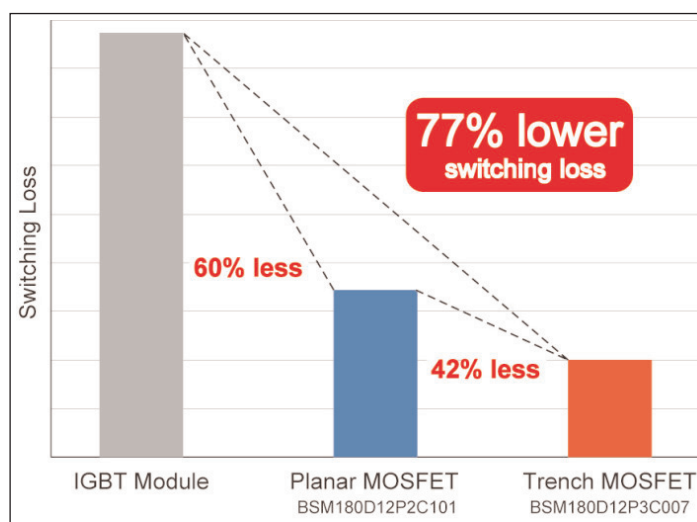
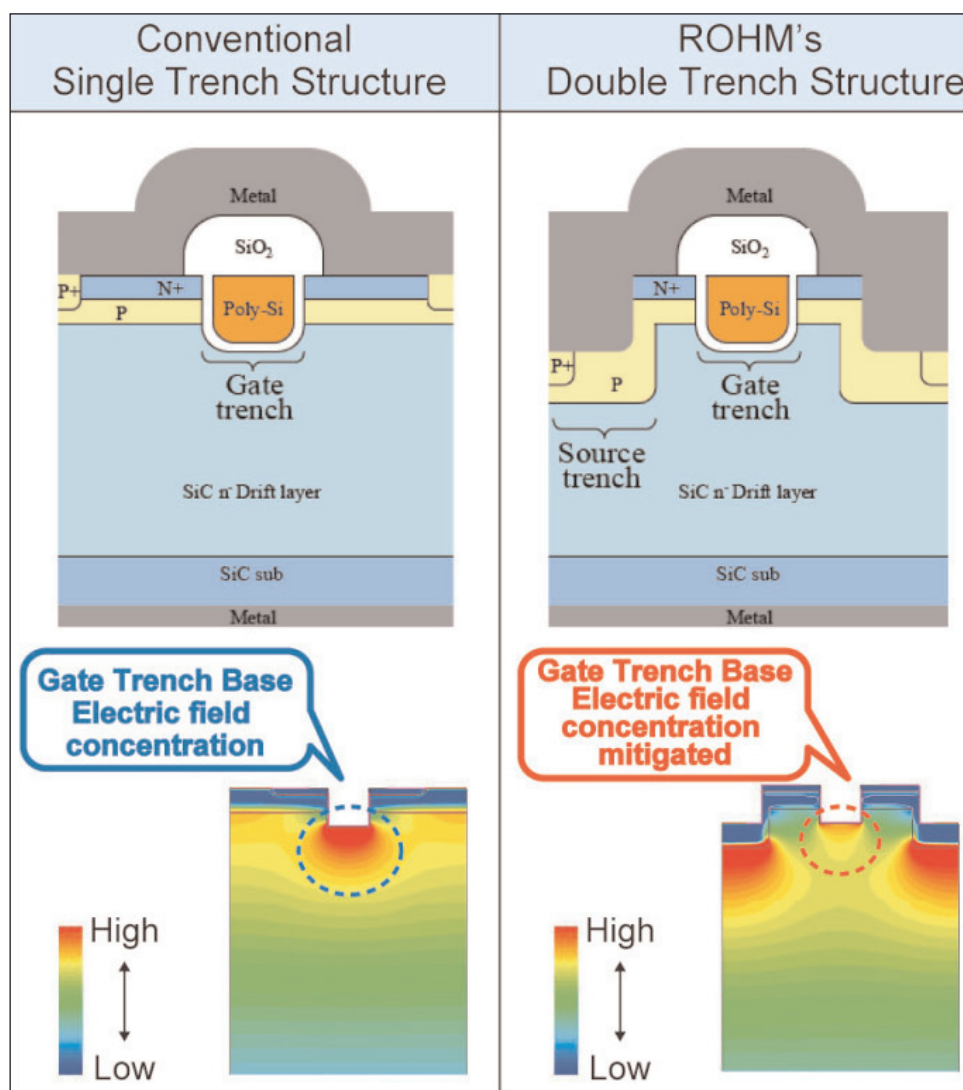
Japan's Rohm Co Ltd has started mass production of what it claims is the first silicon carbide MOSFET with a trench structure (where the gate is formed on the sidewall of a groove in the chip surface). Unlike planar-type MOSFETs, junction gate (JFET) resistance does not exist, enabling greater miniaturization (which is expected to result in on-resistance close to the performance of the original SiC material).

In recent years the requirement to address power supply issues on a global scale has brought increased attention to power supply conversion and the efficient delivery of generated power, says Rohm. SiC power devices are expected to play a major role as key solutions that dramatically reduce loss during power conversion.

As the performance and characteristics of silicon approach their theoretical limits, Rohm was early to focus on SiC as a viable successor to silicon as a semiconductor material due to its higher voltage resistance and lower loss (higher efficiency). The firm claims to have been the first supplier to mass produce SiC MOSFETs in 2010 and it continues to develop products that achieve further reductions in power loss.

Although adopting a trench construction in SiC MOSFETs has been attracting increased attention due to its effectiveness in reducing on-resistance, there has been a need to establish a structure for mitigating the electric field generated in the trench gate region in order to guarantee long-term reliability.

Compared with existing planar-type SiC MOSFETs, in Rohm's new trench-type SiC MOSFET (which uses a proprietary structure) the switching performance is improved (with input capacitance reduced by 35%) and on-resistance is halved in the same chip size. This makes it possible to significantly decrease power loss in a variety of equipment, from industrial inverters and power supplies to power conditioners for solar power systems.



Rohm has also developed a full-SiC power module that incorporates the latest trench-type SiC MOSFETs in a 2-in-1 circuit together with integrated SiC Schottky barrier diodes (SBDs). The 1200V/180A module also features the same rated cur-

rent as silicon insulated-gate bipolar transistor (IGBT) modules while reducing switching loss — through an on-resistance ($R_{DS(on)}$) of 10mΩ — by about 42% compared with planar-type SiC MOSFETs.

In addition, the lineup of discrete trench-type SiC MOSFETs is being

expanded to include three models for each rated voltage of 650V and 1200V, with rated currents of 118A (650V) and 95A (1200V) respectively.

www.rohm.com/web/global/sic-mosfet

Princeton Power demonstrates 30kW power converter with 99% efficiency using SiC JFETs

Princeton Power Systems of Princeton, NJ, USA — which designs and manufactures products for energy management, micro-grid operations and electric vehicle charging — has demonstrated for the first time a grid-tied bi-directional power converter for commercial use based on a silicon carbide (SiC) switching technology platform. The converter operates at 30,000W power throughput and 480V_{ac}, using junction field-effect transistor (JFET) devices provided by United Silicon Carbide (USCi) of Monmouth Junction, NJ, USA and Princeton Power Systems trigger cards integrated in a unique architecture. The converter demonstrated peak efficiency greater than 99% and sustained 100% power overloads.

"This product demonstration shows that silicon carbide technology can play a role in highly efficient and cost-effective commercial products in the very near future, and we intend to expand its use to higher power levels and ultimately across our product line," says Princeton Power Systems' president & CEO Ken McCauley.

The power stage at the heart of the converter was jointly developed by USCi and Princeton Power, using JFET devices from USCi and triggers and controls developed by Princeton Power Systems. The integrated product was designed and tested at Princeton Power's Nationally Recognized Test Lab in Lawrenceville.

"Our JFET and cascode technology deliver the only standard gate drive SiC switch solution, while having the lowest specific on-resistance in the industry," claims USCi's president & CEO Chris Dries. "These advantages enable the most cost-effective SiC solution," he adds. "The demonstration at Princeton Power represents a breakthrough in operating an integrated power block using commercially available silicon carbide devices."

The specifications for a commercial GTIB-30-SiC converter using silicon carbide technology will include a CEC (California Energy Commission) weighted efficiency of 97.5% in a double-conversion bi-directional architecture and will be compatible with advanced

batteries over a wide DC voltage range, 208/480V_{ac}, output, and UL-compliant.

The companies are planning to introduce a 100kW SiC-based product in 2016.

www.unitedsic.com

www.princetonpower.com

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Luftstrom project targets more efficient and quieter battery charging in electric vehicles

GaN and SiC power semiconductors to allow transition from water-cooled to air-cooled and fan-less cooling systems

With funding of about €3.9m from the German Federal Ministry of Education and Research (BMBF), 12 partners in the German automotive sector, its supply industry and the sciences (led by Infineon Technologies AG of Munich, Germany) are collaborating on the three-year project Luftstrom (or Airstream) to investigate how batteries in electric vehicles can be charged more efficiently. The use of gallium nitride and silicon carbide power semiconductors is expected to reduce losses during charging and, ultimately, make charging almost noiseless.

Electric vehicles are mainly charged overnight. However, charging in the charging device and voltage regulators creates heat that fans of water-cooled aggregates,

for example, must dissipate. This can be quite noisy. The Luftstrom research aims to develop electronic power components that lower losses during charging by 30%. A reduction in waste heat and hence cooling effort means that cooling units will become more compact and operate more quietly. Components that already cause very few losses, such as auxiliary power supplies, could even do without the previously required water cooling, so loud fans would be eliminated.

The key to low-loss power electronics lies in power semiconductors based on GaN or SiC. The project will therefore also determine how such power semiconductors can be used reliably in charging devices, voltage regulators and inverters for

auxiliary power units. The research results are expected to accelerate the transition to air-cooled and fan-less systems for future generations of electric vehicles.

The entire automotive value-added chain for the production and use of these new systems is represented in the project. The 12 partners include AVL Software and Functions GmbH, BMW AG, Daimler AG, Fraunhofer Institute for Integrated Systems and Component Technology IISB, the University of Applied Sciences Ostwestfalen-Lippe, Infineon Technologies AG, Lenze Drives GmbH, Robert Bosch GmbH, RWTH Aachen University, Siemens AG, Leibniz University Hannover, and Volkswagen AG.

www.infineon.com

Cree launches record-power GaN HEMTs to replace TWT amplifiers in radar systems

Cree Inc of Durham, NC, USA has launched two gallium nitride (GaN) high-electron-mobility transistor (HEMT) RF devices that are said to solve a number of long-standing issues for radar systems employing traditional travelling wave tube (TWT) amplifiers. GaN-based solid-state amplifiers operating at 50V are not prone to the failure mechanisms seen with high-voltage (kV) TWT power supplies, thus providing longer lifetimes. Also, such solid-state systems provide near-instant on capability — with no warm up, longer detection ranges and improved target discrimination.

Conceived from the start to enable these system benefits, Cree's two new GaN RF transistors have been engineered to provide the highest power and efficiency housed in a small package size. It is claimed the first device (the CGHV59350, 350W/50Ω fully matched GaN HEMT)

is the highest-power C-band transistor on the market, while the second (the CGHV31500F, a 500W/50Ω GaN HEMT) is the highest-power S-band transistor fully matched to 50Ω in a single-ended package of its size. Both devices were demonstrated at the IEEE MTT-S International Microwave Symposium (IMS 2015) in Phoenix, AZ, USA (17–21 May).

"Cree's new C- and S-band products break power records for GaN power and efficiency performance housed in a small 50Ω package," claims Tom Dekker, director of sales & marketing, Cree RF. "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, Cree's 350W C-band device beats the closest

commercial GaN competitor by an estimated 3.5 times. Using the same figure of merit, Cree's 500W S-band device raises the bar by 45% over other commercial S-band products."

Offering pulsed saturated power performance typically greater than 400W, the CGHV59350 is most often used in ground-based defense and Doppler weather radar systems. The 50Ω, fully matched GaN HEMT operates over a 5.2–5.9GHz bandwidth and exhibits 60% typical drain efficiency.

Delivering 700W of typical saturated RF pulsed power, the CGHV31500F is offered for air traffic control radar systems. The 50Ω, fully matched GaN HEMT operates over a 2.7–3.1GHz bandwidth and exhibits 12dB power gain.

Both devices are packaged in an industry-standard 0.7" x 0.9" ceramic/metal flange package.

www.cree.com/rf

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Cree registers for IPO of Power & RF subsidiary

Power & RF initial public offering to support future growth, while Cree focuses on LED and Lighting businesses

Cree Inc of Durham, NC, USA, which makes silicon carbide (SiC) and gallium nitride (GaN) wafers and devices as well as LEDs, has submitted a draft registration statement on a confidential basis to the US Securities and Exchange Commission (SEC) for a potential initial public offering of Class A common stock of its Power and RF subsidiary.

The type and number of shares of stock to be sold and the price range for the proposed IPO has not yet been determined, although Cree intends to remain the majority stockholder of the subsidiary post offering. The IPO is expected to commence after the SEC completes its review process, subject to market and other conditions.

The Power and RF subsidiary is

raising capital to invest directly in the business to support targeted future growth. The offering should enable Cree's management to focus on the firm's LED and Lighting businesses, while also creating a dedicated focus on the Power and RF business. Cree believes that the transaction should allow its shareholders to better realize the full value of both businesses.

Cree launches first 900V SiC MOSFET platform

Cree has launched what it claims is the first 900V silicon carbide (SiC) MOSFET platform. Optimized for high-frequency power electronics applications, including renewable energy inverters, electric vehicle (EV) charging systems, and three-phase industrial power supplies, the new 900V platform enables smaller and higher-efficiency next-generation power conversion systems at cost parity with silicon-based solutions, reckons the firm.

"Compared to equivalent silicon MOSFETs, this breakthrough 900V platform enables a new market for our products by broadening the power range we can address in end systems," says Dr Cengiz Balkas, VP & general manager, Cree Power & RF. "Following our 1200V MOSFETs, which exhibit superior performance to high-voltage IGBTs, we are now able to outperform lower-voltage superjunction silicon MOSFET technology at 900V," he adds. "This platform delivers vastly superior characteristics, thereby providing power designers with the potential to innovate smaller, faster, cooler, and more efficient power solutions... it is beyond the reach of anything currently achievable with silicon."

Built on Cree's SiC planar technology, the new 900V MOSFET platform expands the product



Cree's C3M0065090J SiC MOSFET.

portfolio to address design challenges common to new and evolving application segments in which a higher DC link voltage is desirable. The lead product (C3M0065090J) features the lowest on-resistance rating (65mΩ) of any 900V MOSFET device on the market, it is claimed. Moreover, as well as the industry-standard TO247-3 and TO220-3 packages, the new device is also offered in a low-impedance D2Pak-7L surface-mount package with a Kelvin connection to help minimize gate ringing.

Existing 900V silicon MOSFETs have severe limitations for high-

frequency switching circuits due to extremely high switching losses and poor internal body diodes, says Cree. Further limiting the use of silicon MOSFETs is the on-resistance $R_{ds(on)}$ that increases by 3x over temperature, which causes thermal issues and significant derating. In contrast, Cree's new 900V MOSFET technology delivers low $R_{ds(on)}$ at higher temperatures, enabling a significant size reduction of the thermal management system, says the firm.

The C3M0065090J is rated at 900V/32A, with an $R_{ds(on)}$ of 65mΩ at 25°C. At higher-temperature operation ($T_j = 150^\circ\text{C}$), the $R_{ds(on)}$ is just 90mΩ. Packaged parts will be stocked through distributors DigiKey and Mouser.

● Exhibiting with distributor partner MEV Elektronik Service GmbH, at PCIM (Power Conversion Intelligent Motion) Europe 2015 in Nuremberg, Germany (19–21 May), Cree showcased its portfolio of SiC diodes, MOSFETs, modules, and bare die (including introducing the new family of 900V SiC MOSFETs) and demonstrated how its SiC technology can enable smaller, lower-cost and more efficient power systems capable of switching at higher frequencies and operating at higher temperatures.

www.cree.com/Power/Products/MOSFETs/7L-D2PAK/C3M0065090J

IHS reports developments in power semiconductors highlighted at PCIM Europe 2015

Design engineers now proactively asking for SiC and GaN products

Richard Eden, senior analyst (Power Semiconductors) at market research firm IHS Technology, attended the PCIM (Power Conversion Intelligent Motion) Europe 2015 tradeshow in Nuremberg, Germany (19–21 May), and in a Research Note has reported the following key highlights, including the significance of new product releases, the status of the semiconductor materials battle, and the industries driving current and future market growth.

SiC and GaN developers continue to make headlines

For the past few years, the headlines have been filled with technology announcements by silicon carbide (SiC) and gallium nitride (GaN) startups, and this year's show was no exception, says Eden. The wider market has caught on to these stories, as well-established manufacturers are now explaining their development strategies and introducing their own products.

When it comes to new players coming to market, the attitude of existing SiC and GaN companies as a whole is "the more, the merrier", he adds. For such companies, the main competitors are silicon suppliers, not each other.

In recent years, SiC and GaN semiconductor companies had to explain the benefits of their devices in practical applications, in order to evangelize about the technology. The message appears to have registered with customers, as design engineers are now proactively asking them for products to help provide power conversion efficiency gains. According to IHS Technology, the SiC and GaN power semiconductor market is conservatively forecasted to surpass \$270m in 2015.

The silicon empire strikes back

With SiC and GaN power semiconductor developers intent on gaining market share, the dominant silicon suppliers are reacting, says IHS.

Several new devices were on show at PCIM for the first time.

Fairchild Semiconductor introduced its fourth generation of discrete insulated-gate bipolar transistors (IGBTs), which it claims can slash energy loss by 30%. Fairchild's new approach should enable new ways to efficiently control large amounts of power, it is reckoned.

Germany's Infineon Technologies launched the MIPAQ Pro, a new intelligent power module (IPM) integrating IGBTs, gate drivers, heat-sink, sensors, digital control electronics and digital bus communication into one robust, reliable package. The new module is aimed at providing an integrated solution for new scalable and compact inverter designs for wind, solar, and industrial motor drive applications.

Eden says that these examples illustrate two trends that were increasingly apparent at the show. First, the devices are aimed squarely at improving power efficiency. Second, power transistors are increasingly being integrated with sensing, control and communication functions in common module packaging.

Merger & acquisition activity increases

The number of semiconductor business mergers and acquisitions has increased recently, and the appetite for mergers and takeovers within the semiconductor industry is expected to continue,

Power semiconductor companies can look forward to an environment of continued merger & acquisition activity, customers demanding improved energy efficiency, and exciting new technologies and products

notes Eden. For power semiconductors, the biggest story of 2014 was Infineon's purchase of International Rectifier (IR). The deal completed in January, so the PCIM show was the first time in Europe that the combined power portfolio of Infineon and International Rectifier was presented as one company.

At the event, there was a lot of discussion surrounding the recent \$40bn merger of Netherlands-based NXP Semiconductors and US-based Freescale Semiconductor. NXP already supplies discrete power semiconductors to the automotive sector, so combining this strength with Freescale's significant presence in automotive micro-controllers should increase the merged company's penetration in that market, reckons IHS.

Conclusions from PCIM

Until 2008 the power semiconductor market grew at about 8% each year, but that is no longer the case following the global financial crisis. The overall long-term market growth projection for the next five years has slowed to about 5% per year, according to IHS. The key factors causing this reduced optimism are the general global macro-economic conditions, the weaker Chinese economy, concerns about the Euro-zone countries' prospects, and the Euro-to-dollar exchange rate, notes the firm.

In summary, power semiconductor companies can look forward to an environment of continued merger & acquisition activity, customers demanding improved energy efficiency, and exciting new technologies and products, reckons IHS Technology. However, as long as the need exists to convert electric power into useful work with increasing efficiency, the power semiconductor market will continue to grow, the firm concludes.

www.ihs.com

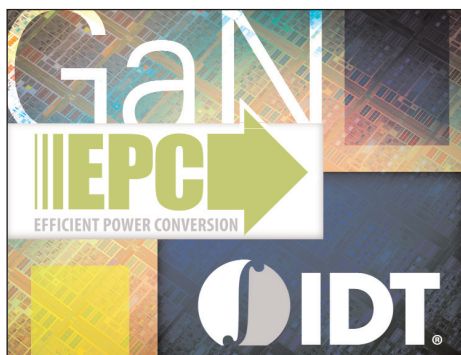
www.mesago.de/en/PCIM/main.htm

IDT teams with EPC to integrate GaN and silicon for faster, higher-efficiency devices

Partners to co-develop technology for wireless power, RF, and communications & computing infrastructure

Integrated Device Technology Inc (IDT) of San Jose, CA, USA is collaborating with 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, to explore integrating EPC's eGaN technology with IDT's mixed-signal system-level solutions. "GaN offers exciting opportunities to develop higher-performance, differentiated products for our customers"

"GaN offers exciting opportunities to develop higher-performance, differentiated products," says Sailesh Chittipeddi, vice president, Global Operations & chief technology officer at IDT. "EPC's leadership in GaN-based power management technology made them the obvious choice to team with, and I look forward to exploring how GaN-based products — with all their inherent benefits — may be brought to market in the not-so-distant future," he adds.



The three areas in which the firms are collaborating are as follows:

● **Communications and computing infrastructure** — GaN's low capacitance and zero QRR coupled with the low inductance of its chip-scale package result in high efficiency at high frequency. It is intended that this increase in efficiency will combine with IDT's commutation and system expertise to drive up power density and deliver advantages to communications and computing infrastructures.

● **Wireless power** — The highly resonant wireless power transfer standard of the Alliance for Wireless Power (A4WP) consortium protocol

operates at 6.78MHz, where the high-speed, low-loss switching ability of GaN drives efficiency to the levels of wired solutions. Combining EPC's GaN expertise and IDT's precision solutions is aimed at delivering a highly efficient, cost-competitive solution that drives widespread adoption of wireless power.

● Radio frequency (RF) —

The two firms will explore collaborating on creating a portfolio of RF products for the communications infrastructure market.

"A growing number of innovative companies, such as IDT, are integrating proven GaN technology into their solutions as a way to move beyond the limitations of silicon," comments EPC's CEO & co-founder Alex Lidow. "Our team looks forward to working alongside IDT engineers to bring the exceptional speed and efficiency of EPC's GaN technology to IDT customers," he adds.

www.IDT.com

www.epc-co.com

Wide-pitch eGaN FET family expanded with 40V, 60V, 100V versions

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 launched three eGaN FETs designed with a wider-pitch connection layout.

The products expand EPC's family of 'Relaxed Pitch' devices featuring a 1mm ball pitch. The wider pitch allows the placement of additional and larger vias under the device to enable high current-carrying capability, despite the device's extremely small 2.6mm x 4.6mm footprint.

Specifically, the new eGaN power transistors extend EPC's portfolio with a high-performance, wider-pitch chip-scale package for ease of high-volume manufacturing and enhanced compatibility with mature manufacturing processes and assembly lines.

The EPC2030 has a drain voltage of V_{DS} 40V, typical on-resistance $R_{DS(on)}$ of 1.8m Ω , typical gate charge of Q_G of 18nC, and pulsed drain current I_D of 495A. The EPC2031 has V_{DS} 60V, $R_{DS(on)}$ of 2.0m Ω , Q_G of 17nC, and I_D of 450A. The EPC2032 has V_{DS} 100V, $R_{DS(on)}$ of 3.0m Ω , Q_G of 14nC, and I_D of 300A.

Compared to a state-of-the-art silicon power MOSFET with similar on-resistance, the new products are much smaller and have many times superior switching performance, claims EPC. They are suitable for applications such as high-frequency DC-DC converters, synchronous rectification in DC/DC and AC/DC converters, motor drives, and class-D audio.

Pricing is \$3.46 for the EPC2030, \$3.48 for the EPC2031 and \$3.52 for the EPC2032, each in 1000-unit quantities. All three are available for delivery from Digi-Key. <http://digikey.com/Suppliers/us/Efficient-Power-Conversion.page>

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GaN Systems raises \$20m in Series C financing

Power-switching transistor maker to ramp up sales & marketing and continue expansion of manufacturing line

GaN Systems Inc of Ottawa, Ontario, Canada, a fabless developer of gallium nitride (GaN)-based power switching transistors based on its proprietary Island Technology for power conversion and control applications, has raised US\$20m in a Series C round of financing led by Canadian venture capital fund Cycle Capital Management and joined by BDC Capital and Beijing-based Tsing Capital as well as existing investors Chrysalix Energy Venture Capital and RockPort Capital. The firm says that, as its customers launch multiple consumer and enterprise products designed with its GaN transistors, the financing will enable it to ramp up sales and marketing support for its rapidly growing international customer base and to continue expansion of its manufacturing line.

With GaN-based transistors increasingly poised to disrupt the \$15bn power transistor market, the firm says that its Island Technology results in devices that are smaller

and more efficient than traditional silicon design approaches, adding that its products enable switching efficiencies that lead to more sustainable energy use and increased power efficiency while reducing costs and environmental impacts of some of the world's fastest growing industries. GaN Systems' power electronics transistors can be used for applications ranging from more efficient data centers and solar inverters to thinner TVs, smaller more powerful motors, longer-range electric vehicles (EVs), and other consumer, enterprise, industrial and transportation applications.

China represents one of the largest and fastest-growing markets for power electronics globally... we look forward to helping support GaN Systems' expansion and product delivery

"This deal was led by Cycle Capital's managing partner Claude Vachet and our semiconductor seasoned investment team," says Cycle Capital's founder & managing partner Andr  e-Lise M  thot.

"With a long history of cleantech venture capital investing in China, we are pleased to add GaN Systems to our portfolio of energy efficiency companies," comments Michael Li, managing partner at Tsing Capital (a global investor in environment and cleantech firms, founded in 2001). "China represents one of the largest and fastest-growing markets for power electronics globally, and we look forward to helping support GaN Systems' expansion and product delivery," he adds.

The diverse group of investors will collectively provide "critical financing, strategic advice, and additional entry points into growth markets," believes GaN Systems' CEO Jim Witham.

www.cyclecapital.com

GaN Systems appoints vice president of operations

GaN Systems has appointed Stephen Coates as VP operations. The newly created post is part of the firm's planned increase in headcount at all levels as it ramps up production of its GaN devices to supply global demand from design engineers.

Coates will be responsible for implementing world-class systems and procedures to handle the firm's rapid growth in shipments and production test data, and establishing a local supply chain management presence in the Far East.

He joins GaN Systems from DigiLens, where he was head of manufacturing. With over 25 years' experience as a technology executive in engineering, manufacturing operations and supply chain man-

agement, Coates has held executive posts with leading optical components and systems companies and power/HV semiconductor fabrication and packaging organizations, including VP operations at Virtuality/SBG Labs, VP operations at Symmorphix Thin Films Inc, VP operations with Fultec Semiconductor Inc/Bourns, and VP production engineering at MaxQ Technology, heading up power module development.

"He brings with him substantial experience in establishing and developing strategic supply chain relationships to support full product commercialization and high-volume manufacturing, while also being an expert in device packaging and integration," comments

GaN Systems' president Girvan Patterson. "His role is a key one as GaN technology and our Island Technology devices become the de facto choice of engineers looking to integrate smaller, lighter and more efficient power electronics into numerous industrial, consumer and automotive applications," he adds.

Coates has an honours degree in Electrical and Electronics Engineering from Nottingham (Trent) University, where he also was engaged as a post-graduate implementing Manufacturing Excellence within the Hawker Siddeley Power Generation, Transmission and Switchgear Groups. He has several patents granted and pending.

www.gansystems.com

MACOM launches fourth-generation GaN technology

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 its fourth generation of gallium nitride on silicon (GaN-on-Si) technology.

Delivering performance that is said to rival more expensive GaN on silicon carbide (GaN-on-SiC) at a projected volume-production cost structure below that of incumbent LDMOS technology, fourth-generation GaN (Gen4 GaN) is targeted at breaking the final technical and commercial barriers to mainstream GaN adoption. Gen4 GaN performance was on display at the IEEE MTT-S International Microwave Symposium (IMS 2015) in Phoenix, AZ (19–21 May).

Gen4 GaN 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. This performance is expected to yield GaN-based devices that are half the semiconductor cost per watt of comparable LDMOS products and much lower-cost than comparably performing GaN on SiC wafers at volume production levels.

MACOM says that Gen4 GaN extends the commercialization trajectories of earlier generations of GaN-on-Si, which have demonstrated field-proven reliability in harsh environmental conditions.

To date, more than 1 million devices have been operating for as long as five years in demanding military applications in Iraq and Afghanistan.

"Gen4 will unlock the full promise of GaN for mainstream commercial applications," believes president & CEO John Croteau. "We expect its impact on the RF & microwave industry will be transformative," he adds. "Our GaN IP portfolio and strategic licensing agreements set the foundation for a sustainable, cost-efficient technology and supply-chain model enabling GaN production at unprecedented economies of scale."

Gen4 GaN-based devices are sampling to customers and are expected to enter high-volume production in 2016.

www.macom.com/gan

MACOM adds wideband GaN-on-Si power transistor for CW, pulsed and linear operation up to 100W

At IMS 2015, MACOM launched the NPT2022, a wideband transistor optimized for DC–2GHz operation and fabricated using a proprietary GaN-on-Si process. "The technical performance of MACOM's NPT2022 complements our expanding GaN portfolio, which offers the industry the best performance, gain, efficiency and low cost products available on the market."

The NPT2022 supports continuous-wave (CW), pulsed and linear operation, with output levels up to 100W (50dBm). The device provides 20dB of gain and 60% drain efficiency at 900MHz when operated at 50V. The depletion-mode (D-mode) high-electron-mobility transistor (HEMT) is available in an industry-standard plastic package with bolt-down flange. The

NPT2022 is suitable for defense communications, land mobile radio, avionics, wireless infrastructure, industrial, scientific & medical (ISM) applications and VHF/UHF/L/S-band radar.

Production quantities and samples of the NPT2022 are available from stock.

www.macom.com/products/product-detail/NPT2022

MACOM adds GaN power amplifier for narrowband to broadband applications

At IMS 2015, MACOM launched the NPA1006, a gallium nitride wide-band power amplifier optimized for 20–1000MHz frequency operation. The GaN-on-silicon depletion-mode (D-mode) HEMT amplifier is suitable for narrowband to broadband applications spanning test & measurement, defense communications, land mobile radio and wireless infrastructure.

The NPA1006 is designed for saturated and linear operation, featuring

output levels up to 12.5W (41dBm). It has 50Ω input matched and output unmatched, 28V operation and 14dB gain. The device also provides 65% drain efficiency at 900MHz. Saturated output power (P_{SAT}) is 24.

MACOM aims to lower the barriers to mainstream GaN adoption by delivering superior technical performance products below LDMOS silicon cost structures. "With our Gen 1 and Gen 2 products fully

qualified and millions of units in the field, we are excited to continue leveraging our global design resources and deep GaN application experience to offer the industry the best performance, gain, efficiency and low-cost products with our new Gen 4 technology," says senior product director Gary Lopes.

Production quantities and samples of the NPA1006 are available from stock.

www.macom.com/products/product-detail/NPA1006

Raytheon completes milestones on path to production-ready GaN-based AESA Patriot radar

Raytheon Company of Waltham, MA, USA recently completed a series of milestones, bringing the combat-proven Patriot Air and Missile Defense System with 360° of coverage one step closer to production readiness.

The milestones involve upgrading the Patriot's radar main array with gallium nitride (GaN)-based active electronically scanned array (AESA) technology. Completion of those milestones keeps Raytheon engineers, who are currently building a GaN-based AESA full-size main panel radar array, on track to having the system up and running in early 2016.

"A GaN-based AESA radar benefits netted sensors, and gives Patriot greater capability and reliability while significantly reducing operations and sustainment cost," says Ralph Acaba, VP of Integrated Air & Missile Defense at Raytheon's Integrated Defense Systems business in Tewksbury, MA. "Raytheon recognizes how important this

capability is for the warfighter and is investing its own resources to bring Patriot's GaN-based AESA radar to the point where it can enter engineering and manufacturing development with low risk," he adds.

The main AESA array is a bolt-on replacement antenna that measures about 9' wide x 13' tall, which is oriented toward the primary threat. Patriot's new rear-panel arrays (which are a quarter the size of the main array) let the system look behind and to the sides of the main array, enabling Patriot to engage threats in all directions. Earlier this year, Raytheon built a GaN-based AESA Patriot rear-panel array, integrated it with the current Patriot radar using the existing, recently modernized, back-end processing hardware and software, and tracked targets of opportunity to seamlessly create a 360° view.

The milestones accomplished to date include fabricating the main radar array's superstructure, and

completing development work on the power and cooling sub-systems. In the months ahead, additional upgrades will focus on integrating the sub-systems and populating the array superstructure with GaN-based transmit-receive units (TRLRU). The GaN TRLRUs are the heart of the radar and are identical to those used for the rear-panel arrays, and are made in the same Massachusetts-based GaN foundry currently producing GaN chips for Navy and Air Force defensive systems.

The GaN-based AESA Patriot radar will work with an open-architecture common command and control (CC2) node and retains backwards compatibility with the current Patriot Engagement Control Station. The CC2 node will be fully interoperable with NATO and the Integrated Air and Missile Defense Battle Command System.

www.raytheon.com/capabilities/products/patriot

AKHAN opens new manufacturing facility

AKHAN Semiconductor Inc of Chicago, IL, USA has begun operations at a new manufacturing facility in Gurnee, Lake County, IL, which has been opened to expand its diamond semiconductor production. AKHAN also plans to create and expand community partnerships with the College of Lake County and Argonne National Laboratory.

AKHAN Semiconductor Inc was formed in 2012 as a subsidiary of AKHAN Technologies Inc, which was founded in 2007 by Adam Khan to commercialize Diamond Lattice Technology for diamond-based semiconductor devices.

"AKHAN SEMI represents a great step forward for our district, both in scientific advancement and economic development," said congressman Randy Hultgren (the US Representative for Illinois'



Founder & CEO Adam Khan addressing the Gurnee Village Board.

14th congressional district). "Their work is a prime example of the power and promise of taking the impressive discoveries that are being made at Argonne and other national labs and bringing them to the marketplace," he adds. "The Incubator partnership with the

College of Lake County to develop hands-on training for students pursuing tech careers is just one of the many incredible programs which AKHAN SEMI brings to the 14th."

It is reckoned that AKHAN SEMI's work with diamond-based electronics and manufacturing will help to develop new industry standards and new commercial ventures.

Starting in June, AKHAN Semi is also beginning the process of commercializing its research and patents as part of its partnership with Argonne. The partnership has also led to the development of a vocational training program, which provides education and the necessary skills for individuals to begin work in the STEM (science, technology, engineering and mathematics) fields.

www.akhantech.com

Transphorm receives \$70m investment led by KKR

Transphorm Inc of Goleta, near Santa Barbara, CA, USA (which designs and provides gallium nitride-based power conversion devices and modules) has announced a \$70m investment round led by global investment firm KKR. This follows initial funding rounds led by funds affiliated with Kleiner Perkins Caufield and Byers, Foundation Capital, Google Ventures, Soros Quantum Strategic Partners, INCI and Fujitsu. Transphorm will use the latest funding to support its growth, product innovation and expansion.

"Transphorm was launched to address the urgent and important problem of losses in power conversion," says chairman Dr Umesh Mishra. "By merging the technological leadership of Transphorm with the semiconductor business expertise of KKR, we are taking a major step forward in solving the global problem of energy wasted in power conversion," he claims.

Transphorm believes that there is a large market for its products as its ultra-efficient power devices and modules can eliminate more than 40% of all electric conversion losses by using gallium nitride.

Transphorm's products have a power efficiency of up to 98% in data centers and telecom applications, resulting in energy savings of over

10GWh annually in a typical data center (equivalent to the annual electricity usage of 1000 typical US homes), it is reckoned. In addition to solar photovoltaic (PV) inverters and data centers, other applications include power supplies, motor drives and automotive systems.

Manufacturers are now producing what are reckoned to be the world's smallest PV inverters by leveraging Transphorm's technology.

Transphorm has established strategic partnerships with customers and suppliers including motion control, robotics and systems engineering firm Yaskawa Electric Corp, which earlier this year used Transphorm's GaN technology to power what is said to be the first GaN-based commercially produced PV inverter launched on the Japan market. Transphorm's products enable approximately 50% smaller PV inverters in residential and small commercial installations up to 5kW, resulting in lower system, installation and service costs while delivering more energy per solar panel to the grid, it is claimed. Tata Power Solar (India's leading power conversion player) has also teamed with Transphorm to develop PV inverters. To provide customers with volume production, Transphorm partnered with Fujitsu

Semiconductor to produce its products in Fujitsu's automotive-class wafer fabrication facility in Aizu-Wakamatsu, Japan.

"Transphorm is the only place where customers can acquire reliable, production-volume GaN products that meet or exceed required performance specs for commercial products," says KKR's senior advisor David Kerko. "Long term, we believe this has the potential to replace all of the existing silicon-based technology used in high-voltage products, and wide adoption of this technology will dramatically reduce the amount of energy that is wasted by electric devices."

For KKR, the investment is part of the firm's growth equity strategy, which is focused on market-leading, high-growth companies for which it can be a unique partner in helping to reach scale and the next level of growth. The firm is funding the investment from the balance sheet of KKR & Co LP.

As part of the transaction, KKR's David Kerko, Brittany Bagley and Eiji Yatagawa will join Transphorm's board of directors, and KKR has also nominated semiconductor industry veterans Mario Rivas (former president & CEO of Anadigics Inc) and Michael White to the board.

www.transphormusa.com

Diamond Microwave adds 100W X-band SSPA

Diamond Microwave Devices Ltd of Leeds, UK (which was spun out in 2006 from the diamond electronics team of Element Six and specializes in high-performance microwave power amplifiers) has re-designed its range of gallium nitride (GaN)-based solid-state power amplifiers (SSPAs) into a new common module format and has added a new X-band model that can be operated in either pulsed or continuous-wave mode.

On show at the 2015 IEEE MTT-S International Microwave Symposium in May, the DMX10001 is an ultra-compact amplifier with 100W out-

put, operating over a 1700MHz bandwidth centred at 8.5GHz.

"At the same time the full range has been re-packaged into a new common module format," says managing director Richard Lang. "These amplifiers are extremely compact, the core microwave assembly being a chip-and-wire design in a slim, low-profile housing. If size is important, we can supply amplifiers without an enclosure, for significantly tighter integration into a microwave sub-system," he adds. "They can also be tailored to suit other frequency ranges in the

1–18GHz range."

The firm now offers SSPAs operating at 2–6GHz (DM-SC80-01), 7.65–9.35GHz (DM-X100-01) and 16.3–17.3GHz (DM-K100-01). The amplifier designs are flexible in layout and architecture, and are fully customizable to meet individual specifications for electrical, mechanical and environmental parameters. All of Diamond Microwave's amplifiers are suitable for use in demanding defence, aerospace and communications applications.

www.diamonddmw.com

Northrop Grumman reports highest-power single-chip Ka-band power amplifier

40W 27–30GHz MMIC made using process being matured through Title III GaN Producibility Program

At the 2015 IEEE MTT-S International Microwave Symposium (IMS) in Phoenix, AZ, in May, Northrop Grumman Corp of Redondo Beach, CA, USA presented what it claims is the highest-power gallium nitride (GaN) monolithic microwave integrated circuit (MMIC) power amplifier ever produced operating at Ka-band frequencies ('High Power and High Efficiency Ka-band Power Amplifier' by Salah Din).

With a peak power of 40W at 27GHz, the 27–30GHz amplifier has an average output power of 36W and a power-added efficiency (PAE) of more than 30% across the band. The MMIC area is a compact 13.5mm², establishing what is reckoned to be a new standard of performance achieved by a single MMIC.

The new 40W circuit was manufactured using the same process

that is being matured through the firm's participation in the US Air Force Research Laboratory (AFRL) Gallium Nitride on Silicon Carbide (GaN on SiC) Advanced EW (Electronic Warfare) Monolithic Microwave Integrated Circuit (MMIC) Production Capacity program (GaN Producibility Program), an initiative funded under Title III of the Defense Procurement Act. The program seeks to establish a domestic, economically viable, open-foundry merchant supplier production capability for Ka-band GaN MMICs.

"This is a big breakthrough for the industry because it will help lead the way to the widespread commercial availability of cost-effective Ka-band GaN components with output powers exceeding 25W," reckons Frank Kropschot, general manager, Microelectronics Products

and Services, Northrop Grumman. "The commercial availability of high-frequency, high-power components will greatly reduce the cost and number of parts needed for communications equipment, making higher data rates and longer-distance communication links more easily obtainable," he adds.

"Designing this circuit was challenging because we aimed for a very small footprint for the amplifier and still had to give consideration to thermal concerns," says Mansoor Siddiqui, a co-author of the paper (along with Mike Wojtowicz). "We managed to minimize output loss while achieving a good 18dB load match in a small area," he adds. "The PAE we have attained establishes a high mark while delivering 35–40W at Ka-band."

www.northropgrumman.com
www.ims2015.org

Northrop Grumman showcases manufacturing advances at IMS, CS ManTech and ROCS

Northrop Grumman Corp of Redondo Beach, CA, USA participated in three conventions in the Phoenix, Arizona area during the week 18–21 May, focused on microwave and semiconductor technology: the IEEE MTT-S International Microwave Symposium (IMS 2015), the International Conference on Compound Semiconductor Manufacturing Technology (CS ManTech 2015), and the 2015 Reliability of Compound Semiconductors (ROCS) workshop.

At all three, Northrop Grumman highlighted its expertise in microelectronics innovation and transitioning new technology to demanding, high-performance communications applications.

"Advancements in compound semiconductor technology have a significant impact on global security and communications markets, affecting a broad range of products from radar systems to satellite systems to mobile devices," says Frank Kropschot, general manager, Microelectronics Products and Services, Northrop Grumman.

Throughout the week, Northrop Grumman presented several papers, including a summary of the highest output power ever achieved from a single-chip Ka-band gallium nitride (GaN) monolithic microwave integrated circuit (MMIC) power amplifier that peaked at 40W at 27GHz, demonstrating a significant advance over existing published results, says the firm.

At IMS, Northrop Grumman sponsored the Student Awards Luncheon, honoring the winners of 16 different design competitions. The firm was also a platinum corporate sponsor for CS ManTech, and had technical leaders in both the Executive Committee and Technical Program Committees.

Northrop Grumman also presented several new semiconductor products, including high-power amplifiers covering X-band, Ku-band and Ka-band.

Limited engineering prototype samples are available from stock to qualified customers by e-mailing MPS at mas-mps.sales@ngc.com.
www.northropgrumman.com/mps
www.ims2015.org
www.csmantech.org
www.jedec.org/home/gaas

Freescall launches its first GaN RF power transistor for cellular base-stations

RF power transistors supplier Freescale Semiconductor of Austin, TX, USA has introduced its first gallium nitride (GaN) RF power transistor for cellular base-stations — the A2G22S160-01S for 30W and 40W amplifiers in wireless infrastructure applications — representing the first of what is planned to become a broad portfolio of Airfast family GaN transistors for the cellular market.

The addition of GaN RF solutions expanded Freescale's portfolio of products for wireless infrastructure markets. The launch follows the introduction just last December of the MMRF5014H — Freescale's first GaN RF power transistor for military and industrial applications, which offers thermal and wideband RF performance for 100W-class GaN transistors.

Freescale is aiming to drive the transition of GaN from niche markets to mainstream applications such as cellular infrastructure, says Paul

Hart, senior VP & general manager of Freescale's RF business. "The time is right to deliver GaN solutions to our extremely broad base of telecommunications customers," he adds, citing Freescale's high-volume production capability and global customer support.

Due to its wider bandgap, higher critical electric field and very high-electron-mobility characteristics, GaN delivers higher power conversion efficiencies, faster switching speeds and greater power densities than silicon, enabling the creation of power transistors that are much smaller in size and that outperform traditional devices. While GaN migration has been cost prohibitive in the past, recent commercial and technological advances are driving manufacturing costs lower. Freescale aims to apply the advantages of GaN to some of the biggest markets in the world and enable a large-scale rollout of GaN power amplifiers in main-

stream commercial base-station markets.

Freescale's Airfast family of RF power products covers the entire range of wireless cellular spectrum from 600MHz to 3.8GHz, with multiple semiconductor technology options. The A2G22S160-01S has a frequency range of 1800–2200MHz. For example, in a 40W Doherty two-way asymmetrical amplifier employing one A2G22S160-01S in the carrier path and two in the peaking path, maximum output power is 56.2dBm. With 8dB output back-off (OBO), gain is 15.4dB and efficiency is 56.7%. Adjacent-channel power (ACP) is –55dBc with digital pre-distortion (DPD) when driven by two 20MHz LTE carriers with an aggregate 40MHz carrier bandwidth.

The A2G22S160-01S GaN RF power transistor is in production now, with reference designs and other enablement solutions available.

www.freescale.com

Ultra-wideband RF power GaN transistors in plastic packages

Freescale Semiconductor has launched two ultra-wideband RF power gallium nitride (GaN) transistors in new plastic packages.

"The industry-leading bandwidth of these two products will enable our customers to replace two or even three separate RF PAs [power amplifiers] with a single RF lineup, vastly reducing system cost," reckons Paul Hart, senior VP & general manager of Freescale's RF business. "In addition, the devices' ultra-low thermal resistance will allow customers to reduce the cost of their cooling systems, or run at full CW-rated power to much higher case temperatures," he adds.

Offered in two-lead and eight-lead configurations, the new OM-270 package extends Freescale's proprietary OMNI RF plastic packaging technology to the smallest

outline yet, and adds compatibility with GaN.

"We have innovated the capability to metalurgically bond our GaN-on-SiC chips to copper flanges, and over-mold them to enable unprecedented thermal performance," says Mali Mahalingam, Freescale fellow & head of RF package development. "In addition, this new package platform supports complex internal matching schemes that enable superior broadband performance."

Freescale's first two plastic RF power GaN transistors to employ the new packaging technology are:

● MMRF5015N: a 100W, 50V, true CW ultra-wideband GaN transistor suitable for high-power military and civil communication systems. Thermal resistance is less than 0.8°C/W (a >30% improvement

over competing products, it is said). The MMRF5015N is sampling now in an evaluation fixture demonstrating what is claimed to be an unprecedented 200–2500MHz bandwidth with a minimum of 12dB gain and 40% efficiency over the entire band.

● MMRF5011N: a 10W, 28V, true CW ultra-wideband transistor, demonstrating 200–2600MHz bandwidth in an available applications circuit. Suited to lower-power military and civil handheld radio communications devices, the MMRF5011 is sampling now.

Freescale demonstrated the transistors at the IEEE MTT-S International Microwave Symposium (IMS).

Planned for volume production in third-quarter 2015, both products are included in Freescale's Product Longevity Program, as are all products in the RF Military portfolio.

Exagan raises €5.7m to produce GaN-on-Si power-switching devices on 200mm wafers

Leti/Soitec spin-off to become European source of devices for solar, automotive, telecoms and infrastructure

Exagan of Grenoble, France, a gallium nitride (GaN) technology start-up that enables smaller and more efficient electrical converters, has raised €5.7m in first-round financing that will be used to produce high-speed power switching devices on 200mm wafers.

The investors include French venture funds with a record of identifying and fostering promising, fast-growth, early-stage technology companies: Technocom2 (managed by French venture capital firm Innovacom); CM-CIC Innovation (the investment arm of European bank group Crédit Mutuel-CIC Group); IRDInov (a regional seed investor in emerging, fast-growth companies); CEA investissement (a manager of funds invested in technology companies, and which invested via the CEA strategic fund); and Soitec (which provides semiconductor materials).

Based in Grenoble (with a branch office in Toulouse), Exagan was spun off from CEA-Leti and Soitec in 2014 (with financial support from each), and licenses materials and technology from both organizations. Exagan aims to accelerate the power-electronics industry's transition from silicon-based technology to smaller and more efficient electrical converters based on GaN-on-silicon technology. Its GaN power switches are designed to be compatible with manufacturing in standard 200mm-wafer silicon foundries in order to provide high-performance, high-reliability products through a robust supply chain.

Following Exagan's announcement in May of an agreement with X-FAB Silicon Foundries AG of Erfurt, Germany to produce devices on 200mm wafers, the financing will help to support Exagan's aim of becoming Europe's primary sup-

plier of GaN-based power switches for the solar, automotive and IT electronics markets. That aim includes its strategic partnership with CEA-Leti, which is developing applications with some of its industrial partners based on Exagan's G-FET 650V platform and its very high power-switching performance and extremely low conduction losses (enabling what is claimed to be unprecedented power integration and efficiency levels).

Power integration is key to meeting the growing demand for less expensive and more efficient electrical converters that silicon power devices cannot meet, says Exagan. In contrast, the material properties of GaN devices offer promising power-integration and efficiency gains that deliver higher power density and switching speed at the device level.

"This significant first round of financing validates our efforts over the past five years with Leti and Soitec to commercialize GaN-on-Si technology and supports our commitment to provide customers with qualified GaN devices in large volumes," says Exagan's CEO & co-founder Frédéric

Dupont. "We are focused on offering our customers reliable, high-performance devices that are developed with industrial partners already sourcing technologies or products for the targeted markets," he adds.

"Their GaN-on-silicon technology, which leverages our own materials expertise, opens very interesting opportunities in promising markets such as electronics, automotive and energy," notes Soitec's CEO Paul Boudre. "Exagan is well positioned to drive innovation in power switching technology, due to its location in Grenoble among the strong mix of innovative companies and technology-integration clusters," he adds.

"Based on our experience with the automotive and aerospace industries, we are convinced of the potential markets for GaN power electronic devices," notes IRDInov's managing director Jean-Michel Petit. "This is all the more reason to further develop its presence in Toulouse, which has a concentration of competencies in power-electronics applications and many potential future clients."

Leti has invested many years in developing GaN technologies because it believes they will drive innovation in the power-electronics industry and accelerate development of sustainable-energy technologies, says Leti's CEO Marie Semeria, who regards Exagan as a European source of new GaN power switches for key industrial partners in transportation and energy as well as broader markets. "Through our partnership with Exagan, Leti will accelerate its investment in this area to further develop our leading expertise in GaN technology and related systems and applications," says Semeria.

www.exagan.com

Based on our experience with the automotive and aerospace industries, we are convinced of the potential markets for GaN power electronic devices... reason to further develop its presence in Toulouse, which has a concentration of competencies in power-electronics applications and many potential future clients

Silicon foundry X-FAB and Exagan to co-develop high-volume production of high-speed GaN-on-Si power switching devices on 200mm wafers

GaN start-up aims to increase manufacturability and reduce costs for highly efficient power switches

X-FAB Silicon Foundries AG of Erfurt, Germany and Exagan of Grenoble and Toulouse, France have entered into a joint development agreement to industrialize Exagan's GaN-on-silicon technology, begin producing high-speed power switching devices on 200mm wafers, and establish a European production center where the two partner companies will manufacture GaN devices for the solar, industrial, automotive, IT electronics and other markets.

Founded in 2014 with support from CEA-Leti and Soitec, Exagan aims to accelerate the power-electronics industry's transition from silicon-based technology to GaN-on-silicon technology, enabling smaller and more efficient electrical converters. Its GaN power switches are designed for manufacturing in standard 200mm wafer fabs to provide high-performance, high-reliability products through a robust supply chain.

Exagan and X-FAB have already begun to demonstrate their capabilities by processing the first GaN-on-silicon devices built on 200mm substrates at X-FAB's wafer fab in Dresden, Germany, and are now transforming that prototype into a process robust enough for the mass-production environment.

Working with CEA-Leti in Grenoble, where some process steps are performed, X-FAB and Exagan are manufacturing the first of Exagan's G-FET 650V, fast-switching power devices on 200mm substrates using a standard silicon manufacturing line. To date, the semiconductor industry's work with GaN has been limited to 100mm and 150mm wafers due to the challenges of creating the required GaN layers on silicon substrates, says Exagan. Without the ability to use larger wafers in mass production, GaN-based semiconductors have not been available at a competitive price-performance point compared to other power-switching alternatives, it adds. The global market for GaN-based semiconductors is forecast to grow to 25-fold to \$600m by 2020, according to market research firm Yole Développement.

Exagan says that its G-Stack technology enables GaN-on-Si devices to be manufactured economically on 200mm substrates by depositing a unique stack of GaN and strain management layers that alleviates the stress between bonded GaN and silicon layers. The resulting G-FET devices meet requirements for high breakdown voltage, low vertical leakage and high-temperature operation, the firm adds. These devices also allow greater

power integration, which improves the efficiency and reduces the cost of electrical converters.

"Our strategic partnership with X-FAB is the latest step in establishing a robust supply chain capable of providing customers with qualified GaN devices in large volumes for demanding applications," says president & CEO Frédéric Dupont. "The industry has long acknowledged the performance and efficiency advantages of GaN devices. We are now driving GaN market penetration to the next level by providing these devices at an attractive price-performance point," he reckons.

"X-FAB's leadership position as a pure-play foundry for More-than-Moore technologies is reinforced by this new alliance and our commitment to innovative manufacturing," says X-FAB's chief technology officer Dr Jens Kosch. "We are proud to support the successful industrialization of Exagan's novel technology, which we believe will have a major impact on the future of automotive and industrial markets."

Exagan was present at the PCIM (Power Conversion Intelligent Motion) Europe 2015 trade show in Nuremberg, Germany (19–21 May).

www.xfab.com

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

www.exagan.com

NI AWR Design Environment V12 now available

NI (formerly AWR Corp) of El Segundo, CA, USA has announced availability of the first major release in 2015 of NI AWR Design Environment for designers of monolithic microwave integrated circuits (MMICs), radio-frequency printed-circuit boards (RF PCBs), and mod-

ules. V12 was previewed initially at the 2015 IEEE MTT-S International Microwave Symposium (IMS) in Phoenix, Arizona, in May, yielding feedback from early-access customers.

This latest release has new load-pull and antenna- and radar-

specific features, as well as ease-of-use improvements, speed enhancements and third-party integration flows for improved stability analysis and design rule checking/layout versus schematic, notes the firm.

www.awrcorp.com/v12

AXT's revenue grows 2.5% in Q1; losses halved year-on-year GaAs revenue stabilizes as InP grows to biggest sector for first time

For first-quarter 2015, AXT Inc of Fremont, CA, USA has reported revenue of \$20.1m, up 2.5% on \$19.6m last quarter and 4% on \$19.3m a year ago.

North America comprised 17%, Asia Pacific 58% and Europe 25% of total revenue. No customer generated more than 10% of revenue; the top five generated just 35% (compared with 39% a year ago), illustrating "success in diversity of both products and customers," says chief financial officer Gary Fischer.

Despite dipping slightly from 25.4% last quarter, gross margin of 23.7% is still up on 14.1% a year ago. After rising from \$5.1m a year ago, operating expenses are up further, from \$5.6m last quarter to \$6.5m, due largely to a doubling (from \$0.6m to \$1.2m) in legal and professional fees from an internal investigation by an audit committee of certain potential related-party transactions (completed in February). SG&A expenses were \$5.3m, up from \$4.3m last quarter.

Net loss was \$1m (\$0.03 per diluted share), up from \$311,000 (\$0.01 per diluted share) last quarter but halved from \$2m (\$0.06 per diluted share) a year ago.

Depreciation and amortization was \$1.4m and CapEx was \$773,000. AXT also used \$617,000 in cash to repurchase stock.

During the quarter, cash and investments hence fell slightly from \$48.9m to \$47.5m.

"As a result of major changes in our business over the last two years, the revenue composition of AXT looks very different today than it did three years ago, now more equally spread among our five product groups, including semi-insulating and semi-conducting gallium arsenide substrates, indium phosphide substrates, germanium substrates and our raw material joint ventures," says CEO Morris Young. "Each diversity has helped AXT mitigate some of the challenges we have experienced and provides

exciting opportunities in a number of emerging applications for our products," he adds.

"For the first time in AXT's history, InP sales in Q1 now outpaced semi-insulating and semi-conducting GaAs and Ge substrates, showing healthy growth from the prior quarter," says Young. "We have been investing in InP substrate for some time. During 2014, we began to see real world in both new and existing applications, including fiber-optic lasers, detectors, solar applications and data-center connectivity," he adds. For example, fiber-to-the-home (FTTH) network demand is actively occurring across the Asia-Pacific region, Singapore and Taiwan, which are nearly completing nationwide fiber networks, while network deployment is in the earlier stage in countries such as Australia, New Zealand and China. In China alone, the plan is to have 200 million homes connected by the end of 2015.

During Q1, semi-insulating GaAs was AXT's second largest subsidiary contributor. "Mobile phones continue to use this material in their power amplifier function as do a number of applications outside of mobile, such as radar, defense and WiFi. We continue to apply resources to gain market share in all of these areas and hope to drive renewed growth this year," says Young.

"In semiconducting GaAs, the fierce competitive landscape changes and general weakness in certain geographic markets continue to be a headwind for us. We are a key player at the high-end of the market for applications such as backlighting, signage and automotive, where the application specifications are more stringent. However, we are consciously stepping away in many cases from highly competitive low-end opportunities, where pricing pressure would damage our corporate gross margin... We're taking a conservative view of the semi-conducting GaAs market in the near future.

Regarding Ge substrates, over the last few quarters the stalling of the CPV market caused a drop in sales. However, the satellite solar market has been very consistent and AXT expects a modest improvement in CPV demand this year. "Further out, SpaceX has reportedly recently received \$1bn in funding from Google and Fidelity Investments to support this plan to deliver hundreds of micro-satellites into a low orbit around the globe for wireless Internet access. This is likely to drive increased demand for Ge substrates over the next several years," says Young.

AXT had a strong quarter in Q1 for its raw material joint ventures.

"Despite the fact that pricing remains slow, we do not expect any major changes in the pricing environment in the near term, but demand is certainly growing," notes Young.

"We established our first joint venture in 1999, and since then have built our portfolio up to ten suppliers of critical materials. These joint ventures have provided us with profitable revenue and additional benefits to our vertically integrated business model. As demand continues to grow, our joint ventures will ensure that we have adequate supply for the business opportunity," he adds.

"As we move into 2015, our goal is to take advantage of developing market conditions," says Young.

"GaAs has stabilized and addresses a market with numerous applications and dynamic opportunities. InP is growing and we are investing in ways to capitalize on industry demand," he adds. "We see catalysts for growth this year in several of our target markets and believe that we continue to benefit from our unique vertical integration. Our diversified revenue base, solid competitive positioning and lower cost structure give us renewed optimism."

For Q2/2015, AXT expects revenue to rise to \$20.5–21.5m. The bottom line should be between breakeven and a \$0.01 per diluted share loss.

www.axt.com

Soitec and SITRI collaborating on high-performance RF-SOI technology for Chinese RF ecosystem

Soitec of Bernin, near Grenoble, France, which makes engineered substrates including silicon-on-insulator (SOI) wafers, and China's Shanghai Industrial μ Technology Research Institute (SITRI), which is developing and commercializing 'More than Moore' technologies for 'Internet of Things' applications, have signed a collaboration agreement focused on developing RF-SOI (silicon-on-insulator) technology using circuit designs based on Soitec's substrate materials and technologies.

The strategic partnership aims to enable both Soitec and SITRI to strengthen their place in high-growth wireless communications and the global market for radio-frequency applications, with a particular emphasis on the fast-developing Chinese RF ecosystem.



The SITRI Accelerator, which works with the IoT Shanghai Science Park.

"Experience shows that Soitec's engineered substrates can optimize RF-SOI technology and applications in terms of both cost competitiveness and power efficiency," claims Soitec's chief technical officer Carlos Mazure. "This strategic partnership will enable us to push the limits of RF circuits and meet future connectivity needs," he adds.

"Enhancing RF signal integrity is a key focus of the mobile communications industry as it builds toward

4G-LTE Advanced and 5G standards," says SITRI's president Dr Charles Yang. "We are excited to partner with Soitec in developing next-generation SOI communication solutions. It is consistent with SITRI's mission to create a collaborative R&D and commercialization environment to catalyze the growth of advanced technologies," he adds.

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Cardiff recruits UCLA's Huffaker to lead new research lab

Compound semiconductor expert appointed as new Chair in Advanced Engineering and Materials

With support from the Welsh Government's £50m Sêr Cymru program (which provides finance to bring leading research with commercial potential and research teams to Wales), Cardiff University has recruited professor Diana Huffaker, currently at the University of California, Los Angeles (UCLA), as Chair in Advanced Engineering and Materials. She will lead a new research laboratory that has the aim of turning the city into a global hub for compound semiconductor research and exploitation.

Specifically, Huffaker will establish a research lab with a focus on fundamental science and device development, building on existing strengths at Cardiff University in expanding areas of optoelectronics, semiconductor devices and materials. The lab will explore novel growth methods and material combinations that industry cannot necessarily accommodate, and will form part of the Compound Semiconductor Research Foundation — a joint venture between Cardiff University and Cardiff-based epi-wafer foundry and substrate maker IQE plc. In March, Cardiff University was awarded £17.3m by the UK Government to underpin the development of the foundation (the first of its kind in the UK) as compound semiconductors represent one of the eight technologies identified by the UK government as essential to leading the country's economic and industrial growth.

Huffaker's research focuses on the development of unique materials that aim to enable the production of new devices with new functionality. She is best known for her work developing quantum dot materials used in optoelectronics and laser physics. Graduate students from her California lab recently formed a spin-off company to commercialize research into high-sensitivity electronic receivers.



Professor Diana Huffaker.

"Diana Huffaker is a truly outstanding researcher, with a record of research excellence in areas of global impact and strategic importance not only to Cardiff University, but also to Wales," comments Cardiff University vice-chancellor professor Colin Riordan. "Securing such an eminent scientist will put Wales firmly on the map as a UK hub for semiconductor technology research and innovation," he reckons.

"The Sêr Cymru Chair in Advanced Engineering and Materials is a unique opportunity to build academic excellence around existing areas of strength within the College of Physical Sciences & Engineering through leveraging partnerships with IQE and small companies within Wales," comments Huffaker. "My research vision is to bring the promise of nanoscale physics to collect and transmit information using light with exquisite speed and

sensitivity. With the Sêr Cymru investment, I shall build an extensive user facility for materials and nanostructure synthesis not currently available in UK. To meet the needs of industry and academic collaborators, this laboratory will feature nimble flexibility to try new ideas, new material systems and growth methodology."

"Professor Huffaker is the fourth world-class researcher brought to Wales under our Sêr Cymru program [a five-year initiative to attract and support world-class scientific researchers and their teams to Wales]," notes Edwina Hart, the Welsh Government's Minister for Economy and Science. Professor Andrew Barron has been appointed as Chair of Low Carbon, Energy and Environment at Swansea University, Professor James Durrant has been appointed as Solar Energy Research Chair, also at Swansea University, while professor Yves Barde has taken up a post at Cardiff University as Research Chair in Neurobiology.

"A strong science research capability is vital to improving our economic well-being and securing a prosperous, healthy and sustainable future for Wales," she adds.

"Semiconductor technology research has the potential to drive developments across many fields including industry, health-care and communications," believes professor Julie Williams, the Welsh Government's chief scientific adviser. "Professor Huffaker's appointment will boost Wales' growing reputation in this field. A female engineer of such eminence will also be an excellent role model for young girls in Wales."



An architect's model of Cardiff University's Innovation Campus, home to the Compound Semiconductor Research Foundation.

www.hefce.ac.uk/rsrch/ukrpif
www.cardiff.ac.uk
www.iqep.com

SemiTEq launches enhanced MBE system

SemiTEq JSC of Saint-Petersburg, Russia, which designs and makes high-vacuum and ultra-high-vacuum (UHV) equipment including molecular beam epitaxy (MBE) deposition systems, has released an improved STE35 MBE system.

The STE35's basic configuration (for growing A3B5 materials on substrates with a diameter of up to 100mm) was developed in 2008. Long-term operation testing in different conditions, as well as in close cooperation with end-users, has since allowed SemiTEq to improve the STE35 system design.

The enhanced STE35 MBE system has a fundamentally new, modernized growth chamber, which resolves several key objectives.

Specifically, the firm has reduced the number of ports for supplying nitrogen. For ease of maintenance, all are now located on the lid of the chamber, combined into a single



SemiTEq's STE35 MBE system.

cryopanel to increase the efficiency of consumption of liquid nitrogen.

SemiTEq has also increased the number of ports for installing source materials, making the system more convenient to use.

Finally, the firm has enabled complete visual control over the progress of technical processes by increasing the number of viewing windows.

<http://semiteq.org>

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Veeco's Q1 shipments include \$25m of deferred revenue for new EPIK MOCVD system

MOCVD systems shipping at fastest rate since Q4/2011; guidance for full-year revenue growth raised from 30% to 35%

For first-quarter 2015, epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA has reported revenue of \$98.3m, down 13% on \$113.6m last quarter but up 8.3% on \$90.8m a year ago (and ahead of the midpoint of the \$92–100m guidance). This includes results from Solid State Equipment Holdings LLC (SSEC) of Horsham, PA, USA (now Veeco Precision Surface Processing PSP) since its acquisition for \$150m on 4 December, including \$7.9m from 3 weeks of revenue in Q4/2014.

Starting this quarter, Veeco is segmenting bookings and revenue by the following four markets: Lighting, Display & Power Electronics; Advanced Packaging, MEMS (micro-electro-mechanical systems) & RF; Scientific & Industrial; and Data Storage. "We cross-sell our products into multiple markets and believe that these end markets will give a better visibility of our business," says chief financial officer Shubham Maheshwari.

Hence, of total revenue, the Advanced Packaging, MEMS & RF segment (mainly PSP) contributed 13% (up from last quarter's \$7.9m to \$13.2m, compared with just \$0.8m a year ago).

Lighting, Display & Power Electronics markets (primarily MOCVD) contributed 66% of total revenue (\$64.3m, down 18% on \$78.4m last quarter but still up slightly on \$63.9m a year ago). However, at the beginning of this year Veeco began shipping its new TurboDisc EPIK700 metal-organic chemical vapor deposition (MOCVD) systems, including a number of which that were not recognized as revenue in Q1 (as per Veeco's usual accounting practice for new products), so actual shipments were higher than revenue. This resulted in an increase of \$25m in deferred revenue, which will

largely be recognized only during the remainder of 2015 as final sign-offs are received from customers.

Scientific & Industrial contributed 14% of total revenue (up from \$8.5m a year ago and \$11.7m last quarter to \$13.6m). Data Storage contributed 7% of total revenue (more than halving from \$17.7m a year ago and \$15.5m last quarter to \$7.2m). "The Data Storage number is much smaller than previously disclosed under the Data Storage segment, as a meaningful amount for our Ion Beam Etch and Ion Beam Deposition products are actually sold to markets like scientific, industrial, MEMS or RF," notes Maheshwari.

By region, 28% of revenue came from customers in the USA, 9% from EMEA (Europe, the Middle East & Africa), 18% from the rest of the world (including Taiwan, Japan and Korea), and 45% from China (largely related to MOCVD sales). Veeco continues to see strong demand from MOCVD customers in China that are either facing capacity constraints or anxious to monetize the government subsidies, says Maheshwari.

Gross margin was 37.7%, down from 38.5% last quarter (due to the significantly lower business volume, offsetting a positive change in product mix). However, this is roughly level with 37.8% a year ago and at the high end of the 36–38% guidance.

Operating expenses (OpEx) fell from \$38.1m last quarter to \$37.1m, despite absorbing a full quarter of expenses from PSP. "We are clearly realizing the full benefit from expense reduction activities announced mid-year in 2014, which have now been fully implemented," says Maheshwari. R&D expenses fell by \$1.2m (from \$19.2m to \$18m) due to the receipt of certain engineering credits, as well as the delay of certain project material-related expenses into Q2.

The better-than-expected gross

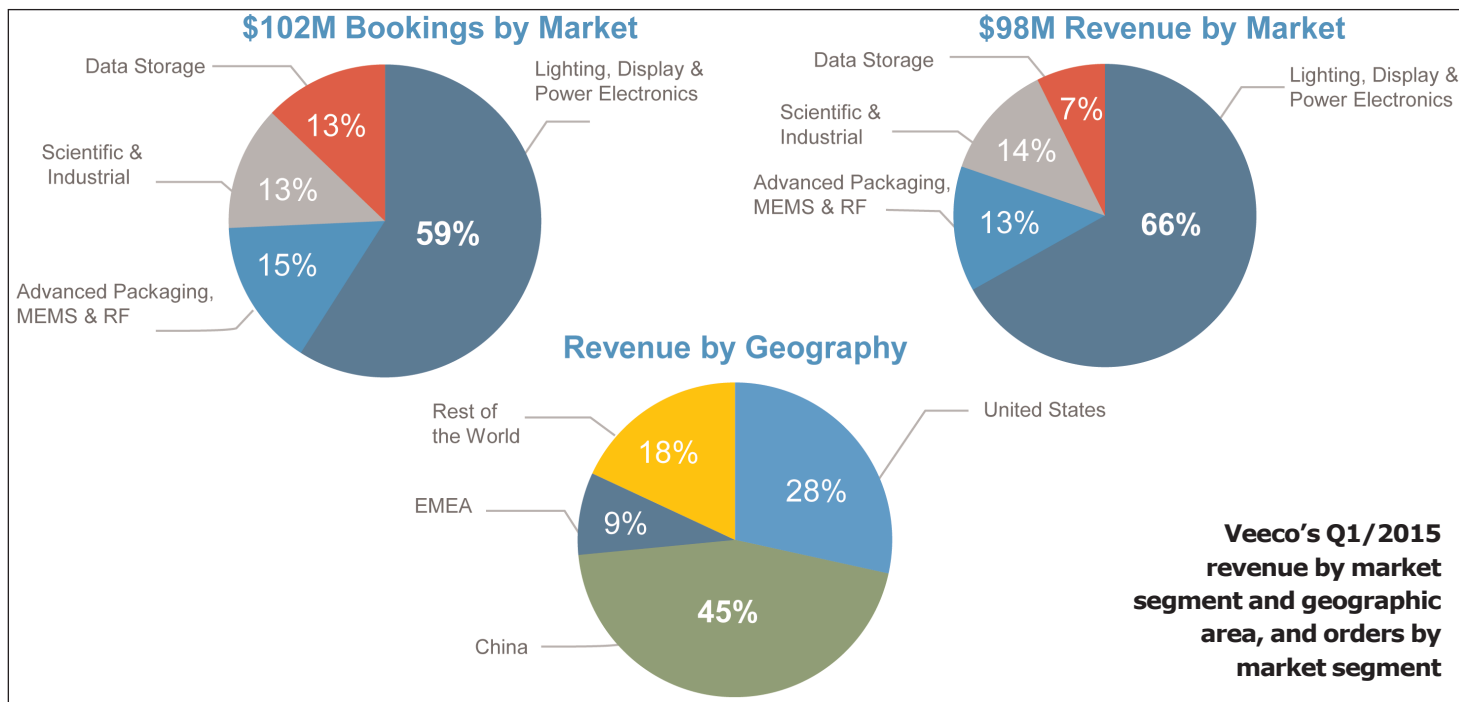
margin, combined with efficient spending controls and a lower-than-expected tax provision, contributed to net loss being cut from \$2.4m (\$0.06 per diluted share) a year ago to just \$0.5m (\$0.01 per diluted share, beating the top end of the \$0.13–0.07 guidance by \$0.06). Operating loss was \$0.1m. So, after depreciation of \$2.8m, adjusted EBITDA was \$2.7m, up from \$0.1m a year ago and exceeding guidance of \$0–2m. Cash flow from operations was \$4m. During the quarter, cash and investments rose slightly from \$391.4m to \$393m.

Following strong orders of \$196m in Q4/2014, first-quarter 2015 bookings were \$102m, near the high end of guidance. Of this, the Lighting, Display & Power Electronics (primarily MOCVD) comprised 59%, Advanced Packaging, MEMS & RF 15%, Data Storage 13%, and Scientific & Industrial 13%. Total book-to-revenue ratio for Q1 was slightly above 1. During the quarter, total order backlog rose slightly from \$287m to \$289m.

"We anticipate future growth from the Lighting, Display & Power Electronics market, as well as from the Advanced Packaging, MEMS & RF markets," says Maheshwari.

"Our new Veeco Precision Surface Processing or PSP business is off to a great start, and will help drive increased sales and profitability in 2015," believes chairman & CEO John R. Peeler. Growth in smartphones, wearables and other mobile devices are driving activity in MEMS wireless devices and advanced packaging.

"China is starting to invest big in MEMS. We received orders in the first quarter for a metal lift-off application. We're also seeing significant activity in the USA and Europe," he adds. "Veeco sales team is actively engaged to drive



new account penetration, particularly in regions like Korea and Japan where SSEC had limited presence. Taiwanese foundries are also investing in MEMS and we had an important strategic order from an Asian foundry in Q1," Peeler continues. "In through-silicon via applications, we're seeing good opportunities and momentum in customer demos, and overall PSP's orders are very healthy, with a book-to-bill ratio consistently over 1."

Demand for MOCVD products continues to strengthen and there were no order cancellations in Q1. "We've seen [LED industry] utilization rates overall tick-up in almost all regions over the last quarter," says Peeler. "We're at 90% or so in China, kind of close to that in Taiwan — probably up three to five percentage points in each of those countries. Korea has come up by a similar amount (probably 85%), and USA and Europe are probably close to 90%," he adds.

Specifically, for the new TurboDisc EPIK700 MOCVD system, all beta customers have qualified the tool and placed follow-on volume production orders, joined by additional customers in multiple countries. "Customers have quickly moved from our K465i and MaxBright platforms to the EPIK700, and nearly all shipments to LED customers are

now EPIKs," says Peeler.

"We expect to shift to a revenue-on-shipment operating model for the EPIK700 sometime in Q2," says Peeler. "Since that timing cannot be accurately predicted, our Q2 revenue has a wide range," he adds. Veeco hence expects revenue to grow in second-quarter 2015 to \$100–150m (with corresponding EPIK700 revenue deferred from Q2 ranging between \$65m and \$25m, respectively — making \$165–175m of shipments in total in Q2).

"In MOCVD, we're shipping products at the fastest rate since Q4/2011, booking orders at higher margins, and extending our market share lead," reckons Peeler.

Gross margin should be 36–39% (hit by a large order from a single customer with higher discount).

"As is consistent with new product introduction, gross margin drags a little bit until we reach critical scale with EPIK," notes Maheshwari.

"While these factors will prevent gross margin from reaching 40% in Q2 and likely Q3, we reiterate our expectation to achieve gross margin of 40% or more by Q4," he adds. "We maintain our focus on driving down manufacturing costs through supply chain management and other initiatives, and expect to see further improvement in gross margin towards the end of the year," says

Maheshwari. "We are seeing improvement in margins on the deals that are currently being booked, which will flow through the profit & loss in 6–9 months."

OpEx should be \$39–42m in Q2, commensurate with higher revenue, as well as higher incentive compensation, commission and R&D costs.

Net earnings should range from a loss of \$3m (\$0.06 per share) to a profit of \$14m (\$0.33 per share). Adjusted EBITDA should range between breakeven and \$20m.

Based on strong EPIK momentum, MOCVD orders are expected to rise significantly to over \$100m in Q2, driving total bookings above \$140m. "EPIK prices are increasing and are well above the low pricing for our initial high-volume order," notes Peeler. "Lead-times are moving out and we are challenging our manufacturing team to build tools faster," he adds. "We do see some significant orders in the second half of the year."

Aided also by deferred revenue, Veeco expects second-half revenue and profit to be much stronger than first half 2015. It has hence raised guidance for full-year 2015 growth from 30% to over 35%. "We guided PSP business to be \$65m for 2015 and we're seeing good order activity there and we expect it to be ahead of that plan," notes Maheshwari.

www.veeco.com

Aixtron improves earnings despite revenue drop while new MOCVD system undergoes qualification

EBITDA break-even expected in second-half 2015

For first-quarter 2015, deposition equipment maker Aixtron SE of Herzogenrath, near Aachen, Germany has reported revenue of €40.3m, down 8% on €43.9m a year ago and 31% on last quarter's €58m. This is "a reflection of the ongoing positioning process of the AIX R6", which is the firm's latest metal-organic chemical vapor deposition (MOCVD) system (currently going through a learning curve and a qualification process with each customer).

Of total revenue, 72% (€29.1m) came from equipment sales and 28% (€11.2m) from spare parts & services (roughly in line with the expect 75%/25% split). Of equipment revenue, by end application, LEDs comprised 49%, silicon 34%, power electronics 9%, and optoelectronics 4%. By region, 82% of total revenue came from Asia, 13% from Europe, and 5% from the Americas.

Although still slightly below 23% a year ago, gross margin has recovered further, from 18% last quarter to 22%. Operating expenses fell to €17.6m, down on €20.9m a year ago and €29.3m last quarter, due to lower R&D expenses and positive currency exchange effects.

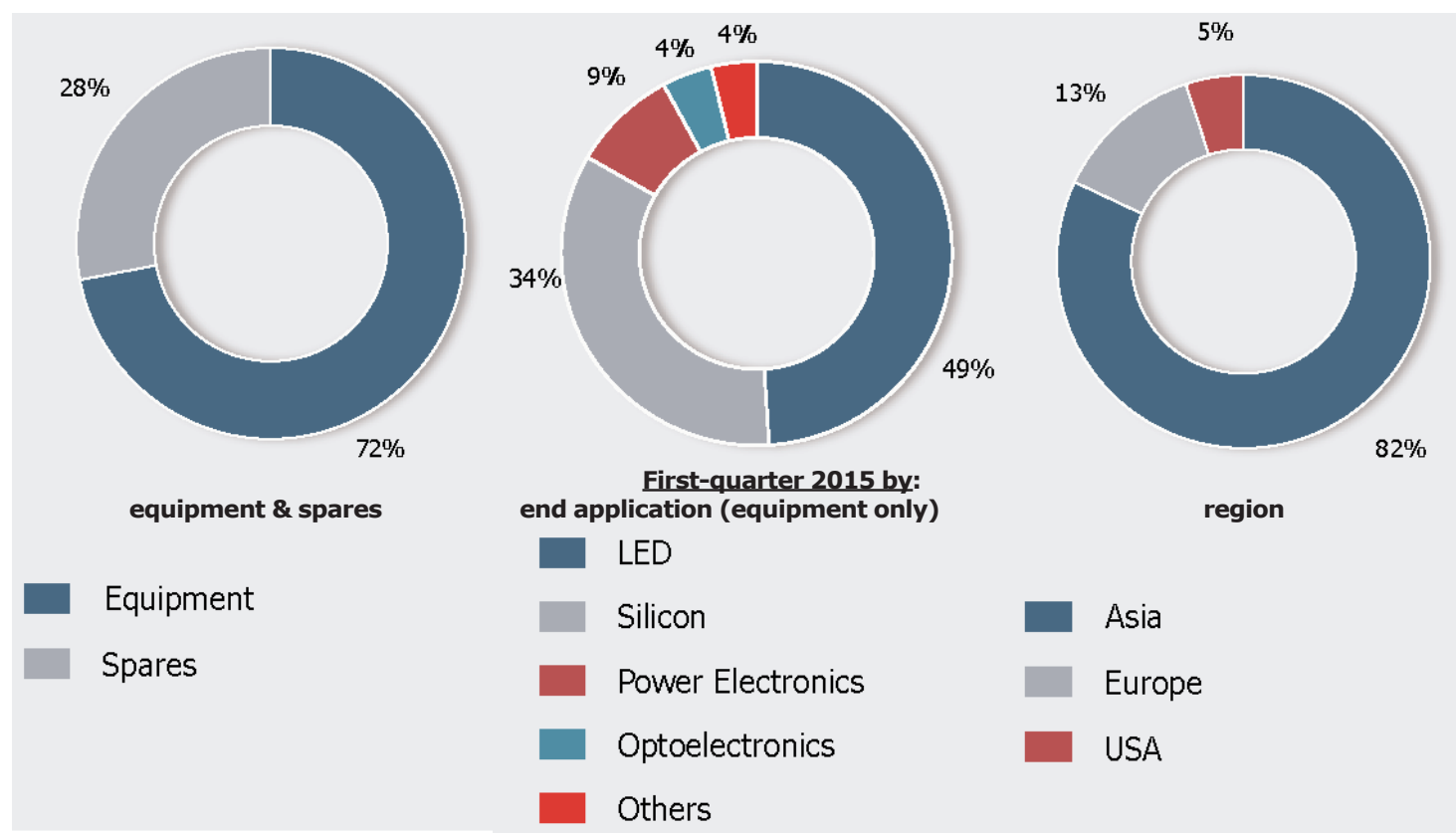
EBITDA (earnings before interest, tax, depreciation and amortization) has improved from -€7.1m a year ago and been more than halved from -€13.9m last quarter to -€6.4m.

On 1 April, Aixtron acquired PlasmaSi Inc of Fremont, CA, USA — which provides low-temperature silicon nitride plasma-enhanced chemical vapor deposition (PECVD) systems for the encapsulation of organic thin-films in OLEDs — for \$16m in cash. Excluding -€1.5m for short-term loans prior to this acquisition, operating cash flow was -€8.6m. Capital expenditure (CapEx) was €3.5m, down slightly from €4m last quarter. Free cash flow

was -€12.1m, an improvement on -€13.8m a year ago. Cash and cash equivalents were €263.2m at the end of March, down €4.9m from €268.1m last quarter and down €28.8m from a year ago. The difference from the free cash flow mainly results from the currency difference of the dollar-based cash and cash equivalents.

"We must continue to focus on the implementation of our 5-Point Program," says president & CEO Martin Goetzeler. Within the framework of the second stage of the 5-Point-Program, Aixtron has changed its organizational structure in line with changing customer and market requirements. "We are continuing to streamline our operations, and in the first quarter we initiated a reduction of our workforce by approximately 60 people," notes Goetzeler.

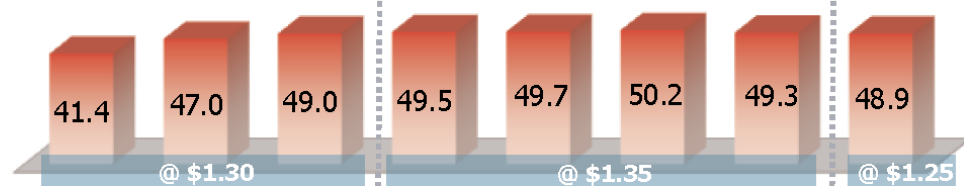
Alongside cost-cutting measures, Aixtron is continuing to pursue new



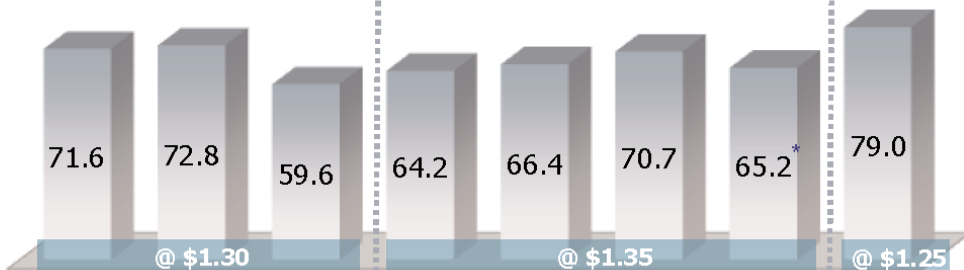
24 - Month Business Development

(€ million)

Order Intake¹

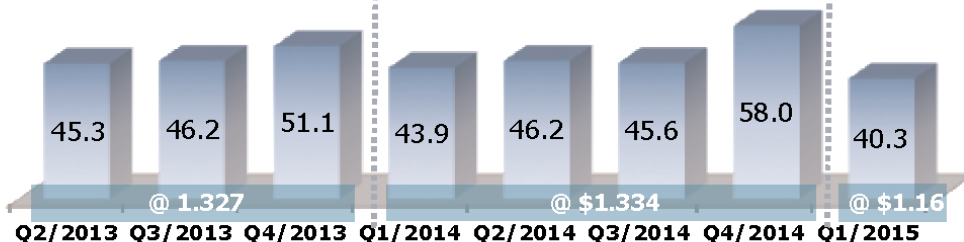


Order Backlog



*) revalued on Jan.1, 2015 to €69.0m at \$1.25/€

Total Revenues



1) total order intake including spares & service from Q1/2015; adopted for Q2/2013~Q4/2014 for comparison reasons

► market opportunities, for example with its new AIX R6 MOCVD product generation and in promising future business fields such as power and logic semiconductors as well as OLEDs.

For the first time, order intake and revenues were influenced by the large multi-tool order from a Chinese LED manufacturer for 50 AIX R6 Showerhead MOCVD tools received last September (since a large portion of this order will be booked in the course of 2015). However, reflecting the cautious market demand, equipment order intake (including spares and services) was merely stable at €48.9m, similar to €49.3m last quarter and €49.5m a year ago. Nevertheless, equipment order backlog was €79m at end-March, up 23% on €64.2m a year ago and up 21% on €65.2m at end-December 2014 (and the strongest backlog since Q3/2013), due largely to the increase in inventory and related advanced payments from customers.

"Currently, we have contracts with seven LED manufacturers that are assuring themselves of the per-

formance of our next-generation system," says Goetzeler. "Due to the increasing utilization rates, we expect a positive development for the demand in production systems... The fact that we are on the right track in this area is demonstrated by the improvement of our performance indicators and progress towards the targeted expansion of our product and technology portfolio," he adds.

"We have successfully expanded the technology portfolio in the field of OLED by the acquisition of PlasmaSi Inc," says Goetzeler. Through increased throughput compared with existing technologies, Aixtron sees significant market opportunities for PlasmaSi's thin-film encapsulation process. The acquisition also offers market as

Through increased throughput compared with existing technologies, Aixtron sees significant market opportunities for PlasmaSi

well as customer synergies with Aixtron's existing OVPD (organic vapor phase deposition) technology, the firm reckons. "We will be able to cover nearly two-thirds of the value chain in the front-end of the OLED production in the future," he notes. "Also, the preparations for putting our Gen8 demonstrator into operation for the production of large-area OLEDs are on track... customer interest in our other technologies remains high."

As the firm is pressing ahead with implementing its innovation roadmaps, productivity and efficiency programs across all areas, Aixtron expects to see a sequential increase in results in both halves of 2015 compared with the previous six-month periods. For full-year 2015, Aixtron forecasts revenue growth to €220–250m (up on 2014's €193.8m). "We do expect profitability to improve as revenues pick up in the second half," says Goetzeler. Specifically, the firm expects to reach EBITDA breakeven in second-half 2015.

www.aixtron.com

Epileds qualifies Aixtron's AIX R6 MOCVD system for LED mass production

Aixtron SE of Herzogenrath, near Aachen, Germany says that its AIX R6 metal-organic chemical vapor deposition (MOCVD) system (launched last November) has been qualified by LED chip maker Epileds Co Ltd of Tainan Science Park, Taiwan for LED epitaxy mass production as part of its capacity expansion.

"The AIX R6 has demonstrated its capabilities during our qualification process, especially with regards to LED brightness, uniformity and throughput," says Epileds' president Ming Sen Hsu. "It features a large capacity and ability to perform multiple continuous runs without any maintenance. As a conse-

quence, we have moved the AIX R6 into production. We are looking forward to benefit from its lowest cost of ownership in the market... we intend to make the AIX R6 the backbone of our high-brightness LED production," he adds.

"We have a long-standing and trustful commercial relationship with Epileds," says Aixtron's

The AIX R6 has demonstrated its capabilities during our qualification process, especially with regards to LED brightness, uniformity and throughput

executive VP & chief operating officer Dr Bernd Schulte. "Due to an already large install base, Epileds has extensive experience with our Close Coupled Showerhead technology which has facilitated the implementation of the AIX R6," he adds.

Epileds manufactures blue, green, red, and white light LED wafers and chips with a full range of wavelengths (ranging from 365 to 940nm) suitable for applications such as indicators of consumer electronics, light sources for fax machines and scanners, indoor or outdoor display boards, automotive lighting, traffic signals and illuminators.

www.epileds.com.tw

Aixtron wins multi-tool order for AIX R6 volume-production system

Aixtron has received a multiple tool order for its AIX R6 MOCVD system (launched last November). Shipments will extend into 2016.

The customer's decision to purchase the AIX R6 Close Coupled Showerhead system for volume production is based on positive experience with Aixtron's Close Coupled Showerhead R&D

tool, says Aixtron. Providing high throughput by continuous runs and low cost of ownership, the R6 enables users to expand production efficiently.

"The AIX R6 has been developed with a strong focus on customer production needs and therefore excels through outstanding material efficiency and intrinsic

deposition uniformity," says executive VP & chief operating officer Dr Bernd Schulte. "In addition to cost advantages, the AIX R6 also convinces with more automation, increased reliability and improved process control for excellent reproducibility and yield," he adds.

www.aixtron.com

k-Space adds auto-exposure capability to RHEED system

k-Space Associates Inc of Dexter, MI, USA (which supplies thin-film metrology tools for the semiconductor, compound semiconductor and solar markets) has announced a new auto-exposure capability available for the kSA 400 analytical reflection high-energy electron diffraction (RHEED) system.

The auto-exposure control feature automatically adjusts the exposure time of the kSA 400 camera as the RHEED pattern intensity increases or decreases so that signal saturation or low signal levels do not occur and important data is not lost. The intensity measured in user-specified

regions is automatically scaled with the exposure time so that both the real-time plots and recorded data reflect the correct intensity over the course of the acquisition. This feature is included with all new kSA 400 software upgrades and kSA 400 system purchases.

"RHEED patterns inherently have a very large dynamic range," notes CEO Darryl Barlett. "In addition, the pattern can change significantly during deposition, due to interference, roughening, desorption, etc," he adds. "By utilizing the large exposure time range of the kSA 400 cameras, we can compensate

in real-time for the changing RHEED pattern, assuring that adequate data is collected throughout an entire deposition run or surface study. It's similar to using an auto gain control capability on video cameras, except in this case the integrity of the absolute intensity values is maintained."

kSA 400 analytical RHEED systems are used in molecular beam epitaxy (MBE), pulsed laser deposition (PLD), sputtering and other thin-film deposition chambers, giving feedback on growth rate, surface roughness, lattice spacing and structural analysis.

www.k-space.com

Chinese LED maker Changelight buys Veeco EPIK 700 MOCVD systems to expand production

Veeco Instruments Inc of Plainview, NY, USA says that Changelight Co Ltd of Xiamen, China has purchased multiple TurboDisc EPIK 700 gallium nitride metal-organic chemical vapor deposition (MOCVD) systems for faster production and greater yield of light-emitting diodes for general lighting applications.

Changelight says that the decision to purchase EPIK 700 systems was based on their reliable performance and on Changelight's existing experience with other Veeco TurboDisc MOCVD reactors (including a large installed base of MaxBright and K475 MOCVD systems for high-volume LED production).

"Veeco's TurboDisc platform has provided Changelight with increased LED wafer production and easy process transfer between systems, saving us both time and money," comments Haifang Cai,

general manager & board member of Changelight. "By adding multiple EPIK 700 MOCVD systems to our fleet of reactors, we can ramp even more quickly, expand high-volume production with best-in-class wafer uniformity and reduce operating expenses," he adds.

Introduced in 2014 and available in one- and two-reactor configurations, the EPIK 700 MOCVD system is reckoned to be the LED industry's highest-productivity system, reducing cost per wafer by up to 20% compared with previous-generation systems. The system features technologies including the IsoFlange center injection flow and TruHeat wafer coil technologies, which provide homogeneous laminar flow and uniform temperature profile across the entire wafer carrier. These innovations produce wavelength uniformity to drive

higher yields in a tighter bin. Veeco says that the EPIK700 system offers a 2.5x throughput advantage over other systems due to its large reactor size. Designed for mass production, it accommodates 31x4", 12x6" and 6x8" wafer carrier sizes. Users can transfer processes from existing TurboDisc platforms to the EPIK 700 MOCVD system, enabling quick-start production of LEDs.

"As the preferred MOCVD system for Changelight, the increased capacity and technology advantages of the EPIK 700 system will support their growth and position as a leading LED manufacturer for general lighting and display markets," says Jim Jenson, senior VP & general manager of Veeco MOCVD Operations.

www.changelight.com.cn/en
www.veeco.com

www.laytec.de

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Park launches high-vacuum scanning spreading resistance microscopy AFM system for failure analysis

Atomic force microscopy (AFM) system maker Park Systems Corp of Suwon, South Korea has launched NX-Hivac, which is claimed to be the only high-vacuum AFM system on the market that meets the current and future needs for failure analysis in semiconductor manufacturing.

The NX-Hivac is suitable for academic and industrial users seeking failure analysis solutions in highly doped semiconductor processing where more highly sophisticated failure analysis tools are now needed.

The high-vacuum scanning spreading resistance microscopy (SSRM) of the NX-Hivac enables two-dimensional (2D) carrier profiling of next-generation devices and measures the high-resolution SSRM image under high-vacuum conditions to minimize sample-tip damage and improve production yield. The NX-Hivac is very sensitive and responsive to the current signal, yielding accurate measurement and

repeatability, says the firm.

"The ever shrinking nanoscale geometries of semiconductor devices require sophisticated failure analysis tools," says president Keibock Lee. "Our customer-centric engineering and product development team is focused on failure analysis solutions for the manufacturing environment that ultimately facilitates the advancement of nanoscale production," he adds. The NX-Hivac was designed in collaboration with "a major semiconductor IC producer".

Designed with the capability for multiple sample loading (up to 5), the Park NX-Hivac can also measure a wide dynamic range of dopant concentration (7 decades). Other features include a fast signal response even at the range of insulator-metal where conductance is changing dramatically. A significant advantage of the NX-Hivac is that the high-vacuum SSRM measure-

ment shows much higher sensitivity and resolution than under ambient conditions, says the firm. This is due to the applied force between the tip and sample under ambient or dry nitrogen conditions being four times higher than in a vacuum. The low force required reduces the strain of thin films of target samples, giving higher spatial resolution, resulting in longer tip life and increased productivity, says Park.

The complete NX-Hivac system includes Park's unique design features such as a closed-loop XY scanner for accurate zoom-in imaging, low noise ratio (0.30Å, even when the vacuum pump is on), increased tip lifetime, and the reliability of guaranteed repeatability. Special features such as software control for automatic pumping and venting, motorized laser alignment and high-resolution axis-optics enhance ease of use for the operator.

www.parkAFM.com

Showa Denko adopts Lasertec's SICA wafer inspection/review tool in SiC epiwafer mass production

Metrology and inspection equipment maker Lasertec Corp of Yokohama, Japan says that Japan's Showa Denko K.K., which manufactures silicon carbide (SiC) epitaxial wafers, has become the latest adopter of its SICA SiC wafer inspection and review system as PTOR (process tool of record) in its mass-production line.

Showa Denko has established the mass-production expertise to manufacture large-diameter SiC epiwafers with low level defect density and high uniformity. SICA has been fully utilized in Showa Denko's R&D since 2011 as an enabling technology. Showa Denko has now decided to introduce the latest, high-throughput version of SICA to its mass-production line as part of its ongoing efforts to further enhance its SiC epiwafer quality.

Silicon carbide's properties are suitable for power semiconductors and hence it is viewed as a vitally important option for power device manufacturing. High-quality SiC epiwafers are therefore becoming critical components in the supply chain. Among various challenges, a key factor in the mass production of high-quality SiC wafers is defect reduction — most commonly generated during grinding and epitaxial processes. More specifically, it is extremely important to accurately and quickly detect and categorize defects that affect device performance. Eliminating killer defects early in the process ensures high device yield in mass production. Defects of interest (DOI) include not only scratches and epi-defects on the wafer surface but also crys-

tal-related defects such as basal plane dislocations (BPD) and stacking faults (SF) inside epilayers.

Lasertec launched the SICA in 2009. Since then, continuous improvements have transformed it into a defect inspection/review system for SiC with installations worldwide. Lasertec is now exploring photoluminescence-based technology that enables the detection of crystal defects at much higher throughput. The integration and simultaneous reporting function of this new feature, in conjunction with the existing surface defect capabilities, will make SICA one of the fastest and easiest defect detection and root cause analysis tools available in the market.

www.sdk.co.jp

www.lasertec.co.jp

Research institutes invest in Oxford Instruments plasma systems for graphene and 2D materials

UK-based Oxford Instruments says that, as developments in graphene and two-dimensional (2D) materials technology continue to increase, research institutes globally are investing in its plasma processing Nanofab equipment using chemical vapour deposition (CVD), plasma-enhanced CVD (PECVD) and inductively coupled plasma CVD (ICPCVD) techniques to further their work in this key area.

Multiple orders have recently been received from research centres in Europe and the USA, including the US Naval Research Laboratory (NRL) and University College London (UCL) in the UK, says the company.

CVD has been one of the most successful techniques for the

fabrication of nanostructured materials such as graphene, carbon nanotubes and other 1D and 2D nanomaterials, notes Oxford Instruments. The Nanofab suits this field of research, the firm adds, as it combines several essential features for high-performance growth, such as a high-temperature heater capable of processing up to 200mm wafers, shower-head technology, automatic load-lock for wafer handling as well as flexible options for liquid/solid precursor delivery.

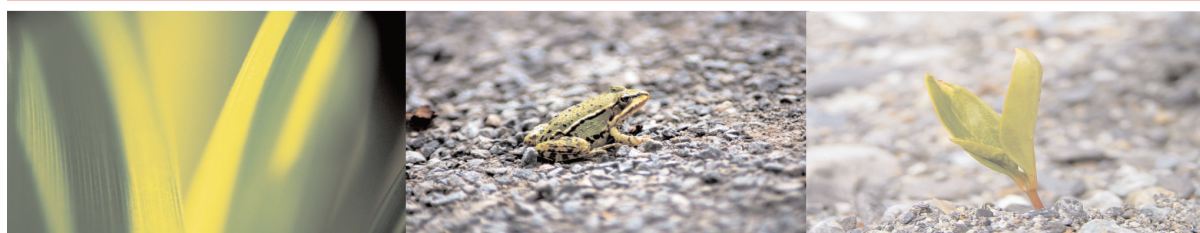
"We recently placed an order for a Nanofab, chosen for its operating capability, process control, and great flexibility for further modification and upgrades," says UCL professor Zheng-Xiao Guo.

"We also like the fact that we will be provided with dedicated after-sales support, not only in running the system, but also in enhancing the scope of our applications," he adds.

"In recent years there has been a great increase in graphene R&D worldwide, due to the impact that this area of research is expected to exert on tomorrow's technologies and world economy," notes Dr David Haynes, sales & marketing director at Oxford instruments Plasma Technology (OIPT).

"Several national research projects as well as industrial companies are now active in graphene production and applications, and more are set to follow."

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Rubicon's Q1 growth in sapphire revenue for mobile devices balanced by weakness in LED market

PSS ramp up in second-half 2015 plus polished wafer cost cutting targets positive cash flow by end-2015

For first-quarter 2015, Rubicon Technology Inc of Bensenville, IL, USA (which makes monocrystalline sapphire substrates and products for the LED, semiconductor and optical industries) has reported revenue of \$8.9m, down on \$14.3m a year ago and level with last quarter.

"The sapphire market continues to be very challenging," says CEO William Weissman. "The market remains in a state of excess supply with fluctuations in demand, resulting in significant price pressure," he adds.

Core revenue was \$5.1m, less than half of the \$11.35m a year ago but up on \$4.75m last quarter. This was mostly due to revenue for 2" sapphire cores (used primarily in the mobile device market), down from \$8.5m a year ago but up from \$3.2m last quarter to \$4m. However, this growth was offset partly by revenue from 4" cores falling (for LEDs) falling further, from \$2.85m a year ago and \$1.55m last quarter to \$1m. "We saw weakness in the LED market and some strengthening in the mobile device market," notes Weissman. "The LED market, which typically strengthened after Chinese New Year, this year remained soft throughout the quarter," he adds.

Wafer revenue was \$1.9m, almost doubling from \$1.1m a year ago but similar to last quarter. Of this, polished wafer revenue was \$1.4m, up from \$1m a year ago but roughly level with last quarter. Revenue for patterned sapphire substrates (PSS) has risen just from \$0.1m a year ago to about \$0.5m (also roughly level with last quarter) but remains limited to qualification levels.

Optical and R&D revenue totaled \$1.9m, down slightly on last quarter's \$2.2m but up slightly on \$1.8m a year ago.

Crystal growth operations continued to run at full capacity, but wafer polishing and patterning operations remain under-utilized. Idle plant costs rose from \$1.8m last quarter to \$2.2m. However, operating expenses have been cut from \$3.2m last quarter to \$2.8m (due to lower bad debt expense and a decrease in consulting fees).

Raw material inventory balance declined sequentially by \$1.6m, from \$14.5m to \$12.9m. "In addition to reducing our per-unit cost through our internal raw material process, we have also reduced the total quantities in inventory," says Weissman.

"We are still cycling through old more expensive raw material stock, so the current low cost of our internal raw material production is not yet fully reflected in our statement of operations," says Weissman. "As a result, the cost of raw material and our cost of goods sold is nearly double that of our current raw material production cost. The impact of this on EPS in the first quarter was about \$0.03. These costs as well as our raw material inventory balance will continue to come down," he adds.

Despite the sustained raw material cost and the continued weakness in the LED market, net loss has been cut from \$10.9m (\$0.43 per share) a year ago and \$9.4m (\$0.36 per share) last quarter to \$8.3m (\$0.32 per share).

Net cash used in operating activities has been cut from \$4.5m a year ago to \$3.9m. During the quarter, cash and short-term investments fell from \$45m to \$41m (with

no debt).

Rubicon's key objectives for 2015 include aggressively pursuing the potential of its PSS product, targeting high-margin optical applications, and driving down product costs.

"We continue to work on furnace re-designs and process improvement to further reduce cost. We also continue to improve on our proprietary raw material processes to reduce crystal growth cost," says Weissman. "We have now begun to convert our 83kg furnaces to 93kg, which not only produces more material at a nominally incremental cost but also reduces defects, which increases crystal yield. As we did with the conversion of our 31kg furnaces to 35kg, this will be done gradually according to our maintenance schedule," he adds.

"Our patterning operation is cost competitive and our patterning capability is strong," believes Weissman. "The area where we have greatest opportunity to reduce cost and where we must reduce cost is in polished wafers. We need to ensure that the incremental revenue from increasing PSS volumes generates positive cash flow in the near term and provides strong margins as the market improves. Addressing polished wafer cost therefore is a high priority. Over the past several months we have been working on a number of initiatives to reduce these costs, including the development of a new polishing platform. In coming the months we will be able to determine the cost-reduction impact of these initiatives," he adds.

"While we work on reducing polished wafer cost, we are focusing on PSS wafer sales rather than polished wafer sales," says chief financial officer Mardel A. Graffy. During Q1, the firm continued qualifying its large-diameter PSS wafers.

We are still cycling through old more expensive raw material stock, so the current low cost of our internal raw material production is not yet fully reflected

► "The general lighting segment of the LED market is still in early stages of adoption and the LED industry is continuing to migrate to larger-diameter substrates," says Graffy. "We are seeing the LED market begin to pick up and expect increased 4" core revenue in the second quarter," adds Weissman. For second-quarter 2015, Rubicon expects revenue to be similar to Q1. While core sale volumes will likely be higher, 2" demand will be limited and pricing will be lower. In addition, PSS revenue will still be limited to qualification volumes. Loss per share is hence also expected to be similar

to Q1, with cost reductions offsetting the additional price pressure.

"While volume PSS orders have certainly been slower in coming than expected, we do have visibility to growing PSS volumes in the second half of the year," notes Weissman. "We believe that we will increase our PSS revenue over the course of this year." Utilization should increase as PSS wafer orders move from qualification to production volumes. "With increased wafer revenue in combination with reducing product costs, we expect a meaningful improvement in operating results by the end of the year," he adds.

"Continuing to lower product cost is a major focus for us this year. It's our goal to ensure that Rubicon is positioned to drive strong margins when the markets strengthen and to ensure that we are cash flow positive by the end of this year, even as the pricing environment remains difficult," continues Weissman. "While it will be challenging to achieve these goals without some pricing improvement, we will be taking action over the next couple of quarters to reduce costs. This, along with increased PSS volumes, should reduce our cash burn."

www.rubicon-es2.com

EVG's NILPhotonics Competence Center generates strong interest for emerging photonic applications

EV Group of St Florian, Austria (a supplier of wafer bonding and lithography equipment for MEMS, nanotechnology and semiconductor applications) says that its NILPhotonics Competence Center, which was established in December 2014 to assist customers in enabling new products and applications in the field of photonics, has generated strong interest from customers and resulted in multiple system orders. New system orders have included the company's EVG700/7000 Series UV-NIL (UV nanoimprint lithography) systems with SmartNIL technology to support high-volume manufacturing applications, including displays, LEDs and wafer-level optics.

Since its launch, the NILPhotonics Competence Center has expanded the products and applications it supports. These include photonic and microfluidic devices for biomedical applications, as well as plasmonic structures that simultaneously carry optical and electrical signals and can be scaled to the smallest dimensions to enable new chip designs as well as better-performing devices, such as waveguides and sensors.

"The prevailing perception has been that despite the potential benefits of NIL technology, the barrier to

entry for integrating it into high-volume manufacturing (HVM) is high. That simply isn't the case. EV Group has invested significant resources over many years in developing NIL technology as an HVM-capable solution for a number of applications," stated Markus Wimplinger, corporate technology development and IP director. "We have the world's largest installed base of more than 200 systems at customer facilities around the globe supporting volume-manufacturing of LEDs, MEMS, optics, photovoltaics and other devices. Our NILPhotonics Competence Center allows us to more easily bring all of our process and product capabilities and expertise to bear in helping our customers enable new photonic products and applications."

EVG's NILPhotonics Competence Center leverages EVG's field-proven process and equipment know-how in NIL and other process areas such as wafer bonding to support emerging photonic applications and significantly shorten time to market through fast process implementation and optimization, as well as through customized equipment design. In addition, EVG has a global partner network to draw from to support its customers' process integration and

optimization efforts across the NIL infrastructure, including template manufacturing, resist materials and supporting equipment. As a result, EVG is able to provide consultation and support across all phases of the product lifecycle — from design for manufacturing and prototyping through process development, qualification runs, pilot manufacturing and process transfer.

"More than a decade ago, EV Group launched the NILCom Consortium with support from companies representing key aspects of the NIL supply chain in order to speed commercialization of NIL technology. Through the dedicated efforts of all of our members, we are pleased to announce that the NILCom Consortium has successfully completed its charter and will end formal operations. That said, we will continue to collaborate with companies across the NIL supply chain including our former members as needed to ensure that NIL technology continues to address future customer roadmap requirements," added Wimplinger.

Companies interested in partnering with the NILPhotonics Competence Center can contact EV Group at: NILPhotonics@EVGroup.com.

www.evgroup.com

Semi-polar GaN LED firm Seren wins best business and investment award at European Photonics Venture Forum

Seren Photonics Ltd of Pencoed Technology Park, UK, which was spun off from the University of Sheffield in 2009 with funding from venture capital firm FusionIP plc (now part of IPGroup plc), was one of six firms to win an award for best business and investment opportunity at the 1st European Photonics Venture Forum (EPVF) in Rome, Italy on 16 April.

Organized by the European Photonics Industry Consortium (EPIC) of Paris, France, the event was conceived to enable European technology firms with high potential to gain

access to more than 30 venture finance companies and to present to a panel of investment experts.

Seren has commercialized technology developed by professor Tao Wang of the University of Sheffield's Electronic and Electrical Engineering Department and uses nano-engineered structures to enhance the properties of III-nitride materials.

Seren's business plan, presented by CEO Dr Carl Griffiths, highlighted the potential of semi-polar gallium nitride material in LEDs and other photonic applications, as well as the significant growth potential

for the firm as interconnected light-emitting devices become ever more embedded in everyday products.

"Receiving this award is an acknowledgment of the growth potential and compelling value proposition offered by Seren's semi-polar GaN products," says Griffiths. "As we now begin the process of ramping up to larger volumes and larger wafer sizes, it's always pleasing to receive positive validation of our business plan."

www.epic-assoc.com/funding/venture-finance

www.serenphotonics.co.uk

Aledia completes \$31m Series B financing

Aledia S.A. of Grenoble, France, which is developing light-emitting diodes based on 'WireLED' three-dimensional (3D) nanowire GaN-on-silicon technology that is claimed to cut manufacturing costs compared to conventional planar (2D) LEDs, has closed its Series B financing round and executed development and supply contracts with major LED buyers.

The round, totalling up to €28.4m (\$31m), includes new investments from Valeo (one of the largest automobile-equipment makers and the second-largest supplier of car lighting systems); IKEA GreenTech AB (the venture capital arm of IKEA); and the Ecotechnologies fund of Bpifrance (the French national industrial bank). Existing investors Sofinnova Partners, Braemar Energy Ventures, Demeter Partners and CEAI/ATi also participated in the round.

"This financing round, abundantly oversubscribed, and particularly the presence of two very large potential corporate customers, testifies to the interest that our cost-disruptive nanowire LED technology is generating in the customer base, as well as in the financial community," comments CEO, chairman &

co-founder Giorgio Anania.

Based on technology originally developed by the CEA-Leti nanotech research institute in Grenoble, Aledia is developing a new generation of LEDs that are fabricated on large-diameter 200mm (8") silicon wafers (allowing manufacturing in existing CMOS foundries), that promise to be significantly less expensive than traditional '2D' LEDs, it is reckoned, and that allow straightforward integration with electronics. Aledia is also working on next-generation displays.

"We are progressing with the development of the technology and this financing round will allow us to accelerate significantly the speed of development and the customer traction," Anania says. "In Valeo we have a major potential customer in the automotive LED market, generally viewed as the most profitable market segment." Simultaneously with the investment, Aledia has signed a supply agreement with Valeo.

"Aledia's 3D LED technology, together with Valeo's expertise in automobile lighting systems, has the potential to put on the market a technological breakthrough in innovative lighting systems, per-

fectly in line with Valeo Lighting System's mission to provide performance and style, and contribute to the safety of road users," says Maurizio Martinelli, Valeo Visibility business group president.

"This technology will be one important part in the IKEA Group strategy to supply high-quality, energy-saving lighting products to consumers worldwide," says IKEA GreenTech's managing director Christian Ehrenborg. "The low-price opportunity for residential use has the potential of faster implementation of the LED technology," he adds. "The connectivity functions of Aledia's technology also open up new interesting possibilities to make life at home more convenient and smarter."

"It proposes a breakthrough technology in a growing market and positions itself as a major actor in the smart-lighting industry. Aledia also benefits from its head start to create a French and European sector in LED, among which partnerships with prestigious industrialists such as IKEA and Valeo constitute the first stage," comments Bpifrance Investissement's investments director Anne-Sophie Carrese.

www.aledia.com

RayVio claims record 30W/cm² DUV LED power density

RayVio Corp of Haywood, CA, USA, which is developing and commercializing deep-ultraviolet (UV) LEDs and consumer disinfection solutions, says that it has demonstrated record-performance deep UV LEDs, resulting in a single-chip device capable of delivering 45mW of continuous power at deep-UV wavelengths from a 0.15mm² emitting area, i.e. record continuous-wave (cw) power density of 30W/cm² at the emission surface.

RayVio's core technology was invented by co-founder Dr Yitao Liao (chief technology officer) and professor Theodore Moustakas, and is exclusively licensed from Boston University. The technology is based on a proprietary and fundamentally different approach compared to

techniques attempted by industry unsuccessfully for the past 15 years, it is claimed, enabling the firm to provide the highest optical power at the lowest cost than is otherwise commercially available. "This enables us to unleash Haitz' Law for deep UV LEDs, the same Haitz' Law that enabled blue and white LEDs to revolutionize the lighting and display industries," says Liao.

RayVio says it is working with OEM customers to develop integrated products enabled by its UV LED devices. Applications range from digital curing to dermatology and biomedical instrumentation, as well as surface, air and water disinfection for consumers.

"Leading OEM and consumer electronics manufacturing partners

have been evaluating our current products for the past several months, while we continue to install more capacity at our facility in Silicon Valley and ramp global supply chain partners to satisfy customer demand," says co-founder & CEO Dr Robert C. Walker.

Together with manufacturing and integration support located around the globe, RayVio reckons that its capital-efficient and scalable manufacturing process allows for rapid capacity expansion and lower manufacturing cost. The firm adds that such high-performance and cost effective UV LEDs make it possible to decrease system price, complexity and time to market, accelerating UV LED adoption.

www.rayvio.com

Bridgelux launches integrated smart module LED array

At the 2015 Light Fair International event in New York, Bridgelux Inc of Livermore, CA, USA debuted the first of its integrated smart module product suite, enabling customers to provide networkable LED arrays for commercial, retail and industrial spaces. The Xenio smart platform is compatible with various standards, protocols and other technologies to ensure ease of integration, greater value and future functionality.

Claimed to be the highest-efficacy integrated module on the market, Xenio features tightly integrated controls, local intelligence and communications capabilities, and smooth dimming down to 0.1% of output. Bridgelux worked with key technology partners and customers to include features in the platform that meet the ease of integration, performance, light quality and value demanded by luminaire makers and end-users.

"For our customers to succeed in a connected, data-driven future, we're introducing new technologies that are integrated, efficient and compatible, that will position smart lighting arrays as the infrastructure to further enable the Internet of Things,"

says CEO Brad Bullington. "This first-generation product sets the tone for how Bridgelux is innovating through hardware and software."

As a truly open platform, the Xenio smart lighting array is compatible with communication protocols including Bluetooth Smart, Zigbee, DMX 512, DALI and common controls standards including 0–10V. It has also been architected to enable advanced software, offering integration with Avi-on's Bluetooth-based system as well as Harvard Engineering's EyeNut platform. The systems offer users the freedom to commission, configure and readily control their lighting to optimize energy savings.

"The Xenio platform brings together Bridgelux's technology with Harvard's EyeNut to enable point control with individual modules, wirelessly — a benefit that no other smart lighting product on the market can currently claim," says Antony Corrie, VP of Harvard Americas. "The EyeNut solution can be used across a wide range of industry and commercial applications."

Available in three array sizes, the smart lighting array self-monitors

its real-time health and temperature and stores historical operating data in order to optimize performance and value with status reporting that is DMX 512/RDM capable.

The product is powered by the emerging 48V_{DC} standard, which is becoming popular for its high efficiency while still being regulated as low voltage. This forward-looking standard offers multiple options for powering light fixtures, says Bridgelux. Xenio's options for 48V_{DC} power supplies include fixture-integrated constant-voltage power supplies, a room-level power hub with Class 2 cabling that uses low voltage to power 8–10 fixtures, and a Power over Ethernet data switch.

The open, integrated platform is architected to help future-proof luminaire designs for easy, cost-effective upgrades to future Bridgelux smart lighting products featuring, for example, tunable white capabilities, sensor technology or other data-focused innovations.

Samples will be available in September, for production from January 2016 in the USA and Europe.

www.bridgelux.com

Samsung unveils second-gen CSP technology for lighting

At the LIGHTFAIR International 2015 trade show in New York (5–7 May), Samsung Electronics Co Ltd of Seoul, Korea introduced chip-scale packaging (CSP) technology for use in a diverse range of LED lighting applications.

The new CSP technology significantly scales down the size of an LED package, which enables more flexible and compact designs when manufacturing consumer LED lighting modules or fixtures, and lowers the manufacturing and operational costs of a LED lighting system, says the firm. It also provides flexibility in adjusting the size of the light-emitting surface and the luminance level to meet the differing requirements of various lighting fixture applications.

“Our LED chip-scale packaging technology will contribute to providing innovative LED component solutions that can overcome the limitations of today’s LED lighting market,” believes Dr Jacob Tarn, executive VP, LED Lighting Business Team, Samsung Electronics. “We will incorporate the new technology in future Samsung LED products and continue to introduce more advanced LED technology, while strengthening our presence in the global LED market,” he adds.

The new CSP technology is actually Samsung’s second generation of chip-scale packaging. Last year, Samsung introduced LED package

products using its first chip-scale packaging technology, which featured a versatile new type of flip-chip packaging. The first-generation CSP was created by flipping over blue LED chips and then adhering a phosphor film to each of them. Unlike conventional LED packages that require a packaging process following the actual chip manufacturing, this allowed chip-scale packages to be created without a mold, enabling more compact LED lighting designs, says Samsung.

In the second-generation CSP, blue LED chips are flipped over and immediately coated with a phosphor substance. The second generation has inherited the advantages of the first-generation CSPs, such as freedom from metal wires and plastic molds, which lead to smaller packages, more compact lighting designs, lower thermal resistance and high current availability, resulting in high flux and greater reliability. In addition, using the second-generation CSP process makes new LED packages even more competitive in raw costs, and achieves higher robustness and reliability with a longer life span, as well as higher operating temperatures and current, claims Samsung.

Based on the new advances, the second-generation CSP technology enables LED packages with an ultra-compact form factor of 1.2mm by 1.2mm — about 30%

smaller than the 1.4mm by 1.4mm of the first-generation CSP, while offering a 10% improvement in light performance. It also provides higher light quality with multi-faceted phosphor coating technology, covering the top and four sides of an LED package with phosphor. Because of the small form factor, the new CSP technology can be used in a wide variety of LED packages for applications ranging from ambient light and spotlight, to downlight and bulb lighting, says Samsung.

Moreover, the second-generation CSP LED packages can bring greater design flexibility by offering added delivery options. In the manufacturing process, 2 by 2 and 3 by 3 CSP arrays can be created and offered to customers, depending on diverse market needs. Samsung says the availability of CSP arrays provides not only more design flexibility, but also better light quality in each LED luminaire through their one-lens design, in which the CSP arrays share a single lens instead of having to use individual lenses for multiple conventional packages.

The ultra-compact, second-generation CSP technology is expected to be applied to new LED packages due to be introduced in fourth-quarter 2015, and will support a wide range of correlated color temperature (CCT) specifications.

www.samsung.com

Seoul Semiconductor makes inroads into automotive lighting after passing GM reliability tests

South Korean LED maker Seoul Semiconductor has launched new LED packages for the automotive lighting segment to further strengthen its presence in automotive LED lighting.

Since 2011, the firm has developed LED packages for the automotive lighting market and has supplied LEDs for headlamps to global auto makers. Earlier this

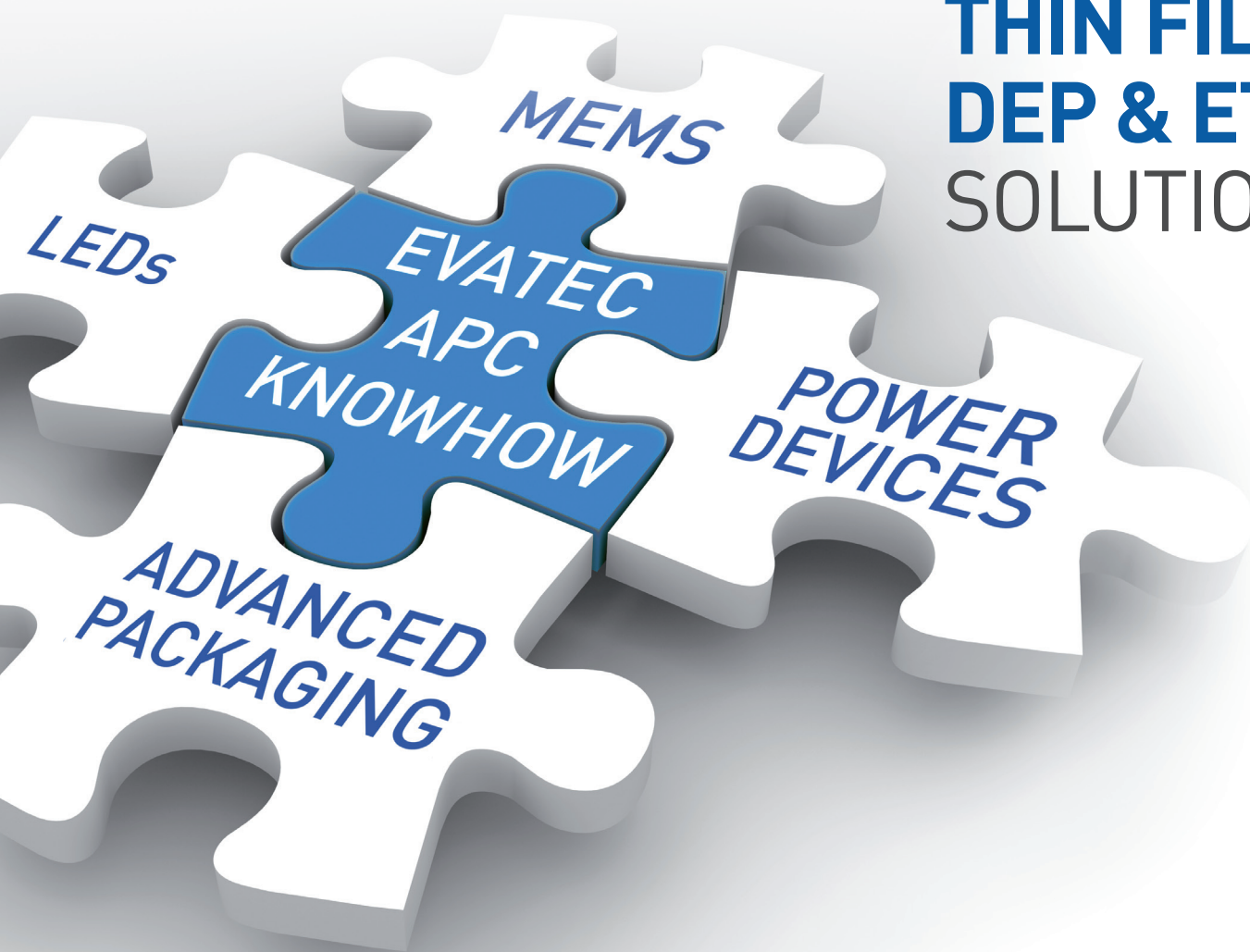
year, its 14 LED packages designed specifically for automotive applications passed reliability tests at General Motors. Seoul Semiconductor says that it is the first Korean firm to have LEDs that conform to GM’s reliability standards, and its LED packages have been used in various GM vehicles.

“LEDs for automotive applications have to meet strict certification

standards for reliability, lumen output and efficiency set by automobile manufacturers in Europe, USA and Japan,” notes Lae-hyun Kim, VP of the automotive business division. “Seoul Semiconductor is already recognized for its performance and now the sales revenue for its automotive LEDs continues to grow,” he adds.

www.SeoulSemicon.com

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Leti demonstrates new process for fabricating high-brightness micro-LED arrays for next-generation head-mounted and head-up displays

GaN and InGaN technology scalable to standard microelectronic large-scale process, targeting markets for wearable vision systems

At SID's Display Week 2015 event in San Jose, CA, USA (31 May–5 June), Grenoble-based micro/nanotechnology R&D center CEA-Leti of France announced that it has demonstrated a path to fabricating high-density micro-LED arrays for the next generation of wearable and nomadic systems in a process that is scalable to the IC manufacturing process.

High-brightness, enhanced-vision systems such as head-up and head-mounted displays can improve safety and performance in fields such as aeronautics and automotive, where the displays allow pilots and drivers to receive key navigation data and information in their line of sight. For consumers, smart glasses or nomadic projection devices with augmented reality provide directions, safety updates, advertisements and other information across the viewing field. LED microdisplays are suited to such wearable systems because of their low footprint, low power consumption, high contrast ratio and ultra-high brightness, says Leti.

Leti researchers have developed gallium nitride (GaN) and indium

gallium nitride (InGaN) LED technology for producing high-brightness, emissive microdisplays for these applications, which are expected to grow dramatically in the next 3–5 years. For example, the firm MarketsandMarkets forecasts that the market for head-up displays alone will grow from \$1.37bn in 2012 to \$8.36bn in 2020.

"Currently available microdisplays for both head-mounted and compact head-up applications suffer from fundamental technology limitations that prevent the design of very low-weight, compact and low-energy-use products," notes Ludovic Poupinet, head of Leti's Optics and Photonics Department. "Leti's technology breakthrough is the first demonstration of a high-brightness, high-density micro-LED array that overcomes these limitations and is scalable to a standard microelectronic large-scale process," he adds. "This technology provides a low-cost, leading-edge solution to companies that want to target the fast-growth markets for wearable vision systems."

Leti says that its technology innovation is based on micro-LED

arrays that are hybridized on a silicon backplane. Key developments include epitaxial growth of LED layers on sapphire or other substrates, micro-structuring of LED arrays (10µm pitch or smaller), and 3D heterogeneous integration of such LED arrays on CMOS active matrices.

These innovations make it possible to produce a brightness of 1 million cd/m² for monochrome devices and 100kcd/m² for full-color devices with a device size below 1-inch and 2.5 million pixels. This is a 100- to 1000-times improvement compared with existing self-emissive microdisplays, with very good power efficiency, it is reckoned. The technology should also allow the fabrication of very compact products that significantly reduce system integration constraints.

The high-density micro-LED array process was developed in collaboration with III-V Lab (a joint venture between Paris-based Alcatel-Lucent Bell Labs France, Thales Research and Technology, and CEA-Leti).

www.leti.fr

www.3-5lab.fr

Nichia's white LED patents ruled invalid in Germany and USA following Everlight lawsuits

Taiwanese LED maker Everlight Electronics Co Ltd says that, on 22 April, the jury before the US District Court for the Eastern District of Michigan found that all asserted claims of the white LED patents of Japan's Nichia Corp are invalid in Germany and the USA for obviousness and/or lack of enablement.

In April 2012, Everlight filed for declaratory judgment of invalidity

and non-infringement of Nichia's US patents related to white LEDs. The US patents 5998925 and 7531960 concern yttrium aluminium garnet (YAG) phosphor being used with a blue LED chip to emit white light, and its phosphor concentration.

In March 2012, Everlight also filed for invalidation trial against Nichia's corresponding white LED patent in Germany, specifically patent

DE69702929 (EP0936682). The German Patent Court in September 2014 also declared all the claims of the patent invalid, and that Nichia has to bear the litigation fee.

Everlight says it respects intellectual property and will continue to defend the rights and benefits of its customers and shareholders.

www.everlight.com

www.nichia.com



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Cree restructuring LED Products business due to higher-than-expected ASP erosion and factory under-utilization \$500m stock buyback & annual operating plan authorized for fiscal 2016

LED chip, lamp and lighting fixture maker Cree Inc of Durham, NC, USA says that its board of directors has approved the following: a restructuring of the LED Products business; a \$500m stock buyback authorization for fiscal 2016; and the fiscal 2016 annual operating plan (which targets increases in revenue to \$1.8bn and in non-GAAP operating margin to 8%, as well as free cash flow of about \$75m).

Due to recent market trends that have resulted in higher LED average selling price (ASP) erosion than previously forecast and the continued under-utilization of its LED factory, Cree has decided to restructure its LED Products business to reduce excess capacity and overhead in order to improve the cost structure. Additionally, the firm is increasing LED reserves to reflect the more aggressive pricing environment experienced in the current quarter, and to factor in a more conservative pricing outlook for fiscal 2016. Restructuring charges are targeted

to be about \$85m (comprising \$47m in capacity and overhead cost reductions; \$27m in channel revenue reserves; and \$11m in inventory reserves).

Cree expects most of the capacity and overhead related charges to be reflected in operating expenses for fiscal fourth-quarter 2015 (ending on 28 June), with the balance in fiscal first-half 2016. The channel revenue reserves should be reflected as a reduction in revenue and the inventory reserves as an increase in cost of revenue, both in fiscal Q4.

For fiscal Q4, Cree now targets revenue of \$375m (including the \$27m revenue reserve):

- Lighting Products revenue is expected to increase slightly sequentially, as strong growth in commercial lighting should more than offset a greater-than-targeted

Revenue reserves and lower pricing is forecast to reduce revenue by \$35m

seasonal slowdown in consumer bulb sales;

- Power & RF Products revenue is tracking in-line with targets;

- LED Products customer unit demand is generally in-line with targets, but the combination of the revenue reserves and lower pricing is forecast to reduce revenue by \$35m;

- overall gross margin and operating margin are now forecast to be lower than previously targeted due to the restructuring costs, the more aggressive LED pricing environment, and the larger-than-targeted seasonal slowdown in consumer lighting; and

- during fiscal Q4, Cree completed the previously announced \$550m share buyback program by repurchasing 4.8 million shares of common stock at an average price of \$33.37 per share (totaling \$160m); for fiscal 2015, it repurchased 16 million shares at an average price of \$34.33.

www.cree.com

New high-intensity class of LEDs more than doubles performance

Cree Inc of Durham, NC, USA claims that its new XLamp XP-L High Intensity LED is the first single-die LED to deliver more than 100,000 candela with a 50mm diameter optic at 10W (more than double the candelas of the industry's previous highest-performing single-die LED — the XP-L — through the same optic).

Based on Cree's SC5 Technology Platform and leveraging the existing 3.45mm x 3.45mm XP-L package, the new high-intensity LEDs allow lighting manufacturers to quickly boost performance, reduce size and lower system cost for applications such as track, outdoor and stadium lighting, says Cree.

Featuring Cree's new primary optic design that reduces optical

source size by more than 50%, the XP-L High Intensity LED delivers unprecedented candela at 185 lumens per watt at one watt. The new High Intensity LED offers a drop-in-ready upgrade for XP-based luminaire designs, enabling manufacturers to achieve higher luminous intensity with minimal redesign to speed time to market.

"The XP-L High Intensity LED allows us to boost the efficacy and intensity of our XP-G2 LED based designs without changing optics or drivers," comments Jon Quenzer, electrical engineer at Trek.

The new LED delivers both lumens and unprecedented intensity in a small form factor, claims Dave Emerson, VP & general manager for Cree LEDs. "The XP-L

High Intensity LED will allow lighting designers to fundamentally change the way they think about using LEDs in high-intensity lighting and enable lighting manufacturers to reach performance levels previously not possible," he adds.

Characterized and binned at 1050mA (85°C), the XP-L High Intensity LED is available with a color rendering index (CRI) of up to 90 and color temperatures ranging from 2700K to 8300K. For lighting manufacturers seeking ENERGY STAR qualification, 6000 hours of LM-80 long-term testing data is available.

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

www.cree.com/xlamp/hi

Osram launches variable LED family offering design flexibility for automotive lighting

Osram Opto Semiconductors GmbH of Regensburg, Germany has launched the Synios P 2720 family of LED light sources, designed and qualified for use in automotive lighting.

From the outside, the 15 versions in the new family can hardly be distinguished from each other (with all of them having the same solder pad design and package dimensions), but on the inside various chip sizes (with an edge length between 500µm and 1mm), different levels of brightness, and a broad range of colors make the LEDs extremely variable.

Car headlights and tail-light clusters are increasingly becoming identifying features in cars, says the firm. Individual headlight design is the vehicle's signature and increases brand recognition. The compact dimensions and scalable package concept of the light sources provide engineers with greater design freedom, particularly for car headlights. The 2.7mm x 2.0mm x 0.6mm packages are equipped with various chips in different sizes and colors. The LEDs' materials provide high reliability and temperature cycling stability, says the firm. Due to their



SMT design, the components can be used in standard processes.

With their 120° emission characteristic and compact dimensions, the flexible light sources are particularly suitable for injecting light into light guides. They can be used in headlights, for example as daytime running lights (DRLs), and perform various functions in tail-light clusters. Due to optimum light extraction from the package and good thermal properties, the LEDs offer more light per cost unit, says the firm. For example, luminous efficiency is 110lm/W in white, and 80lm/W in red.

The Synios P 2720 family comprises three chip sizes with

Efficiency is 110lm/W in white, and 80lm/W in red

edge lengths of 500µm, 750µm and 1mm (and thermal resistances of 20–30K/W, 10–14K/W and 7–9K/W, respectively), and is available in the following colors: white ($C_x = 0.32$, $C_y = 0.33$ as per CIE 1931), converted yellow ($C_x = 0.57$, $C_y = 0.42$ as per CIE 1931), yellow (586–595nm), red (612–630nm), and super red (627–639nm).

Depending on chip size, brightness is easy to scale, and various levels can be selected according to demand. Also, due to their identical solder pad design and packages, the various LED versions offer setmakers great flexibility for their processes, allowing the use of various levels of brightness and different colors in applications without the need to change any processes. It is also easier to meet prescribed standards such as ECE and SAE, claims the firm, as product design and solder pad design remain the same.

"Nine of the 15 Synios versions are now available on the market," says Thomas Christl from LED Marketing Automotive. "The remaining InGaAlP LEDs with 750µm and 1mm chip will follow in the summer," he adds.

www.osram-os.com

DOE publishes updated SSL R&D Plan

The US Department of Energy (DOE) has published the 2015 edition of the Solid-State Lighting (SSL) R&D Plan.

A consolidation of DOE's SSL Multi-Year Program Plan and SSL Manufacturing R&D Roadmap of previous years, the new R&D Plan was developed in conjunction with community experts through inputs received at roundtable meetings held in October 2014 and at the DOE SSL R&D Workshop in January in San Francisco. The discussions covered R&D needs for LED and organic LED (OLED) technologies, ranging from core technology

research and product development, through manufacturing and applied technology R&D.

Referenced by industry and government both in the USA and abroad, the R&D Plan reflects the consensus view of the community on key barriers, technology challenges to address, and where R&D efforts are required over the next 3–5 years. It provides analysis and direction for ongoing R&D activities to advance SSL technology and increase energy savings, reviewing SSL technology status and trends for both LEDs and OLEDs and offering an overview of the current DOE

SSL R&D project portfolio.

While the entire R&D Plan has been updated with the latest figures, some revisions are more extensive. Among the more noteworthy changes are deeper dives into source efficacy, light utilization, and improved performance and design, as well as the addition of sections on cost of ownership, sustainability, and new functionality such as spectral control and tuning, improved controls, integration with building automation, and visible light communication.

www.ssl.energy.gov/techroadmaps.html

Osram develops high-power Duris S 10 as compact, single-LED alternative to multiple low-lumen CoB LEDs

Osram Opto Semiconductors GmbH of Regensburg, Germany has added to its Chip Array SMD family (CAS) with the Duris S 10 LED, which is characterized by high efficiency, high light output and uniform color appearance.

Efficient surface-mounted device (SMD) technology makes assembly simple and leads to significant cost savings in system and optic designs of up to 30%, depending on the particular application, says the firm. The Duris S 10 has a compact footprint and is available in two luminous flux output classes of up to 1400 lumens (at a drive current of 300mA and a correlated color temperature of 3000K at 85°C), simplifying the design of lamps and luminaires. This makes the new LED suitable for use in spotlights, down lights, and directional and omnidirectional retrofits.

"With typical luminous flux packages of 1050 lumens [for the GW P7LM32.EM] and 1400 lumens [for the GW P7LP32.EM] and a light-emitting surface of only 7.7mm in diameter, the new Duris



Osram's new Duris S 10 LED, an alternative to low-power CoB LEDs.

S 10 forms the basis for compact optics and extremely narrow beam angles," says Marc Dyble, marketing & business development manager for general lighting.

The lumen packages were chosen specifically for standard applications, such as MR16 retrofits, and enable the creation of lamp and luminaire designs on the basis of a single Duris S 10. This helps to prevent multiple shadow effects — an advantage over the frequently used multi-LED clusters, says the firm. Both single-spot versions of the Duris S 10 have the same footprint

of 7mm x 7mm, offering flexibility in the design of compact luminaires with high luminous flux. The small size of the LED and simplified design of the optics makes it is easier to integrate standard accessories, such as lenses and reflectors, the firm adds.

Both Duris S 10 CAS LEDs are binned according to the familiar MacAdam ellipses, resulting in a more uniform color appearance. In view of the surface-mounted design of the LED, a printed circuit board (PCB) must be incorporated in the luminaire. This opens up numerous design options such as integrating thermal fuses, connectors or driver components on the LED board. In standard chip-on-board (CoB) solutions, these functions need to be accommodated on a separate PCB, taking up more space, notes Osram Opto. Compared with these established solutions, the two new Duris S 10 LEDs provide compact alternatives in this luminous flux category, the firm adds.

www.osram-os.com/duris

'Borderless' chip-size Duris S2 LED as fluorescent tube replacement

Osram Opto Semiconductors is extending its Duris product portfolio with a compact version without a classic package. Joining the existing S 5 and S 8 versions, the Duris S2 is in the low to middle output range and offers a high typical luminous efficacy of 160lm/W (at 65mA) and what is claimed to be excellent color homogeneity and color stability. It is therefore capable of achieving homogeneous illumination in LED products designed as replacements for fluorescent tubes.

Due to its compact footprint of only 2.0mm x 1.6mm, the space-saving LED (the smallest in the Duris family) is suitable for linear lighting solutions. With an emission

beam angle of 150°, the chip-size LED emits more light to the side than LEDs with classic packages. The light is therefore better distributed in linear lamps and luminaires, and hot spots (visible points of light) are reduced, says Osram. This in turn enables the number of LEDs and hence costs also to be reduced. By overdriving the LED up to a current of 150mA, the range of applications for the new Duris S 2 can be extended to recessed ceiling luminaires and panel luminaires.

The S 2 is the first Osram LED to use a new lead frame material, an epoxy molding compound (EMC). "Thanks to this material the Duris S 2 has a longer life of up to

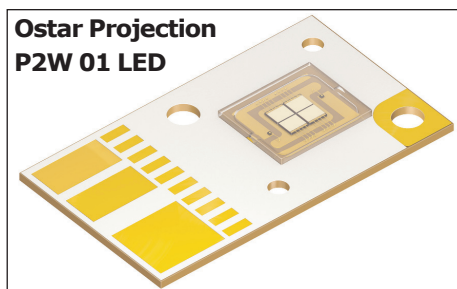
50,000 hours," says Tony Tam, project manager responsible for the Duris product family. This is more than that of existing Duris products such as the 35,000 hours of sister LED Duris E 3. "Other products featuring this technology will follow," adds Tam.

The Duris S 2 is available in different correlated color temperatures (CCTs): 3000K, 3500K, 4000K and 5000K. From summer, additional versions with color temperatures of 2700–6500K will follow. The new LED is currently being subjected to extensive quality testing. Certification based on the LM-80 standard (Energy Star) is in progress and the results are likely to be available in winter 2015/2016.

Osram's new four-chip Ostar Projection LED ensures 24/7 operation for rear projection systems

Osram Opto Semiconductors GmbH of Regensburg, Germany has added the P2W 01 LED to its Ostar Projection series. The new LED contains four chips that can be controlled in two separate groups, providing an integrated solution that, in the event of emergencies, offers trouble-free operation in safety-related and security-related applications such as control-room monitors.

"The redundant systems of the new Osram Ostar Projection LED make it ideal for 24/7 applications," says product marketing manager Andrew Lin. "If a chip should ever unexpectedly fail, the second system will continue to operate without any problem at all," he adds. Up to now, only the chips in the larger Ostar Projection P3W could be controlled separately. The P2W 01 makes this possible with a compact LED that has two self-contained parallel systems with two chips each. The connection design has also been improved, from 2-pad to 3pad, providing three connections instead of two. All four chips occupy one pad,



and the other two pads are each reserved for a group of two. "A new soldering process ensures that the heat produced in the application remains low, enabling the connection between the chip and the package to withstand higher-temperature operation," says Lin.

The high-current chips in the new Ostar Projection are based on Osram's most advanced thin-film and UX:3 chip technologies. They produce high luminance, resulting in extremely bright and vivid images, says Osram. The new LED enables lighting solutions to be more compact than before, because a smaller active surface is required to achieve the same light output, the firm adds (a 2.6mm x 3.2mm illuminated area

in a 27mm x 16mm x 2.1mm package). Customers who are currently using the P2W can easily upgrade their design to the new P2W 01 because the size and optical and technical data correspond to those of the P2W version. Connectors and other accessories are readily available on the market.

The new LED can be used in particular as a light source for rear projection systems (involving projecting the image onto a screen with the aid of reflective optics). Such systems are often designed without borders. Multiple systems can be arranged seamlessly next to each other, creating a large borderless display with multiple screens on which one image can be shown or a different image can be shown on each screen. These systems are used predominantly in the security sector, where 24-hour operation is needed. Applications include control rooms for subway stations, railroad stations and underground car parks, as well as major events and industrial plant control.

Second-generation Duris S 8 LED launched with 17% greater efficacy

Osram Opto Semiconductors has launched a new generation of its compact high-power Duris S 8 LED with significant efficacy improvement of up to 17%, achieved by introducing a new leadframe material and chip generation.

Available in the same 5.0mm x 5.0mm footprint, the new LED is available in three different lumen packages (GW P9LM31.EM, GW P9LR31.EM and GW P9LT31.EM) containing six, eight or ten chips yielding different luminous flux brightness levels of 375, 500 and 610 lumens (typical), respectively, at a correlated color temperature (CCT) of 3000K.

Due to an enhanced epoxy-based package, the new LEDs offer long lumen maintenance, even at high

currents and temperatures. With a forward voltage ranging from 19V to 32V (depending on type), simpler and more compact driver designs can be realized, says the firm. Due to the high-lumen packages, single light source design can be implemented, avoiding multiple shadows, simplifying lens and PCB design, and leading to lower systems costs as well as improved total system efficacy of up to 17%.

Exhibiting a color rendering index (CRI) of 80 and CCT between 2700 and 6500K, the new Duris S 8 LED has improved efficacy of 135lm/W for the six- and eight-chips versions and 131lm/W for the ten-chip version (at a CCT of 3000K and a drive current of 150mA). All three versions of the multi-chip LEDs are

binned according to the MacAdams principle, based on a 3-step or 5-step MacAdams ellipse for color consistency. To create realistic application conditions, the new LED is grouped at 85°C instead of at room temperatures for color binning. The new product generation is hence suitable for use in indoor lighting solutions, especially for directional retrofits, spotlights and downlights.

The new Duris S 8 is pin-to-pin compatible with the previous generation (and hence usable with the same optics and accessories), so users can find the optimal LED for their lighting application (e.g. omni-directional and directional retrofits or downlights), says Osram.

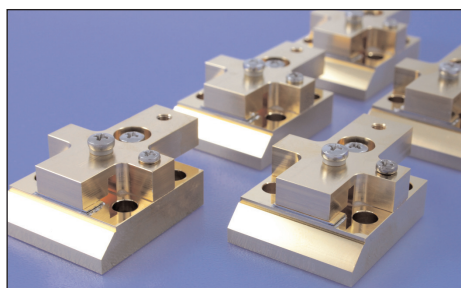
www.osram-os.com

FBH reports record 2kW output from single 1cm-long diode laser bar as part of CryoLaser project

In a talk and tutorial at CLEO 2015 (Conference on Lasers and Electro-Optics) in San Jose, CA, USA (10–15 May), a team led by Paul Crump from FBH (Ferdinand-Braun-Institut, Leibniz-Institut für Hoechstfrequenztechnik) of Berlin, Germany presented the latest results from the project CryoLaser (which ran from January 2012 to December 2014), demonstrating for the first time that a single 1cm laser bar can deliver at least 2kW of optical output power, when cooled to 203K.

Ultra-high-energy lasers are tools for basic science, for novel medical applications and, not least, for laser-induced fusion. The systems require diode lasers that are not just extremely capable, but also manufacturable at low costs in very high volumes. Specifically, diode lasers bars in the wavelength range 930–970nm are the fundamental building blocks for pump sources for ytterbium-doped crystals in large laser facilities, where optical pulses are generated with petawatt-class peak energies and picosecond pulse widths. The individual laser bars in these pump sources have a typical output power of 300–500W.

FBH is currently optimizing both the necessary design and technology as a part of the project CryoLaser,



Laser bars with optimized mounting for high-power operation on CCP mount, developed within the CryoLaser project (photo: FBH/P. Immerz).

which is funded by Germany's Leibniz Association. If the cost per photon is to fall, a higher optical power density must be generated, reducing the amount of material needed. The conversion efficiency must also be dramatically improved for enhanced system efficiency. CryoLaser uses a novel design concept, developing innovative structures that are optimized for operation far below the freezing point (–70°C, 203K), since the performance of diode lasers is substantially improved at such temperatures.

Building on advances in epitaxial design and packaging technology, FBH bars emitting at a wavelength of around 940nm at temperatures of –70°C (203K) delivered what is reckoned to be a record 2kW peak power per bar at a current of 2kA,

a pulse width of 200µs and 10Hz repetition rate (corresponding to a pulse energy of 0.4J). Peak power was limited by the available current. To date, such powers could only be achieved by combining the optical beams from at least four single bars. The electro-optical energy conversion efficiency was 65% at 1kW output and 56% at 2kW. Such bars have the potential to play an important role in future high-energy-class laser facilities, says FBH. Currently, the team is working to further increase the conversion efficiency of the laser bars.

The FBH is responsible for the full value chain within the CryoLaser development project, from design to construction of first prototypes. The final pump sources are being evaluated for potential use in high-energy-class diode-pumped solid-state laser systems together with various groups in the field — LIFE in the USA and HiPER (European High Power laser Energy Research) in the EU. Project partners include the USA's Lawrence Livermore National Laboratory and the Central Laser Facility (CLF) at the UK Science and Technology Facilities Council (STFC) Rutherford Appleton Laboratory.

www.cleoconference.org
www.fbh-berlin.com/business-areas/diode-lasers/ba-lasers-bars/cryolaser

DILAS delivers 20,000th fiber-laser pump module

Diode laser maker DILAS of Mainz, Germany has delivered its 20,000th high-power, high-brightness tailored bar-based (T-Bar) fiber-laser pump module.

Shipping its first unit in 2009, the milestone product was designed and developed as a pump source for kilowatt-class fiber-laser systems. Planned as a volume product from the very beginning, the production process has a high degree of automation.

Through optimization of chip structures and optical parameters, DILAS' T-Bar architecture delivers high beam quality and high power using standard micro-optic fast-axis and slow-axis collimators (FACs and SACs), all assembled with automated processes. The T-Bar is a monolithic multi-emitter source allowing the handling of multiple emitters during each manufacturing step, to lower complexity and ease manufacturing. The result is

enhanced reproducibility, beam quality and fiber-coupling efficiency.

Conservatively specified to 135W out of 200µm-diameter, 0.22NA fiber when designed, the T-Bar module was later increased to 200W by optimizing the chip structures and fiber-coupling processes. DILAS' latest generation has a higher density of tailored diode laser bars with output of 250W out of 200µm fiber and 270W out of 225µm fiber.

www.dilas.com

VI Systems wins €2m European Horizon 2020 SME grant Phase 2 funding to further develop pre-production of VCSEL-based optical interconnects

VI Systems GmbH of Berlin, Germany (a fabless spin-off of the Technical University of Berlin and the A. F. Ioffe Physico-Technical Institute in St Petersburg, Russia) has been chosen by the European Commission to receive €1.97m in funding under the SME Instrument scheme of European Horizon 2020 (the EU's framework program for Research and Innovation for 2014–2020), which has been designed to turn small- and medium-size enterprises with highly innovative business ideas and international ambitions into commercial successes.

Specifically, the Horizon 2020 SME Instrument scheme aims to accelerate the uptake of nanotechnologies, advanced materials or advanced manufacturing and processing technologies by SMEs.

VI Systems has developed technology that uses ultra-high-speed vertical-cavity surface-emitting lasers (VCSELs) in combination with integrated circuits for the next generation of interconnects in data-centers, super-computers and consumer products such as next-generation displays and mobile devices.

The VCSEL and photo-detector technology is suited to energy-efficient interconnects at distances up to a few hundred meters. VCSELs developed by the firm with bit data rates well beyond 40Gb/s enable error-free data transmission over 100m of standard multi-mode fiber. Future markets such as Ethernet transceivers operating at 400Gb/s and customized products such as active optical cables (AOCs) and

mid-board assemblies are targeted.

VI Systems says it has received the SME Instrument phase 2 funding to further develop its innovation and pre-production activities, such as demonstration, testing, piloting, scaling up and miniaturization of its

VCSEL-based optical interconnect technology.

www.v-i-systems.com

<https://ec.europa.eu/easme/en/sme/5604/photonic-transmitters-optical-networks-and-interconnects-energy-efficient-datacentres>

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POET appoints GlobalFoundries' senior VP of technology development as its CEO

POET Technologies Inc of Toronto, Canada — which, through subsidiary OPEL Defense Integrated Systems (ODIS Inc) of Storrs, CT, USA, has developed the proprietary planar-optoelectronic technology (POET) platform for monolithic fabrication of integrated III-V-based electronic and optical devices on a single semiconductor wafer — has appointed Dr Suresh Venkatesan (an industry veteran with over 22 years of experience in semiconductor technology development) as CEO.

Venkatesan was most recently senior VP technology development at GlobalFoundries, responsible for its technology R&D. He joined GlobalFoundries in 2009, where he led the development and ramp of the 28nm node and was instrumental in the technology transfer and qualification of 14nm. In addition, he was responsible for the qualification and ramp up of multiple mainstream value-added technol-

ogy nodes. Previously, Venkatesan held various leadership positions with Freescale Semiconductor in Austin, Texas.

Venkatesan holds over 25 US patents, and has co-authored more than 50 technical papers. He has a Bachelor of Technology degree in Electrical Engineering from the Indian Institute of Technology and Master of Science and PhD degrees in Electrical Engineering from Purdue University.

"He has the unique skill set of product and device development and a deep understanding of the physics involved in the process," comments Peter Copetti (interim CEO since February 2014), who will continue to serve as executive co-chairman. "We have been looking for over one year for the perfect permanent CEO and I believe we have found that person. He brings tremendous leadership and foundry industry development and strategy

experience. This is a critical milestone in the Company's succession plan as we continue our 'lab-to-fab' transition," he adds.

"I see immense market potential for POET Technology's III-V complementary semiconductor fabrication process," says Venkatesan. "The industry is at inflection point where new innovative solutions are needed. Integrating electronics and optical devices on the same chip monolithically can revolutionize many segments of the semiconductor market," he believes.

"On behalf of the board of directors, I would like to express our most sincere thanks to Peter for his vision and his determination to take POET to the next level. The financial turnaround of the company was remarkable and is now complete," says POET founder Dr Geoff Taylor. "We are now focused on product development and achieving revenue." www.poet-technologies.com

POET adds Alfalight president & CEO to board

Following its annual meeting of shareholders and subsequent meeting of directors on 12 June, the board of POET has increased the number of directors from 8 to 10 and appointed CEO Dr Suresh Venkatesan and Mohandas Warrior to fill the vacancies created by the increase.

Since February 2004, Warrior has been president & CEO of Alfalight Inc of Madison, WI, USA, a gallium arsenide (GaAs)-based high-power diode laser manufacturing firm that serves military, telecom and industrial customers. Warrior restarted the firm in 2004 and established it as a provider of high-powered laser diode solutions in both commercial and defense segments. The firm sold the commercial business in 2013. He continues to run the retained defense and security segments of Alfalight,

which is now focused on providing solid-state laser systems for targeting, tracking and illumination applications to the US military. Under his leadership, Alfalight has grown profitably and is anticipating a value-added merger & acquisition (M&A) transaction during 2015. Prior to joining Alfalight, Warrior's career included 15 years at Motorola Semiconductors (now Freescale) where he led the test & assembly operations (a group of 3500 staff) in the USA, Scotland and South Korea.

Warrior has a BTech in Chemical Engineering from IIT Delhi, an M.S. in Chemical Engineering from Syracuse University, and an MBA from the Kellogg School of Management at Northwestern University.

"He brings a new dimension to the board, with his unique GaAs foundry experience serving com-

mercial and defense markets for high-powered laser diode solutions," comments Venkatesan. "He is the latest addition to our world-class technical team on the board of directors that we have assembled over the past six months," he adds. "We look forward to working with Mohan and the board as we continue the drive from 'lab-to-fab' as part of our monetization strategy."

At their annual meeting, shareholders approved the following:

- re-election of all directors of the company, as recommended by management; and
- authorizing (subject to regulatory approval) the filing of articles of amendment to consolidate common shares on the basis of one new share for a maximum of every three shares issued and outstanding and a change company name to POET Technologies Corp.

Mellanox announces promotions pending retirements of both senior VP of engineering and chief operating officer

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, has promoted Dr Mehdi Asghari to VP of silicon photonics, Eyal Babish to VP of hardware, Ronnen Lovinger to VP of operations & corporate quality, Henning Lysdal to VP of active interconnect engineering, and Alon Webman to VP of silicon engineering. Asghari, Babish, Lovinger and Webman will report to president & CEO Eyal Waldman, while Lysdal will report to VP of silicon engineering Alon Webman (with a dotted line to Waldman). "I am pleased to announce the promotions of Mehdi, Eyal, Ronnen, Henning and Alon. Their longstanding record of leadership and their ability to execute have been instrumental to Mellanox's growth and success"

"Their long-standing record of leadership and their ability to execute have been instrumental to Mellanox's growth and success," comments Waldman. "They will lead Mellanox to our next stage of growth and product leadership."

The promotions complete the succession plan following the announcement on 21 April that senior VP of engineering Roni Ashuri and chief operating officer Shai Cohen (both co-founders of Mellanox in 1999) will retire in fourth-quarter 2015

VP of silicon photonics Asghari is

responsible for all aspects of Mellanox's silicon photonics technology and product development. Asghari has over 20 years of research and product development experience within the silicon photonics industry. Previously, he was chief technology officer at Kotura Inc (acquired by Mellanox in 2013). Prior to Kotura, he was VP of R&D at Bookham Inc (responsible for R&D and manufacturing transfer activities behind all of Bookham's silicon-based technologies and products). Asghari has a Ph.D. degree in Optoelectronics from England's University of Bath and an M.Sc. degree in Optoelectronics and Laser Devices from the Heriot-Watt and St. Andrews universities in Scotland. He also holds Master's and B.Sc. degrees in Engineering from the UK's Cambridge University.

VP of hardware Babish joined Mellanox in 2001 and is responsible for all hardware and system products. Previously, he was VP of system solutions (responsible for managing the firm's system solutions and product engineering organization including development, qualification, certification, production testing, program management and customer support). Previously, Babish was a hardware engineer at Elbit Systems. He graduated with a B.Sc. in Computer Science from the Technion Institute of Technology, Israel.

VP of operations & corporate quality Lovinger joined Mellanox in 1999 and is responsible for all operations and corporate quality. Previously,

he was VP of manufacturing operations. Prior to Mellanox, Lovinger worked at Intel Corp, where he held several engineering positions in microprocessor circuit design. He has a B.Sc. in Electrical Engineering from the Technion Institute of Technology, Israel.

VP of active interconnect engineering Lysdal is responsible for Mellanox's analog interconnect integrated circuits. He was co-founder, chief operating officer and later VP of engineering for IPtronics A/S (acquired by Mellanox in 2013). Prior to the founding of IPtronics in 2003, Lysdal served as high-speed PHY development manager at Giga A/S and Intel Corp. He has 18 years of experience with ICs for optical communication and has a Master's degree in Microelectronics Engineering from the Technical University of Denmark.

VP of silicon engineering Webman was a co-founder of Mellanox in 1999 and is responsible for all IC design, including front-end and back-end. Previously, he was VP of engineering, switch products. Webman has served the firm in numerous roles over the past 16 years, including chip development, post-silicon management, program management, and customer support. Prior to Mellanox, he held various engineering positions at Intel and Nexus. Webman holds a BSEE in electrical engineering from the Technion Institute of Technology, Israel.

www.mellanox.com

Luna and Advanced Photonix complete merger

Luna Innovations Inc of Roanoke, VA, USA (which manufactures fiber-optic sensing and test & measurement products for the telecoms, energy, healthcare, automotive, aerospace and defense markets) and Advanced Photonix Inc (API) of Ann Arbor, MI, USA (which designs

and makes APD, PIN, and FILTRODE photodetectors, HSOR high-speed optical receivers, and T-Ray terahertz instrumentation) have completed their merger (which was announced on 12 February).

In an annual meeting, Luna's stockholders approved the issuance

of 0.31782 shares of Luna common stock to API stockholders for each share of API common stock they own. API's stockholders approved the merger in a separate special meeting.

www.advancedphotonix.com
www.lunainc.com

IBM unveils fully integrated wavelength-multiplexed silicon photonics chip for 100Gb/s transceivers

Error-free operation demonstrated up to 32Gb/s from CMOS integrated monolithic nano-photonic transmitter

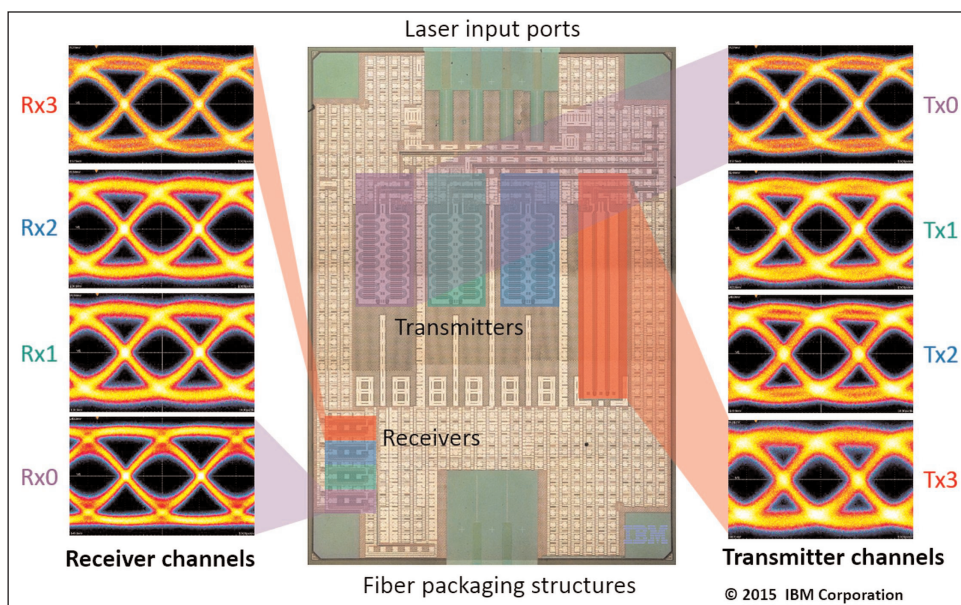
IBM has designed and tested the "first fully integrated wavelength-multiplexed silicon photonics chip", enabling manufacturing of 100Gb/s optical transceivers.

"Making silicon photonics technology ready for widespread commercial use will help the semiconductor industry keep pace with ever-growing demands in computing power driven by big-data and cloud services," says Arvind Krishna, senior VP & director of IBM Research in Yorktown Heights, NY. "This technology is designed to make future computing systems faster and more energy efficient."

Silicon photonics optical components can be used to transfer large volumes of data at very high speed between computer chips in servers, large data-centers and supercomputers, overcoming the limitations of congested data traffic and high-cost traditional interconnects. IBM's new development enables the integration of different optical components side-by-side with electrical circuits on a single silicon chip using sub-100nm semiconductor technology.

The silicon photonics chip uses four wavelengths of light within the optical fiber (rather than traditional copper wiring) to transmit data in and around a computing system. The new transceiver can download an entire high-definition digital movie in just 2 seconds, it is estimated.

The technology industry is entering a new era of computing that requires IT systems and cloud computing services to process and analyze huge volumes of data in real time, both within data-centers and especially between cloud computing services, notes IBM. This needs data to be moved rapidly between system components without congestion. Silicon photonics greatly reduces data bottlenecks inside systems and between computing components, improving response times, says IBM.



Eye diagrams illustrate four separate transmitter channels (right) exchanging high-speed data with four receiver channels (left), each running at 25Gb/s. Credit: IBM.

Silicon photonics to transform data-centers

Most of the optical interconnect solutions used within data-centers are currently based on vertical-cavity surface-emitting laser (VCSEL) technology, where the optical signals are transported via multi-mode optical fiber. Demands for increased distance and data rate between ports, due to cloud services for example, are driving the development of cost-effective single-mode optical interconnect technologies, which can overcome the bandwidth-distance limitations inherent to multi-mode VCSEL links.

IBM reckons that, by combining monolithically the essential optical and electrical components of an optical transceiver (as well as structures enabling fiber packaging) onto a single silicon chip, its CMOS Integrated Nano-Photonics Technology can provide a cost-effective solution to extend the reach and data rates of optical links. Also, manufacturing makes use of standard fabrication processes at a

silicon chip foundry, making the technology ready for commercialization, reckons IBM.

IBM engineers in New York and Zurich, Switzerland and IBM Systems Group have demonstrated a reference design targeting data-center interconnects with a range up to 2km. The chip demonstrates transmission and reception of high-speed data using four laser frequencies, each operating as an independent 25Gb/s optical channel. Within a full transceiver design, these four channels can be wavelength multiplexed on-chip to provide 100Gb/s aggregate bandwidth over a duplex single-mode fiber, minimizing the cost of the installed fiber plant within the data-center.

IBM presented the work at May's Conference on Lasers and Electro Optics (CLEO) in San Jose in the invited presentation 'Demonstration of Error Free Operation Up To 32Gb/s From a CMOS Integrated Monolithic Nano-Photonic Transmitter'.

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GigOptix reports record income in Q1

driven by 40G data-center & 100G coherent linear telecom installations

For first-quarter 2015, GigOptix Inc of San Jose, CA, USA (a fabless supplier of analog semiconductor and optical communications components for fiber-optic and wireless networks) has reported revenue of \$9.1m, up only slightly on \$9m last quarter but up 23% on \$7.4m a year ago, and above the expected \$8.5–8.7m. In particular, product revenue was up 6% on last quarter and 28% on a year ago, in what is historically a seasonally weaker quarter. Joint development program (JDP) revenue was \$0.5m, down from \$0.9m last quarter.

Growth came primarily from fast-growing areas within the High-Speed Communications business, driven by the continuing strong demand for 40Gbps devices for Web 2.0 data-center infrastructure installations and for 100Gbps coherent linear devices for telecom infrastructure installations. The High-Speed Communications business (Datacom and Telecom optical communications products plus wireless RF point-to-point products) has hence grown further, from 66% of total revenue last quarter to 68%, rising to \$6.2m (up 3% on last quarter and 17% on a year ago).

The contribution from the Industrial (ASIC) product line has correspondingly fallen further, from 34% of total revenue last quarter to 32% (\$2.9m, although this is down only slightly on \$3m last quarter and up 36% on a year ago due to some customers moving to smaller-geometry ICs).

On a non-GAAP basis, gross margin was 62%, level with last quarter and up from 60% a year ago. Operating expenses have risen from \$4.7m last quarter to \$4.9m, driven mainly by higher payroll taxes at the beginning of the year, normal year-end audit fees, and industry tradeshow expenses.

Net income was \$0.7m (\$0.02 per diluted share), down slightly from

\$0.9m (\$0.03 per diluted share) last quarter but an improvement on a net loss of \$0.7m (\$0.02 per diluted share) a year ago (and the fourth consecutive quarter of positive net income, representing the firm's most profitable first quarter). Likewise, adjusted EBITDA (earnings before interest, taxes, depreciation, and amortization) was \$1.4m, down slightly from \$1.6m last quarter but up on \$47,000 a year ago (and the 15th consecutive quarter of positive adjusted EBITDA). Spending on property, plant & equipment (PP&E), including production assets, was level at about \$0.4m. However, driven by a build-up for High-Speed Communications business, inventory has risen from \$5.1m to \$6m. Hence, altogether during the quarter, cash and cash equivalents fell from \$18.4m to \$17.7m.

"At the recent OFC [Optical Fiber Communications] conference a few weeks ago, we featured several new Datacom and Telecom 100Gbps and 400Gbps products, all of which have already been accepted by leading Telecom and Datacom customers, and which will be the main drivers of our expected continuous revenue growth this year," says chairman & CEO Dr Avi Katz. "In addition, we are releasing new products in our High-Speed Communications product lines, including our first 100Gbps linear TIA [transimpedance amplifier], which will be available shortly for sampling by key telecom customers,"

We are releasing new products in our High-Speed Communications product lines, including our first 100Gbps linear TIA, which will be available shortly for sampling by key telecom customers

he adds. "These products will expand on our already strong position in areas within the telecom and data-center markets that are quickly moving to 400Gbps and 100Gbps platforms, respectively."

In the Industrial business, GigOptix recently launched new power management mixed-signal ASIC products to address high-end applications in the automotive industry. "This represents a new and complementary business approach with our ASIC technology wherein we initiate engagements for sophisticated mixed-signal, RF and optical ASIC devices that leverage on our skills in high-speed and high-frequency RF device design," says Katz.

"Additionally, these engagements expand upon our ASIC design knowledge and should open up new opportunities in what is a very stable and highly profitable segment of our business," he adds.

"The positive momentum we have seen in the last year should continue into the June quarter," believes VP & chief financial officer Darren Ma. For Q2/2015, GigOptix expects revenue of \$9.3–9.5m (up 3–5% sequentially and 16–18% year-on-year). Gross margin should be about 60%, while operating expenses should fall slightly. "While it is still early in our fiscal year, we reinforce our previous forecast of annual revenue to be approximately \$37–38m, or growing approximately 14% over the prior year," Ma adds.

"With a strong start to our fiscal 2015, a solid backlog for the coming quarter and encouraging revenue projections for the rest of the year, we have increasing confidence that our financial performance this year will result in record revenue, and non-GAAP and adjusted EBITDA profitability, while at the same time getting us closer to achieving our next goal of delivering GAAP profitability," notes Katz.

www.gigoptix.com

GigOptix launches 3rd-generation 100G Ethernet chipset

GigOptix has launched its third-generation chipset for 100Gbps Ethernet data-center and cloud computing applications.

The HXT8204 28Gbps 4-channel vertical-cavity surface-emitting lasers (VCSELs) driver array and HXR8204 28Gbps trans-impedance amplifier (TIA) receiver array enable the next generation of lower-power 100Gbps Ethernet SR4 module and active optical cable (AOC) solutions.

The HXR8204 four-channel receiver with integrated TIA provides 60 μ A_{pp} input sensitivity at 28Gbps with 10⁻¹² bit-error rate (BER), AGC and ATC, and a limiting post-amplifier stage. Linear, per channel RSSI outputs are provided to enable active alignment during manufacturing to yield optimum performance and manufacturability. The

1MHz I2C interface enables full control of additional functionality such as signal detect and squelch, pre-emphasis, maskable interrupt generation, internal temperature monitor selection, channel polarity inversion, and output voltage swing with enable.

The HXT8204 four-channel VCSEL driver supports modulation and average VCSEL currents up to 10mA with a dedicated burn-in capability up to 15mA average current. The 1MHz I2C interface enables full control of all driver functions including input equalization, output peaking and peaking duration, signal detect and squelch, channel polarity inversion, diagnostics such as average current and temperature monitoring as well as user maskable interrupts and VCSEL

voltage supervisory functions.

The datacom Ethernet market is expected to show a compound annual growth rate (CAGR) of 60% over the next seven years, according to LightCounting's 'Ethernet Transceivers Forecast – June 2014'. "Our third-generation solution enables a 20% typical reduction in power dissipation over our earlier chipset solutions without sacrificing performance or robustness," says datacom marketing director Tom Kapucija. "In addition, in certain applications such as active optical cables, we see up to 30% power reduction."

The HXT8204 and HXR8204 are sampling now and will ship in full production volumes in third-quarter 2015.

www.gigoptix.com

GigOptix renews expanded line of credit with Silicon Valley Bank

GigOptix has renewed an expanded revolving line of credit with Silicon Valley Bank (SVB).

The latest amendment to the credit facility extends through 6 May 2016, and immediately provides GigOptix with an additional \$3.5m of borrowing capacity, providing a \$7m accounts receivable revolving line of credit, while also maintaining an existing separate

facility under which GigOptix is entitled to borrow up to \$3.5m with specific re-payment conditions, for a total borrowing capacity of \$10.5m.

"The expansion of our line of credit adds additional flexibility to our already strong financial position, which includes almost \$18m of cash and zero debt," says chairman & CEO Dr Avi Katz.

"While we have no current plans to

draw on this line, having the increased \$10.5m line of credit readily available improves our ability to quickly execute on potential strategic acquisitions as we continue to look for ways to further increase shareholder value."

The full text of the loan agreement and the latest amendment has been filed with the US Securities and Exchange Commission (SEC).

GigOptix renews interest in acquiring GSI for \$6.50 per share

GigOptix has renewed its proposal of 18 August 2014 to acquire GSI Technology Inc of Sunnyvale, CA, USA — a provider of static random access memory (SRAM) products primarily incorporated in networking and telecoms equipment — for \$6.50 per share. This represents a 32% premium to the then share price, and a 10% premium to the highest price at which the shares have traded since GigOptix withdrew its offer on 14 November 2014. From 18 August to 14 November, GSI had rejected efforts to engage in a direct dialogue, says GigOptix.

In May, GSI announced the settlement of litigation with Cypress Semiconductor. "GSI Technology incurred over \$30m in litigation expenses for which the net result was a wash to GSI," notes GigOptix founder, chairman & CEO Dr Avi Katz in a letter to GSI's board. "This, despite setting unreasonably high expectations for your investors, such as the comment made during a May 2014 presentation at the B. Riley & Company investor conference, '[w]e put in our claim construction for damages recently... could be as little as few tens of mil-

lions to as high as hundreds of millions,'" he adds.

"GSI Technology results continue to disappoint the investor community," says Katz. Revenues for GSI's fiscal 2015 (to end-March) were down 8.7% year-on-year.

"A combination would further enhance our collective product and service offerings, allowing us to strengthen the value proposition that we provide to our customers through a wider range of companion and complementary products and more effectively challenge our respective competitors," Katz says.

JDSU's quarterly revenue of \$410.7m hit by \$7m drop in 3D sensing ...but Datacoms revenue grows 23% year-on-year

For fiscal third-quarter 2015 (to 28 March), JDSU has reported revenue of \$410.7m, down 6% on \$437.1m last quarter and 1.7% on \$418m a year ago (and below the guidance midpoint of \$418m).

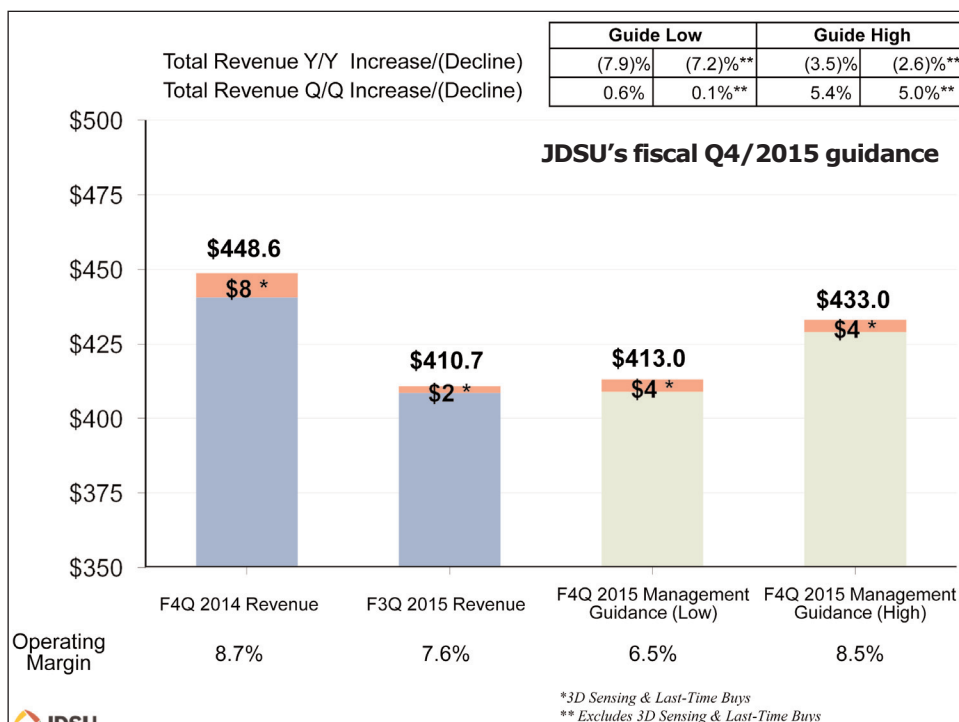
The Americas, Asia-Pacific and EMEA represented 49.4%, 29% and 21.6% of total revenue, respectively, compared with 43.3%, 34.3% and 22.4% last quarter.

By application sector, revenue for Network Enablement (NE) was \$128.1m (31.2% of total revenue), down 4.2% on \$133.7m last quarter and 5.8% on \$136m a year ago. Revenue for Service Enablement (SE) was \$39m (9.5% of total revenue), up 7.4% on \$36.3m a year ago but down 14.7% on \$45.7m last quarter (and below the \$45m guidance). Revenue for Optical Security and Performance Products (OSP) was \$48.4m (11.8% of total revenue), down 4.3% on \$50.6m last quarter and 5.3% on \$51.1m a year ago (and below the \$50m guidance).

Revenue for Communications and Commercial Optical Products (CCOP) was \$195.2m (47.5% of total revenue), down 5.7% on \$207.1m last quarter but up 0.3% on \$194.6m a year ago.

Of this, CCOP's Commercial Laser revenue was \$31.5m (7.7% of total revenue), up 1.9% on \$30.9m a year ago but down 21.3% on \$40m last quarter, due to seasonal weakness from solid-state laser products plus fiber-laser revenue falling to just under \$10m as a result of customer inventory management (following three consecutive record revenue quarters).

CCOP's Optical Communications revenue was \$163.7m (39.8% of total revenue), down 2% on \$167.1m last quarter but level on a year ago, offsetting a \$7m drop in 3D sensing revenue (to below \$2m). Excluding 3D sensing, revenue would



have risen by 4.7% year-on-year, driven by 23.2% growth in Datacoms (led by higher-speed 40G and 100G transmission products, including 40G QSFP+, 100G CFP2 and 100G CFP4). Telecom revenue was down 1.4% year-on-year, impacted mainly by declines in average selling prices (ASPs) outweighing the increases in unit volumes. However, within Telecom, JDSU is seeing strength in ROADM (reconfigurable optical add-drop multiplexer), modulator, pump laser and submarine product lines (all up over 10% year-on-year). ROADMs have seen strength from the newer TrueFlex products, which are moving from lab trials to new network deployments. "Our TrueFlex products are key to recently announced North American metro deployments, which could support continued growth for us in the coming year," comments Alan Lowe executive VP & president CCOP.

Optical Communications revenue mix was 71% Telecom, 23% Datacom and 6% Consumer & other (compared with 72%, 19% and 9% a year ago, respectively). In partic-

ular, revenue for higher-speed transmission (40G and 100G) has risen to 48% of overall transmission revenue from 44% a year ago (with 100G revenue doubling year-on-year).

The quarter-on-quarter decline in the ASP for Optical Communications components was 4.7%, consistent historically with 4.9% a year ago (and in line with the expected 10-14% year-on-year for full-year fiscal 2015, as the March quarter typically experiences the largest decline of the year).

On a non-GAAP basis, gross margin was 48.3%, down from 49.1% last quarter but up from 47.6% a year ago. In particular, CCOP gross margin has fallen back from 33.4% last quarter to 30.3%, down on 32.4% a year ago due to an unfavorable product mix from both Commercial Lasers (down from 48.9% a year ago to 43.2%) and Optical Communications (down from 29.3% to 27.9%, due to the lower 3D sensing revenue).

Operating margin was 7.6%, down from 9.9% last quarter but

► up from 6.5% a year ago (and exceeding the 5.5–7.5% guidance). CCOP operating margin was 8.9% (below the midpoint of the 8.5–10.5% guidance range), down from 11.5% a year ago, driven largely by higher-than-expected payroll-related accruals.

Net income was \$27.6m (\$0.12 per share), down from \$35.4m (\$0.15 per share) last quarter but up from \$23.4m (\$0.10 per share) a year ago (and exceeding the \$0.07–0.11 guidance), driven by overall favorable product mix and operational improvements.

"JDSU delivered better-than-expected operating margin and EPS despite muted carrier spending that impacted our Network and Service Enablement businesses," comments president & CEO Tom Waechter.

During the quarter, total cash and investments fell from \$867.6m to \$815.5m. This was after capital expenditure of \$18.3m (cut from \$23.9m last quarter) and operating cash outflow of -\$22.9m (compared with operating cash generation of +\$16.6m last quarter), due primarily to activities related to JDSU preparing to split into two businesses. Last September, JDSU

announced plans to separate into two independent, publicly traded companies (the optical components and commercial lasers company Lumentum Holdings Inc consisting of JDSU's CCOP segment, and the network and service enablement company Viavi Solutions Inc consisting of JDSU's NE, SE and OSP segments).

Meanwhile, during fiscal Q3, both Optical Communications and Commercial Lasers had book-to-bill ratios below 1 due to (1) a combination of orders that pushed into Q4 and (2) having a higher-than-usual proportion of revenue from customers who previously placed longer-term orders with delivery dates spanning multiple quarters.

For fiscal fourth-quarter 2015 (ending 27 June), JDSU expects total revenue to rise to \$413–433m. Operating margin should be 6.5–8.5% and earnings per share \$0.09–0.13.

For CCOP, revenue is expected to rise to \$197–207m. In particular, Optical Communications revenue should be up sequentially, driven by continued growth in Datacoms as well as growth in key Telecom products. Commercial Lasers rev-

enue should be up modestly. The lower proportion of higher-gross-margin Commercial Lasers in the revenue mix will limit CCOP gross margin. Due to this, along with continued growth in critical R&D spending, CCOP operating margin is expected to be 8.5–10.5%.

JDSU's quarterly operating model targets for CCOP are now \$210m in revenue, 33–35% gross margin and 12–14% operating margin.

"Lumentum and Viavi Solutions are building momentum and we remain on plan to complete the spin off in the third calendar quarter this year," Waechter says. "We remain on track to achieve net \$50m in cost reductions and are also on track to take substantially all associated charges in fiscal-year 2015 [the estimated cash requirements for the separation is \$75–100m]," notes executive VP & chief financial officer Rex Jackson. "We expect \$8–9m of savings at Lumentum, with the balance coming from Viavi through reductions in corporate G&A [general & administrative] expenses and COGS [cost of goods sold] operating expenses in NE and SE."

www.jdsu.com

Amada to purchase stock in subsidiary of Lumentum

Japan's Amada Holdings Co Ltd (a manufacturer of machine tools for metal fabrication) has signed a definitive agreement with to purchase up to \$40m of preferred stock of a subsidiary of Lumentum Holdings Inc, the publicly traded company that will result from the planned spin-off of JDSU's Communications and Commercial Optical Products (CCOP) business unit. The spin-off is expected to happen in third-quarter 2015 and the final amount of Amada's investment will be determined based on initial trading of Lumentum Holdings Inc common stock.

"We look forward to continued collaboration, as we have for more than eight years," says Amada's president & CEO Mitsuo Okamoto.

JDSU and Amada co-developed kilowatt-class turnkey laser systems incorporating JDSU's CORELIGHT Series fiber-laser and direct-diode laser engines.

Upon initial trading of Lumentum's common stock, Amada will purchase from JDSU Series A Preferred Stock in a Lumentum subsidiary. The preferred stock may be converted into shares of common stock of Lumentum Holdings Inc starting from the second anniversary of the closing of the stock purchase (provided that there is no change of control or such like in Lumentum Holdings Inc) using a conversion price calculated on the basis of 125% of the volume-weighted average price per share of Lumentum's common stock in the five

trading days following the spin-off. Cumulative dividends will accrue at the annual rate of 2.5%, but will be paid only when and if declared by Lumentum's board.

The investment is contingent upon the consummation of the spin-off and is also subject to other customary closing conditions. No preferred stock will be offered to other parties, including the public.

The transaction is expected to close in the second week following the spin-off. Further terms of the proposed transaction are set forth in a stock purchase agreement to be filed as an exhibit to Lumentum's Registration Statement on Form 10 with the US Securities and Exchange Commission (SEC).

www.amada.co.jp/english

Oclaro's revenue constrained by 100G client-side CFP and CFP2 module capacity

CapEx increase to enable adjusted EBITDA break-even by end-2015

For its fiscal third-quarter 2015 (ended 28 March), Oclaro Inc of San Jose, CA, USA (which provides components, modules and subsystems for optical communications) has reported revenue of \$83m, down 13% on \$95.4m a year ago and down 4% on \$86.8m last quarter (or 2% for continuing operations, excluding \$1.8m from the firm's Industrial & Consumer business sold on 27 October 2014).

By end-market, Telecoms yielded 54% of sales and Datacoms 46%. By region (versus last quarter), China grew again, from 29% to 35% of revenue, while the Americas fell from 30% to 26%, Europe from 21% to 20% and Southeast Asia 18% to 16%, while Japan bounced back slightly from 2% to 3%. Showing increasing diversification, the number of customers contributing over 10% of total revenue each has risen from three to four (specifically, 19%, 16%, 11% and 10%).

Revenue from 10G products rebounded slightly from \$32m last quarter to \$33.8m (rising from 37% of total revenue to 41%), driven by strong demand for the 10G tunable laser product line plus growth for lower-speed laser and detector chips. "We are supplying these chips to customers, who are well positioned in markets where Oclaro is not aggressively competing at the module level," notes CEO Greg Dougherty. "Examples of these markets are 40G pluggables, which use four optical channels of 10Gb/s... These chips sales also bring us healthy incremental gross margins," he adds.

Revenue for 40G products was flat on last quarter at about \$19m (23% of total revenue), and quarterly revenue is expected to ramp down over the next 12–15 months to just a few million dollars.

Revenue for 100G products shrank from \$33.7m to \$30.2m (falling back from 39% of total revenue to

36%), due to three main factors: (1) registering the last shipments of legacy 100G large-form-factor modules (about \$2m) in fiscal Q2; (2) a much greater-than-normal reduction in average selling price (ASP) for 100G client-side products; (3) capacity constraints limiting the benefit from strong unit volume growth across 100G client-side CFP and CFP2 modules.

"In addition to our market-leading CFP and CFP2 100G client-side products, we introduced and began shipping our CFP4 LR4 product. We have received very positive initial customer feedback on its performance," says Dougherty. "We also continue to see steady progress and growth in our 100G lithium niobate modulators and narrow-linewidth micro-iTLA laser product lines. One year ago we had essentially zero revenue for both of these products. We have successfully grown our market share, and they now both represents strong revenues for us," he adds.

"Results came in at the higher end of our guidance ranges despite the impact of the annual price declines inherent in the first calendar quarter of every year," notes Dougherty. On a non-GAAP basis, gross margin was 15.8%, down from 16.5% last quarter but roughly flat for continuing operations (at the high end of the expected 13–17% range) and up from 12.3% a year ago.

Operating expenses were \$22.6m, cut by 6% from \$24.2m last quarter (due mainly to elimination of the Industrial & Consumer-related costs) and by 22% on \$29.1m a year ago (reflecting the positive results of restructuring and divestiture programs).

This has helped Oclaro to deliver its fourth consecutive quarter of better non-GAAP operating results. With depreciation of \$4.2m, adjusted EBITDA (earnings before interest, taxes, depreciation and

amortization) was –\$5.3m, cut from –\$5.5m last quarter and more than halved from –\$12.3m a year ago (and near the upper end of the guidance range of between –\$9m and –\$5m). "These results further demonstrate the continuing benefits that our cost management and portfolio improvement programs are having on our bottom line," says Dougherty.

On 19 February, Oclaro completed a placement of \$65m of five-year 6% convertible senior notes (due 2020), resulting in a net cash increase of \$61.6m to further strengthen the balance sheet and to support expansion of the 100G product portfolio.

Hence, despite the EBITDA loss of \$5.3m plus capital expenditure (CapEx) of \$4.6m (flat on last quarter) and restructuring charges of \$2.2m (up from \$0.3m), total cash, cash equivalents, restricted cash and short-term investments rose during the quarter from \$79m to \$123.9m.

For fiscal fourth-quarter 2015 (ending 27 June), Oclaro expects revenue of \$77–83m, with growth in 100G products outweighed by a \$5m decline in end-of-life 40G telecom business to \$14m (prior to a further \$4m drop in fiscal Q1/2016 to about \$10m). Due to the greater mix of 100G products plus operational improvements, increased fab utilization and continued cost control, gross margin should be 15–19% while adjusted EBITDA should improve further to between negative \$6m and negative \$2m (keeping the firm on track for adjusted EBITDA break-even by the end of calendar 2015). This is despite restructuring charges rising to \$3–5m (rather than the expected \$1–3m) as Oclaro completes its global staff reductions initiated in March.

"We also continue to develop new products and to share plans with

► customers for data rates beyond 100G,” says Dougherty. “We continue to work with customers at 100G and 200G.” During the March quarter, Oclaro began shipping beta units of its coherent CFP2-ACO transceiver (demonstrated last September at ECOC 2014, operating at 200G in a 16-QAM configuration). “We are now supporting numerous customers for applications in the metro and data-center interconnect

markets,” says Dougherty. At March’s Optical Fiber Communication event (OFC 2015), the coherent CFP2-ACO transceiver received the Lightwave Innovation Award. “Demand continues to be very strong [for the coherent CFP2-ACO transceiver] and we have built up a healthy backlog,” he adds. “We expect to further increase our production capability in the current quarter and we remain on track to begin

having meaningful revenue late this calendar year.”

To support its growth plans, Oclaro expects to increase CapEx to \$5–8m per quarter. “We remain committed to innovation by investing in R&D [maintaining R&D spending level with last quarter, at \$11.3m] and bringing leading-edge technology to market,” concludes Dougherty.

www.oclaro.com

Oclaro expands presence from Virginia to Maine via sales representative deal with SJ Associates

Oclaro has signed a sales representative agreement with SJ Associates Inc, which is said to be one of the largest groups of technical electronic-component sales representatives in the North Eastern USA.

The relationship should enable Oclaro’s entire portfolio of optical transceivers for 10G, 25G, 40G and 100G applications to reach a key geographic region with a broad range of telecom, enterprise

and data-center customers. Oclaro reckons it will also give it the expert resources to further expand its traditional customer base into government, military and storage markets.

“We view Oclaro as a leader in optical components, modules and subsystems for the core optical, enterprise, data-center, and wireless access markets,” comments SJ Associates’ president Mark Wachtel.

“This agreement with SJ Associates brings us a partner with the reputation, expertise and feet on the street to provide excellent customer support and service in a region with high growth potential, while helping us deliver the industry’s best optical transceivers and modules to a broader range of customers,” says Oclaro’s chief commercial officer Adam Carter.

www.sjassoc.com

OIF launches integrated photonics projects Two Implementation Agreements published

In the wake of its April quarterly meeting in Lisbon, Portugal, the Optical Internetworking Forum says that initial work has begun on technical specifications for high-bandwidth optical modulators and receivers for coherent applications. Members also approved implementation agreements (IAs) for 100G applications. The Q2 meeting also saw several OIF technical committees meet to continue the Forum’s work on the FlexEthernet and Common Electrical Interface (CEI) projects begun in 2014. Finally, based on the success of technical demonstrations in 2014, Forum members held initial discussions on an SDN-focused demo for 2016.

“With as many as 19 documents going to ballot this quarter alone, we are completing technical work at an extremely fast pace,” says Karl Gass of Qorvo Inc, the OIF

Physical and Link Layer Working Group vice chair, Optical. “These two new electro-optical component projects will fill a gap in the line-side component space, providing systems engineers more tools to increase channel capacity beyond 100Gb/s.”

The utilized coherent ASIC Baud Rate is no longer sufficient information to define the frequency response requirements for coherent electro-optical (EO) components now that the industry has embraced the use of pre-conditioning. The High Bandwidth Polarization Multiplexed Quadrature Optical Modulator project enables coherent electro-optical modulation of a wider optical spectrum per optical carrier defined in terms of frequency response. The Intradyne Coherent Receiver project proposes an improved RF high-frequency response that enables coherent electro-optic demodula-

tion of a wider optical spectrum per optical carrier.

Implementation Agreements approved for public

The IA for Integrated Dual Polarization Micro-Intradyne Coherent Receivers targets coherent 100G PM-QPSK applications with nominal symbol rates up to 32 GBaud in a CFP2 form factor. This IA also defines a low-speed electrical interface incorporating an SPI bus for control of transimpedance amplifiers (TIAs) in the coherent receiver.

The IA for Generation 2.0 100G Long-Haul DWDM Transmission Module-Electromechanical applies to optical line interface applications. The IA reduces the size and power consumption requirements by defining a 4x5 module for 100G long-haul DWDM transmission.

www.oiforum.com/documents/implementation-agreements

Finisar's quarterly revenue grows despite annual telecom price reductions

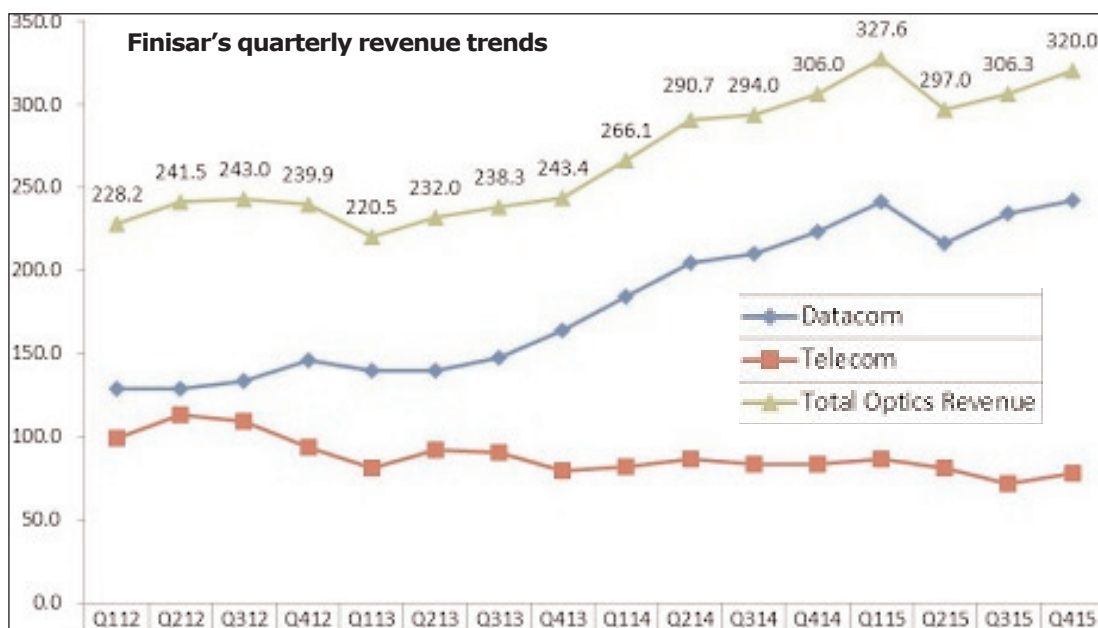
Profits boosted by improvement in yields for new optical engine

For fiscal fourth-quarter 2015 (ended 3 May), fiber-optic communications component and subsystem maker Finisar Corp of Sunnyvale, CA, USA has reported revenue of \$320m, up 4.5% on about \$306m both a year ago and last quarter. The increase was due mainly to an extra (14th) week in the fourth quarter, offset partially by the impact of Chinese New Year. Telecom product sales hence rose by 8.6% on last quarter, despite the impact of three months of the annual telecom price reduction that typically takes effect on 1 January. Datacom product sales rose by 3.2% on last quarter.

Full-year fiscal 2015 revenue was a record \$1250.9m, up 8.1% on fiscal 2014's \$1156.8m, due primarily to Datacom product sales rising by 13.6%, counteracting Telecom product sales falling by 5.2%.

"Revenue is driven primarily by the growth in worldwide demand for bandwidth with the ever increasing distribution and use of video, images and digital information," notes CEO Eitan Gertel. "In addition, Finisar continues to benefit from the growth in Cloud services, which drives networking hardware upgrades of existing data centers and the build-out of new hyperscale data centers."

On a non-GAAP basis, full-year gross margin has fallen from 35.9% to 30.9%. However, although down on 34.2% a year ago, quarterly gross margin has rebounded slightly from the low of 30% last quarter to 30.3% in fiscal Q4. This is due mainly to the improvement in yields for a new optical engine product for supercomputing applications that started to ramp last quarter (negatively impacting gross margin), partially offset by the impact of the annual telecom price reduction.



Operating expenses rose from \$65.1m last quarter to \$68.2m, due to the extra week of salaries, higher R&D project materials associated with the qualification of new products (pushed out from fiscal Q3), and higher sales & marketing expenses (due to the higher revenue level).

Full-year operating income has fallen from \$162.3m (an operating margin of 14% of revenue) last year to \$116.1m (9.3% of revenue). However, due to the higher gross margin in fiscal Q4, quarterly operating income rose from \$26.9m (an operating margin of 8.8% of revenue) last quarter to \$28.8m (9% of revenue).

Likewise, full-year net income fell from \$157m (\$1.53 per diluted share) to \$110.4m (\$1.04 per diluted share). However, quarterly net income has risen slightly from \$26.7m (\$0.25 per diluted share) last quarter to \$26.9m (\$0.25 per diluted share).

Capital expenditure was \$30.1m (less than the forecasted \$35m, as the timing of some of the expenditures associated with the building construction in Wuxi, China were pushed into fiscal Q1). During the quarter, cash, cash equivalents and short-term investments rose by \$1.3m, from \$488.9m to \$490.2m.

For fiscal first-quarter 2016 (a 13-week quarter), Finisar expects revenue of \$308–\$328m (versus \$327.6m a year previously, when there was a big spike in sales for wireless, which is currently down). Gross margin should be 30.5% (benefitting from the greater weekly volumes, offset partially by the impact of increased competition). Operating expenses are expected to fall slightly to \$67–\$68m. Operating margin should be 8.8–9.8%, and earnings per diluted share should be \$0.23–\$0.29.

CapEx is expected to be \$35m. Construction of the second building of the new factory in Wuxi, China is now complete, including fit-out of two of the four floors. "We've decided to fit out the remaining two floors starting in the first quarter," notes executive VP & chief financial officer Kurt Adzema. "This work will be completed by the end of fiscal 2016," he adds.

"Our ultimate goal is to get OpEx to approximately 20% of revenue... by early part of next fiscal year hopefully," says Adzema. "That will be driven mainly by increases in revenue and some leverage on the operating expense line."

www.finisar.com

NeoPhotonics' revenue grows 3% in Q1 to record \$81.4m, boosted by more-than-expected \$12m in Emcore products 100G to drive 10% annual growth; product pruning targets 35% margin

For first-quarter 2015, NeoPhotonics Corp of San Jose, CA, USA (a vertically integrated designer and manufacturer of hybrid photonic integrated optoelectronic modules and subsystems for high-speed communications networks) has reported record revenue of \$81.4m, up 3% on \$79m last quarter and up 19.4% on \$68.2m a year ago (and exceeding the \$75–81m guidance). Growth outpaces the traditional seasonal softness due to annual price negotiations and the Chinese New Year. However, revenue included a better-than-forecasted \$12m from Emcore products.

"We're particularly excited about the strengthening of our market position within the 100G market with our acquisition on 2 January of the tunable laser products of Emcore, which has enhanced our position as the market-share leader for both 100G coherent receivers and 100G narrow-linewidth tunable lasers," says chairman & CEO Tim Jenks.

In accord with its focus on growth in 100Gb/s-and-beyond products, NeoPhotonics has realigned its product group reporting for 2015 from 'Speed & Agility' (including 40 and 100Gb/s products) and 'Access' to 'High Speed Products' (for 100Gb/s and beyond) and 'Network Products and Solutions' (including 40Gb/s products — previously included in the High Speed product group — joining lower-data-rate products). On a like-for-like basis, a record 57% came from High Speed Products (for 100Gb/s and beyond) and 43% from Network Products and Solutions (<100Gb/s).

Two customers comprised over 10% of revenue: Ciena (23%, up from 16% last quarter) and Huawei Technologies (40%, down from 42%). Of total revenue, the Americas hence rose from 23% to 30% and China fell from 55% to 48%, while Japan rose slightly from 4% to 5% and rest of the world fell from 18% to 17%.

On a non-GAAP basis, gross margin rose for a third quarter, from 22% a year ago and 30.3% last quarter to 31.3% (above the expected 26–30%).

Operating expenses (OpEx) were \$20.2m, cut from \$22.8m a year ago but up from \$19.2m last quarter due mainly to integration of personnel and associated costs related to the Emcore tunable laser product line. Nevertheless, OpEx has been within the target model of 25% of revenue for the last three quarters.

Compared with a loss of \$7.8m (operating margin of –11.5%) a year ago, operating income was \$5.3m (6.6% margin), up from \$4.8m (6.1% margin) last quarter.

Although dropping from \$6.3m (\$0.19 per diluted share) last quarter, net income was \$4.2m (\$0.13 per diluted share — above the high end of the guidance range of a \$0.09 loss to earnings of \$0.02). This is a third quarter of profit, versus a \$9.5m loss (\$0.30 per diluted share) a year ago.

Operating cash generation was \$7.4m. So, after capital expenditure of \$2.2m, free cash flow was \$5.2m. "This represents the third consecutive quarter of positive cash flow from operations and free cash flow as we focus on effective management of our working capital assets and on driving profitability," notes senior VP & chief financial officer Ray Wallin.

During the quarter, cash and cash equivalents, short-term investments and restricted cash and investments rose from \$64.3m to \$74.3m.

Driven mainly by the ramp-up in production to support demand (primarily for 100G products) plus the acquisition of Emcore tunable laser products, net inventory rose by \$7.4m during the quarter to \$64.7m (from 92 days on hand to 102 days).

Despite seasonal declines in ASP (average selling price) and product pruning actions (impacting revenue through first-half 2015), for Q2/2015 NeoPhotonics expects revenue to rise to \$83–89m. Gross margin

should be 28–32%, hit by further minor ASP changes, pruning low-margin products (with the remaining \$5m of \$25m in revenue to go by the end of Q2), a stronger-than-expected mix of Access products (which are lower margin, and seasonally greater in Q2 than Q1), volume and manufacturing utilization, and ongoing manufacturing process improvements. OpEx should rise slightly to about \$21m. Diluted earnings per share are expected to be \$0.09–0.18.

"Our 100 gigabit business will continue to accelerate as we see metro launches and switching growth, such as Verizon's launch of CDC [colorless directionless contentionless] ROADMs including MCS [multi-cast switching], plus additional strength from data-center interconnection deployments of 100 gigabit coherent systems," believes Jenks. "Also, 100G deployments remain strong in China as well, and we are adding capacity where needed to support demand. Further, our Access business continues to be stronger than expected," he adds. "While some of this growth is offset by our product pruning initiatives which will be largely complete by the end of Q2, at this time and including our Emcore product acquisition, we believe there are a number of potential accelerators to our business and we are optimistic that our 2015 revenue can approach 10% growth over 2014. We are focused on sustained profitability and we will continue to work toward this goal, as well as toward greater alignment with our target operating model," continues Jenks.

"During the last several quarters, we introduced our long-term operating model," notes Wallin. "NeoPhotonics can ultimately deliver, on an annualized basis, gross margin of 35%, R&D expenses in the 13–14% range, SG&A expenses in the 11–12% range and operating margin of 10%."

www.neophotonics.com

Emcore's quarterly revenue rises a more-than-expected 3.5% to \$19.1m

Break-even targeted at \$18–19m per quarter as CATV drives growth

For its fiscal second-quarter 2015 (to end-March), Emcore Corp of Alhambra, CA, USA (which provides compound semiconductor-based components, subsystems and systems for the broadband and specialty fiber-optics market) has reported revenue of \$19.1m (slightly exceeding the guidance of \$17–19m). This is up 3.5% on \$18.4m last quarter and \$13m a year ago due to the continued momentum in cable TV from major ODM customers plus strength in the components product lines.

Emcore completed its sales of its Space Photovoltaics business on 10 December to SolAero Technologies Corp (for \$150m) and of its Telecommunications Fiber Optics business (the tunable laser and transceiver Digital Products lines) on 2 January to NeoPhotonics Corp of San Jose, CA, USA (for \$17.5m, comprising \$1.5m in cash and a note from NeoPhotonics with a two-year maturity and an escalating interest rate). The continuing Broadband Fiber-Optics business includes products for cable television (CATV) and fiber-to-the-premise (FTTP) networks as well as satellite communications, video transport and specialty photonics.

"In the Broadband Cable TV segment, over the past three years, we've seen a significant improvement in the results and outlook," says chief financial officer Mark Weinswig. "In general, after more than two years of tough times, we believe that the Cable TV Optical Network Infrastructure business is seeing improving market trends," he adds. "Normally, the CATV CapEx cycle is at its low point in the first calendar quarter," notes president & CEO Jeffrey Rittichier.

On a non-GAAP basis (for continuing operations), gross margin was 33.5% (the highest in the past five years). This is up from 28.1% last

quarter due to higher revenue, lower inventory-related reserves, and operational improvements (better factory utilization and absorption of the fixed costs as a percentage of revenue).

Total operating expenses were \$8m, cut from \$10.2m last quarter due mainly to lower transaction-related compensation and lower severance expenses (primarily associated with the departure of executives).

"Corporate costs were higher than normal due to the related work and activity associated with de-integrating the divisions we have sold," notes Weinswig. "In addition, we have moved our corporate headquarters to Alhambra, CA, which has resulted in some increased near-term spending," he adds. "We expect to see cost reductions in G&A (general & administrative expenses) over the next couple of quarters, as we begin to operate out of our new headquarters as the broadband business."

Income from continuing operations was break-even, an improvement on a loss of \$0.9m (\$0.03 per share) last quarter and \$3.3m (\$0.11 per share) a year ago.

During the quarter, cash and cash equivalents fell from \$147.6m to \$141m due to the pay-down of certain accrued expenses associated with the transaction.

Driven by continued strength in cable television and growing strength in chips, for fiscal third-quarter 2015 (to end-June), Emcore expects revenue to grow to \$19–21m.

"As we evaluate the market for CATV components and systems, we see continued strength over the next few quarters," says Rittichier. "Our customers, the OEMs, continue to consolidate as the definition of the network evolves. Clearly, the ability to closely integrate set-

top boxes with the rest of the network is becoming more important than ever, as is the move to greater bandwidths for streaming applications and services. Based on what we're being told by our customers, DOCSIS 3.1-compliant products will figure heavily into their plans going forward," he adds.

"Our satcom and video revenues have been at or near our internal expectations, as we look to find additional opportunities. These products have had better margins than our consolidated margin and we're looking at some additional opportunities to add revenue from these product lines," continues Rittichier. "We did start production shipments of Fiber Optic Gyros in Q2 and expect to ramp slowly in response to orders from three customers," he adds.

"We made chip shipments this past quarter and are working to expand our fab capacity to address demand from the Chinese market for GPON chips," Rittichier notes. "We expect to have additional capacity online in fiscal first-quarter 2016."

Emcore's goal continues to be to remain at a break-even level at \$18–19m per quarter of revenue, depending on product mix and the timing of certain spending.

"We resolved many delinquent backlog issues and turned our efforts toward reducing cycle times, developing our EMS [electronic manufacturing services] suppliers and optimizing our own manufacturing operations — we've already completed Six-Sigma White Belt training for virtually all of our professional staff in Alhambra and Langfang in China, and are beginning to roll out Green Belt training in both facilities," says Rittichier. "We've already started work on outsourcing assembly operations from Alhambra to our Asian EMS

► partners and expect to also move operations from Langfang that we don't execute as cost effectively as some leading EMS providers. This will enable our captive Chinese operations to concentrate on higher-value-added work that has a stronger IP content and results in differentiation from our competitors," he adds. "Ultimately, we're only going to support high value-added processes internally and we'll re-design our products and processes to transition operations from a high-fixed-cost or high-headcount model to one that is

driven by variable cost in a supply chain. This will improve our agility and performance in the future."

"Technology development has also progressed well this quarter, and we're currently on track to launch our cable television EML [externally modulated laser] in the fall," reports Rittichier. "We have a strong customer interest in this product and are currently designing transmitter subsystems around this part for launch sometime around the end of the calendar year," he adds. "We're also starting to focus our plans for accelerating growth outside of

CATV and hope to talk about those opportunities sometime in the fall."

"To demonstrate our ongoing commitment to providing shareholder value, we announced that our board of directors has authorized to purchase up to approximately \$45m of our shares of common stock through a modified Dutch auction tender offer," says Weinswig. Emcore is financing the share repurchase from proceeds from the sale of the Space Photovoltaics business and the Telecommunications Fiber Optics business.

www.emcore.com

Results of \$45m modified Dutch auction tender offer

As a result of its modified Dutch auction tender offer (pursuant to an Offer to Purchase dated 15 May), which expired on 15 June, Emcore has accepted for purchase 6,870,229 shares of its common stock at a price of \$6.55 per share, for a total cost of about \$45m (excluding fees and expenses).

Based on the final count by

American Stock Transfer & Trust Company LLC (the depositary for the tender offer), 8,771,526 shares of common stock were properly tendered and not withdrawn. Due to the offer being oversubscribed, Emcore purchased only a pro-rated portion of shares tendered by each tendering shareholder (other than 'odd lot' holders whose shares were

purchased on a priority basis) at or below the final per-share price. Emcore has been informed by the depositary that the final pro-ration factor for the offer was about 78.32%. The 6,870,229 shares accepted for purchase represent about 21.19% of the firm's currently issued and outstanding shares of common stock.

Emcore appoints VPs of sales and operations

Emcore has appointed Shane Mortazavi as VP of operations and David Wojciechowski as VP of sales, reporting to president & CEO Jeffrey Rittichier and starting on 1 and 15 June, respectively.

Wojciechowski is a 20-year sales veteran in the optical communications, semiconductor and renewable energy industries with a track record in sales strategy, business development and management of direct sales and customer service functions in the USA, Canada and internationally, including North American and global distributors and channel partners. In previous experience in sales with Emcore, from 1986 to 1989 and from 2001 to 2009 he was director of global sales for Emcore Broadband, responsible for sales strategy and market development in North America and China for products including 1310nm and 1550nm transmitters, laser modules,

satellite communications RF links, video transport and FTTx products. He was most recently VP of global & America sales for Maxwell Technologies. Prior to that, he was VP for renewable energy sales in North America for Power One Inc (acquired by ABB) and VP of sales for SMA Solar Technology America.

"Not only is he a highly qualified sales executive with a well-established record of success, Dave has extensive experience with our current broadband fiber-optics product line," notes Rittichier. "He is a great fit for our organization and the global markets we serve and are developing."

Mortazavi has over 25 years of leadership experience in manufacturing operations and supply chain management for global technology firms with operations and profit & loss responsibility in the electronics, aerospace, automotive, oil & gas

and telecoms industries. From 2000 to 2013 he was VP of operations for STEC Inc, a designer and manufacturer of high-end solid-state drives, flash and DRAM memory for telecoms, storage, military and medical systems. Prior to that, he was manufacturing operations manager for General Monitors Inc, a designer and manufacturer of electronic UV/IR instrumentation and safety systems for the oil and gas industry.

"We are very excited to have Shane join Emcore to lead our global operations team for product assembly in both the US and China," says Rittichier. "His extensive experience as a strategic planner, solution provider, MBB and TPS/lean transformation expert, and his excellent project management skills will be key in helping Emcore develop our competitive advantage in manufacturing," he reckons.

www.emcore.com

Soitec divests solar system business

Engineered substrate firm retains four-junction Smart Cell technology, plus solar power plants for future disposal

Soitec of Bernin, France, which makes engineered substrates including silicon-on-insulator (SOI) wafers for the electronics and energy industries, has announced a definitive agreement to sell its solar system business — including all technology assets and manufacturing operations in Freiburg, Germany and San Diego, CA, USA — to ConcenSolar, a privately held business partner of concentrator photovoltaic (CPV) firm Suncore Photovoltaic Technology Co Ltd of Huainan, Anhui Province, China (which is owned by San'an Optoelectronics Co Ltd, the largest LED maker in China).

Suncore was founded in 2010 as a joint venture owned 40% by US-based Emcore Corp and 60% by San'an Optoelectronics Co Ltd of Xiamen, China (which designs and manufactures products including high-brightness LED chips and wafers, solar cells, and PIN photodiodes).

Suncore manufactures CPV components, modules and systems for terrestrial solar power applications. In June 2013, Emcore exited the JV by selling its stake to San'an.

Soitec is retaining for future disposal other assets of its solar system business, including its stake in certain solar power plants. The firm will also continue to develop and bring to market (based on its existing industrial capacity) a four-junction solar cell ('Smart Cell') that is distinguished by achieving record solar energy conversion efficiency of 46% (reported in December 2014).

As announced on 19 January, Soitec's board of directors unanimously decided to implement a strategic plan to refocus Soitec's activities on its core semiconductor business. "This agreement represents a key milestone for Soitec and a reinforcement of our core semiconductor business," says Soitec's

CEO Paul Boudre. Soitec has already reduced the solar business' staffing from 385 at the end of December 2014 to 272 at the end of March.

"Soitec's CPV solar modules represent the most advanced technology with proven reliability and project bankability, as well as competitive cost structure due to production automation and high-efficiency performance," comments ConcenSolar's Dr Charlie Wang. "Combining our experience of solar project development and financing capability from our established financing partners, this acquisition further strengthens our position to provide the most cost-effective solar power solutions for our utility-scale customers," he believes.

Soitec expects the transaction to close in third-quarter 2015 (subject to regulatory approvals and other customary closing conditions).

www.soitec.com
www.suncorepv.com

Four-junction cell raises CPV module efficiency record to 38.9%

Soitec has announced a new step in its SmartCell project by raising the concentrated photovoltaic (CPV) module solar energy conversion efficiency record from 36.7% (announced in last July) to 38.9%

Previously (last December), a stand-alone SmartCell four-junction solar cell raised the solar cell efficiency record from 44.7% to 46%. Now, the four-junction SmartCell has been integrated into a module.

Developed by Soitec in cooperation with Fraunhofer Institute for Solar Energy Systems ISE of Freiburg, Germany and French research center CEA-Leti, the four-junction solar cell uses technologies and know-how inherent in Soitec's Smart Cut and bonding techniques (which enable optimal semiconductor combinations, says Soitec).

"While we announced earlier this year Soitec's refocus on its core semiconductor materials business, we also decided to keep all assets related to our SmartCell project in the company's new strategic scope," notes CEO Paul Boudre.

"Indeed, it opens many business opportunities in different kinds of industries for Soitec. In the present case, the SmartCell paves the way for further cost reductions in solar energy, as it can be integrated in a record-efficiency CPV module suitable for mass production."

For the new record, SmartCells were integrated into the same platform as existing CPV modules using traditional three-junction cells.

The record module efficiency has been measured indoors and outdoors. Over 10,000 outdoor data-sets have been recorded.

Fraunhofer ISE performed a detailed analysis and revealed a module efficiency of $38.9 \pm 0.9\%$ for a 1000W/m^2 direct normal irradiation (DNI) and a 25°C cell temperature. The record module has an aperture area of 812cm^2 and uses 36 lenses and secondary optical elements.

SmartCell's development has been supported by Germany's Federal Ministry for Economic Affairs and Energy and the Federal Ministry for Environment (through the Magnus project) and by the French government's 'Investissements d'Avenir' ('Invest for the Future') program (through the GUEPARD project, managed by the French environment and energy management agency — ADEME).

www.ise.fraunhofer.de
www.leti.fr
www.soitec.com

CEA Tech and Fraunhofer ISE strengthen cooperation by forming Virtual Lab

Collaboration to develop prototype high-efficiency multi-junction cells

To strengthen the existing collaboration between the CEA's technological research unit CEA Tech in Grenoble and Chambéry, France and the Fraunhofer Institute for Solar Energy Systems ISE in Freiburg, Germany, the two partners have concluded a collaboration agreement to create a common 'Virtual Lab', combining forces in near-industry research to further develop high-efficiency multi-junction solar cells, educate young scientists, and work together to develop prototypes of next-generation ultra-high-efficiency solar cells. The launch of the joint lab officially began in May with the signing of the collaboration agreement.

The main focus of the planned collaboration is to create the most efficient photovoltaic products possible. The existing expertise and infrastructure of CEA Tech in microelectronics and photovoltaics, through its two labs Leti and Liten, and of Fraunhofer ISE in epitaxy and solar cell development are being brought together in Virtual Lab with the common goal of developing new products and opening up new markets.

Aside from concentrator photovoltaics (CPV), the target markets include solar cells developed specifically for consumer devices as well as solar cells for the classic photovoltaic market. Research results from the collaboration will be presented to industry regularly. In the medium term, collaboration with industry will contribute significantly to financing the Virtual Lab.

Both research institutes have long-standing experience in strategic partnerships, e.g. achieving the solar cell efficiency record of 46% in collaboration with their common business partner Soitec of Bernin, France. This work follows the SolarBond project between Fraunhofer ISE and France's Carnot-Institut, which was financed



CEA Tech and Fraunhofer ISE combine forces in near-industry research with French-German "Virtual Lab". © Fraunhofer ISE, map from OpenStreetMap – published under ODbL

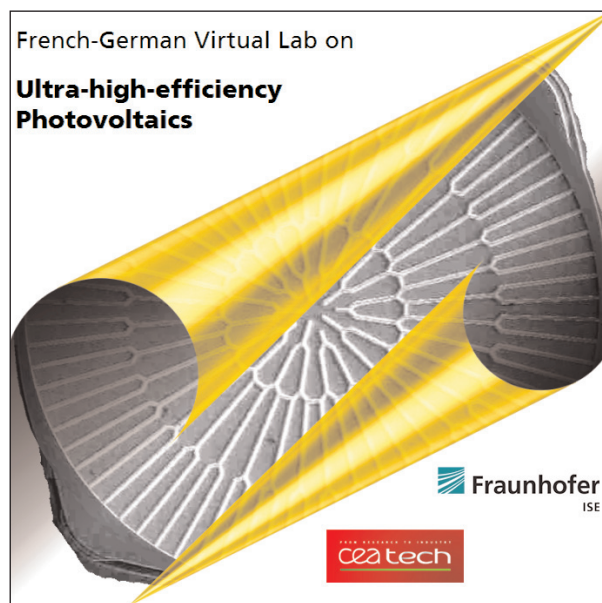
by Germany's Federal Ministry for Education and Research (BMBF) as well as France's National Research Agency (Agence Nationale de la Recherche — ANR) between 2009 and 2011. The solar cell was designed and developed under

France's 'Invest for the Future' (Investissements d'Avenir) program GUEPARD.

Cooperation between Germany and France in high-efficiency multi-junction solar cells has already been acknowledged through CEA

Tech (CEA-Leti) and Fraunhofer ISE in 2011 jointly receiving the German-French Industry Awards (AHK Chamber of Commerce). Mutual recognition between France and Germany of each other's research was demonstrated in 2010, when Frank Dimroth of Fraunhofer ISE received the Fondation Louis D award, the most important science award presented in France.

www.soitec.com
www.cea-tech.fr
www.ise.fraunhofer.de



Solar Junction developing four-junction cells for space 31%-efficient early prototypes to yield 33%-efficient lattice-matched, dilute nitride products by late 2016

Solar Junction Corp of San Jose, CA, USA, which claims to make the highest-efficiency commercially available multi-junction solar cells for terrestrial concentrated photovoltaic (CPV) applications, plans to become a provider of solar cells for space power applications. Specifically, at the Space Power Workshop in Manhattan Beach, CA (11–14 May), it presented to the aerospace community its progress in developing next-generation space solar cells.

Solar Junction claims that, since introducing its terrestrial CPV technology more than seven years ago, it has proved that dilute nitrides can be produced in high volume on 6-inch wafers with industry-leading manufacturing yields and significant cost savings using molecular beam epitaxy (MBE). The firm is now poised to enter the space PV market. Its proprietary dilute nitride technology is lattice matched on both germanium and gallium arsenide substrates, provides a range of



Four-junction space cell prototype.

bandgaps from 0.9eV to 1.4eV, and is the only technology platform that enables low-cost monolithic growth beyond three junctions, it is claimed.

Solar Junction currently produces a high-efficiency three-junction (3J) space cell using its dilute nitride material as the bottom active junction on a GaAs substrate. Last year saw the first commercial shipment of the 3J space cell, with air mass zero (AM0) efficiencies exceeding 31%. The 3J product is currently undergoing qualification.

During the Space Power Workshop, The Aerospace Corporation presented radiation degradation results from two Aerospace AeroCube picosats that have been on-orbit since June 2014 carrying Solar Junction 3J space cells. The results demonstrate that dilute nitride materials have radiation hardness comparable to conventional cells and show great promise for Solar Junction's next-generation space products, says the firm.

Enabled by its proprietary dilute nitride technology platform, Solar Junction is now developing a next-generation fully lattice-matched, four-junction (4J) space cell product. Early prototypes with an industry-standard Ge bottom junction have already reached AM0 efficiencies of 31%. Solar Junction plans bring to market its 4J lattice-matched, dilute nitride Ge-bottom-junction space cell by late 2016 with a minimum average efficiency of 33%.

www.sj-solar.com

Japan's National Institute for Materials Science claims record 15% efficiency in perovskite solar cells over 1cm²

Led by Dr Liyuan Han, the Photovoltaic Materials Unit of Japan's National Institute for Materials Science (NIMS) has achieved record 15% energy conversion efficiency for perovskite solar cells, as certified by the Calibration, Standards and Measurement Team at the National Institute of Advanced Industrial Science and Technology (AIST) Research Center for Photovoltaics. The results were presented at the International Conference on Hybrid and Organic Photovoltaics 2015 in Rome, Italy (10–13 May).

A prior efficiency record of 20.1% for perovskite solar cells had been reported, but the measurement error was large due to the small-sized cells used (0.0955cm²), while

the report did not present the measurement method.

The research group at NIMS achieved increased efficiency and reproducibility for the perovskite solar cells by controlling morphology of the perovskite layer using a new fabricating method. In addition, since the conventional material used for a charge carrier transport layer is hydrophilic, the cell's efficiency deteriorates rapidly. The team developed a new charge transport material that shows both high carrier mobility and hydrophobicity, improving the stability of the solar cells. Based on these results, the team has both expanded the solar cell to more than 1cm² and improved the method for creating the device.

On the basis of these results, the team aims to further improve conversion efficiency by developing new carrier transport materials with even higher performance and controlling the interfaces in the solar cells.

The research was in part conducted in conjunction with a JST (Japan Science and Technology Agency) sponsored research project 'Device physics of dye-sensitized solar cells' (research supervisor: Masafumi Yamaguchi, Principal Professor at Toyota Technological Institute), under the research area 'Creative research for clean energy generation using solar energy' in the Core Research of Evolutional Science & Technology (CREST) program.

www.nims.go.jp

Imec reports perovskite PV module with 8% efficiency

Perovskite cell atop silicon solar cell could boost efficiency beyond 30%

At Intersolar Europe 2015 in Munich, Germany (10–12 June), nano-electronics research center Imec of Leuven, Belgium reported a thin-film perovskite photovoltaic (PV) module with a solar energy power conversion efficiency of 8% measured over an aperture area of 16cm².

The geometrical fill factor of over 95% for this size of module demonstrates the potential of scaling up the thin-film PV technology from cell to module level, says Imec. It also represents a step in realizing a marketable thin-film solution for applications such as building-integrated photovoltaics (BIPV), it adds.

Organometal halide perovskites are considered to be excellent materials for thin-film solar cells as they have shown high conversion efficiencies at cell level. While efficiency of this new class of thin-film solar cells has increased rapidly in the last few years, further improve-

ments are still needed to make it an attractive technology for industrial production, says Imec. Larger-area processing and narrow interconnections are prerequisites for processing efficient thin-film modules. Imec's results demonstrate the achievement of both factors for perovskite-based solar cells.

"Not only is Imec improving the perovskite material, but it is also adjusting the cell and module structure to enhance the conversion efficiency of perovskite solar cells and modules by more than 20%," says Tom Aernouts, R&D manager for thin-film photovoltaics. "The rapid progress that

Imec is working to further increase the efficiency of silicon solar cells by creating a stack with a perovskite cell on top

we are making is based on our strong background and track record in traditional organic photovoltaics."

Imec is developing a platform for glass-based perovskite modules and collaborates with the European thin-film PV research initiative Solliance to develop foil-based processes. Due to its high conversion efficiency and stand-alone integration in building elements, both glass-based and thin-film perovskite PV technologies are widely considered to be important technologies for the BIPV market. Imec is working to further increase the efficiency of silicon solar cells by creating a stack with a perovskite cell on top of a silicon solar cell. The perovskite cell will capture the light that is not absorbed by silicon, enabling conversion efficiencies of over 30%.

www.imec.be
www.solliance.eu
www.intersolar.de

Dyesol becomes industrial partner of Solliance

Three-year deal for access to processing equipment and expertise to aid commercialization of perovskite solar cells on steel

Dyesol Ltd of Sydney, Australia, which is industrializing perovskite solar cell (PSC) technology, has agreed to become an industrial partner of Solliance, a European thin-film photovoltaic (TFPV) solar energy R&D consortium based in Eindhoven, The Netherlands.

Solliance is a partnership of companies, research institutes and universities in The Netherlands, Belgium and Germany, including ECN, imec, TNO, Holst Centre, TU/e, Forschungszentrum Jülich, University Hasselt and Delft University of Technology. Solliance provides laboratories and pilot-production lines that are jointly used for dedicated research programs.

The new three-year agreement gives Dyesol access to processing equipment and expertise suited to

the commercialization of the firm's perovskite solar cell (PSC) technology on steel.

It is reckoned that Solliance's capability in roll-to-roll processing of flexible PV-enabled substrates, together with Dyesol's expertise in PSC processing, device design and materials, will enable both parties to accelerate the readiness of a commercially viable PSC-based steel product for supply to the substantial global cladding and roofing markets.

The agreement gives Dyesol access to the foreground and background IP of its Solliance R&D partners related to the R&D program, while protecting Dyesol's background IP.

"This commitment of Dyesol is a confirmation of the excellence, know-how and infrastructure that

Solliance combines via its research partners," comments Solliance's director Huib van den Heuvel.

"Utilization of Solliance's laboratories and pilot-production lines will enable Dyesol to reduce its steel-related capital expenditure and increase internal focus on its core PSC technology development," says Dyesol's managing director Richard Caldwell. "The Solliance activities will be supervised from Dyesol UK and will complement Dyesol's participation in its other collaborations, including SPECIFIC [an open innovation center managed by Swansea University in Wales, UK that focuses on development and commercialization of functional coatings], where it will continue to benefit from close collaboration."

www.dyesol.com
www.solliance.eu

First Solar raises thin-film PV module efficiency record to 18.6%

CdTe efficiency surpasses best multi-crystalline silicon multi-PERC PV module

First Solar Inc of Tempe, AZ, USA has raised its world record for cadmium telluride (CdTe) photovoltaic (PV) module conversion efficiency to 18.6% aperture efficiency for a full-size module, as measured and certified by the US Department of Energy's National Renewable Energy Laboratory (NREL).

The firm says that, for the first time ever, a module has been demonstrated that is more efficient than the best multi-crystalline module recorded. The 18.6% aperture-area efficiency corresponds to a full-area conversion efficiency of 18.2%, beating the best recorded multi-crystalline silicon PERC (passivated emitter rear contact) module with an approximate full-area efficiency of 17.7% (based on 19.1% aperture efficiency and published module area data).

This is the First Solar's eighth substantial update to CdTe record efficiency since 2011. In January, it produced a research cell with 21.5% efficiency, certified at Newport Corp's Technology and Applications Center (TAC) PV Lab and confirmed by NREL.

"At one time, we might have been characterized as a low-cost, low-

efficiency technology, but consistent with our technology projections we are now proving that CdTe thin film delivers both industry-leading performance and sustainable thin-film cost structures," says chief technology officer Raffi Garabedian, who emphasizes that First Solar's significant sustained investment in development of CdTe technology has enabled it to meet or exceed its aggressive projections for improvements in research cells and modules, as well as commercialized technology.

"While silicon technologies have approached their theoretical efficiency entitlement and leveled out in terms of performance and cost, First Solar continues to harvest the upside available from its superior thin-film technology," Garabedian says. "Our CdTe modules are now more efficient than the best multi-crystalline Si modules, and we still have a great deal of technology head room for further innovation," he adds.

Efficiency, combined with other real-world performance attributes, results in First Solar technology delivering higher energy density than multi-crystalline silicon (m-Si)

solar panels, notes senior manager of technology Nick Strevel. Given the same installed nameplate module capacity (Watts) with equivalent ground coverage ratio, First Solar's CdTe product will provide up to 8% more useable energy from the same land area than m-Si, he adds.

"A narrow focus on simple metrics such as standard-test-condition (STC) efficiency or cost per STC-watt obscures the actual value of solar generation technologies," says Strevel. "Customers value energy produced by a solar power plant (kWh), not its nominal STC power rating. Metrics with greater relevance to real-world conditions — including specific energy yield, energy density, cost/kWh and long-term reliability — ultimately tell a much more comprehensive story of real-world performance and are more influential in reducing leveled cost of solar electricity [LCOE]."

Strevel adds that First Solar's modules have also passed the industry's most rigorous multi-stress testing protocols such including Atlas 25+, IEC Long Term Sequential and Thresher Tests.

www.firstsolar.com

8point3 Energy Partners prices IPO at \$21 per share

8point3 Energy Partners LP — a limited partnership formed in March by telluride (CdTe) module maker First Solar Inc of Tempe, AZ, USA and solar panel and system maker SunPower Corp of San Jose, CA, USA to own, operate and acquire a portfolio of solar energy generation projects — has priced its initial public offering of 20 million Class A shares (representing limited partner interests in 8point3 Energy Partners) at a price of \$21 per share.

In addition, the underwriters have

a 30-day option to purchase up to an additional 3 million shares at the IPO price, minus the underwriting discount. The shares have begun trading on the NASDAQ Global Select Market under the symbol 'CAFD'.

8point3 Energy Partners intends to use the net proceeds to purchase the common units of 8point3 Operating Company LLC, the entity that holds 8point3 Energy Partners' project assets. 8point3 Operating Company intends to use

the proceeds from the sale of its common units (i) to make a cash distribution to each of First Solar and SunPower and (ii) for general corporate purposes, including to fund future acquisition opportunities.

Goldman, Sachs & Co and Citigroup Global Markets Inc are acting as lead book running managers for the IPO. Deutsche Bank Securities Inc, J.P. Morgan Securities LLC and Credit Agricole Securities (USA) Inc are acting as joint book-running managers.

First Solar and OrionGroup form Philippines JV

First Solar and OrionGroup International, Inc of Manila, Philippines have launched the Philippine joint venture FSO Energy Solutions Inc to realize solar energy projects in the commercial and industrial market space through power purchase agreements (PPAs).

"Our business strategy is to provide the best product offerings and services as we strengthen our market reach in the Philippines," says OrionGroup's executive VP Engr. Rynor G. Jamandre.

OrionGroup's solar solutions have powered hotels, hospitals, golf courses, offices, factories and houses all over the Philippines. Its flexible financing solutions allow customers to own renewable energy systems without any down payments.

Through FSO, First Solar and OrionGroup will focus on providing large commercial and industrial customers with electricity through long-term agreements. FSO will provide a fully integrated renewable energy package that will create compelling value for our customers.

"We are delighted to be collaborating with OrionGroup to address the demand of commercial and industrial consumers in the Philippines who are looking for an alternate energy source that is reliable, less volatile in price, and lower in cost," says Jack Curtis, First Solar's regional manager for Asia Pacific. "With tremendous experience, an established footprint, and engineering and technology integration capabilities, OrionGroup is the ideal

partner to accelerate the adoption of PV technology in the commercial and industrial space. This initiative will help to address the gap in demand-supply imbalance caused by various factors like grid supply, costly alternate diesel power and rising electricity costs," he adds.

A vertically integrated solar energy company, with 10GW installed worldwide, First Solar brings international experience and established technology leadership. The collaboration will combine the best of both company's capabilities to increase the number of commercial and industrial PV installations in the Philippines. It will also provide a reliable alternative source of power generation to an energy constrained country.

www.firstsolar.com

First Solar allies with Caterpillar to develop integrated photovoltaics for microgrid applications

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 a strategic alliance with Caterpillar Inc to develop an integrated photovoltaic (PV) solar solution for microgrid applications.

First Solar will design and manufacture a pre-engineered turnkey package for use in remote microgrid applications, such as small communities and mine sites. The package will feature Cat-branded solar panels manufactured by First Solar and will include a balance of system (BoS) components.

Caterpillar (which manufactures construction and mining equipment, diesel and natural gas engines, industrial gas turbines and diesel-electric locomotives) will exclusively sell and support the integrated solution featuring Cat-branded solar panels through its worldwide Cat dealer network, along with its existing offerings of

generator sets and energy storage. Acting as a central source, it is reckoned that Cat dealers will be uniquely positioned to provide customers with this fully integrated and supported single solution in the large and rapidly growing microgrid market.

Microgrids provide value to prime power diesel and gas customers by integrating renewable energy, such as solar power, with generator sets. Caterpillar says that, with these solutions, it can help deliver reliable, cost-effective and sustainable energy.

The alliance is underpinned by First Solar's 10GW of global experience in solar energy, coupled with Caterpillar's knowledge of generator sets and distributed power as well as the strength of its dealer network, says Steve Niehaus, Caterpillar's VP with responsibility for the Electric Power Division. "By working with First Solar, we will optimize the efficiency and integration of solar power with our offerings," he adds.

"This strategic alliance provides yet more evidence of a global energy transition, where solar energy's reliability and cost competitiveness with traditional fuels effectively allows it to complement conventional generation," says Marc van Gerven, First Solar's VP for global marketing. "It is also evidence of the role that solar can play in enabling the local generation and distribution of energy to address specific needs," he adds. "By entering into this alliance with Caterpillar, with its extensive experience and reach, we are establishing an important new precedent for the commercialization and scaling of microgrid-based distributed generation solutions."

Caterpillar expects to first market the new microgrid solution in the Asia Pacific, Africa and Latin America regions, with the integrated PV solution (including Cat-branded solar panels) available in second-half 2015.

www.firstsolar.com

Sharc25 EU project targets 25% CIGS PV cell efficiency

Increase from 21.7% record to drive module manufacturing below €0.35 per watt peak

Launched in May and due to last three and a half year, the new European research project Sharc25 ('super high efficiency Cu(In, Ga)Se₂ thin-film solar cells approaching 25%') aims to increase the solar energy conversion efficiency of thin-film solar cells (made by the coevaporation of copper indium gallium (di)selenide) from the existing record of 21.7% to 25%.

The project has received €4.6m in funding from the European Union via Horizon 2020 (the EU's framework program for Research and Innovation for 2014–2020) under grant agreement 641004. The Swiss government is providing a further €1.6m.

To develop the improved cells, the project will pool the multi-disciplinary skills of 11 research partners in eight countries. Coordinated by ZSW (Zentrum für Sonnenenergie- und Wasserstoff-Forschung — or Center for Solar Energy and Hydrogen Research — Baden-Württemberg) of Stuttgart, Germany, the other partners are the

EMPA (Swiss Federal Laboratories for Materials Science and Technology), the universities of Luxembourg, Rouen (in France), Parma (in Italy) and Aalto (in Finland), nanoelectronics R&D center IMEC (in Belgium), the HZB (Helmholtz-Zentrum Berlin für Materialien und Energie in Germany), the International Iberian Nanotechnology

Laboratory INL (in Portugal), Flisom AG (in Switzerland), and Manz CIGS Technology GmbH (in Germany).

In recent years, the performance of thin-film solar cells based on chalcopyrite material has improved markedly. Able to achieve 20.4% efficiency, CIGS solar cells on plastic foil are almost on a par with multi-crystalline solar cells. CIGS cells on glass exceeded that for the first time in 2013 and increased their lead by 1.3 percentage points to 21.7% in 2014. These two records were achieved by two partners in the Sharc25 project: EMPA holds the record for the foil substrate and ZSW for glass.

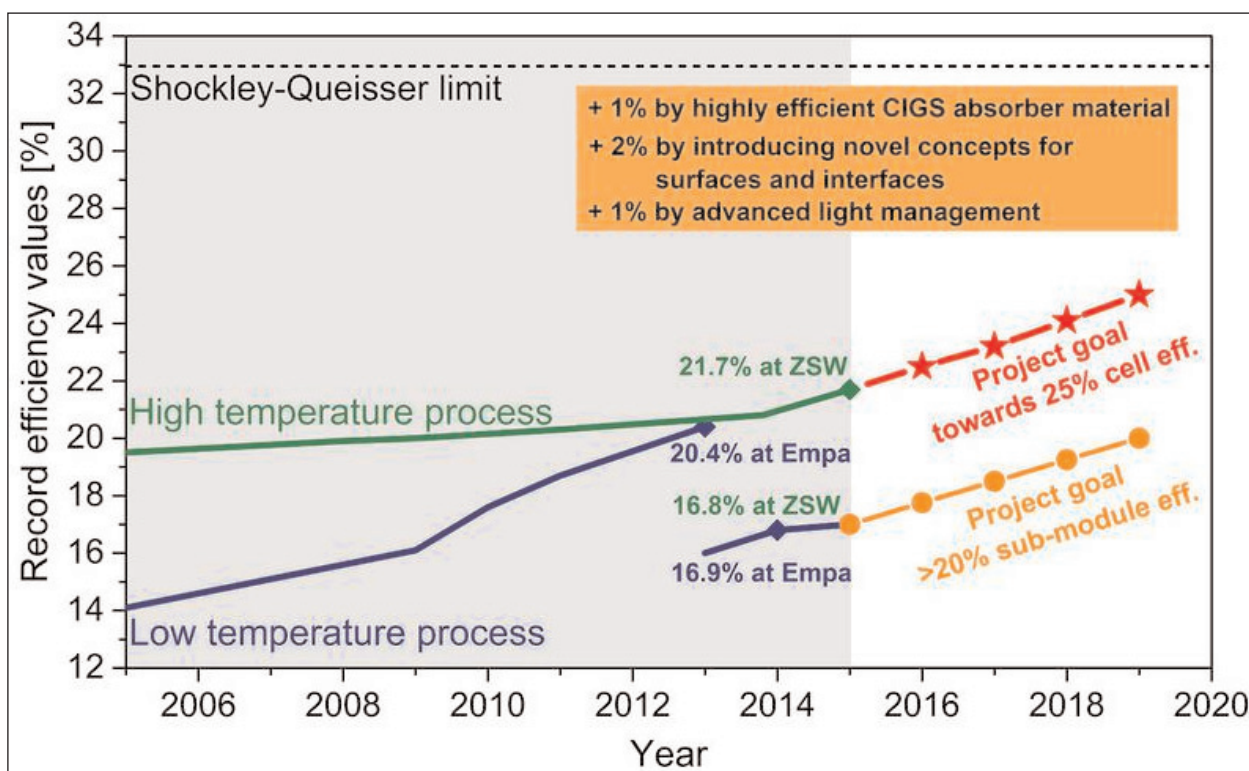
The five research institutes, four universities and two companies involved in Sharc25 are pursuing three strategies to harness the power of new designs for more efficient surfaces and interfaces, and to optimize light management to raise the efficiency threshold further, targeting an increase of about three percentage points in

efficiency to 25%.

An improvement on this scale would challenge the dominance of multi-crystalline solar cells from Asia, and the newfound competitive edge could give the European thin-film PV industry a decisive boost, reckons ZSW. The project's mission also calls for the researchers to devise a strategy for translating research results into industrial applications.

If the solar industry succeeds in applying the technology, the cost of manufacturing solar modules in Europe could drop below €0.35 per watt peak and the cost of installed PV systems to below €0.60 per watt peak, it is reckoned. Further savings could be achieved by ramping up the new technology for mass production. This would drive down investment costs, for example, to less than €0.75 per watt peak for solar CIGS module factories with more than 100MW manufacturing capacity, it is estimated.

www.zsw-bw.de



Goals of the Sharc25 project.

TSMC raises its commercial-size CIGS PV module efficiency from 15.7% to new record of 16.5%

Production-line efficiency improved to average 14.7%

TSMC Solar Ltd, which was founded in 2009 as a subsidiary of the world's biggest silicon wafer foundry Taiwan Semiconductor Manufacturing Co Inc (TSMC), says that its latest commercial-sized (1.09m²) copper indium gallium diselenide (CIGS) champion C2 module has achieved record total area efficiency of 16.5%, as confirmed by testing firm TUV SUD.

This improves on TSMC Solar's previous record of 15.7% set in mid-2013, as well as the latest record of 16% announced by Manz AG of Reutlingen, Germany just

earlier this week. TSMC Solar's latest record module was produced using the equipment and materials at its manufacturing facility in Taichung, Taiwan.

"We continue to prove our ability to develop record-setting process improvements in full-size modules," says TSMC Solar's president Chia-Hsiang Chen. "By bringing past innovations to mass production, our current production-line efficiency has improved to an average 14.7%," he adds.

TSMC Solar has also launched its new TS-CIGS Series Model C2 HV

module, which has nameplate power spanning 150–165W. Certified by UL for 1000V system operation, the high-reliability modules have a double-glass module design and are produced with 100% electroluminescence (EL) quality screening.

"Our tariff-free Model C2 HV modules are designed for the North America MW-scale market, delivering high energy yield, low system costs and high reliability," says Marc Spaulding, worldwide sales & marketing VP at TSMC Solar.

www.tsmc-solar.com

Magnolia awarded patents for lightweight flexible cells

Magnolia Solar Corp of Woburn, MA and Albany, NY, USA says that its subsidiary Magnolia Solar Inc was recently awarded three additional patents by the US Patent and Trademark Office (USPTO). US Patents 8,921,687, 8,969,711 and 8,981,207 describe and protect Magnolia's innovations in lightweight flexible solar cells for photovoltaic applications, and expand the firm's intellectual property portfolio to five issued patents.

Magnolia is developing flexible, lightweight, high-efficiency solar cell technologies for a wide range of portable power applications. The firm's technology portfolio includes nanostructured anti-reflection coatings, advanced thin-film photovoltaic absorber structures, and novel, low-cost manufacturing processes. The firm says that thin-film solar cells are an attractive source of portable and mobile power, as they can be integrated into flexible, lightweight photovoltaic modules that can operate in both terrestrial and space environments. Several other patent applications by the firm are currently under review.

US Patent 8,921,687 (issued on 30 December 2014) pertains to a novel device structure for increasing the efficiency of high-performance thin-film solar cells. Specifically, the patent describes an advanced thin-film solar cell structure employing quantum-structured III-V absorber materials and nanostructured transparent conductive coatings. This novel structure leverages optical light trapping mechanisms to increase the current output of III-V thin-film solar cells.

US Patent 8,969,711 (issued on 3 March) describes a solar cell employing nano-crystalline superlattice material as a full-spectrum absorber that can be deposited on a stainless-steel flexible substrate. This patent provides a means to boost the efficiency of low-cost flexible thin-film solar cells.

US Patent 8,981,207 (issued on 17 March) details a high-efficiency thin-film solar cell with a quantum-dot-sensitized layer that provides a tunable bandgap to cover the infrared, visible and ultraviolet bands of the solar spectrum. The increased absorption can increase the current output of thin-film solar cells,

including copper indium gallium diselenide (CIGS) structures deposited on flexible substrates.

"We have been aggressively pursuing more than a dozen US patent applications as a means to protect our intellectual property (IP) in the field of flexible photovoltaics," says president & CEO Dr Ashok K. Sood. "These patents pertain to novel device structures for increasing the efficiency of lightweight, high-performance and low-cost thin-film solar cells. These novel structures employ nanostructured absorbers and leverage optical light-trapping mechanisms to increase the current output of thin-film solar cells," he adds.

"Magnolia has begun exploring various ways to use its intellectual property for commercial applications and for generating revenue and profits," Sood continues. "We have also initiated preliminary discussions with various solar companies to help accelerate the commercialization of these technologies. As we move forward in these endeavors, we intend to provide additional information."

www.MagnoliaSolar.com

Flisom gains \$10.7m more from Tata in 4th funding round

15MW flexible CIGS PV pilot-production plant inaugurated

Flisom AG of Dübendorf, Zurich, which was spun off from the Laboratory of Solid State Physics of the Swiss Federal Institute of Technology Zurich (ETH Zurich) in 2005 to develop manufacturing of flexible thin-film copper indium gallium (di)selenide (CIGS) solar modules, has closed its fourth round of funding with a further CHF10m (about \$10.7m or €9.5m) from existing India-based strategic investor Tata group (following an earlier investment of CHF42.5m, or about \$45.5m, in 2013). The new funding comes on the eve of the inauguration of Flisom's pilot-production plant in Niederhasli-Zurich, which has an annual capacity of 15MW.

Over the last few years Flisom has improved the design of its roll-to-roll manufacturing equipment for processing and scaled them up from 50cm- to 1m-wide rolls — which is claimed to be an unprecedented scale of manufacturing capability for continuous processing of monolithically interconnected flexible CIGS solar modules on plastic foil.

"We appreciate the systematic approach towards innovation and the continuous hard work of Flisom's team in developing a unique manufacturing plant, while partnering with Empa [the Swiss Federal Laboratories for Materials Science and Technology], one of the world's leading labs, with several efficiency-related records for flexible solar cells," comments Tata Industries' executive director K.R.S. Jamwal. "This investment marks Tata group's interest in next-generation technology for the solar photovoltaic industry," he adds.

"With the investment received in 2013, Flisom refurbished an old manufacturing building of 4500m² ground area in Niederhasli, in the outskirts of Zurich, to install all the needed machines for solar module manufacturing on 1m wide rolls,"

says Flisom's chief operating officer Dr Sudheer Kumar. "At the same time, Flisom continued technology development on 50cm-wide rolls at its Dübendorf plant, located on the campus of Empa," he adds.

"After the successful installation of machines and other factory infrastructure in Niederhasli, the next step is to transfer the process know-how on these high-tech machines using specifically customized designs," says CEO Ulfert Rühle. "Some of the machines are based on many years of development by experts, innovative proprietary designs and complex engineering, making Flisom's machines unique for achieving cost and performance efficiency targets," he claims.

"The 15MW plant will serve as a proven blueprint for establishing larger production plants having a production capacity greater than 100MW as well as low capital and operating expenditures," Rühle continues. "Flisom has been working steadily towards lowering the costs of manufacturing of flexible solar modules."

Flisom reckons that its light-weight, robust products and systems could lower the price of solar electricity due to low material usage, economic production technology, and reduced

The 15MW plant will serve as a proven blueprint for establishing larger production plants having a production capacity greater than 100MW as well as low capital and operating expenditures. Flisom has been working steadily towards lowering the costs of manufacturing of flexible solar modules

storage, transportation and installation costs. Markets addressable by its flexible solar module manufacturing technology include utility-scale solar farms, building-integrated photovoltaics (BIPV), building-applied photovoltaics (BAPV), transportation and portable power.

Empa and Flisom have been cooperating for a number of years to develop a unique industrial-scale production platform for CIGS solar modules. "Scale-up for large-area solar modules and adapting these complex innovative processes for industrial manufacturability is quite a challenge and requires close collaboration between research labs and industrial partners for transferring research excellence to industrial usability," says Empa board member Pierangelo Groening (head of the Department of Advanced Materials and Surfaces). "For industrial partners such as Flisom, we provide support on different topics to enable industrial development of novel and innovative concepts, which often require sophisticated analytical tools and skilled experts," he adds.

"We are pleased that Empa's innovations in the field of renewable energy, especially in photovoltaics, are being transferred to industry," says Empa's CEO Gian-Luca Bona. "This example perfectly illustrates Empa's role as a bridge between research and practical applications."

"Flisom also thanks Swiss federal and European funding agencies for their continuous support," notes Rühle. "Besides the technological progress, the number of employees during the last two years has gone up to more than 55 now, and of course more employment opportunities for technically skilled persons are open for the production plant in Niederhasli."

www.flisom.ch
www.empa.ch
www.tata.com

Solar Frontier completes acquisition of Gestamp Solar's 280MW US pipeline and begins construction

In late April, Tokyo-based Solar Frontier — the largest manufacturer of CIS (copper indium selenium) thin-film photovoltaic (PV) solar modules — completed the acquisition of the 280MW US pipeline of Gestamp Solar of Madrid, Spain (the photovoltaic energy division of Gestamp Renewables), a global developer and operator of utility-scale solar power plants.

The 280MW pipeline consists of ten projects in various stages of development primarily in California. Construction has been initiated on a 15MW project in Kern County, CA. The second project is a 20MW site, with construction beginning in second-quarter 2015. Talks are underway with a select group of long-term investors regarding the sale of designated solar projects.

Charles Pimentel has been named CEO of Solar Frontier Americas' new division, Solar Frontier Americas Development LLC, and Cary Vandenberg has been appointed managing director of the development organization. Pimentel continues in his role as chief operating officer of Solar Frontier Americas.

Solar Frontier says that a key attribute of the acquisition is the addition of an experienced development team. The expansion of the US organization provides the platform to scale the US business and underscores Solar Frontier's commitment to the US market, the firm adds. The move comes as part of its global expansion plans, which include strengthening its position as a comprehensive solar energy solutions provider in international

markets.

"Solar Frontier is making substantial investment within the Americas and, with this acquisition, we expect to build and deliver some of the highest-performing solar energy projects in the industry," says Pimentel. "Solar project investors and developers are keenly focused on long-term energy yield and they are starting to recognize and understand the value of partnering with Solar Frontier to maximize the value of their PV plants," he adds.

"Our investment in this highly skilled team will be a catalyst to broaden our services in the Americas," believes Solar Frontier's CEO Atsuhiko Hirano.

www.gestampsolar.com

www.solar-frontier.com

Solar Frontier and NEW to develop 100MW of CIS PV plants in UK

Solar Frontier says its subsidiary Solar Frontier Europe GmbH of Munich, Germany has entered into a definitive agreement with system integrator New Energy for the World GmbH (NEW) of Regensburg, Germany to develop, build, commission and sell up to 100MW of turnkey CIS solar power plants in the UK. NEW is an engineering, procurement & construction (EPC) firm specializing in developing renewable energy projects. The agreement marks the continued global expansion of Solar Frontier's partnership approach in the large-project segment.

"Solar Frontier is going global as part of our long-term growth strategy and the UK is a key market for us," says CEO Atsuhiko Hirano. "We already have a strong standing in the residential, commercial and utility segments in Europe, and are now proud to introduce new and broader market solutions also in the UK," Hirano adds.

Construction of the first project of the 100MW pipeline is slated to begin in third-quarter 2015. Land and grid connection have already been secured, and first talks are now underway with investors regarding the sale of the first designated solar power plants. Projects will be closely based on the implementation approach of a previous 7.15MW project by Solar Frontier and NEW in Banwell.

"Solar Frontier and New Energy for the World have worked closely together on similar projects," says Solar Frontier Europe's managing

director Wolfgang Lange.

"The Banwell project, which commenced operations in 2015, serves as a front-runner for future projects — it demonstrates the performance advantages of CIS especially in UK weather conditions, the benefit of optimizing system components to leverage the advantages of CIS, and the importance of an experienced development team," he adds.

"Our past projects with Solar Frontier attest to the quality and performance of CIS solar power plants in the UK," comments NEW shareholder and general manager Jochen Kleimaier (who founded the firm in 2011).

For the 7.15MW CIS solar power plant in Banwell, Solar Frontier provided its CIS modules and optimized system components. Habdank was partner as general contractor for substructure and mounting and NEW provided EPC services.

www.ne4tw.de

Solar Frontier is going global as part of our long-term growth strategy and the UK is a key market for us. We already have a strong standing in the residential, commercial and utility segments in Europe

Long-wavelength room-temperature InAs interband cascade lasers

Record 7 μm lasing wavelength achieved with less than 1kA/cm² threshold current density.

Researchers from Germany and the UK claim record long wavelengths of 7 μm for interband cascade lasers (ICLs) based on indium arsenide (InAs) heterostructures [Matthias Dallner et al, Appl. Phys. Lett., vol106, p041108, 2015]. Devices with threshold current densities less than 1kA/cm² were fabricated by the team from University of Würzburg and University of St. Andrews. "These pulsed threshold current density values are the lowest at room temperature reported so far for InAs-based ICLs," the researchers add.

The team sees applications for efficient and reliable InAs ICL sources as including tunable laser absorption spectroscopy (TLAS). The 3–5.6 μm wavelength range for such applications could be covered by gallium antimonide (GaSb, 726meV bandgap) devices, but longer wavelengths require the narrower bandgap of InAs (354meV). At cryogenic temperatures InAs-based devices have achieved wavelengths as long as 10.4 μm . For room-temperature operation, InAs ICLs have previously managed 6.8 μm wavelengths.

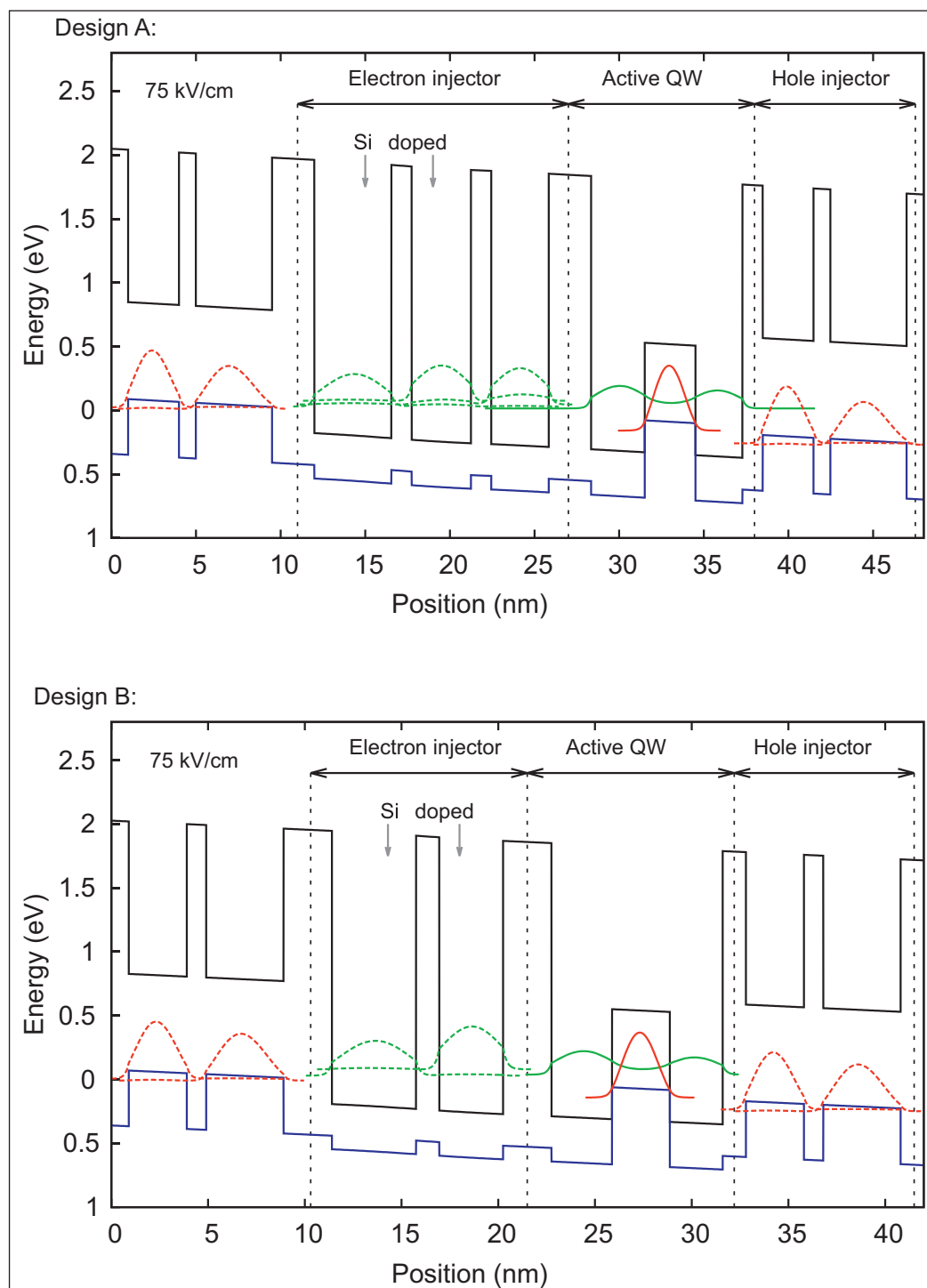


Figure 1. Simulations under electric field of 75kV/cm for cascade period designs A and B. Black lines indicate conduction band-edge, blue curve indicates heavy hole band-edge. Electron and hole probability densities are represented by green and orange curves, respectively.

The hetero-structures were produced by molecular beam epitaxy (MBE) on n-type indium arsenide (n-InAs) substrates. Two cascade period designs were grown (Figure 1). The carrier injector sections are described as being 'short', with design B using shorter injectors than design A. The researchers comment:

"General benefits expected from a shortened injector design are

slightly increased mode intensities in the active region and hence a higher gain, and less hetero-interfaces."

The barrier layers in the cascade structures were mostly aluminium antimonide (AlSb) or gallium antimonide. The design A layer sequence was 2.5nm AlSb / 4.55nm InAs / 1.2nm AlSb / 3.5nm InAs / 1.2nm AlSb / 3.4nm InAs / 2.5nm AlSb / 3.15nm InAs / 3.0nm Ga_{0.76}In_{0.24}Sb / 2.75nm InAs / 1.0nm AlSb / 3.0nm GaSb / 1.0nm AlSb / 4.5nm GaSb / 2.5nm AlSb.

Design B replaced the three-well electron injector region 2.5nm AlSb / 4.55nm InAs / 1.2nm AlSb / 3.5nm InAs / 1.2nm AlSb / 3.4nm InAs with the shorter two-well sequence 2.5nm AlSb / 4.35nm InAs / 1.2nm AlSb / 3.3nm InAs.

The number of cascade sections in the fabricated devices was increased on previous work by the group to compensate for the higher losses expected from trying to extend the emission wavelength. Also, electron-hole wavefunction overlap was expected to be reduced in the active region of the cascade period.

The cascade region was sandwiched between thick equal-width InAs waveguide layers (1130–1370nm). The cladding was 1600nm highly silicon-doped n-InAs.

The epitaxial material was fabricated into ridge waveguide lasers with silicon nitride and silicon dioxide passivation to avoid current leakage. The devices were

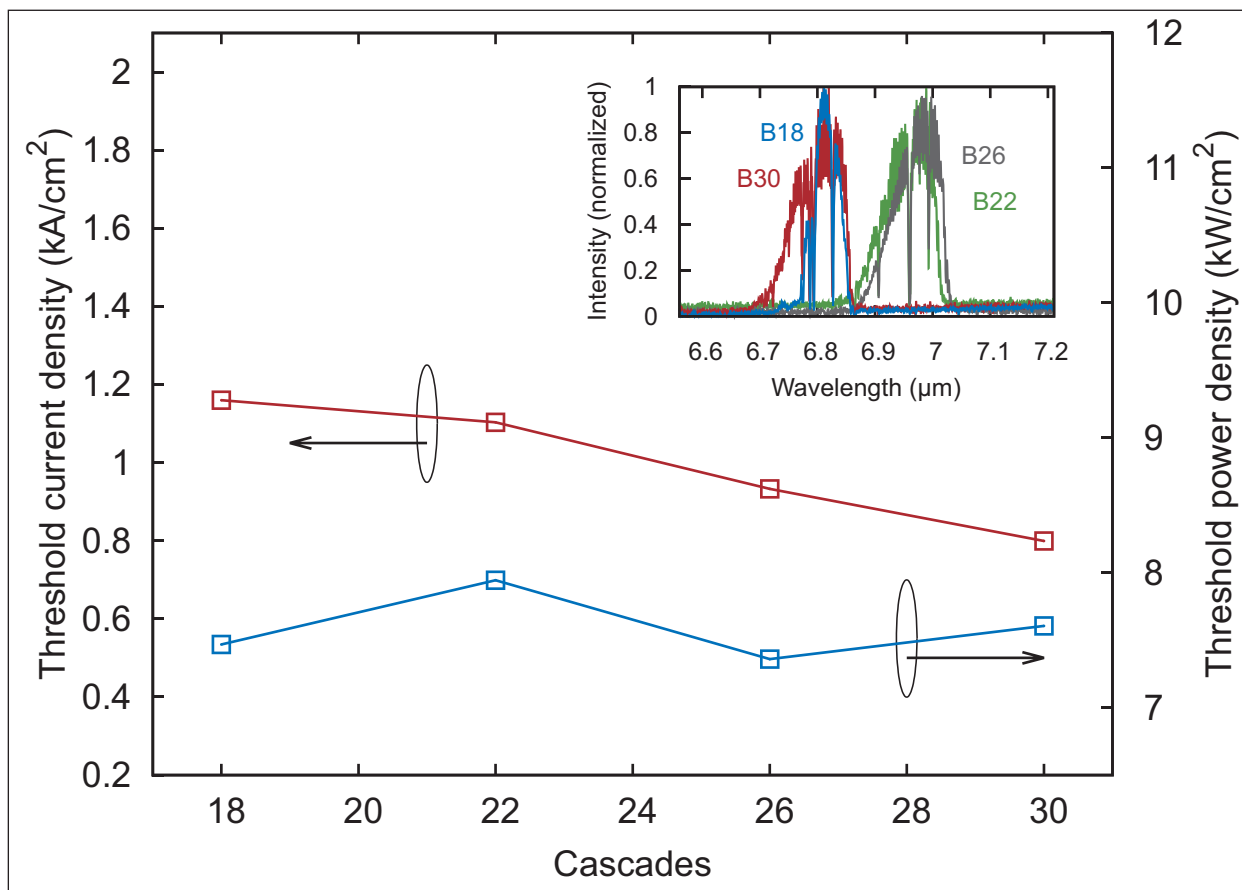


Figure 2. Threshold current densities (red) and threshold power densities (blue) of ICLs using samples B18 (18 cascades), B22, B26 and B30. Inset: emission spectra of devices at 20°C.

cleaved into laser bars and tested epi-side up without facet treatment. The current injection was pulsed (1kHz, 100nsecs) to avoid self-heating effects.

A device using design A with 22-periods (A22) emitted laser light with a wavelength of 7μm at 20°C. "This is the longest-wavelength ICL working at room temperature reported so far," the researchers write.

The gross dimensions of the device were 2mmx45μm. The threshold current density at 20°C was 940A/cm². The researchers say that the reduced threshold compared with their previous work was due to "higher doping in the active region for carrier rebalancing and the increased number of cascades". The maximum operating temperature was 55°C.

A rate of 4.8nm/K was found for tuning of the wavelength by changing the temperature. Cryogenic-temperature ICLs with similar wavelength emission tend to have a tuning rate of 3.2nm/K.

A 22-period design B device (B22) with the same dimensions had a slightly higher threshold of 1100A/cm² at 20°C (Figure 2). However, a B device with 30 periods had a threshold at 800A/cm² — "the lowest pulsed threshold current density at room temperature reported for InAs-based ICLs so far", according to the researchers. ■

<http://dx.doi.org/10.1063/1.4907002>

Author: Mike Cooke

Red lasers from III-nitride nanowire forests on silicon

Small-signal modulation for plastic fiber optical communication.

Researchers in USA and Saudi Arabia have been producing 610nm-wavelength red lasers with III-nitride nanowires (NWs) grown on silicon [Shafat Jahangir et al, Appl. Phys. Lett., vol106, p071108, 2015]. With a view to plastic fiber optical communication, the team from University of Michigan and King Abdullah University of Science and Technology (KAUST) studied the small-signal modulation characteristics.

Other potential applications include mobile projectors, head-up displays in automobiles, and photodynamic therapy. Production on silicon promises lower-cost pro-

duction and mass manufacturing.

The array of vertical nanowires was produced on (001) n-type silicon using molecular beam epitaxy (MBE). The disk-in-nanowire structure was grown along the c-direction (Figure 1). The gain medium consisted of a 6-period structure with 2nm indium gallium nitride ($\text{In}_{0.51}\text{Ga}_{0.49}\text{N}$) disks in 12nm gallium nitride barriers.

The GaN regions of the device were grown at 800°C. The InGaN disk region was deposited at 545°C. The lattice-matched indium aluminium nitride ($\text{In}_{0.18}\text{Al}_{0.82}\text{N}$) cladding layers were applied at 510°C. InAlN was cho-

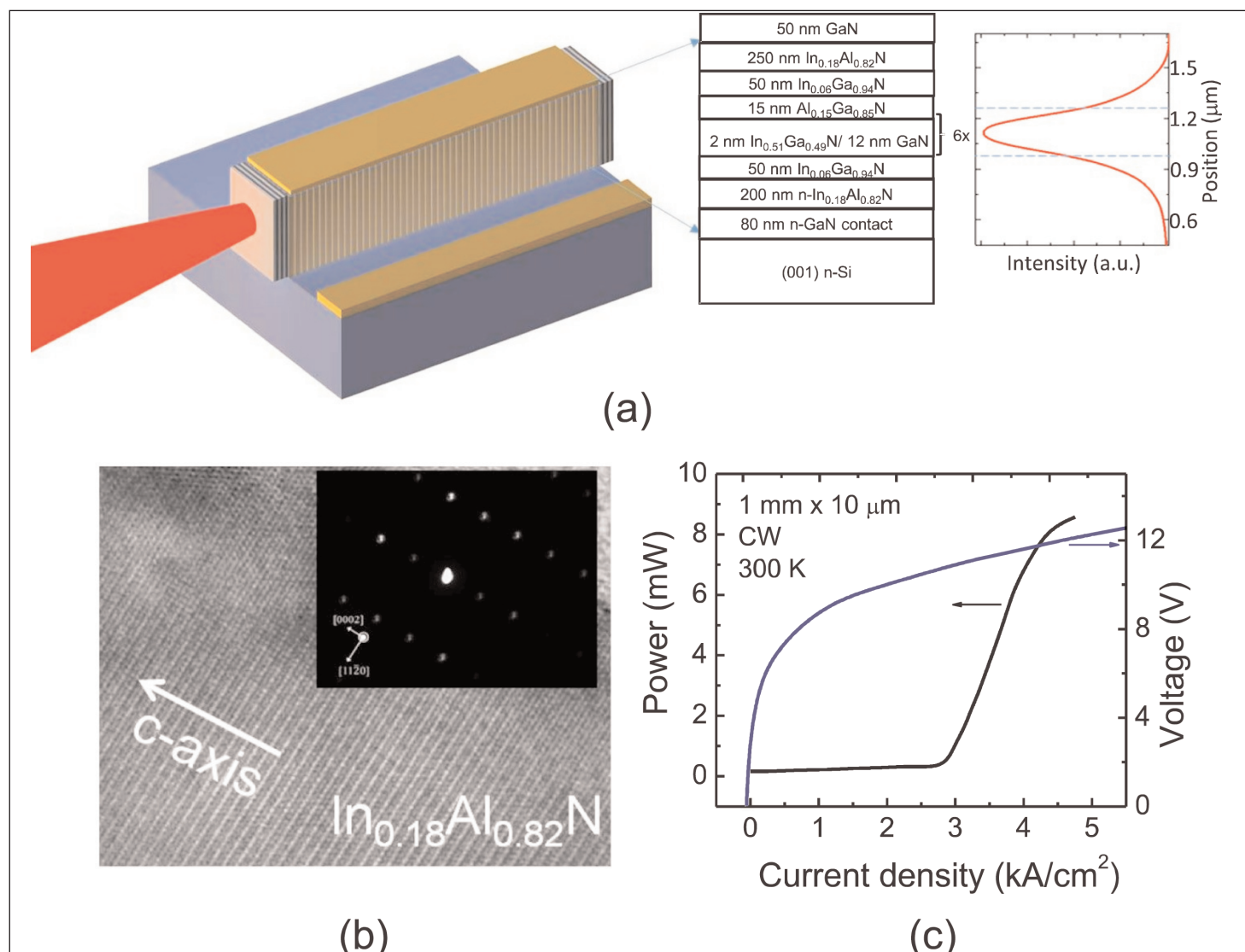


Figure 1. (a) Schematic of nanowire array laser heterostructure with calculated mode profile; (b) high-resolution transmission electron micrograph (HRTEM) of $\text{In}_{0.18}\text{Al}_{0.82}\text{N}$ nanowire showing relatively defect-free crystal structure along growth direction. Inset: selective-area diffraction pattern from HRTEM study. (c) Light-current-voltage characteristics from 10 µm x 1 mm laser at room temperature.

sen to improve optical confinement over AlGaIn.

The average nanowire had 60nm diameter and 800nm height. The random array density was $2 \times 10^{10}/\text{cm}^2$ with 7nm average spacing.

Ridge waveguide laser were produced from the epitaxial nanowire arrays. Mesas were produced with plasma etching. Conformal parylene was applied to planarize the structures and passivate the nanowires. The GaN tips of the nanowires were left exposed for ohmic p-contacts with nickel/gold (5nm/5nm) followed with 250nm indium tin oxide (ITO). The n-contact was through aluminium deposited on the bare region of the n-silicon substrate.

The laser cavity was cleaved with perpendicular facets, which were flattened with focused ion-beam (FIB) etching and coated with titanium dioxide/silicon dioxide distributed Bragg reflectors (DBRs) of reflectivity ~ 0.35 and ~ 0.95 .

A device with a 1mm cavity and $10\mu\text{m}$ -wide ridge had a $2.9\text{A}/\text{cm}^2$ threshold current density at room temperature under continuous-wave operation. The output-slope and wall-plug efficiency were 2.5% ($\sim 0.1/\text{A}$) and 0.2%.

The peak emission mode wavelength was about 610nm with a minimum linewidth of 9Å. The wavelength blue-shifted by 14.8nm when the current density increased between $1.4\text{kA}/\text{cm}^2$ and $3.6\text{kA}/\text{cm}^2$.

Temperature-dependent measurements of the threshold current gave a T_0 characteristic temperature of 234K. The researchers comment: "The large value of T_0 indicates good thermal stability in these devices. This value of T_0 is comparable with those measured in red-emitting self-assembled InGaIn/GaN quantum dot lasers."

Sub-threshold Hakki-Paoli optical gain measurements suggested the presence of InGaIn quantum dots in the gain region. The researchers add: "The formation of self-organized islands in the InGaIn disk region, which behave as quantum dots, has been confirmed by us by transmission electron microscopy (TEM) and the observation of single photon emission."

Modulation measurements were made on a $4\mu\text{m} \times 400\mu\text{m}$ device (Figure 2). The differential gain was $3.1 \times 10^{-17}\text{cm}^2$, according to the current-dependence of the resonance frequency, assuming radiative efficiency of 0.52 and confinement factor of 0.018. Differential gain "compares favorably with the differential gain of red-emitting self-organized quantum dot lasers," say the researchers.

The chirp under small-signal modulation was around 0.8Å up to 6GHz. The researchers comment: "The low value of chirp is very encouraging in the context of optical communication in plastic fibers. Chirp is usually small in lasers with quantum-confined gain media. Furthermore, in GaIn and related materials, the change in refractive index with carrier injection is small."

The $f_{-3\text{dB,max}}$ modulation bandwidth was 3.1GHz. ■

<http://dx.doi.org/10.1063/1.4913317>

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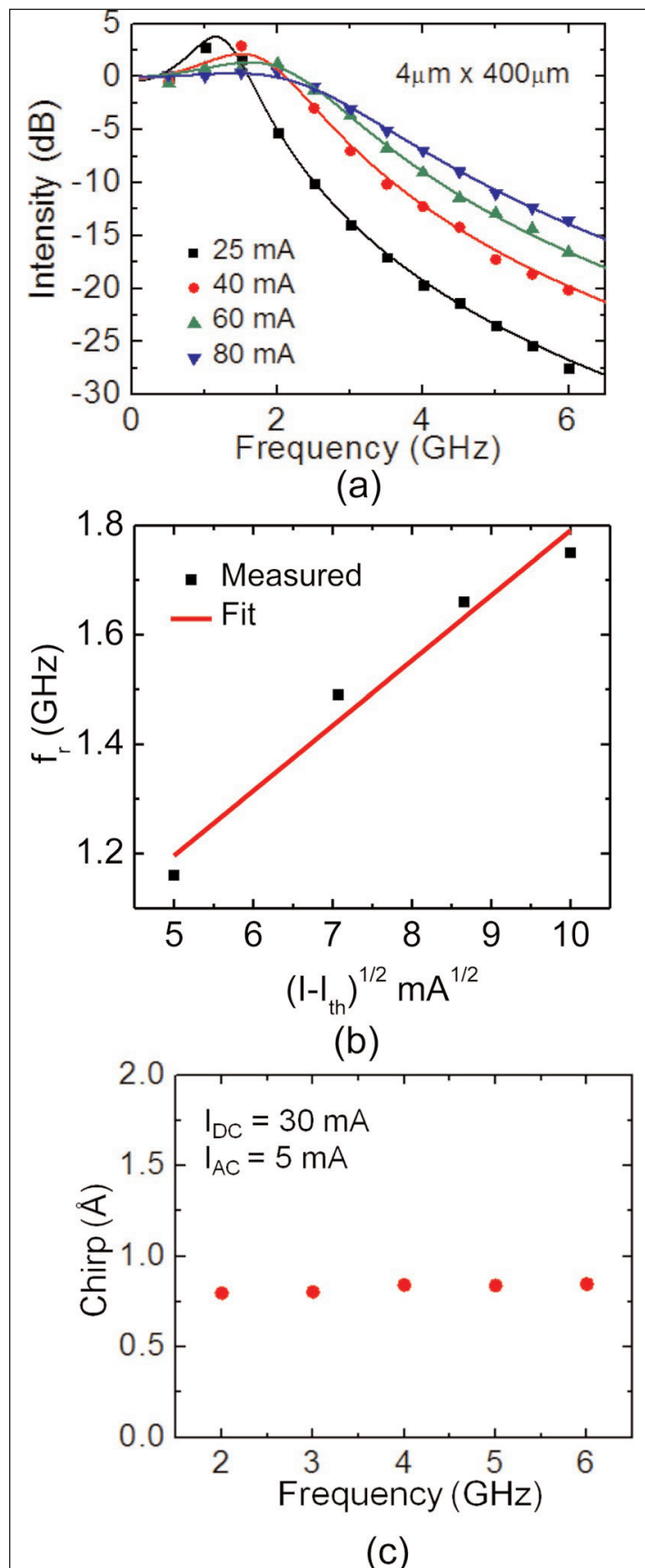


Figure 2. (a) Measured small-signal modulation response of a $400\mu\text{m} \times 4\mu\text{m}$ nanowire ridge waveguide laser for varying DC injection currents; (b) resonance frequency, f_r , versus square root of injection current; (c) measured chirp as function of small-signal modulation frequency.

Sidewall emission-enhancement for deep UV light-emitting diodes

Techniques have been developed to overcome anisotropic photon emission in high-aluminium-content aluminium gallium nitride.

Researchers in Korea and USA have developed sidewall emission-enhanced (SEE) deep ultra-violet (DUV) light-emitting diodes (LEDs) to improve light extraction efficiency [Dong Yeong Kim et al, *Light: Science & Applications*, vol4, e263, published online 10 April 2015].

DUV LEDs with wavelengths less than 300nm become very inefficient due to an increasing tendency for the photons to be emitted in the plane of the device. The problem arises from the band structure of high-aluminium-content aluminium gallium nitride (AlGaN) used for short-wavelength LEDs.

In such materials the dominant electron transition is from the conduction band to a crystal-field split-off hole state in the valence band. This transition emits photons with transverse magnetic polarization that propagates perpendicular to the c-direction of the crystal structure.

There has been some progress in improving DUV LEDs, with an external quantum efficiency (EQE) of 10% reported for 278nm wavelengths. However, commercial devices languish around 5% EQE. These values fall far short of the EQE of more than 80% for visible LEDs based on gallium indium nitride (GaInN).

If these problems can be overcome, applications beckon such as air/water/food purification/sterilization, polymer curing, semiconductor photolithography, and high-density optical recording. LEDs would then be

able to replace bulky, fragile, poisonous mercury lamps or more complex, expensive systems.

The researchers from Pohang University of Science and Technology and Samsung Electronics in Korea and Rensselaer Polytechnic Institute in the USA have developed the SEE structure to enable better extraction of the in-plane transverse-magnetic radiation.

To enable extraction of light directed in the plane of the 1mmx1mm LED chip, multiple narrow mesa strips were formed through 1µm reactive ion etch into the wafer (Figure 1). Selective metal-organic vapor phase epitaxy (MOVPE) re-growth of n-GaN with silicon dioxide masking was used to create mirror structures in the gap between the strips.

The n-contacts of 900°C-annealed titanium/aluminium/nickel/gold were formed on these n-GaN trapezoid cross-section micro-structures, along with other n-AlGaN exposed regions. The p-contact was 650°C-anneal nickel/gold. The LED was completed with evaporation of aluminium to form a mirror surface on the n-GaN micro-structures and deposition of titanium/gold contact pads.

The DUV 285nm-wavelength emitting wafer (Figure 2) included a five-period $\text{Al}_{0.4}\text{Ga}_{0.6}\text{N}/\text{Al}_{0.55}\text{Ga}_{0.45}\text{N}$ multiple quantum well grown on 4-inch c-plane sapphire by MOVPE.

The stripes increase the effective perimeter of the device out of which light emerges, increasing light out-

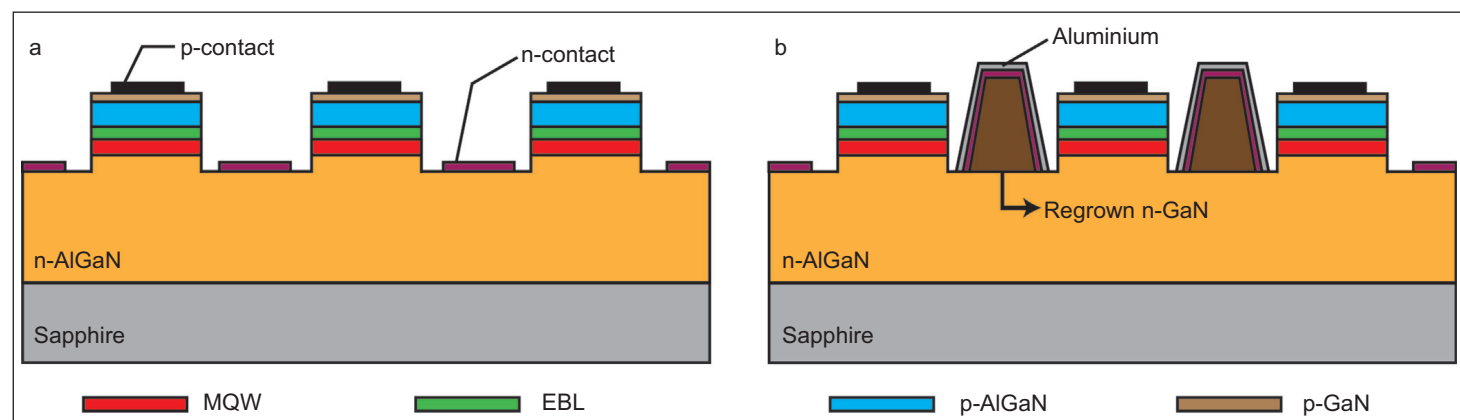


Figure 1. Device geometries. (a) Schematic of the conventional DUV LED structure (reference device) having narrow mesa stripes and (b) a proposed SEE DUV LED structure.

put power (LOP), EQE, and light extraction efficiency (LEE) (Figure 3). At the same time, the internal quantum efficiency (IQE) droops somewhat, due to an increase in current density in the reduced active region area for a given injection current. The placement of the n-GaN micro-structures in the gap between the mesa strips also increases output power.

The researchers explain: "Compared with reference LEDs with the same number of stripes, SEE DUV LEDs show higher LOPs because a part of the emitted DUV photons through the sidewalls is more likely to be reabsorbed by the MQW and the p-GaN contact formation layer of the neighboring mesa stripes in the reference LEDs than be reflected by the Al reflectors in the SEE DUV LEDs."

The researchers also believe there is improved efficiency due to the shorter lateral distance that electrons have to travel from the n-contacts and the active regions of the devices when the strips are narrower, giving a larger perimeter.

Angular-dependent measurements showed strong emission from the sidewalls in the reference LEDs without n-GaN micro-structure mirrors. The SEE LEDs gave more radiation in the forward direction, similar to the pattern of c-plane GaInN LEDs.

SEE LEDs with 45 stripes also had a reduced forward voltage of 7.55V at 100mA compared with the reference devices, which needed about 0.25V larger bias for the same current. Both types of device showed reduced forward voltage requirements as the effective perimeter increased.

Contact	p-GaN	20nm
Cladding	p-AlGaIn (graded 65%-0% Al)	20nm
Electron blocking	p-Al _{0.7} Ga _{0.3} N	20nm
Multiple quantum well	5x(Al _{0.4} Ga _{0.6} N/Al _{0.55} Ga _{0.45} N)	5x(3nm/10nm)
Cladding	n-Al _{0.55} Ga _{0.45} N	2μm
Buffer	AlGaIn/AlN superlattice	
Buffer	AlN	
Substrate	Sapphire	

Figure 2. DUV LED wafer.

The improved forward voltage of the SEE LED was attributed to the better ohmic contact with the re-grown n-GaN and the larger contact area, compared with the contact with the flat n-AlGaIn surface.

The researchers say there are various ways in which the mirror micro-structures can be changed by altering the process. A version for bottom emission through the substrate is being developed to take advantage of flip-chip devices that allow heat dissipation through a suitable sub-mount rather than thermally insulating sapphire.

The researchers point out that, as the aluminium content of the active region increases to access even shorter wavelengths, the SEE DUV LED structure will become even more effective, since a larger proportion of the emitted photons will be in the plane of the MQW. ■

www.nature.com/lsa/journal/v4/n4/abs/lsa201536a.html

Author: Mike Cooke

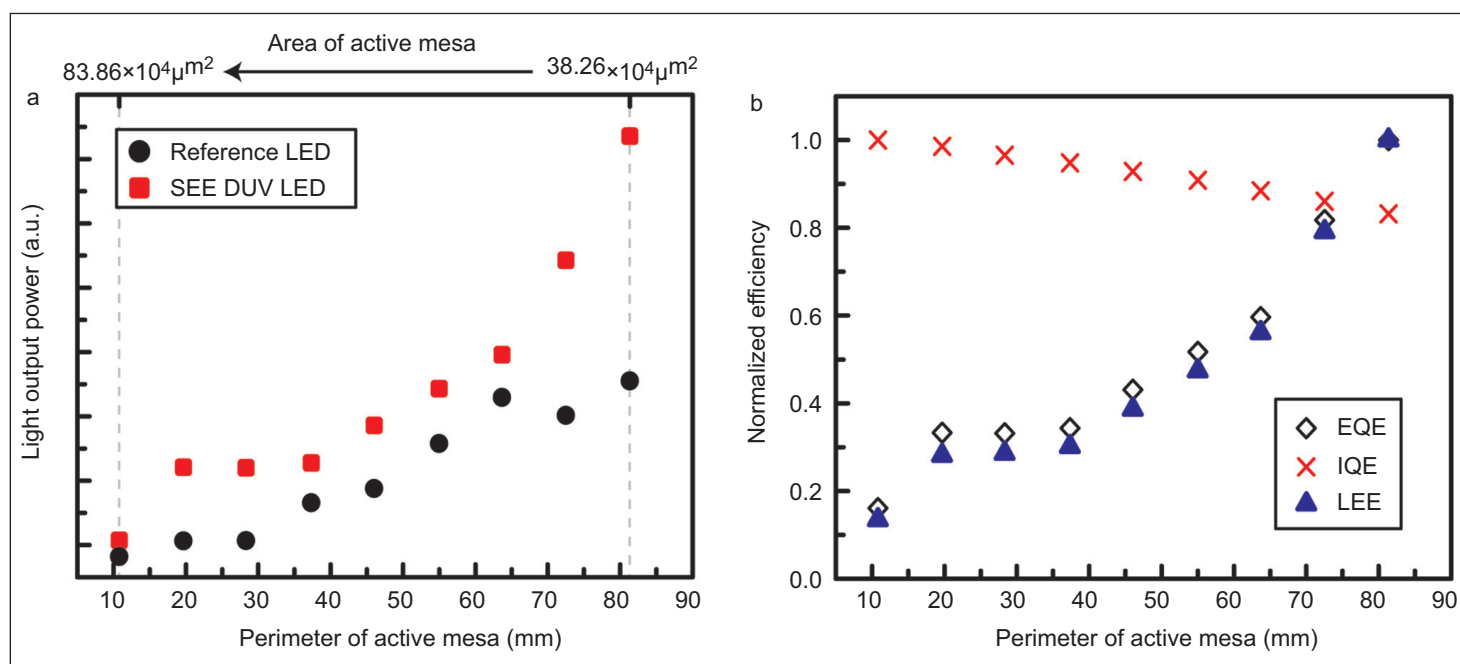


Figure 3. (a) LOPs of reference and SEE DUV LEDs measured in surface normal direction at injection current of 100mA as function of perimeter of active region. (b) Normalized EQE, IQE and LEE of SEE DUV LEDs.

Stressed out InAlN/GaN fin-HEMT boosts performance

Record transconductance and electron velocity achieved at room temperature.

Researchers based in Singapore and USA have stress engineered three-dimensional (3D) triple T-gate (TT-gate) lattice-matched indium aluminium nitride/gallium nitride ($\text{In}_{0.17}\text{Al}_{0.83}\text{N}/\text{GaN}$) nano-channel (NC) fin high-electron-mobility transistors (fin-HEMTs) to achieve record electron velocities and transconductance at room temperature [S. Arulkumaran et al, Appl. Phys. Lett., vol106, p053502, 2015]. The devices were produced on silicon substrates.

The fin-HEMT structure (Figure 1) allows for improved electrostatic control of the channel

current, reducing short-channel effects that negatively impact performance in ultra-small devices.

One fin-HEMT device with silicon nitride passivation/stress achieved a maximum drain current

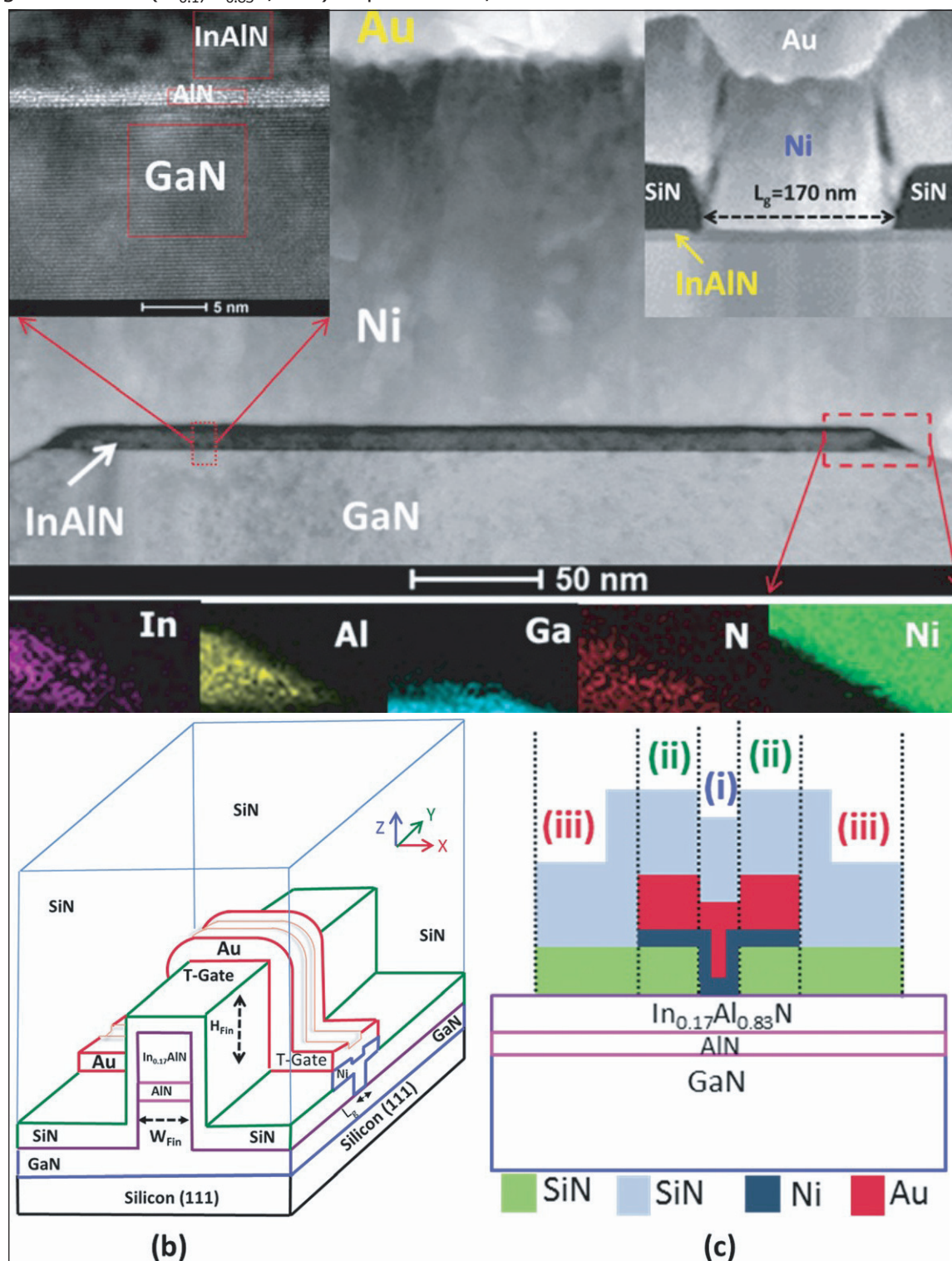


Figure 1. (a) Cross-sectional HR-TEM image of InAlN/GaN HEMT structure, cross-sectional area EDX mapping for different elements in InAlN/GaN nano-channel (NC): inset 1 - InAlN/AlN/GaN heterostructure; inset 2 - T-gate NC Fin-HEMT. (b) Three-dimensional schematic view of Triple T-gate on InAlN/GaN nano-channel. (c) Schematic cross-section of T-shape gate configuration with different stress regions [(i) SiN/Au/Ni stress layers, (ii) SiN/Au/Ni/SiN stress layers and (iii) SiN/SiN stress layers] to InAlN/GaN nano-channel.

Figure 2. (a) Drain current versus voltage ($I_{DS}-V_{DS}$), (b) drain current and transconductance ($I_D(g_m)/|I_g|-V_g$) transfer characteristics of conventional InAlN/GaN HEMTs and 3D TT-gate InAlN/GaN NC Fin-HEMTs. (c) Calculated electron velocity (v_e) for 3D TT-gate InAlN/GaN NC fin-HEMT, conventional HEMT, and 2D model.

of 3940mA/mm of effective gate width (200nm), and transconductance of 1417mS/mm at 6V drain bias. The researchers comment: "The observed I_{Dmax} and g_{mmax} values are the highest ever reported in the literature for NC Fin-HEMTs on Si(111)."

Conventional passivated InAlN/GaN HEMTs produced along with the fin-HEMTs achieved 1225mA/mm maximum drain current. AlGaIn/GaN HEMTs on very expensive silicon carbide (SiC) substrates have achieved 4000mA/mm drain current.

The researchers were variously associated with Singapore's Nanyang Technological University and Institute of Materials Research and Engineering (IMRE), along with Ohio State University in the USA.

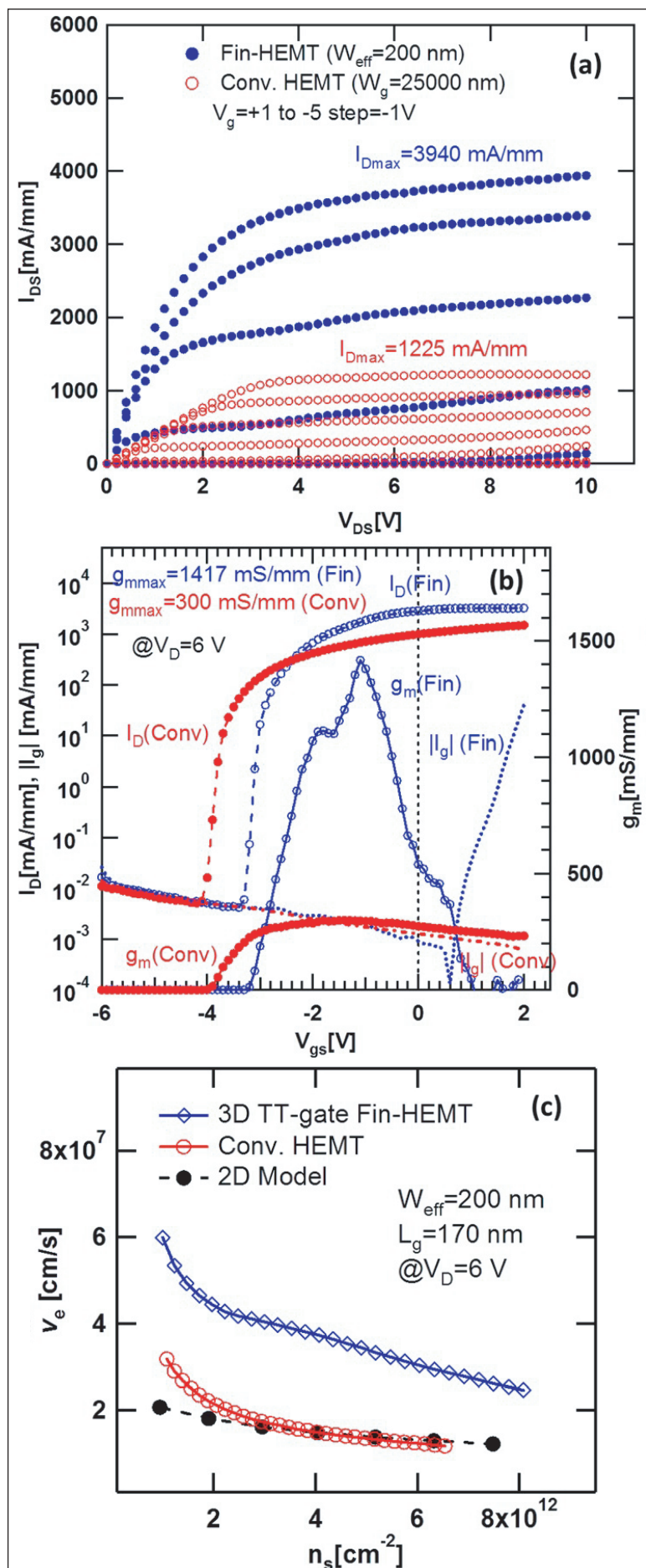
The epitaxial structure was grown on high-resistivity (111) silicon by metal-organic chemical vapor deposition (MOCVD). The barrier layer was $In_{0.17}Al_{0.83}N$, separated from the GaN buffer/channel by an AlN spacer. Measurements on Hall van-der-Pauw structures gave a carrier density of $2.74 \times 10^{13}/cm^2$ and mobility of $760 cm^2/V-s$ for the two-dimensional electron gas (2DEG) channel at 300K.

Device fabrication began with mesa isolation and nano-channel fin formation. The fin height was 12nm. The widths were 176nm or 314nm. The nickel/gold 3D triple gate was formed into T-shapes with optional silicon nitride passivation/stress layer.

The performance of the NC fin-HEMTs was compared with conventional HEMTs. The gate lengths of all devices were 170nm. Also, the devices had fixed dimensions for source-gate (850nm) and gate-drain (1800nm) separation.

The researchers estimated an electron velocity of $6.0 \times 10^7 cm/sec$, compared with $3.17 \times 10^7 cm/sec$ for the conventional HEMT. The fin-HEMT value is also greater than reported drift velocities for InAlN/AlN/GaN structures at high electric field of $3.2 \times 10^7 cm/sec$, although AlGaIn/GaN structures have achieved $6.8 \times 10^7 cm/sec$ with 0.3MV/cm field at 4.2K. The researchers suggest that the 3D geometry of the fin-HEMT combined with stress could alter the optical-phonon spectrum or scattering rates that control electron velocities in the 2DEG.

Devices without silicon nitride stress/passivation demonstrated poorer performance. Raman spectroscopic analysis showed that the silicon nitride introduced tensile stress to the fin structures. ■



<http://dx.doi.org/10.1063/1.4906970>

Author: Mike Cooke

Raising GaN Schottky diode breakdown with recessed double-field plate anode

University of Notre Dame claims record breakdown voltage of 1.9kV for lateral AlGaIn/GaN Schottky barrier diodes on silicon.

Researchers at University of Notre Dame (UND) in the USA have claimed record high breakdown voltage for aluminium gallium nitride (AlGaIn/GaN) lateral Schottky barrier diodes (SBDs) on silicon [Mingda Zhu et al, IEEE Electron Device Letters, published online 16 February 2015]. Two researchers from IQE LLC in the USA were also involved in the work.

The team achieved a breakdown voltage (BV) of 1.93kV (Figure 1). The researchers comment that "this BV value is the highest among the reported GaN-on-silicon diodes" and that the devices are comparable in performance with "state-of-the-art GaN diodes on SiC, sapphire and bulk GaN substrates". While devices grown on these latter substrates benefit

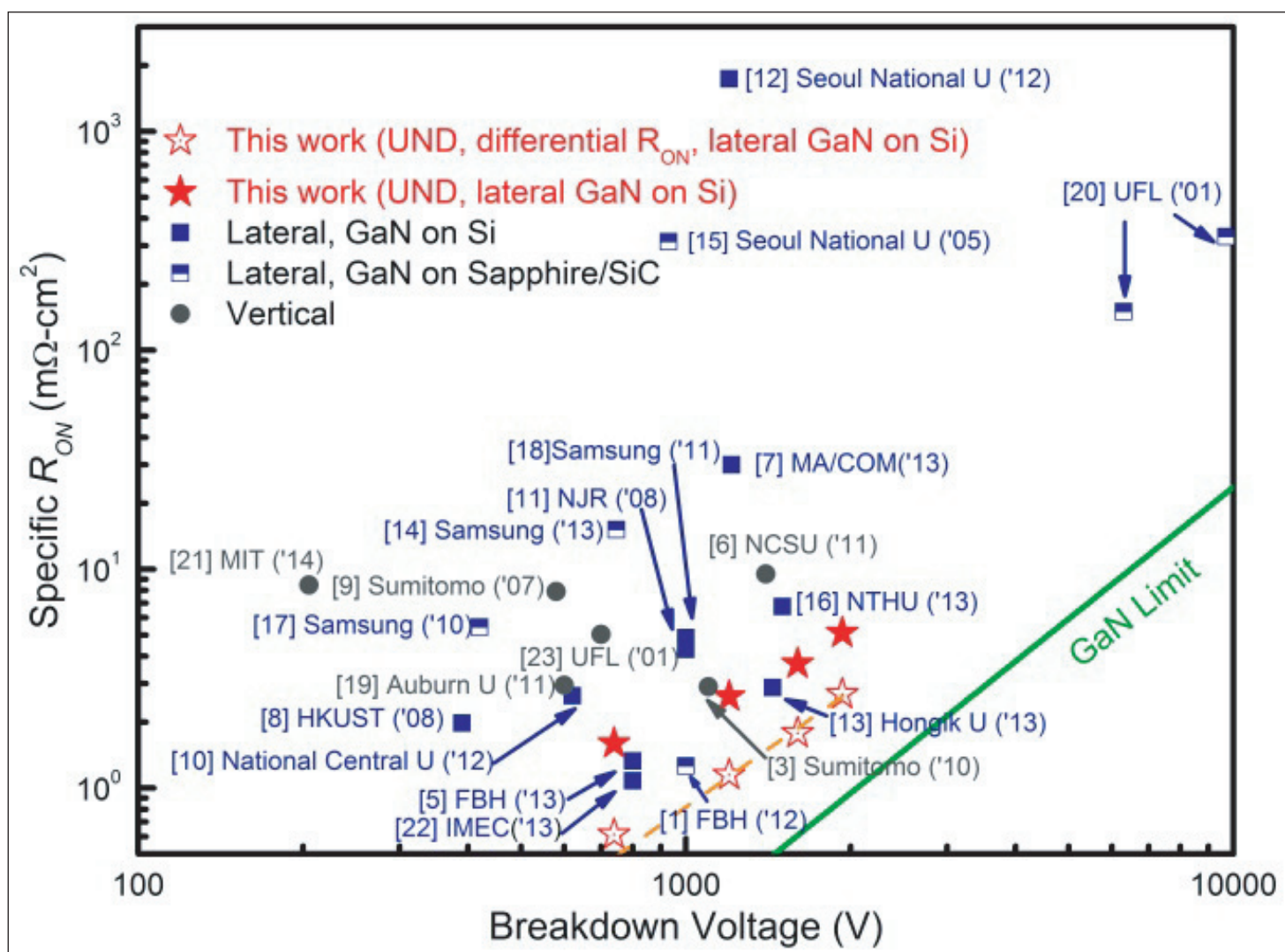


Figure 1. Benchmark plot of BV versus $R_{ON,SP}$. Reference values are re-calculated based on reported data using UND's definition of $R_{ON,SP}$ to take into account diode turn-on effect (100mA/mm on-current). Differential R_{ON} of diodes also extracted (hollow stars) and modeled (dash line). Green line shows FOM limit of bulk GaN.

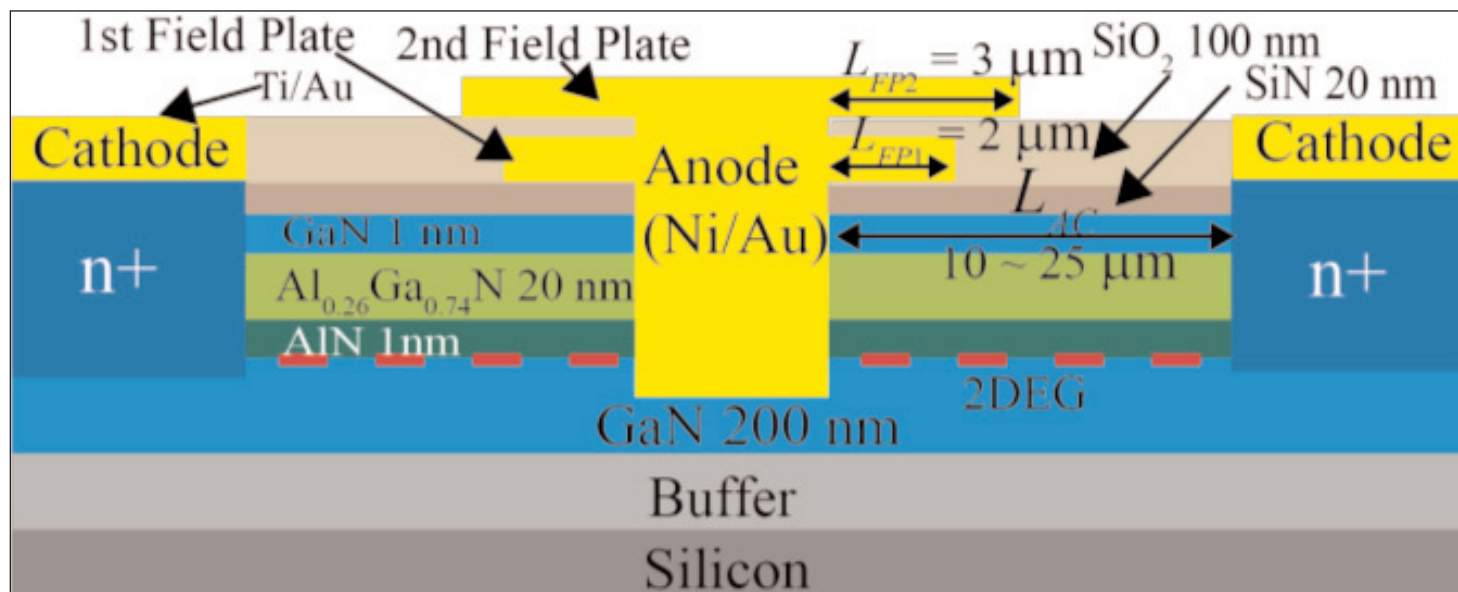


Figure 2. Schematic cross section of the recessed anode Schottky barrier diode with double field plates.

from lower dislocation density in the nitride semiconductor material, the cost of silicon is much lower. Manufacturers, of course, want low cost combined with high enough quality for reliable power electronics applications.

The University of Notre Dame SBD used epitaxial material grown on 6-inch (111) silicon by metal-organic chemical vapor deposition (MOCVD). The 100nm n⁺-GaN cathode ohmic contacts (Figure 2) were re-grown using molecular beam epitaxy (MBE). The cathode metal was unalloyed titanium/gold.

The recessed anode with two field plates was built in stages. First the silicon nitride (SiN) dielectric was deposited before the recess etch which drilled 50nm into the AlGa_{0.26}Ga_{0.74}N/GaN layers. The nickel/gold (Ni/Au) for the recessed anode and first field plate was then deposited.

Finally, relative thick silicon dioxide (SiO₂) and nickel/gold were used to form the second field plate. The SiO₂ layer was chosen to be thick to support a large anode-cathode voltage drop. The anode-cathode distance (LAC) was varied between 10μm and 25μm.

The turn-on voltage of the device was around 0.67V. The reverse bias BV of 1.93kV (1mA/mm cut-off) was achieved with an LAC of 25μm. The devices had a specific on-resistance (R_{ON,SP}) of 5.12mΩ-cm² at 100mA/mm forward current. The researchers also quote a power figure of merit (FOM = BV²/R_{ON,SP}) of 727MW/cm². Corresponding values for a 20μm-LAC device were 1.6kV, 3.7mΩ-cm², and 691MW/cm². The researchers comment that the FOM values are comparable to other state-of-the-art devices.

The estimated switching time of the devices was ~350ps, despite the significantly increased capacitance of the double field-plate structure. The researchers estimate that the presence of the second field plate increased the BV by between 5% and 25%, dependent on LAC.

The researchers believe that there is room to improve the BV further by bringing the effective critical field closer to the value for bulk GaN with better engineering of the surface fields. ■

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Author: Mike Cooke

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Opening windows for silicon carbide junction termination extensions

Companies keen to commercialize SiC for high-voltage power applications need production flows that are robust against process variation. **Mike Cooke** reports on attempts to improve the effectiveness of junction termination extensions across a range of parameters.

Power devices fabricated using silicon carbide (SiC) technology benefit from a high critical electric field of 3MV/cm due to the wide energy bandgap of 3.26eV. Also attractive for power applications is high thermal conductivity in the range 3–3.8W/cm-K. Despite the difficulties in working and processing the material, a range of companies is developing SiC for a range of high-voltage power applications.

Market analysis firm Yole Développement says that there are more than 30 companies worldwide that have established dedicated SiC device manufacturing. According to Yole, Infineon and Cree lead the way, with Rohm, STMicroelectronics and Mitsubishi Electric also

in the running. In Japan, there are also Fuji Electric, Panasonic, Toshiba, and Hitachi.

China has Global Power Technology commercializing SiC power devices with a capacity of 1000 wafers per year. The big State Grid Corporation of China and China South Locomotive & Rolling Stock Corporation Ltd are developing SiC devices for grid and rail applications, respectively. In addition, automobile and electronics company BYD Co Ltd has tested Cree SiC devices for electric and hybrid electric vehicles.

In other parts of Asia, Taiwan's Hestia Power is a fabless developer that has begun commercializing SiC diodes, and in Korea Maple Semiconductor and

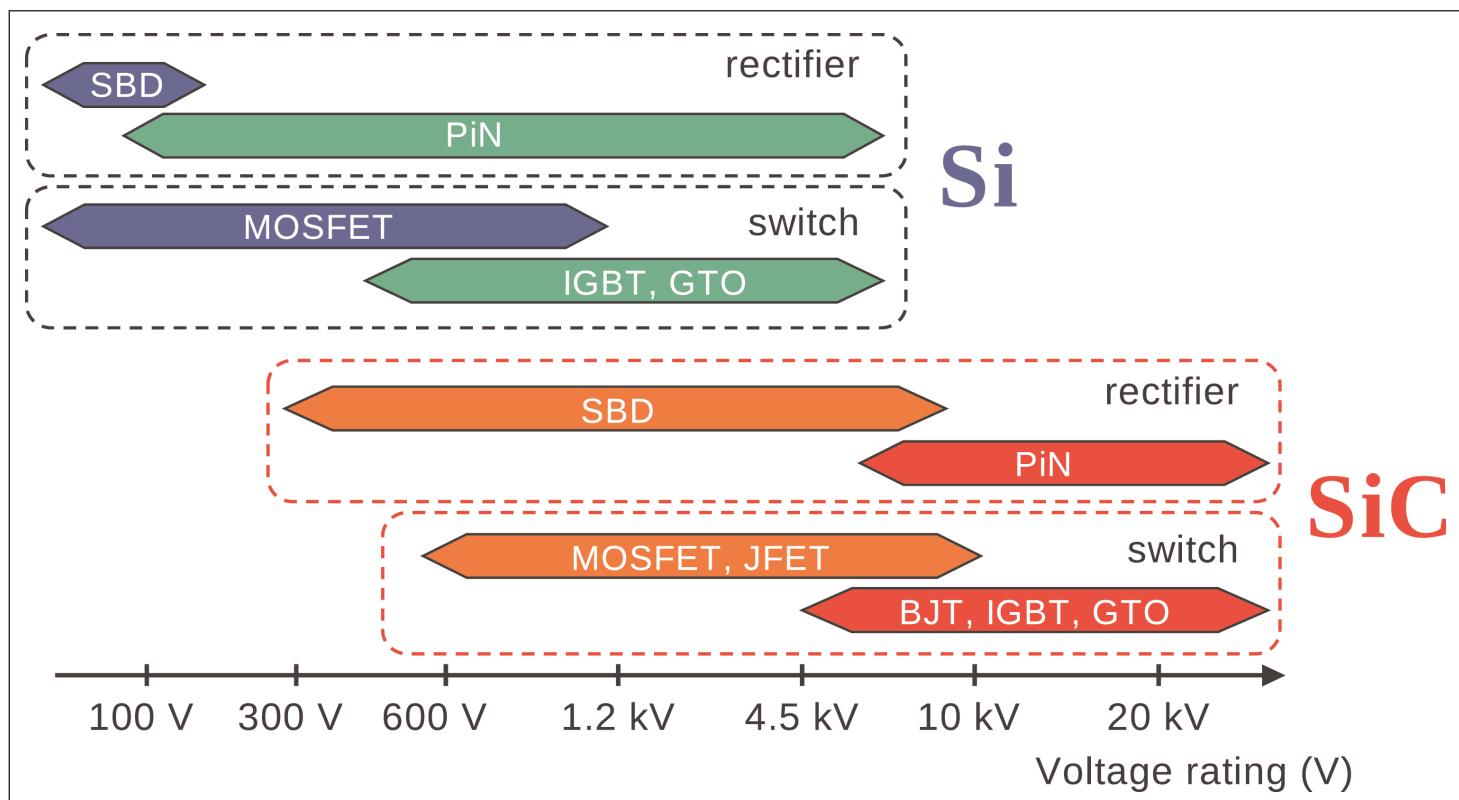


Figure 1. Major territories of individual unipolar and bipolar power devices for Si and SiC in terms of rated blocking voltage, according to a recent review [Tsunenobu Kimoto, Jpn. J. Appl. Phys., vol54, p040103, 2015].

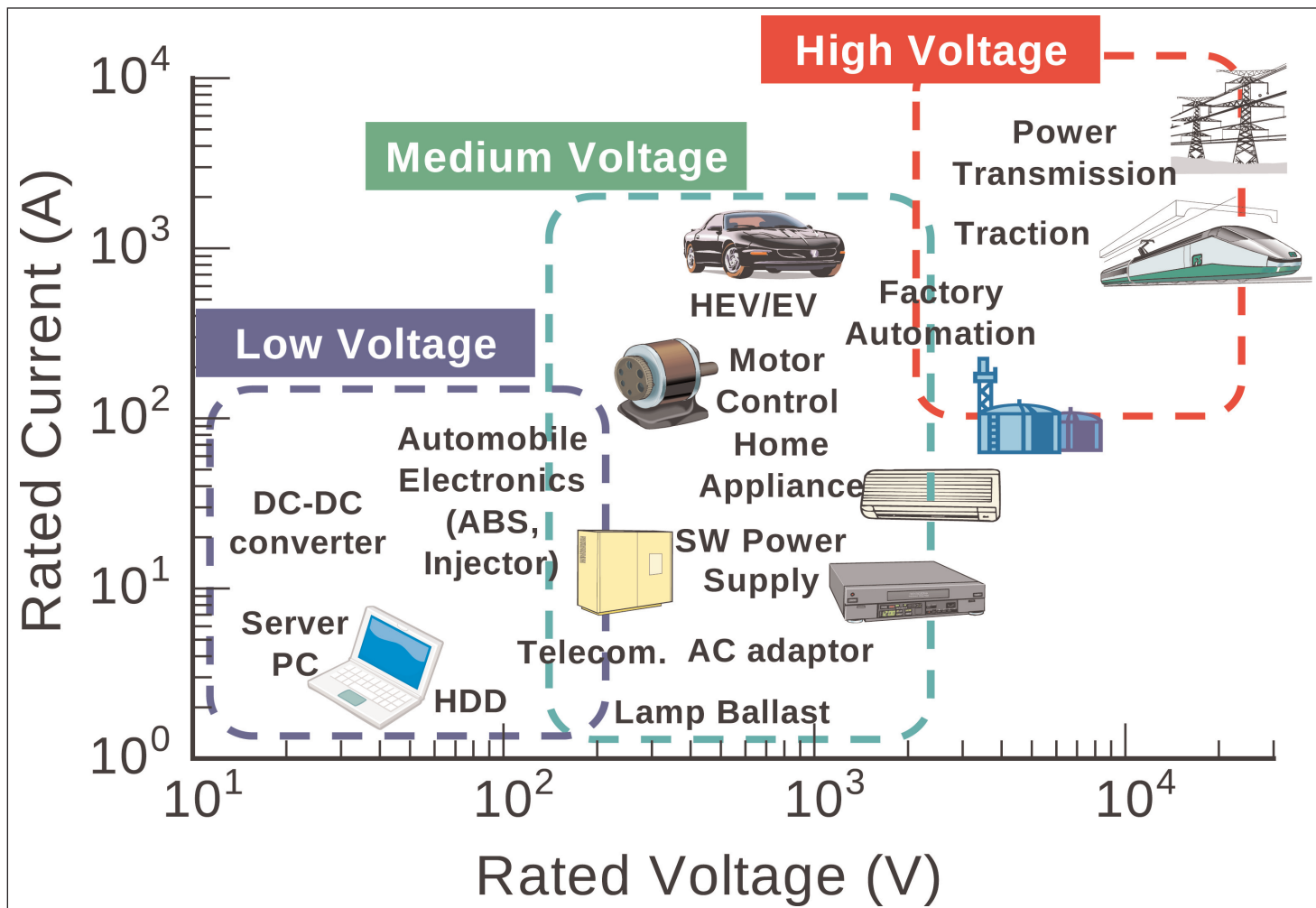


Figure 2. Major application areas of power devices plotted as a function of rated voltage [Tsunenobu Kimoto, Jpn. J. Appl. Phys., vol54, p040103, 2015].

Hyundai have agreed to jointly develop SiC technology.

Market analysts and developers see potential applications for SiC's high voltage (up to 1.7kV, according to Yole, although higher ratings of more than 25kV have been achieved in the laboratory — see Figure 1), frequency and temperature capabilities in rail, electric vehicle and hybrid electric vehicle (EV/HEV), electricity grid and renewable energy, such as wind and solar power (Figure 2). Typical subsystems that could benefit include power factor correction (PFC) circuits and inverters for DC to AC conversion. Meanwhile gallium nitride — another wide-bandgap material with high critical field that can be grown on large-area silicon, reducing production costs — is being developed for power switching at relatively low voltages, compared with SiC.

Electric power is growing in importance — comprising 22.3% of total final energy consumption in 2012, according to the International Energy Agency. SiC has the potential to improve delivery at low cost through more efficient power conditioning and conversion. Presently, power conversion steps lose between 5% and 15% of energy throughput to heat.

Although problems with SiC crystal growth and device

processing have been largely overcome, there continue to be concerns related to defects and reliability.

Edge terminations are designed to avoid field crowding effects that cause premature breakdown. Various groups have developed a number of techniques such as floating field rings, junction termination extension (JTE), and multi-step etched JTE. The aim of these methods is to shift and reduce the peak field to where it can do least harm to device performance and reliability.

Unfortunately, these techniques can take up a large amount of space on the chip (about three times the drift layer thickness) — an economic concern, given the high price of silicon carbide substrates. Added process complexity also increases production costs. The techniques also suffer from a narrow window for process variations such as critical dimensions and doping implant dosage, which naturally hits the yield of devices working to spec.

The nature of silicon carbide makes standard isolation techniques such as trench etching difficult. For SiC, this would need deep reactive ion etch, which can be prohibitively time consuming given the hardness of the material.

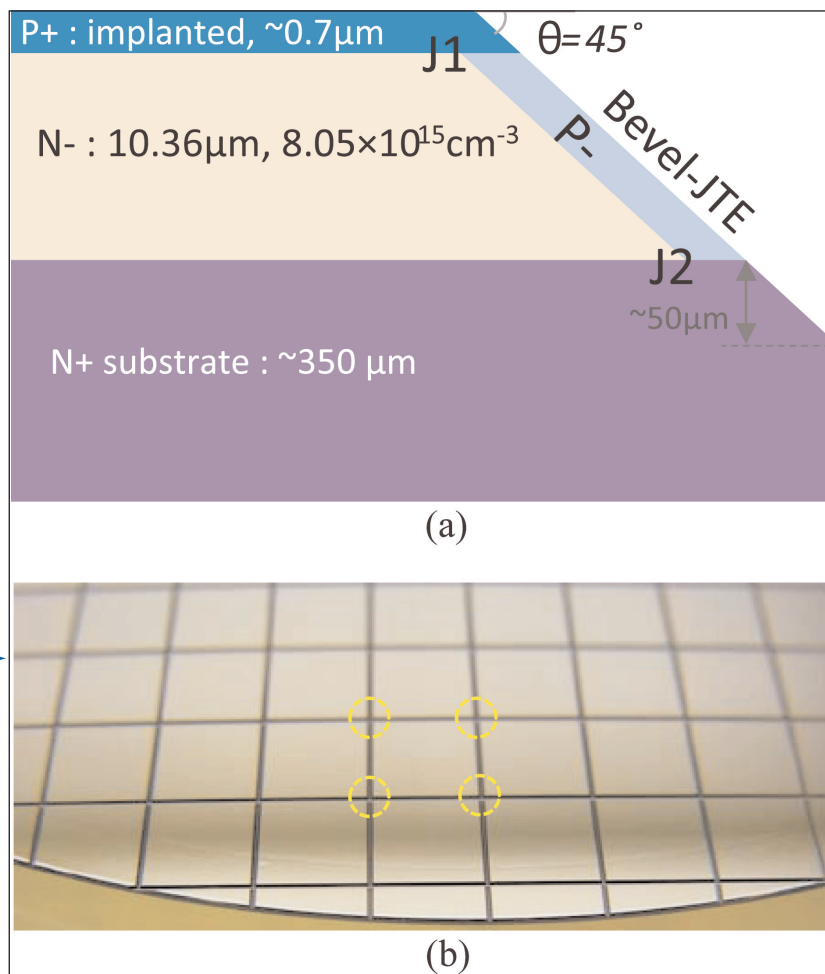


Figure 3. (a) Schematic cross section of a PiN rectifier with the Bevel-JTE. Over-diced area into the substrate is used for the final dicing, (b) wafer image after bevel dicing. Corners of the Bevel-JTE are indicated by dashed circles.

Bevel JTE

North Carolina State University (NCSU) in the USA has developed a new edge termination technique for 4H-SiC high-voltage devices [Woongje Sung et al, IEEE Electron Device Letters, published online 29 April 2015]. The technique involves beveling the device and creating a JTE with implanted aluminium doping (Figure 3).

The researchers used an angled dicing blade to create the bevel. Angles between 30° and 90° could be achieved easily. The angle and feed speed were chosen to reduce surface roughness and chipping.

The doping of the JTE needs to be adjusted to avoid locating the high field at either the bottom of the pn junction (high doping) or at the main junction (low doping). Both extremes result in lowered breakdown voltage. The high doping condition also increases leakage currents.

A range of 4H-SiC PiN rectifiers was fabricated with a chip size of $4\text{mm} \times 4\text{mm}$. The top p^+ layer was doped with aluminium implantation of total

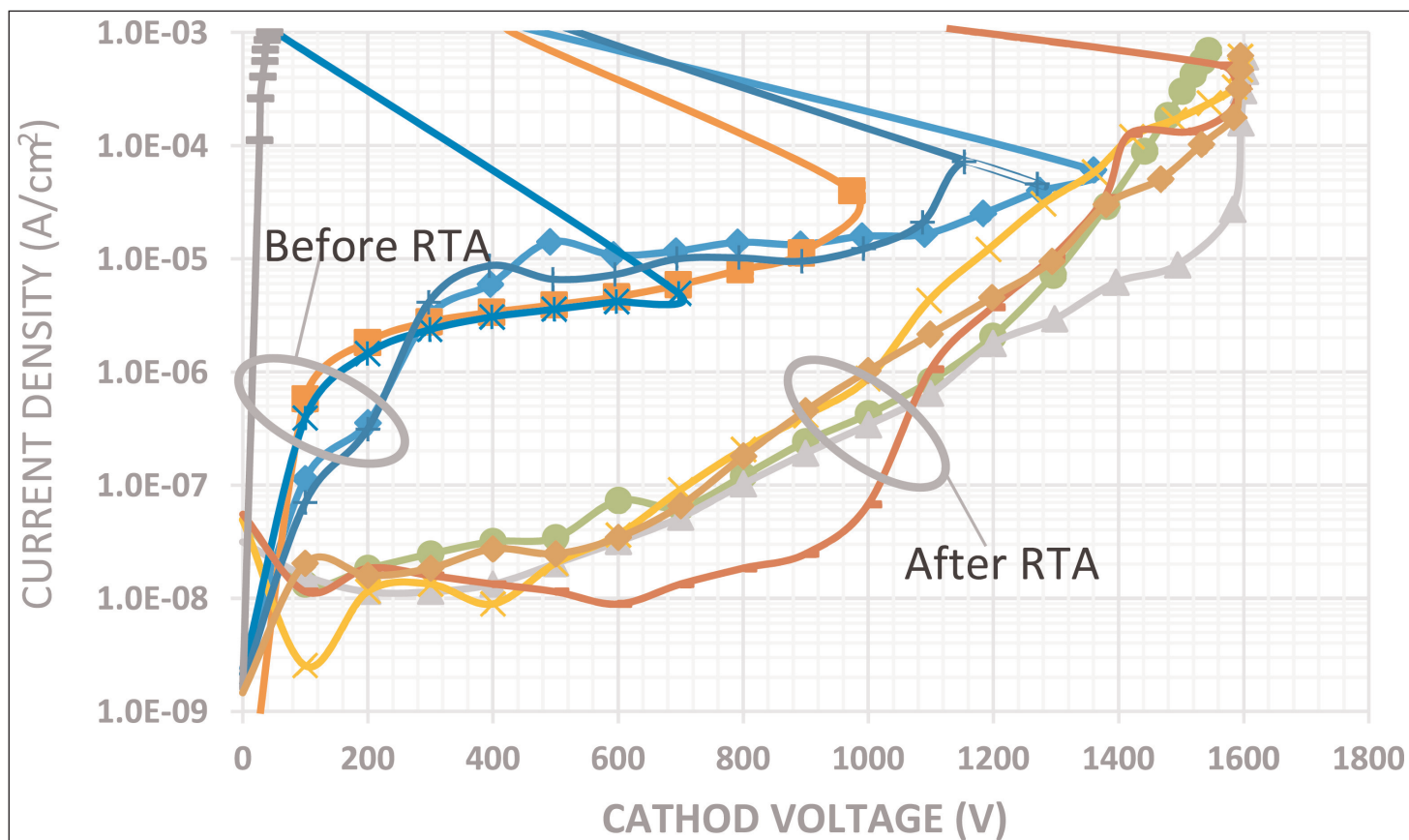


Figure 4. Effect of RTA on reducing leakage current. Reverse blocking characteristics before and after the RTA process on same dies implanted at $2 \times 10^{13}/\text{cm}^2$.

dose $2 \times 10^{15}/\text{cm}^2$ at 300keV.

The bevel-JTE was formed using orthogonal bevel dicing and ion implantation. The dicing blade was V-shaped with a 45° angle. Damage from the sawing step was removed with a $0.3\mu\text{m}$ reactive ion etch. Doping activation was achieved with annealing at 1800°C for 5 minutes. Leakage current could be reduced by rapid thermal annealing (RTA) at 1000°C for 1 minute in laughing gas, more soberly known as nitrous oxide (N_2O).

The researchers achieved a maximum breakdown voltage of 1600V with an anode current density of $1\text{mA}/\text{cm}^2$. The breakdown was 95% of the maximum theoretical value for a one-dimensional model. Bevel implant doses in the range $1\text{--}2 \times 10^{13}/\text{cm}^2$ gave the maximum breakdown. The breakdown was reduced to $\sim 800\text{V}$ for $3 \times 10^{13}/\text{cm}^2$ dosage due to current leakage.

Comparison with simulation results suggests incomplete activation of the doping ($\sim 50\%$). The researchers suggest that the annealing may evaporate some of the dopant and create unintentional doping elsewhere in the structure. "This results in higher measured breakdown voltages than shown by simulation," the team adds.

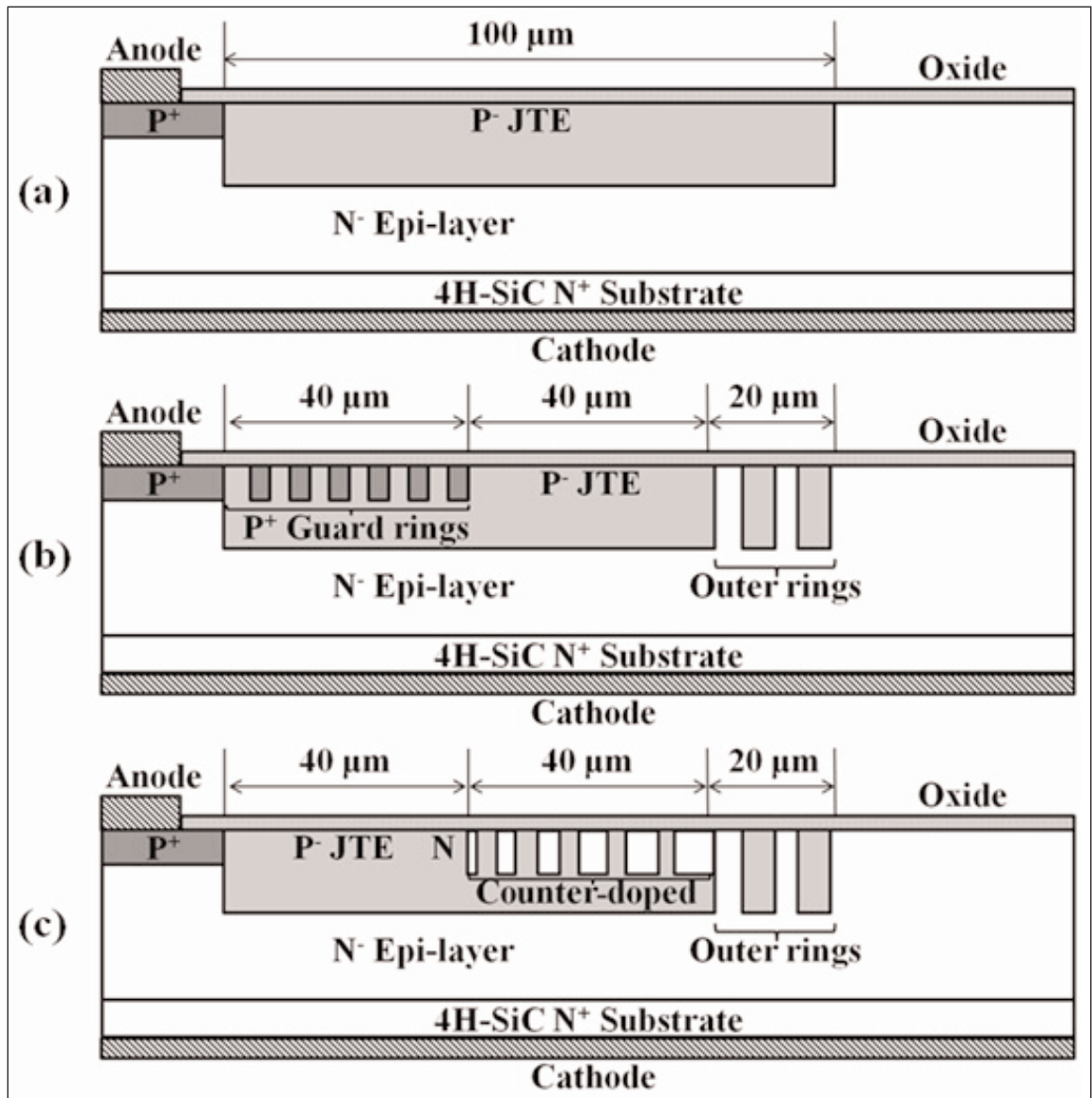


Figure 5. Cross-sectional schematics of three termination structures: (a) single-zone (SZ) JTE, (b) GAJ plus ORs, and (c) CD-JTE plus ORs.

Since the Bevel-JTE is fabricated with a dicing blade, it can be simply applied to any vertical device in SiC that has a drift layer of different thickness by adjusting the dicing depth. It is more attractive to use the Bevel-JTE structure for higher-voltage devices because a significantly large area of the wafer is occupied by edge termination structures using conventional approaches

The RTA process reduced current leakage significantly (Figure 4). The researchers attribute the improvement to curing of implant-induced defects and damage, reducing the concentration of active carrier trapping centers.

The researchers comment: "Since the Bevel-JTE is fabricated with a dicing blade, it can be simply applied to any vertical device in SiC that has a drift layer of different thickness by adjusting the dicing depth. In fact, it is more attractive to use the Bevel-JTE structure for higher-voltage devices because a significantly large area of the wafer is occupied by edge termination structures using the conventional approaches."

The team estimates that the bevel-JTE is three times narrower than conventional approaches to edge termination. Also, the complexity and implant dose sensitivity is reduced. The researchers believe that the technique can be used for other devices with different ranges of breakdown voltage.

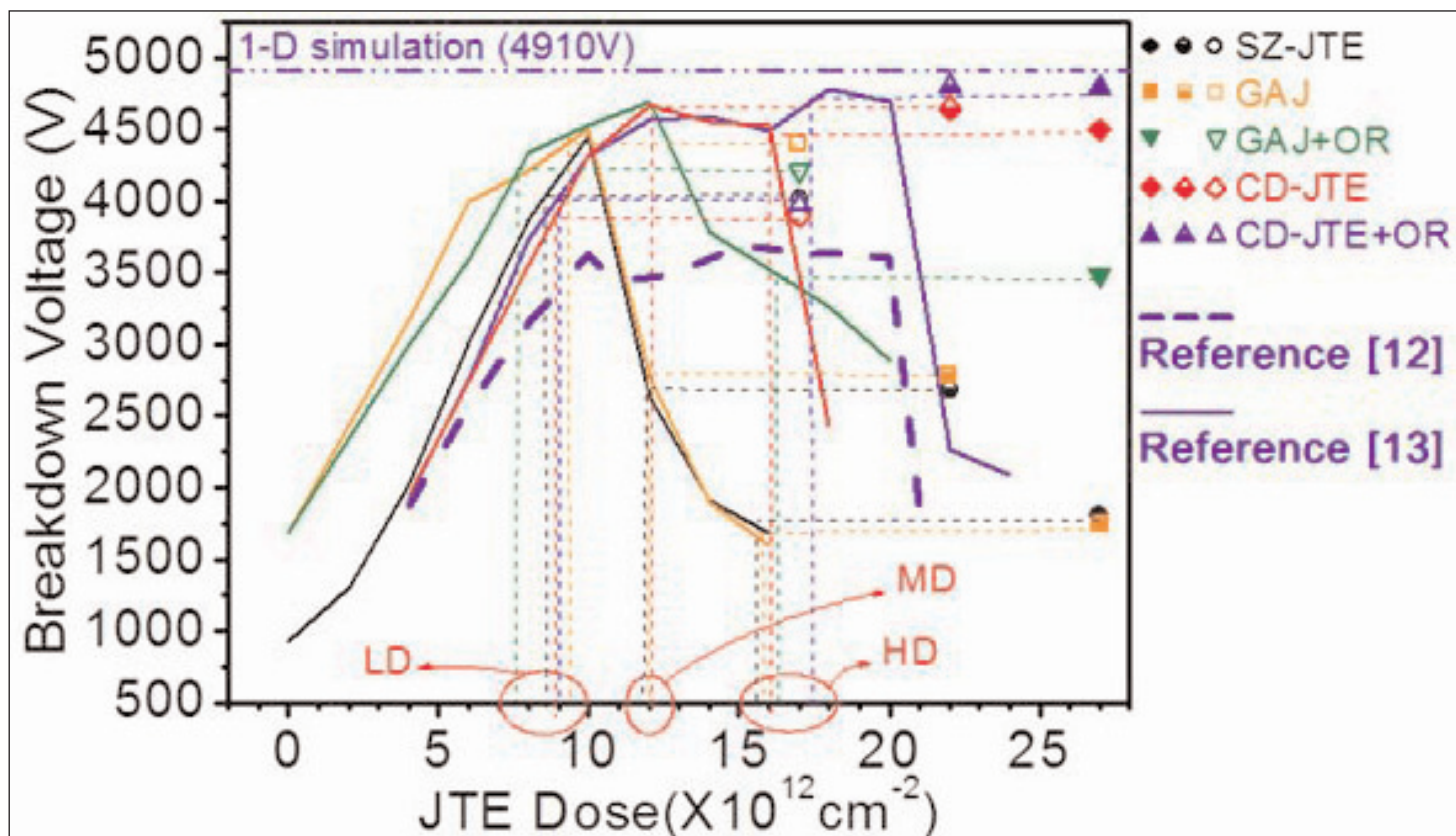


Figure 6. Reverse breakdown voltages (BVs) measured on 30 μm PiN diodes with all termination structures and high (HD), medium (MD), and low (LD) JTE doses. Also shown are simulation results using two different impact ionization models (dashed and solid line).

► Counter doping

Another approach to improving JTEs has been developed by Taiwan's National Tsing Hua University and Washington State University in the USA [Jheng-Yi Jiang et al, IEEE Electron Device Letters, published online 30 April 2015], based on theoretical work carried out in conjunction with Taiwan's Industrial Technology Research Institute [Chih-Fang Huang et al, IEEE Transactions on Electron Devices, vol.62, p.354, 2015].

The researchers were keen to produce JTEs with larger process windows in terms of giving a wider implant dose range. In particular, the theoretical work suggested that suitable counter-doping (CD) could increase the dose range for JTEs. Alternative JTE strategies, involving guard-ring assisted junctions (GAJs) around the anode or outer rings (OR), were produced for comparison and combination with counter-doping (Figure 5). The theoretical simulations also suggest reduced sensitivity of

performance to the presence of surface charges for the CD strategy.

PiN devices were produced using N^- epitaxial layers and P^+ main junction implants of aluminium at up to 180keV. The JTE P^- doping was achieved with implants up to 360keV. The N-type counter-doping used phosphorus implants at up to 200keV. The implants were activated with annealing at 1650°C for 10 minutes in argon, where the surface was protected with a carbon cap layer. The researchers believe that the activation was around 60% for the JTE and 70% for the counter doping.

The annealed ohmic contacts were titanium/aluminium/nickel for the anode and titanium/nickel for the cathode. The active area of the devices was $7.85 \times 10^{-3} \text{ cm}^2$.

The measured specific on-resistance for devices with 30 μm n-type epilayers ranged between $7.75 \text{ m}\Omega\text{-cm}^2$ and $8.57 \text{ m}\Omega\text{-cm}^2$ with diode ideality of about 1.6. The reverse leakage current was of the order of nanoamps — the accuracy of the measurements was limited by the noise floor of the equipment ($\sim 10^{-7} \text{ A/cm}^2$).

A series of different device structures was tested for breakdown in Fluorinert liquid (Figure 6, Table 1). The highest breakdown of 4720V occurred for CD-JTE with outer rings (OR). A thinner n-type epitaxial layer of 11 μm gave a breakdown of 1850V for the CD-JTE+OR structure with medium and high doping. ■

Author: Mike Cooke

Table 1. Breakdown voltages for different device structures with 30 μm drift layer.

Structure	Breakdown
SZ-JTE	~2000V
GAJ	~2000V
GAJ+OR	3500V
CD-JTE	4420V
CD-JTE+OR	4720V

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InGaAs-on-insulator transistors with buried yttrium oxide

A simple MOS back-gate stack has been used to demonstrate what is claimed to be the first InGaAs-on-insulator transistor with a buried yttrium oxide layer, achieving effective mobility of $2000\text{cm}^2/\text{V}\cdot\text{s}$.

Korea Institute of Science and Technology has presented what it says is the first demonstration of indium gallium arsenide on-insulator ($\text{In}_{0.53}\text{Ga}_{0.47}\text{As-OI}$) transistors with a buried yttrium oxide (Y_2O_3 BOX) layer [SangHyeon Kim et al, IEEE Electron Device Letters, published online 31 March 2015].

The researchers see InGaAs-OI as a promising alternative to more complicated tri-gate devices. The use of Y_2O_3 should enable reduced equivalent oxide thickness (EOT) compared with aluminium oxide, on the basis of a higher dielectric constant (16 versus 9–12). Reduced EOT brings the gate effectively closer to the channel, improving electrostatic control.

A simple metal-oxide-semiconductor (MOS) back-gate stack transistor was constructed by layer transfer of InGaAs from its indium phosphide (InP) growth

substrate to silicon with a Y_2O_3 buried layer (Figure 1). The InGaAs surface was prepared by native oxide removal and passivation with acetone, ammonium hydroxide, ammonium sulfide solutions. The clean surface was covered with 10nm of Y_2O_3 produced through electron-beam evaporation. The silicon target substrate was also covered with 10nm Y_2O_3 , after cleaning with hydrofluoric acid.

The wafer bonding was achieved with hand pressure in air. The InP growth substrate and an InGaAs sacrificial layer were removed with hydrochloric and phosphoric acid wet etching. Nickel/gold was used for the source and drain electrodes. An InP etch-stop layer was selectively removed from the source and drain areas, but left in place over the channel region to reduce surface effects, which can impact effective mobility.

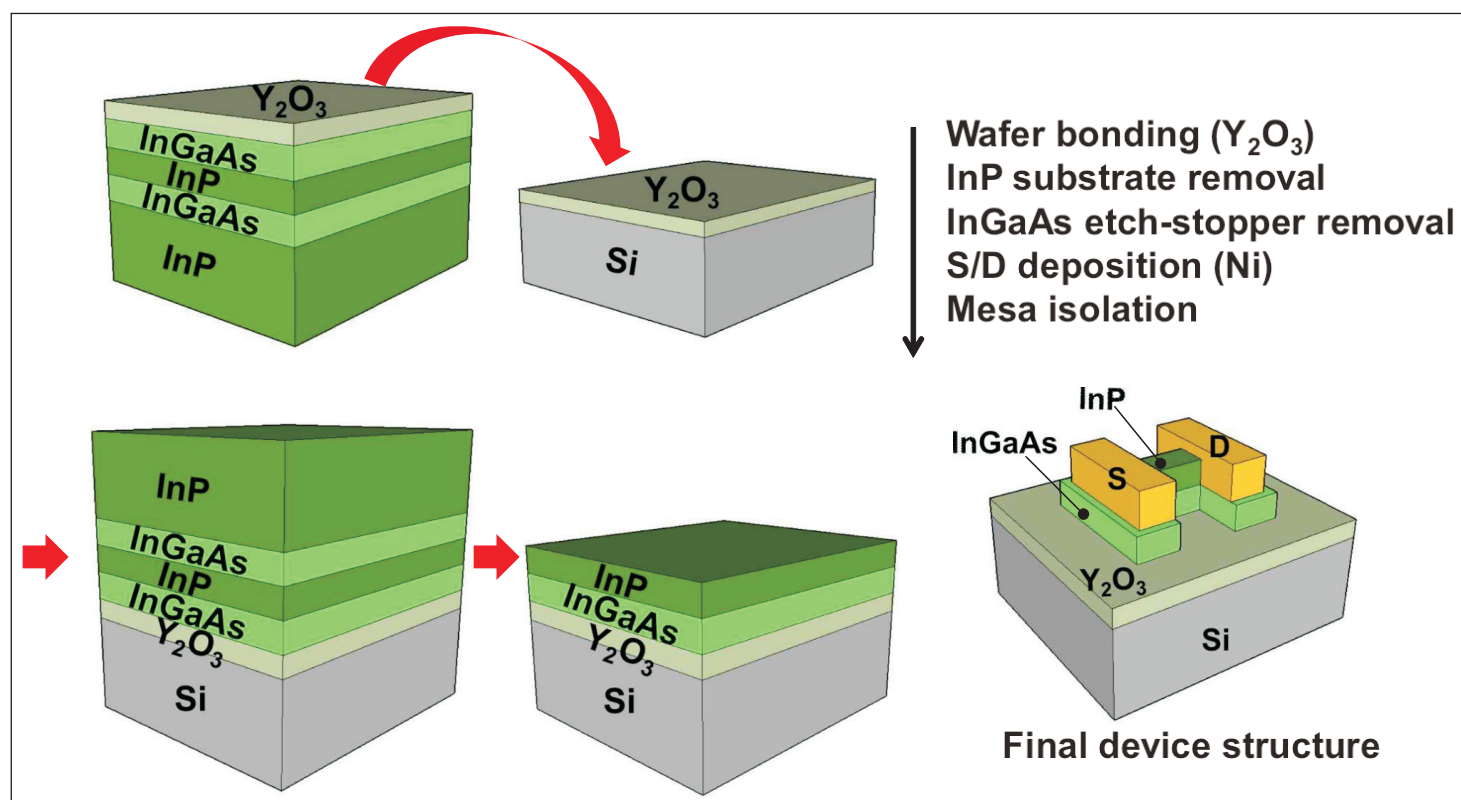


Figure 1. Fabrication process for InGaAs-OI on Si wafer by direct wafer bonding and schematic of final device.

The final device was subjected to rapid thermal annealing at 300°C. The gate length was 2µm and the body (channel) thickness was 10nm. The subthreshold swing was 90mV/decade, described by the researchers as 'very low' in view of the relatively large EOT.

The effective mobility was enhanced by a factor 2.5x over the value for silicon-based devices, even without annealing (Figure 2). Annealing at 300°C increased the effective mobility to 2000cm²/V-s. These first results should be improvable with process optimization, according to the researchers.

The interface trap density extracted from the subthreshold behavior was 1.1x10¹²/eV-cm², comparable with values from MOS capacitor measurements. These capacitor structures were produced on InGaAs/InP substrates with 10nm Y₂O₃ dielectric and top and bottom electrodes of platinum/gold and nickel/germanium/gold, respectively. Post-metal annealing at 350°C reduced interface the trap densities to as low as 4x10¹²/eV-cm² near the conduction-band edge, according to capacitance-voltage measurements. Hysteresis was 15mV. ■

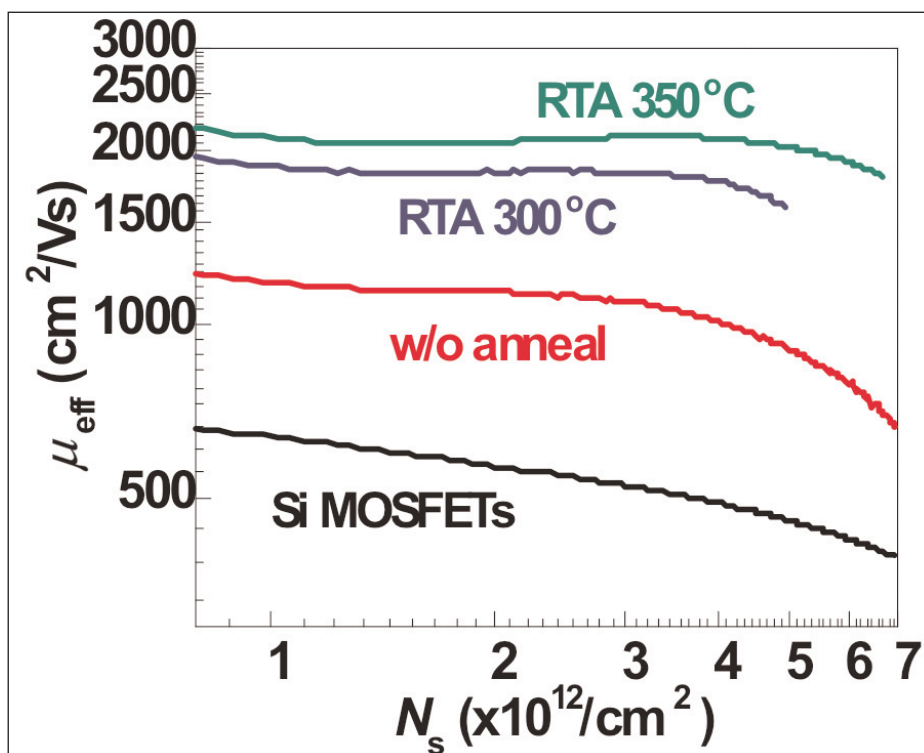


Figure 2. Effective mobility (μ_{eff}) characteristics of InGaAs-OI transistors produced with various annealing temperatures.

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Direct demonstration of 1THz performance in InP HEMTs

Northrop Grumman has used indium phosphide high-electron-mobility transistors to create a 10-stage amplifier with 9dB gain at terahertz frequency.

Northrop Grumman Corp in the USA is claiming the first ever direct demonstration of gain at 1THz in indium phosphide (InP) high-electron-mobility transistors (HEMTs) [X. B. Mei et al, IEEE Electron Device Letters, published online 24 February 2015]. Usually, claims of 1THz+ frequency performance are made on the basis of extrapolations from lower-frequency measurements. The team has also developed a 10-stage amplifier circuit based on the technology.

Northrop Grumman Aerospace Systems (NGAS) has been developing high-frequency transistor performance over two decades (Table 1).

Researchers at NGAS have also been developing terahertz monolithic integrated circuit (TMIC) processing techniques to enable wiring together the transistors into amplifier circuits with gain beyond 1THz.

The researchers write of their achievement of

1THz-capable HEMTs and the associated amplifier circuit: "The transistor and next-generation circuits will find applicability in a variety of emerging applications at THz frequencies, including high-data-rate communication systems, atmospheric sensing, planetary exploration, and new classes of imagers."

The researchers see "transistor gate and lay-

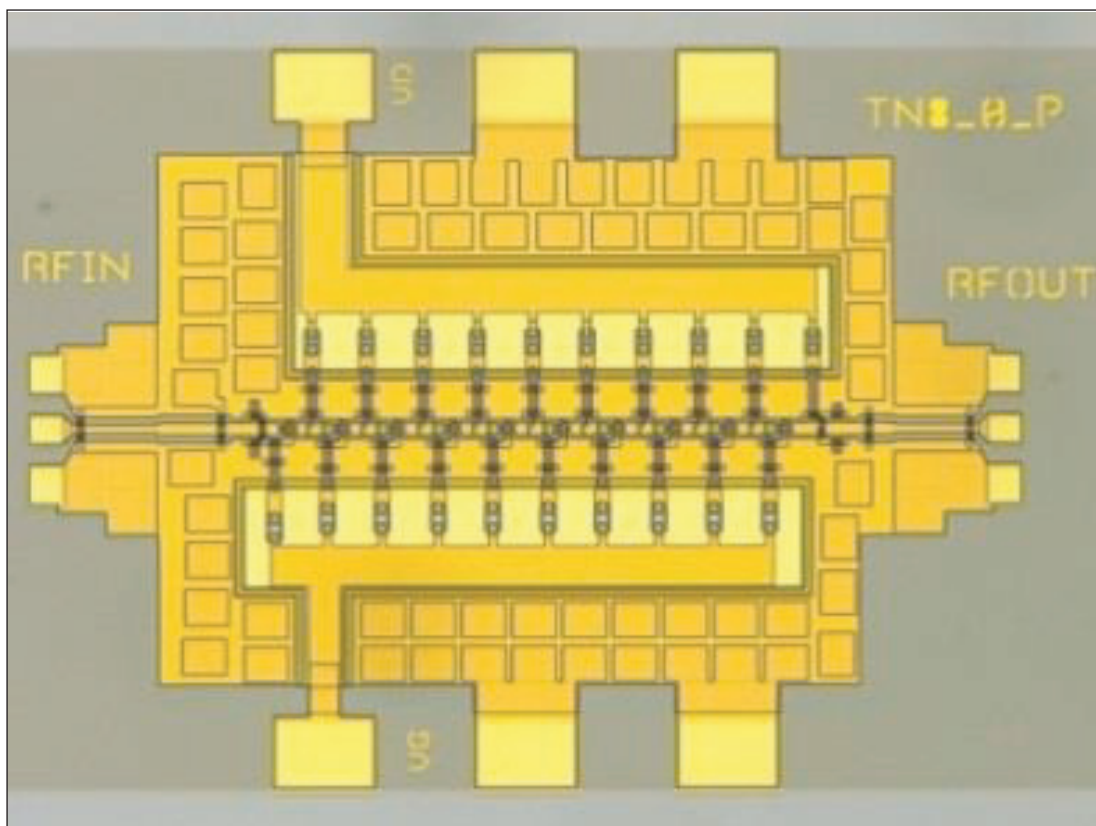


Figure 1. Microphotograph of 1.0THz TMIC amplifier.

out scaling for parasitic reduction, epi material enhancement for improved electron transport properties, and process improvement associated with the aggressive scaling" as being key technologies for their achievement.

Table 1. Summary of InP HEMT processes developed at NGAS.

Gate length	100nm	70nm	35nm	30nm	25nm (latest work)
Year	1998	2003	2007	2010	2013
In _x Ga _{1-x} As channel indium composition	60%	75%	100%	100%	100%
Source-drain spacing (μm)	2	2	1.5	1.0	0.5
R _c (Ω-mm)	0.12	0.1	0.04	0.04	0.04
g _{mp} @ 1V (mS/mm)	1000	1400	2000	2500	3000
f _{MAX} (THz)	0.4	0.6	1.1	1.3	1.5
Associated f _T (THz)	0.2	0.25	0.4	0.5	0.61
Highest-frequency amplifier demonstrated (THz)	0.19	0.24	0.48	0.85	1.0
Associated amplifier device width (μm)	30	30	20	14	8

The transistor heterostructures were grown on semi-insulating InP by molecular beam epitaxy (MBE). The 95Å composite channel was indium arsenide (InAs) sandwiched between two lattice-matched indium gallium arsenide ($\text{In}_{0.53}\text{Ga}_{0.47}\text{As}$) layers. The channel carrier concentration was enhanced with silicon-doping planes above and below the channel. The Hall mobility was $13,000\text{cm}^2/\text{V}\cdot\text{s}$ with $4 \times 10^{12}/\text{cm}^2$ carrier density.

The barrier layer was 20Å thick, measured between the bottom of the gate and the upper silicon-doped plane.

The HEMTs were fabricated with unalloyed titanium/platinum/gold ohmic contacts. The source-drain distance was reduced to 0.5µm to give low source resistance of 130mΩ-mm and contact resistance of 40mΩ-mm. The recessed T-shaped gate of titanium/platinum/gold had a 25nm footprint. The device was also passivated with silicon nitride grown by chemical vapor deposition (CVD). The aim of the passivation was to improve reliability and robustness.

The TMIC wiring process capability includes nickel-chromium thin-film resistors, metal-insulator-metal capacitors and two levels of metal interconnect. The second metal level can be air-bridged to give higher signal speed over dielectric insulated wiring. The back-end processing also includes wafer thinning to 18µm and full metalized back-side vias.

The TMIC wiring process capability includes nickel-chromium thin-film resistors, metal-insulator-metal capacitors and two levels of metal interconnect. The second metal level can be air-bridged to give higher signal speed over dielectric insulated wiring. The back-end processing also includes wafer thinning to 18µm and full metalized back-side vias.

Frequency performance measurements were carried out over three bands: 10–110GHz, 500–700GHz, and

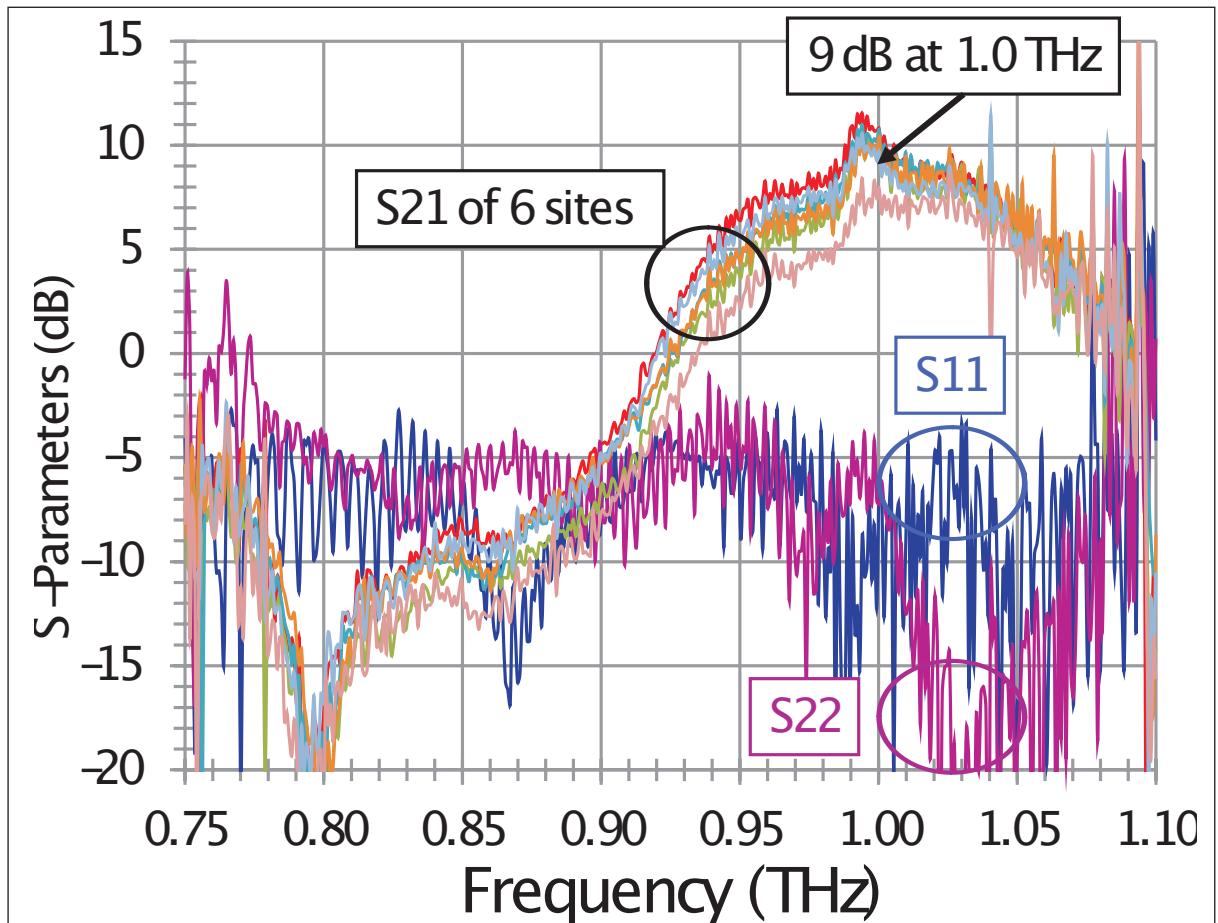


Figure 2. On-wafer measurement results showing 9dB on-wafer gain at 1.0THz.

This transistor and TMIC technology shows promise in enabling a new suite of components bridging microwave through THz frequencies... indicating a variety of space and airborne applications

750GHz–1.0THz. The available gain at 1.0THz was ~3.5dB. Extrapolating the data to unity gain gave a maximum oscillation frequency (f_{MAX}) of 1.5THz. The cut-off frequency (f_T) was 650GHz.

The TMIC process was used to create a 10-stage 1.03THz common-source amplifier, based on 8µm wide HEMTs (two 4µm fingers). The circuit (Figure 1) also included matching, DC-blocking and decoupling capacitors. The TMIC is described as a 'first iteration' scaling of a previous 850GHz design. The researchers expect improvement and optimization from future iterations.

The frequency performance was measured on equipment capable of 750–1100GHz testing. The circuit achieved 9dB gain at 1.0THz — "the first demonstration of transistor amplifier gain at or above the 1.0THz mark," according to the researchers (Figure 2). At 1.05THz the gain reduced slightly to 7dB.

The researchers comment: "This transistor and TMIC technology shows promise in enabling a new suite of components bridging microwave through THz frequencies." The 1THz shares "significant commonality" with NGAS' existing space-qualified 100nm InP HEMT technology, indicating a variety of space and airborne applications. ■

<http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=7047678>

Author: Mike Cooke

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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

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

28–29 October 2015

UV LED 2015

Troy, N.Y., USA

E-mail: mickey@radtech.org

www.uvled2015.com

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

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