ISSN 1752-2935 (online)

semiconductor TODAY

COMPOUNDS & ADVANCED SILICON

Vol. 12 • Issue 3 • April/May 2017 www.semiconductor-today.com

WIN Semiconductors expands

Kaiam buys Compound Photonics' fab • Sivers buying CST Global

Cree and San'an forming JV for mid-power packaged LEDs

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

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

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

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

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

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

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

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

Veeco's New TurboDisc EPIK700 GaN MOCVD System

contents

Editorial 4

Markets News 6
LED materials growing at 9.9% CAGR to $12.55bn by 2021

Microelectronics News 8
WIN increases GaAs wafer manufacturing capacity by over 20% • Qorvo's quarterly revenue hit by delayed smartphone launches in China and Korea

Wide-bandgap electronics News 14
X-FAB and Exagan demonstrate mass production of GaN-on-Si devices on 200mm wafers • Nitride Solutions closes $2.75m funding round • PowerAmerica funding speeds Transphorm's development of 900V GaN HEMT product • News from PCIM Europe 2017: ST & Monolith present 1200V SiC Schottky diodes and MOSFETs

Materials and processing equipment News 24
Cardiff councils invest £38m to establish compound semiconductor foundry • AXT's Q1 revenue exceeds guidance despite fire • Picosun expands to supplying ALD precursors • Veeco's Q1 revenue up 21% year-on-year to $94.4m, driven by LED demand • Monocrystal launches sapphire wafers for microLEDs

LED News 36
Cree and San'an forming Hong Kong-based JV to produce mid-power lighting-class packaged LEDs • Osram qualifies AIX G5 C MOCVD system for GaN LED production

Optoelectronics News 48
Sivers IMA acquiring CST Global • CST Global leading CoolBlue project on next-gen GaN laser technology

Optical communications News 50
Kaiam buys Compound Photonics fab in UK • TowerJazz announces silicon photonic foundry process • Oclaro quarterly revenue grows 60% year-on-year

Photovoltaics News 56
Manz sells CIGS PV research subsidiary for €50m to partners Shanghai Electric and Shenhua, forming NICE PV Research JV • Imec and Solliance boost efficiency for 4cm x 4cm perovskite PV module to 12.4%

Technology focus: Photodetectors 58
Graphene phototransistor promises high-performance opto-electronics

Technology focus: Opto/microelectronic integration 60
Monolithic III-V transistors and lasers integrated on germanium

Technology focus: Optoelectronic integration 62
Semi-polar InGaN laser/waveguide photodiode combination

Technology focus: Nitride LEDs 64
Towards polarized white light via tunnel junctions & hybrid growth

Technology focus: GaN-on-silicon 66
Getting the best cost and performance out of GaN-on-Si devices

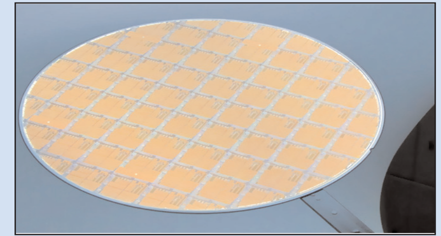
Technology focus: Silicon carbide 72
Benefits and advantages of SiC power devices over silicon

Suppliers' Directory 76

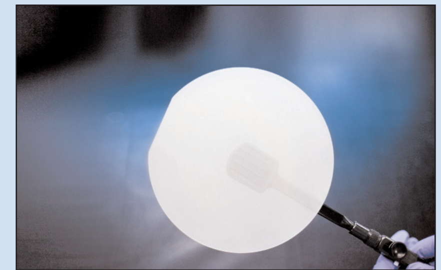
Event Calendar and Advertisers' Index 82

semiconductorTODAY
COMPOUNDS & ADVANCED SILICON

Vol. 12 • Issue 3 • April/May 2017



p20 X-FAB and Exagan have demonstrated mass production of GaN-on-Si devices on 200mm wafers.



p35 Monocrystal's Ultra-Clean sapphire wafers target high-precision opto applications including microLEDs.

p48 Wireless component supplier Sivers IMA has agreed to acquire Scottish foundry CST Global, gaining optoelectronic capabilities.

Cover: Taiwan's WIN Semiconductors has completed the Phase 2 expansion at its newest wafer plant, FabC, increasing the firm's GaAs wafer manufacturing capacity by over 20%, including new process lines for optical devices. **p11**

Consolidation and diversification

The last few months have seen news of two acquisitions involving the optoelectronics sector. In March, California-based Kaiam said that it was acquiring the manufacturing facilities of Compound Photonics Group Ltd in Newton Aycliffe, UK (the deal was completed in early May — see page 51). While Compound Photonics' 300,000ft^2 manufacturing space includes both 3" and 6" wafer processing lines for fabricating III-V devices including pHEMTs, HBTs, photodetectors and lasers, Kaiam targets expanding its manufacturing capacity for silica-on-silicon planar lightwave circuits (PLCs) and 40Gb/s and 100Gb/s transceivers, while developing a roadmap to adding integrated indium phosphide (InP) photonic integrated circuit (PIC) technology for advanced transceivers. Formerly a Fujitsu DRAM silicon fab (before acquisition by first Filtronic then RF Micro Devices for GaAs transistor manufacturing), the Newton Aycliffe facility continues Kaiam's strategy of vertical integration that began with its acquisition in 2013 of the PLC fab of Gemfire in Livingston, Scotland, UK.

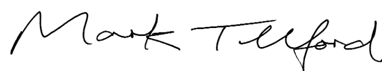
Also, in mid-April, Sweden's Sivers IMA (a fabless developer of microwave and millimeter-wave components) agreed to acquire optoelectronic device maker Compound Semiconductor Technologies Global Ltd (CST Global) — which was spun off from Scotland's universities of Strathclyde and Glasgow in 1999 (page 48). "Sivers IMA can now supply photonic, microwave and millimetre-wave solutions for the rapidly expanding data-center, cloud and telecommunications markets in China, Europe and America" as part of a "strategic plan to establish Sivers IMA as a leading global electronics component supplier within data and telecommunications," says the firm.

Adding to broader optoelectronic industry consolidation in recent years, such acquisitions highlight the trends to both vertical integration and diversification, as wireless-focused firms seek the capabilities to address fast-developing optoelectronic markets. This follows wireless component maker Anadigics developing vertical-cavity surface-emitting laser (VCSEL) manufacturing capabilities, before its acquisition by II-VI Inc in early 2016. Meanwhile, planar optoelectronic technology firm POET last year acquired first DenseLight Semiconductors then BB Photonics, targeting the burgeoning data-center market with datacom products based on VCSELs.

In fact, while still impacted by the LED industry slowdown, in full-year 2016 34% of Aixtron's equipment revenue was for optoelectronics (the firm's largest market sector, exceeding LEDs on 26%, silicon on 21% and power electronics on 14%). Of course, LEDs have since rebounded (to 52% of its revenue in first-quarter 2017) and optoelectronics has conversely shrunk. But the longer-term trend remains for firms to diversify from being heavily dependent on narrow markets (e.g. Anadigics on GaAs transistors; Aixtron on MOCVD systems for LED making), so that they are less vulnerable to downturns in certain sectors. After its thwarted takeover by China's Grand Chip Investment, Aixtron says that "To better focus R&D costs for the development of future technologies, we will group our portfolio for future technologies and transfer it into clearly defined independent units to be financed with respective technology partners" (page 31).

While fellow MOCVD system maker Veeco is also seeing an upturn in demand from LED makers in Q1/2017 (page 28), it too is diversifying. It expects its acquisition of Ultratech to close in late May (driving business in advanced packaging).

Mark Telford, Editor
mark@semiconductor-today.com



semiconductor TODAY
COMPOUNDS & ADVANCED SILICON

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

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

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

Original design Paul Johnson
www.higgs-boson.com

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

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

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

© 2017 Juno Publishing and Media Solutions Ltd. All rights reserved. *Semiconductor Today* and the editorial material contained within is the copyright of Juno Publishing and Media Solutions Ltd. Reproduction in whole or in part without permission is forbidden. In most cases, permission will be granted, if the author, magazine and publisher are acknowledged.

Disclaimer: Material published within *Semiconductor Today* does not necessarily reflect the views of the publisher or staff. Juno Publishing and Media Solutions Ltd and its staff accept no responsibility for opinions expressed, editorial errors and damage/injury to property or persons as a result of material published.

AIXTRON
Our technology. Your future.

YOU THINK,

GaN POWER DEVICE MANUFACTURING REQUIRES HVM SOLUTIONS.

WE THINK THAT TOO.

THE NEW AIX G5+ C

DISCOVER THE NEW AIX G5+ C.

Introducing the G5+ C: built on Award Winning Planetary technology for best Single Wafer performance with Batch Reactor benefits – now coming with Cassette to Cassette wafer loading, In-Situ Reactor Cleaning and pre-qualified device processes.
Enabling full automation of your processes and a seamless integration into your Silicon line.

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

HVM: High Volume Manufacturing

LEDs rising from 60% of overall lighting market in 2016 then 80% in 2020 and 98% by 2025

LED lighting market grew 18.1% to $47,303m in 2016

The LED lighting market grew 18.1% to $47,303m in 2016, accounting for almost 60% of all lighting, according to the report 'Global LED Lighting Market (2017 Update)', part of Frost & Sullivan's Homes & Buildings Growth Partnership Service program. By 2020, LED lighting is likely to account for 80% of the total lighting market (creating an $80bn market), rising to 98% by 2025.

The residential LED lighting market in particular will see grow 16.7% year-on-year in 2017. However, although the residential, outdoor and retail sectors make the highest contributions at present, office, industrial and hospitality are expected to be future growth sectors.

LED market evolution continues with a steep decline in cost per unit, high energy-efficiency ratings, a market shift toward these lighting solutions, and favorable government initiatives driving adoption, notes the report. The Internet of Things (IoT) will disrupt the market, shifting focus from energy efficiency, product reliability and O&M costs to include controllability, connectivity and technology integration in smart buildings and smart cities.

"New technologies driven by IoT, such as light-as-a-service (Laas), will usher in connected lighting and living, enabling better energy management and new services and business models like financing and leasing," says Frost & Sullivan's Energy & Environment research analyst Sabnam Gafoor. "On the flip side, new business models and an influx of new players from the Asia-Pacific will make the future market a fragmented one."

The Asia-Pacific region contributes the most to global market revenue. Express construction in many Asian countries, government endorsement of energy-efficient lights in India and China, and the existence of a large number of LED chip and package factories in China, Japan, South Korea and Taiwan are factors driving growth. Worldwide, the regions that will see the highest growth rates are India, Asia-Pacific, Latin America and Africa.

Frost & Sullivan notes that organic LEDs (OLEDs) are gaining popularity as a solid-state lighting (SSL) technology due to their ability to emit warm light over large areas, provide color comfort, and bring improved form factors to the lighting industry.

"To remain competitive and relevant in an evolving ecosystem, LED players should seek to improve manufacturing efficiencies by adopting a larger wafer size, utilize intelligent lighting through integrated control devices, implement active and passive cooling techniques for device longevity, and replace expensive substrate materials with cheaper alternatives," concludes Gafoor.

https://ww2.frost.com/research/industry/energy-environment/homes-buildings

LED materials growing at 9.9% CAGR to $12.55bn by 2021

The LED materials market is rising at a compound annual growth rate (CAGR) of 9.9% from 2016 to $12.55bn in 2021, forecasts a report from MarketsandMarkets.

The market is driven by growing demand for LED materials in general lighting applications, resulting from an increase in demand for LEDs for residential and industrial facilities.

Asia-Pacific the largest market for LED materials

Asia-Pacific is currently the largest market for LED materials. China is the leading country where there is major consumption of LED materials in end-use industries such as general lighting, automotive lighting, and backlighting. Moreover, the growing population with rising disposable income in China is driving demand for better-quality LED materials.

Wafers largest market segment

Of the LED materials market in 2016 in terms of value, the wafer segment accounted for the largest share, followed by the epitaxy segment. The wafer segment is also projected to grow at the highest CAGR to 2021.

General lighting dominating LED materials market

The general lighting application segment is projected to drive the LED materials market, aided by increased demand from residential LED markets to reduce overall energy costs. Industrial lighting is also expected to contribute to the growth. The use of LEDs in industrial settings has increased, as they are better than conventional lighting sources at overcoming challenges such as extreme temperature ranges and continuous or long operational hours.

Key players in the LED materials market are cited as Sumitomo Electric Industries (Japan), Hitachi Metals (Japan), Cree (USA), Seoul Semiconductor (South Korea), Nichia (Japan), Epistar (Taiwan), Philips (Netherlands), Osram Licht (Germany), II-VI Inc (USA), and Akzo Nobel (The Netherlands).

www.marketsandmarkets.com/Market-Reports/led-material-market-116248392.html

GENxplor™

Discover The Future

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

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

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

Veeco

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

Innovation. Performance. Brilliant.

Qorvo's quarterly revenue hit by delayed smartphone launches in China and Korea

30% growth in September quarter to drive 10% full-year growth

For fiscal fourth-quarter 2017 (to 1 April), Qorvo Inc of Greensboro, NC, USA (which provides core technologies and RF solutions for mobile, infrastructure and defense applications) has reported revenue of $642m, up 5.7% on $607.1m a year ago but down 22% on $825.4m last quarter.

Revenue for Mobile Products (MP) was $474m, down 28% on $656.8m last quarter and up just 2% on a year ago, as two leading customers in China and a tier-1 customer in Korea delayed flagship smartphone launches. With Samsung and Huawei comprising just over 10% of Mobile Product revenue each and open-market China lower than normal at 24%, China fell from 41% of Mobile Product revenue to 35%.

Revenue for Infrastructure & Defense Products (IDP) was $168m, roughly equal to last quarter's record and up 18% on $142m a year ago, due to continued growth in defense, Wi-Fi and Internet of Things (IoT), reflecting the repositioning of the firm's product portfolio to target high-growth segments. In particular, Wi-Fi grew more than 40% year-on-year, with notable strength in 5GHz power amplifiers (PAs) and 802.11ac front-end modules (FEMs). Defense & Aerospace grew more than 20% year-on-year, with strength in gallium nitride (GaN)-based power amplifiers.

"In the March quarter, we collaborated with all major infrastructure OEMs on next-generation 4G and pre-5G macro base-station GaN PAs, we supported 1Gbps throughput in the ZTE Gigabit smartphone, we supplied the industry's first 5G RF front-end in collaboration with Intel, and we achieved full certification of the first single-placement integrated module [spanning all major RF functions required in the main path, including amplifiers, switches and filters] covering low, mid and high bands on a MediaTek baseband," says president & CEO Bob Bruggeworth.

Also during the March quarter, Qorvo shipped its first BAW 5-based bulk acoustic wave filters (launched in the December quarter) in its RF Fusion WiFi integrated front-end modules (iFEMs), in support of Xiaomi, Oppo and Vivo;

"In premium-tier smartphones, we're enjoying strong demand for RF Fusion for cellular," notes Bruggeworth. Qorvo added ZTE to the list of customers buying its full suite of RF Fusion solutions, combining low-band, mid-band and high-band placements. "These highly compact solutions cover multiple modes and bands and require more temperature-compensated SAW and more BAW."

Also during the quarter, Qorvo commenced shipments of Power Class 2 solutions to Sony, LG and HTC, and secured design wins for Power Class 2-capable RF Flex and high-band RF Fusion solutions.

The firm also secured multiple design wins at Samsung, Huawei, Xiaomi and others, in support of performance-tier smartphones.

In IDP, during the quarter Qorvo secured an important 802.11ac design win in the recently released Sonos sound bar for home audio networks (incorporating a BAW filter). "The integration of BAW filters into our Wi-Fi solutions is a focus for IDP," notes Bruggeworth. The firm also secured a design win in a recently launched dual-band 802.11ac wireless router, delivering up to 1.2Gb/s. "We're quickly filling this Wi-Fi sales funnel, including for 802.11ax programs," he adds.

Qorvo also expanded its optical product portfolio by launching five phase amplitude modulation 4 (PAM4) products for data center interconnect applications.

On a non-GAAP basis, gross margin was 46.2%, down from 50% a year ago but up from 44.3% last quarter (and exceeding the expected 46%) due mainly to improved product mix (lower low-band PAD volumes) and cost-related activities (ongoing productivity and quality efforts).

Operating expenses rose further, from $142.9m a year ago and $157.1m last quarter to $163.1m, including $108.9m in research & development and $132.7m in selling, general & administrative.

Operating income was $133.4m (operating margin of 20.8% of sales), down from $208.7m (operating margin of 25.3%) last quarter and $160.6m (operating margin of 26.5%) a year ago.

Net income was $111.7m ($0.85 per diluted share, $0.05 over the midpoint of the $0.70–0.90 guidance range), down from $177.3m ($1.35 per diluted share) last quarter and $142.6m ($1.04 per diluted share) a year ago.

Operating cash flow has rebounded from last quarter's $220.4m to $247.1m (up 50% year-on-year). Capital expenditure (CapEx) has risen further, from $136.5m to $165.8m, primarily due to the timing of filter capacity additions. Free cash flow hence fell further, from $83.9m to $81.3m. During the quarter, cash and short-term investments rose from $495.8m to $545m. This was after Qorvo also returned $51m to shareholders under its $500m share repurchase program.

For fiscal first-quarter 2018 (to end-June 2017), Qorvo has lowered its original forecast (of 7–10% sequential revenue growth to $680–685m) by $50–55m to $610–650m. Of the shortfall, about $30m is related to end-manufacturers working through unforeseen inventory, $10m is due to one of the delayed Asia-region smartphone models eventually being canceled, and $10m is due to not seeing the traditional market recovery after Chinese New Year. In contrast, rev-

enue from South Korea's Samsung should grow.

Despite the $630m mid-point of this guidance range being down quarter-to-quarter, gross margin will still rise to about 47%. Operating expenses should rise sequentially by about $5m, due partly to R&D related to custom product development for Qorvo's largest customer. Net income is expected to be $0.70-0.90 per diluted share. "This guidance reflects normal seasonal effects at our largest customer and weaker-than-expected near-term China demand [roughly flat quarter-to-quarter]," says chief financial officer Mark Murphy.

Nevertheless, for fiscal full-year 2018 Qorvo sees strong growth in revenue and gross and operating margins.

"Our newly released BAW 5 technology has immediately gained commercial traction in cellular, Wi-Fi and other applications," notes Murphy. "This technology, along with our proven design capabilities, is providing us the opportunity to work on the industry's most complex integrated modules and enabling us to participate in the largest and most attractive markets in RF," he adds.

"IDP's portfolio continues to grow more attractive, with broad-based exposure to many high-growth markets including 5G, Wi-Fi, automotive, and other IoT [leading to double-digit growth again in IDP for fiscal full-year 2018]," says Murphy. Although we're a bit slower out of the gate than expected due to near-term softness in China demand, our forecast outlook for the full year of fiscal 2018 looks good."

Driven by the timing of marquee smartphone launches plus continued growth at Samsung, Qorvo expects sequential revenue growth of over 30% in the September quarter then more in the December quarter prior to the normal seasonal decline in the March quarter, amounting to double-digit growth for full-year fiscal 2018 over fiscal 2017 (though closer to 10%, due to the slow start in China). This will be joined by higher BAW-based product mix [rising from under 30% of Mobile Product revenue now to about 40% by fiscal 2019], higher utilization rates and ongoing productivity and quality improvements to help the firm achieve its 50% gross margin target exiting fiscal 2018. "Operationally, we continue to make solid progress on yield improvements, wafer size conversions [to 8" BAW and 6" temperature-compensated SAW, complementing significant reductions in die size], capacity rationalizations, sourcing initiatives and other productivity efforts to drive margin expansion," notes Murphy. OpEx efficiency should continue to improve, achieving operating expenses of about 20% of sales for the year, forecasts the firm. "We are resolute in hitting our operating model of 30% operating margin during the fiscal year 2018," says Murphy.

CapEx is forecast to fall to about $400m, as the firm completes its expansion to support multi-year above-market growth of filter-based products.

With strong revenue growth, expanding gross margins, improving OpEx efficiency (lower OpEx as a percent of sales) and lower CapEx, free cash flow is expected to double from fiscal 2017 to fiscal 2018.

www.qorvo.com

Wi-Fi front-end modules & BAW filters implemented for 802.11ax

Qorvo says that customers are implementing its recently released portfolio of Wi-Fi front-end modules (FEMs) as part of the migration to 802.11ax. It adds that its new 2.4GHz and 5GHz FEMs, and bulk acoustic wave (BAW) filters, provide the throughput and thermal efficiency that are central to high-density 802.11ax Wi-Fi connectivity.

"Qorvo's Wi-Fi FEM and BAW filter products are examples of the RF components which will be required to enable the developing 802.11ax standard and help Wi-Fi manufacturers realize the benefits of increased capacity and broader coverage indicative of 802.11ax," says Brad Shaffer, senior analyst, Mobile Devices & Networks at IHS Markit.

"Our customers are seeing first-hand how Qorvo technology is improving capacity and supporting multiple, high-performance Wi-Fi applications operating simultaneously in the same space," says James Klein, president, Qorvo Infrastructure & Defense Products (IDP). "We are expanding our Wi-Fi portfolio across retail, enterprise, service provider and set-top-box markets, and will support the earliest market releases of 802.11ax solutions."

The 802.11ax standard will deliver significantly greater capacity — translating into more data, more devices and more services — over different frequency networks. In 2016, ABI Research forecasted that 802.11ax will account for nearly 60% of the 21 billion Wi-Fi chipsets expected to ship by 2021.

The most recent Qorvo Wi-Fi FEM family lays the foundation for 802.11ax with its support for 802.11ac and Wave 2 1024QAM (quadrature amplitude modulation). The 5GHz FEMs in the family offer over 1.2Gbps throughput per stream (with up to eight streams), the highest achievable data rate. These capabilities support the essential requirements of 802.11ax, such as multi-user multiple-input/multiple-output (MU-MIMO), extended range and high throughput, as well as denser-capacity orthogonal frequency-division multiple access (OFDMA) modulation. Qorvo adds that its BAW technology addresses thermal concerns, harmonic compliance and band-edge performance to enable broad power transmission across the full allocated spectrum, enabling maximum range and reliable throughput for Wi-Fi.

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

Skyworks' quarterly revenue of $851.7m up a more-than-expected 10% year-on-year

Accelerating growth driven by Internet of Things applications

For fiscal second-quarter 2017 (to 31 March), Skyworks Solutions Inc of Woburn, MA, USA has reported revenue of $851.7m, down seasonally by 6.8% on $914.3m last quarter but up 10% on $775.1m a year ago and exceeding the $840m guidance.

Mobile sales (include integrated mobile systems as well as power amplifiers) were slightly below 75% of total revenue. Comprising slightly more than 25% of total revenue, Broad Markets sales were up 18% year-on-year, driven by Internet of Things (IoT) applications, which comprised about 70% of Broad Markets revenue.

The three greater-than-10% customers were: Foxconn (falling slightly to just below 40% of total revenue), then Huawei and Samsung (each slightly above 10%). China collectively comprised about 25% of total revenue.

"Skyworks exceeded financial expectations in the second fiscal quarter of 2017, driven by insatiable demand for high-speed, reliable, always-on connectivity spanning Mobile and Internet of Things [IoT] ecosystems," says president & CEO Liam K. Griffin.

"We are aggressively expanding our design-win pipeline," says Griffin. "In mobile, we are extending our reach across all premier smartphone OEMs. Specifically, we enabled Huawei's P10 and P10+ models with low-, mid- and high-band SkyOne solutions, along with antenna tuner, carrier aggregation switching, and power management devices. We powered Samsung's Galaxy S8 platform with proprietary DRx and SkyOne solutions as well as GPS and DC/DC converters, and we secured reference design sockets across MediaTek's next-generation architectures," he adds. "In IoT [Internet of Things], we supported Cisco's enterprise-grade MIMO gateways, delivered analog control ICs across Nintendo's gaming platforms, including the recently introduced Switch console, ramped audio solutions for Sonos' high-fidelity wireless speakers, extended Wi-Fi mesh networking wins at Google and Plume, deployed high-power smart-meter devices for Itron, and we shipped custom connectivity engines to Fitbit, Garmin and LG." Skyworks also secured strategic design wins with three leading auto manufacturers, providing advanced LTE modules supporting high-reliability connectivity, GPS and data transport capabilities.

"Expanding content gains, coupled with successful product ramps across a diverse customer set, are enabling Skyworks to demonstrably outpace our addressable markets," says senior VP & chief financial officer Kris Sennesael.

On a non-GAAP basis, gross margin was 50.4%, down from 51.2% last quarter and 50.8% a year ago, but 20 basis points higher than expected.

Operating expenses (OpEx) were $116m (13.7% to revenue), cut from $132.7m a year ago.

Although down on last quarter's $354.3m, operating income was $312.5m (operating margin of 36.7%), up from $285m a year ago.

Net income was $272m ($1.45 per diluted share, exceeding the $1.40 guidance), down from $301.6m (a record $1.61 per diluted share) last quarter but up on $242.3m ($1.25 per diluted share) a year ago.

Cash flow generated from operations was $235.9m, down from last quarter's record $495.9m but up from $154.5m a year ago. Capital expenditure (CapEx) has risen further, from $37.4m (4.8% of total revenue) a year ago and $50m (5.5% of revenue) last quarter to $54.9m (6.4% of revenue) — mostly for the back-end facility in Mexicali, Mexico, which is running at full capacity. During the quarter, Skyworks made dividends payments of $51.9m. The firm also spent $95.2m to repurchase 1 million shares of common stock. Overall, cash and cash equivalents hence rose by $56.4m, from $1.35bn to $1.41bn (compared with a drop of $55.7m a year ago).

Inventory was up $22m in fiscal Q2. "That's clearly in anticipation of the strong sequential revenue growth that we see in the next three quarters — the June quarter, the September quarter and the December quarter," says Sennesael.

For fiscal third-quarter 2017 (to end-June), Skyworks expects revenue to grow 4.5% sequentially and 18% year-on-year to $890m, driven by content gains at Huawei and Samsung. Gross margin should grow to 50.5–51%. Operating expenses are expected to rise to $122m, as Skyworks continues to invest in growth initiatives, including its IoT business. Diluted earnings per share increase to $1.52.

"We expect to continue to build some further inventory in the current quarter in Q3, all in anticipation, of course, to the peak, which is in the December quarter," Sennesael. "We also expect three quarters of gross margin improvements benefiting from that revenue growth as well, of course, as all the other operational efficiency that we continue to drive there," he adds. "We also continue to benefit from filter in-sourcing. All that will help us to make further progress towards our target model of 53% gross margin and 40% operating margin."

"We are continuing to make the necessary investments to grow the business; grow the business in mobile, grow the business in IoT," continues Sennesael. "Especially in IoT, we are adding some resources from an R&D point of view, as well as a sales & marketing point of view, to address that diverse market segment." Skyworks targets OpEx of 13% of revenue on a full-year basis.

www.skyworksinc.com

WIN Semiconductors increases GaAs wafer manufacturing capacity by over 20%

Phase 2 expansion of Fab C features cleanrooms and new process lines for optical devices

WIN Semiconductors Corp of Taoyuan City, Taiwan — the largest pure-play compound semiconductor wafer foundry — has completed the phase 2 expansion at its newest wafer fab. Fab C is now fitted with state-of-the-art cleanrooms, efficient process lines and the latest equipment for gallium arsenide (GaAs) monolithic microwave integrated circuit (MMIC) production, epitaxial growth of compound semiconductors, as well as fabrication and test of optical devices. WIN reckons that the continued build-out of the new manufacturing facility further validates the pure-play foundry model in the compound semiconductor industry.

Serving customers in mobile power amplifier (PA), WiFi, wireless infrastructure and optical markets, WIN provides a broad portfolio of heterojunction bipolar transistor (HBT), pseudomorphic high-electron-mobility transistor (pHEMT), integrated BiHEMT technology solutions and optical devices. The firm's manufacturing services can support most applications from 50MHz to 150GHz and through light-wave.

"In response to increasing demand across all market segments, we continue to add manufacturing capacity at our third wafer fab located in Guishan, Toayuan City, Taiwan," says senior VP & chief operating officer Kyle Chen. "Known as Fab C, the facility now supports mass production of a wide range of compound semiconductor technologies," he adds. "When fully built out, the 706,000ft^2 facility will more than double our capacity."

www.winfoundry.com/en_US/Index.aspx

Skyworks achieves year-on-year reductions of 22% in CO2 emissions, 20% in municipal waste and 16% in hazardous waste

Skyworks Solutions Inc of Woburn, MA, USA (which manufactures analog and mixed-signal semiconductors) has released its 2016 Sustainability Report, a voluntary public document that provides a self-assessment of its commitment to sustainable business practices. The report highlights Skyworks' record efficiency improvements in energy and water use, reductions in municipal and hazardous waste, and progress across environmental, labor, supply chain, health, safety, ethics and community activities.

Skyworks has continued its trend of manufacturing products with decreased environmental impact (per 1000 production units). Year-over-year, Skyworks:

- lessened its carbon dioxide emissions by 22%;
- lowered its hazardous waste generation rate by 16%;
- reduced its energy usage rate by 13%; and
- cut its water consumption rate by 12%.

"Skyworks' unit sales and revenue reached all-time highs in fiscal 2016 as global demand for our connectivity solutions continued to accelerate," says Steven C. Machuga, VP of worldwide operations. "In meeting this re cord demand, Skyworks never wavered in its commitment to sustainability… incorporating sustainable business practices within our own facilities as well as our supply chain, working towards improving operations, and aligning with customers," he adds.

www.skyworksinc.com/Sustainability.aspx

Fraunhofer IAF's InGaAs-based 54–243GHz amplifiers to be used in ESA's second-generation MetOp satellites

In the coming years, the European Space Agency (ESA) will be launching a series of new weather satellites to measure important meteorological data (such as precipitation, water vapor or temperature) better than ever before. The heart of the measuring devices consists of extremely sensitive indium gallium arsenide (InGaAs)-based microwave amplifiers developed at the Fraunhofer Institute for Applied Solid State Physics (IAF) of Freiburg, Germany that can perceive even very weak signals from the environment (key for more accurate weather predictions).

For whether predictions, meteorologists rely on computer simulations fed with thousands of pieces of measurement data. For decades, such data have mainly been supplied by satellites that use sensitive sensors to measure the temperature or the precipitation on the earth. The better these sensors are, the more accurate the measured values and hence the weather predictions. In the next two years, ESA will therefore be launching the second generation of its MetOp Meteorological Operational Satellites (six in total), equipped with state-of-the-art measurement technology. A total of €1.4bn has been earmarked for their construction (not including launch and operation).

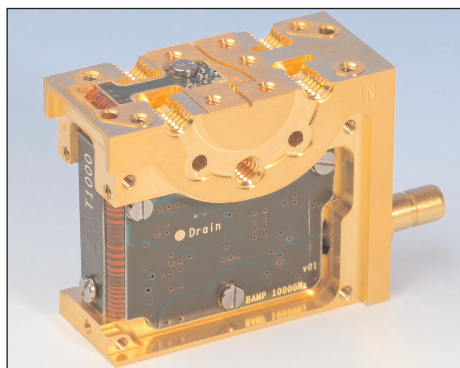
ESA's second-generation MetOp satellites (artwork of B satellite). © European Space Agency (ESA).

Measurements in the upper atmosphere

With the satellites, small, highly precise amplifiers from Fraunhofer IAF that absorb microwave radiation will also be launched. The radiation is emitted from every surface of every single object. The amplifiers are calibrated to microwave frequencies because these provide key meteorological information: they capture microwaves emitted by water vapor, rain, fog or ice crystals — particularly also from ice crystals in the cirrus clouds high up in the atmosphere, which are believed to have an important effect on the climate and weather. Due to the microwave radiation, it is also possible to reach precise conclusions about the temperature on the ground.

However, the signals received by the satellite's microwave antennae are extremely weak — just a few nanowatts. To measure these microwave signals with any degree of reliability, highly sensitive amplifiers are needed. However, transistors made of conventional silicon would be far too insensitive.

"A characteristic of InGaAs is that it is very easily traversed by electrons, even if the electric field that drives the electrons is very small," notes Dr Michael Schlechtweg, who heads Fraunhofer IAF's High Frequency Electronic business unit. Accordingly, the electrons in the transistor are already set in motion by very weak microwave signals, which makes the transistor extremely sensitive. "Thanks to the microwave circuits developed by the Fraunhofer IAF, the MetOp satellite will be able to determine temperature, water vapor and type of precipitation even more precisely in the future. This increases the reliability of the weather forecast," comments ESA project manager Ville Kangas.



Fraunhofer IAF's InGaAs-based low-noise, high-sensitivity microwave amplifiers. © Fraunhofer IAF

Small electrodes with high accuracy

In addition to using InGaAs, the amplifiers' small size contributes to making them so sensitive. The electrodes of the transistors are just 50–35nm long, enabling the measurement of such small electron currents (signals). "This extreme sensitivity and small size are the result of 25 years of research," Schlechtweg says. "During this time, we have developed a highly accurate manufacturing process in which the amplifier circuits are built in 150 production steps [including forming the electrodes with an electron beam]," he adds."

On the MetOp satellite, the amplifiers are used in three different microwave instruments that measure different things: precipitation, water vapor, ice crystals or the temperature. Different sensors therefore had to be produced, each calibrated to the corresponding microwave frequency (five frequency bands between 54GHz and 243GHz, with the higher the frequencies requiring higher-power amplifiers).

Fraunhofer IAF says that, in addition to ESA, a US firm has also recently inquired about the microwave amplifiers, so it is possible that they may also be launched aboard US satellites.

www.iaf.fraunhofer.de/en.html

Analog Devices and Renesas collaborate on 77/79GHz automotive radar technology to improve ADAS applications and enable autonomous vehicles

Analog Devices Inc (ADI) of Norwood, MA, USA (which designs and manufactures ICs for analog and digital signal processing applications) is collaborating with Tokyo-based Renesas Electronics Corp on a system-level 77/79GHz radar sensor demonstrator to improve Advanced Driver Assistance Systems (ADAS) applications and enable autonomous driving vehicles. The new demonstrator combines the RH850/V1R-M microcontroller unit (MCU) from the Renesas autonomy Platform and ADI's Drive360 28nm CMOS RF-to-bits technology. Seamless system-level operation of these two technologies promises to make driving safer by enabling earlier detection of smaller and faster-moving objects at greater distances. It can also lower radar system integration efforts and reduce evaluation risks for automotive OEMs and tier-one suppliers.

"Radar sensors play a crucial role for all ADAS or automated driving functions," says Jean-Francois Chouteau, VP of Renesas Global ADAS Centre. "This cooperation ideally combines the best of ADI and Renesas assets to deliver performance and enable OEMs and tier-one suppliers to reduce development cost and time to market," he adds.

"Analog Devices' collaboration with Renesas will be a key enabler for the highest-performance radar systems," says Chris Jacobs, general manager, ADAS & Automotive Safety, Analog Devices. "This innovative system approach will significantly reduce risk by providing digital interoperability at the system level for our customers. The new RH850/V1R-M MCU, coupled with ADI's high-performance Drive360 radar platform, will bring unparalleled performance to advanced ADAS and autonomous driving systems," he adds.

The Drive360 28nm CMOS radar technology platform builds on ADI's established ADAS, MEMS, and radar technology portfolio. For sensors in ADAS applications, Drive360 is claimed to be the world's first automotive radar technology based on 28nm CMOS

The Drive360 28nm CMOS radar technology platform builds on Analog Devices' established ADAS, MEMS, and radar technology portfolio that has been widely used in the automotive industry for the past 20 years. For sensors in ADAS applications, Drive360 is claimed to be the world's first automotive radar technology based on 28nm CMOS. ADI's radar solution enables earlier detection of smaller and faster-moving objects. High output power enables greater range and identification of smaller objects, while low phase noise enables unambiguous detection of smaller objects in the presence of large objects.

Renesas claims to be the only automotive semiconductor supplier to offer end-to-end solutions from secure cloud connectivity and sensing to autonomous control. The new Renesas autonomy Platform is an open platform for ADAS and automated driving, supported by the firm's sustainable and scalable system-on-chip (SoC) and MCU roadmaps. The RH850/V1R-M MCU was designed specifically for use in radar applications as part of the sustainable and scalable portfolio. The new MCU includes optimized programmable digital signal processing (DSP), a dual CPU cores each operating at 320MHz with high-speed flash of 2MB, and 2MB internal RAM, while meeting the industry's highest temperature requirements.

www.analog.com
www.renesas.com

Anokiwave signs representative agreement with M-RF

Anokiwave Inc of San Diego, CA, USA — which provides highly integrated silicon core chips and III-V front-end integrated circuits for millimeter-wave (mmW) markets and active electronically scanned array (AESA)-based terminals — has signed a representative agreement with Japan's M-RF Co Ltd, aligning with its goal of supporting new customers and opportunities in Japan.

M-RF has specialized in high-frequency components for 21 years and is focused on sales and technical service that matches high-frequency component manufacturers worldwide to customers in Japan.

"This agreement strengthens the technical support we can provide to customers in Japan and increases our ability to promote our 5G active antenna core IC solutions in the region," says Anokiwave's VP of business development Vincent Pelliccia. "With detailed knowledge of the Japanese wireless market, M-RF is ideally positioned to drive the adoption of our IC solutions into the 5G, radar and SatCom markets."

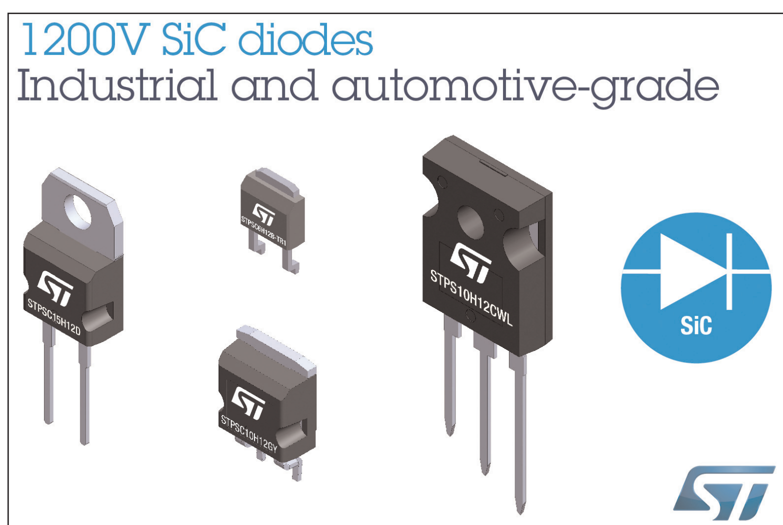
www.anokiwave.com
www.mrf.co.jp

ST launches 1200V SiC junction barrier Schottky diodes spanning 2–40A current ratings

STMicroelectronics of Geneva, Switzerland has launched a full range of 2–40A 1200V silicon carbide (SiC) JBS (junction barrier Schottky) diodes that enable a wider range of applications to benefit from the high switching efficiency, fast recovery, and consistent temperature characteristics of SiC technology.

ST claims that its SiC diode manufacturing process creates extremely robust devices with best-in-class forward voltage (lowest V_F), giving circuit designers extra freedom to achieve high efficiency and reliability using diodes with lower current rating and therefore lower cost. This makes SiC technology more accessible for cost-conscious applications including solar inverters, industrial motor drives, home appliances, and power adapters, says ST.

At the same time, performance-oriented applications that demand SiC for superior efficiency, low weight, small size or the best thermal properties can extend these advantages using ST's latest 1200V SiC diodes. The higher efficiency margin provided by their lower forward voltage drop (V_F) delivers benefits for automotive equipment such as on-board battery chargers (OBC) and charging stations for plug-in hybrid or electric vehicles (PHEV/EV). On the other hand, overall robust electrical performance ensures suitability in telecom and server power supplies, high-power industrial switched-mode power supplies (SMPS) and motor drives, uninterruptible power supplies (UPS) and large solar inverters.



Achieving the lowest V_F also helps to reduce operating temperature and extend application lifetime.

ST's new 1200V SiC diode family spans current ratings from 2A to 40A, including automotive-qualified devices, in surface-mount DPAK HV (high-voltage) and D²PAK, or through-hole TO-220AC and TO-247LL (long-lead) packages. ST claims to be the only supplier to offer 1200V SiC diodes in the D²PAK package. Pricing starts at $2.50 for the 10A STPSC10H12D in TO-220AC, in 1000-unit quantities.

www.st.com/content/st_com/en/products/sic-devices/sic-diodes.html

Littelfuse and Monolith present 1200V SiC Schottky diodes and 1200V SiC MOSFET technology platform

At the PCIM (Power Conversion and Intelligent Motion) Europe 2017 conference in Nuremberg, Germany (16–18 May), Littelfuse Inc, which provides circuit protection technologies (including fuses, semiconductors, polymers, ceramics, relays and sensors), presented the new GEN2 Series of 1200V silicon carbide (SiC) Schottky diodes, the first commercially available SiC devices developed through its partnership with SiC diode and MOSFET power device start-up Monolith Semiconductor Inc of Round Rock, TX, USA (in which it is the majority owner).

Visitors also got a first look at the partnership's next technology platform for the power semiconductor market, a line of 1200V silicon carbide MOSFETs.

At PCIM Europe, Monolith also participated in two poster presentations and an industry forum:

Poster Dialogue Session:
- PP017: 'System Level Comparison of SiC IGBTs and SiC MOSFETs';
- PP019: 'Characterization and Optimization of SiC Freewheeling Diode for Switching Losses Minimization Over Wide Temperature Range'.

Industry Forum:
- 'SiC MOSFETs — How Can We Match the Success of SiC Diodes?'.

In December 2015, Littelfuse and Monolith formed a strategic partnership to develop power semiconductors for industrial and automotive markets. Early this March, Littelfuse made an incremental $15m investment in Monolith, increasing its stake to majority ownership.

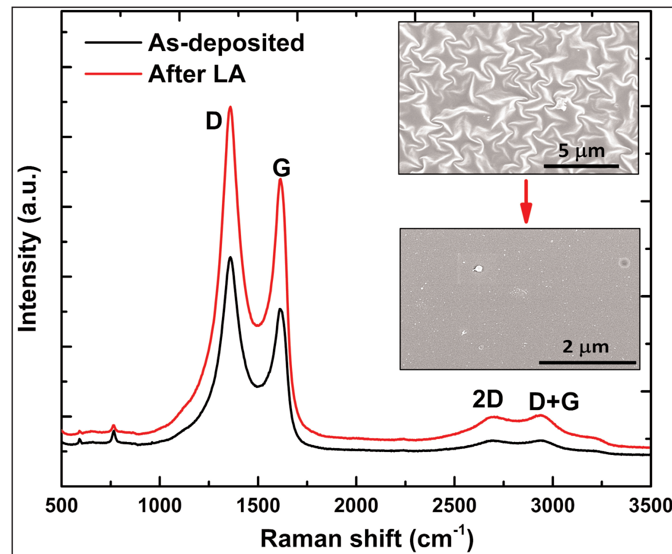
The two firms say that their joint demonstrations at both PCIM Europe and the Applied Power Electronics Conference & Exposition (APEC 2017) in Tampa, Florida (26–30 March) demonstrate the level of resources that both partners are willing to commit to develop applications and support customers in the use of the designs.

www.mesago.de/en/PCIM/main.htm
www.monolithsemi.com
www.littelfuse.com

NCSU converts p-type reduced graphene oxide to n-type

With support from the US National Science Foundation (NSF), North Carolina State University (NCSU) has developed a technique for converting positively charged (p-type) reduced graphene oxide (rGO) into negatively charged (n-type) rGO, creating a layered material that can be used to develop rGO-based transistors for use in electronic devices (Bhaumik and Narayan, 'Conversion of p to n-type Reduced Graphene Oxide by Laser Annealing at Room Temperature and Pressure' J. Appl. Phys. 121 (2017), 125303).

"Graphene is extremely conductive, but is not a semiconductor; graphene oxide has a bandgap like a semiconductor, but does not conduct well at all — so we created rGO," says Jay Narayan, the John C. Fan Distinguished Chair Professor of Materials Science and Engineering at NC State. "But rGO is p-type, and we needed to find a way to make n-type rGO," he adds. "Now we have it for next-generation, two-dimensional electronic devices."



Specifically, Narayan and Ph.D. student Anagh Bhaumik demonstrated two things. They integrated rGO onto sapphire and silicon wafers, across the entire wafer.

Second, they used high-powered laser pulses to disrupt chemical groups at regular intervals across the wafer. This disruption moved electrons from one group to another, effectively converting p-type rGO to n-type rGO. The entire pulsed laser deposition (PLD) process is done at room temperature and pressure using high-power nano-second laser pulses, and is completed in less than a fifth of a micro-second. The laser radiation annealing provides a high degree of spatial and depth control for creating the n-type regions needed to fabricate p-n junction-based two-dimensional electronic devices.

The result is a wafer with a layer of n-type rGO on the surface and a layer of p-type rGO underneath. This is critical, since the p-n junction between them is what makes the material useful for transistors.

http://aip.scitation.org/doi/full/10.1063/1.4979211
www.mse.ncsu.edu

EPC issues ninth Reliability Report

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 issued its Phase Nine Reliability Report, documenting a combined total of over 9 million GaN stress device-hours with zero failures after rigorous thermo-mechanical board-level reliability testing.

The report adds to the knowledge base in EPC's first eight reports and represents an ongoing commitment to study, learn and share information on the reliability of GaN technology, says the firm. "Demonstration of the reliability of new technology is a major undertaking," comments CEO & co-founder Dr Alex Lidow. "Test results described in this ninth reliability report show that EPC GaN products in wafer-level chip-scale packages have the superior reliability, cost and performance to displace silicon as the technology of choice for semiconductors. The time has come to finally ditch the package."

EPC FETs and ICs are made in wafer-level chip-scale packages (WLCSP), which improves performance, lowers cost, and minimizes board real-estate, while improving reliability, says the firm. WLCSP offer excellent thermal dissipation, which is critical when the devices are soldered to printed circuit boards for end-use applications, EPC adds. The main section of the report covers thermo-mechanical board-level reliability.

Devices for this study were chosen that span package size and solder layout configurations and a predictive model for solder joint integrity was developed. Customers can apply the thermo-mechanical stress model given in the report to predict reliability in their specific end-use applications. Using the correlation between strain at the solder joint together with fatigue lifetime, the model can be used to predict thermal cycles to failure for arbitrary stress conditions related to specific end-use applications.

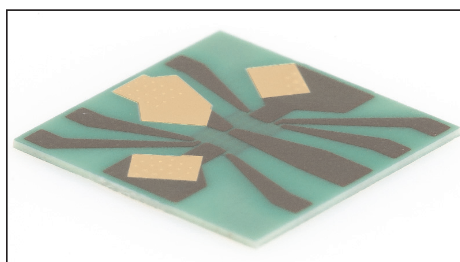
Cumulative reliability information compiled over EPC's nine reliability reports shows that eGaN FETs and ICs have solid reliability and can operate with very low probability of failures within expected lifetimes of end-products, says EPC. Given the superior performance, cost and reliability reported of GaN products over silicon devices, the time has come to move away from the less reliable packaged silicon devices and move to chip-scale GaN technology FETs and ICs, the firm asserts.

www.epc-co.com

Fraunhofer IAF's GaN-on-Si monolithic multi-level power converter demonstrated using AT&S' embedded component technology

The Fraunhofer Institute for Applied Solid State Physics IAF of Freiburg, Germany has developed a fully integrated monolithic multi-level converter in high-voltage AlGaN/GaN-on-Si technology. The integrated inverter circuit is designed for maximum voltages of ±400V and currents of 5A. The multi-level converter comprises four transistors and six diodes but covers an area of just 2mm x 3mm, suiting compact voltage-converter applications. DC/AC inverter operation has been demonstrated for US mains voltage. The circuit exhibits minimal dynamic losses at very high frequencies. The switching performance of the multi-level converter was demonstrated with a test setup based on the Embedded Component Technology (ECP) of printed-circuit board (PCB) maker AT&S (Austria Technologie & Systemtechnik) AG.

A corresponding test setup is necessary in order to evaluate the chip, since the packaging of the die constitutes a key factor. If lateral components are employed, then the source, drain and gate pads are on one side and the back of the die is used for heat dissipation. Since the conventional approach using wirebonds imposes restrictions, the second step of the evaluation saw AT&S' ECP technology being used. The power components — like the multi-level converter — are hence embedded into the PCB material and can be connected from both sides. The chips are connected directly via copper-plated microvias. This permits low-impedance connections and significantly lower inductances compared with wirebond technology. The rear of the die is also connected by means of copper-plated microvias, ensuring excellent heat dissipation.



Fraunhofer-IAF's multi-level inverter.

"We see this [AT&S ECP] mounting technology as opening up entirely new possibilities — particularly also for more complex monolithic integrated GaN power circuits, as used on our multi-level converter chip," says Fraunhofer IAF's Richard Reiner. "With a conventional design, we were hardly able to use and/or evaluate the powerful chip," he adds.

"Power electronics constitutes a major field of application and focus for the embedding technology from AT&S," says Dietmar Drofenik, CEO of AT&S' Advanced Packaging business unit. "Particularly for the use of wide-bandgap semiconductor materials such as GaN, the embedding technology makes innovative miniaturized power packages possible for higher efficiencies, enhanced thermal performance and higher power densities," he adds. "In collaboration with partners, AT&S has for example already implemented various GaN power circuits, which are characterized by excellent switching performance and high efficiency."

AT&S and Fraunhofer IAF presented their power solutions at the PCIM (Power Conversion Intelligent Motion) Europe 2017 event in Nuremberg, Germany (16–18 May).

www.iaf.fraunhofer.de/en.html
www.ats.net

Analog Devices expands GaN power amplifier portfolio

Analog Devices Inc (ADI) of Norwood, MA, USA has launched a pair of gallium nitride power amplifier (PA) modules that are said to offer one of the highest power density levels in their class, minimizing size and weight of the subsystem.

The HMC7885 and HMC7748 broadband modules target applications at 2–6GHz, including test & measurement, communications, traveling-wave tube (TWT) replacement, military/aerospace surveillance and counter-measures, and radar. The fully integrated, all-solid-state devices expand ADI's existing line of GaN-based PAs, and feature ease of use to accelerate prototyping and system design.

The HMC7885 is a 32W, hermetically sealed, hybrid amplifier housed in a 1" x 1.4" x 0.15" 18-lead hermetic ceramic/metal multi-chip module flange-mount package for high-reliability applications. The hybrid amplifier typically provides 21dB of small-signal gain and 45dBm of saturated RF output power. It draws 2.2A of quiescent current from a $28V_{dc}$ supply. Both RF input and output are DC blocked and matched to 50Ω for ease of use. An evaluation board is available with layout and bill of materials to facilitate design-in and user application.

The HMC7748 is a 3.75" x 3" x 0.6" 6-lead fully integrated multi-stage power amplifier module with connector interface that delivers 25W of saturated output power, accepts inputs up to −8dBm maximum, and provides small-signal gain of 60dB. It includes bias sequencing and regulation, and is internally matched to 50Ω. The PA draws 0.7A from a 12V supply and up to 4A from 28V. An enable pin provides shutdown capability so it can be turned on and off without cycling power supplies.

www.analog.com/HMC7885
www.analog.com/HMC7748

Fuji Electric
Innovating Energy Technology

Fuji Electric Lambda Series
New, Compact, Powerful

The New Generation of Low Voltage Earth Leakage Circuit Breakers

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

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

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

or contact us: x-fea-fuji-dc@fujielectric.com

PowerAmerica funding speeds Transphorm's development of 900V GaN HEMT product

Due to funding assistance from PowerAmerica — a private–public partnership between the US Department of Energy, industry and academia — Transphorm Inc of Goleta, near Santa Barbara, CA, USA, which designs and manufactures what it claims are the industry's only JEDEC-qualified 650V gallium nitride (GaN) field-effect transistors (FETs) for high-voltage power conversion applications, has developed what it says may be the first offerings of their kind on the market.

The first is a bilateral switch that will enable a reduction in 2–4x part count as well as a reduction in losses. The second is a 900V GaN HEMT, which will enable increased energy efficiency. The products are used to convert power in applications such as power supplies, solar inverters, AC–AC converters, industrial converters and electric vehicles.

Transphorm already has several GaN products on the market in the 650V range (its second-generation 650V GaN FET recently became the first GaN solution to earn automotive qualification). These have helped to dispel doubts about the reliability and manufacturability of GaN, says Transphorm. Previously, though, 900V GaN was not thought possible, the firm adds. While Transphorm had set a roadmap target to develop the higher node, its partnership with Power America enabled it to focus specifically on the higher-node 900V GaN devices.

"The fact that PowerAmerica provided 50% of the funding for this project allowed us to focus on it as a roadmap item and develop streamlined technology — and offer first engineering samples with a datasheet — within a year," says Transphorm co-founder & chief operating officer, Primit Parikh. "PowerAmerica helped to get us to the next level with our product," he adds.

"Working with PowerAmerica, we were able to leverage our strong baseline of industry's highest-reliability, highest-quality GaN to improve existing technologies and get them closer to product commercialization," Primit continues. "PowerAmerica helped accelerate and risk reduce our roadmaps of these advanced devices."

Transphorm has preliminary samples released to select customers, and is continuing to focus on broader product release.

www.poweramericainstitute.org

Transphorm showcases GaN FETs at PCIM Europe

At the 2017 Power Conversion and Intelligent Motion (PCIM) Europe expo in Nuremberg, Germany (16–18 May), Transphorm Inc of Goleta, near Santa Barbara, CA, USA — which designs and manufactures JEDEC-qualified 650V gallium nitride (GaN) field-effect transistors (FETs) for high-voltage power conversion applications — demonstrated its high-voltage GaN FETs for power electronics systems (including power supplies, servo motors and photovoltaic inverters) as well as showcasing its AEC-Q101 qualified GaN FET (launched in late March, and claimed to be the industry's first automotive-qualified 650V GaN FETs):

- **3.5kW integrated half-bridge module preview**: Transphorm's easy-to-use surface-mount half-bridge module is designed to simplify PCB layout and shorten design time. The firm will soon offer this module as a building block for bridgeless totem-pole, half-bridge, full-bridge and LLC topologies.
- **First GaN servo motor**: Targeting 100-400W applications, the Yaskawa integrated servo motor uses Transphorm's GaN FETs to increase system power density and efficiency, to simplify system architecture, and to deliver a dramatic reduction in system size.
- **First GaN redundant power supply**: Targeting 500W applications, the Telcodium redundant AC power supply uses Transphorm's TPH3206PS and TPH3202PS GaN FETs to increase efficiency and power density while reducing standby power (to less than 1W) and internal temperature yields.
- **First GaN AC-DC power supply with bridgeless totem-pole PFC**: Targeting 3kW applications, the Bel Power TET3000 uses Transphorm's TPH3205WS to achieve 80 Plus Titanium efficiency while reducing system size to meet a 1U design.
- **High-voltage GaN reference design previews**: Transphorm's 4.2kW PV inverter (DC-to-DC, DC-to-AC) and 3.3kW totem-pole power factor correction (PFC) reference designs, scheduled for release later this year, exemplify one type of customer design resource provided by Transphorm's Silicon Valley Center of Excellence (formally opened in March).

Transphorm's PCIM showcase was hosted in the HY-LINE Power Components booth. Additional demonstrations were displayed in the GLYN GmbH & Co booth.

Transphorm also led an educational session on high-voltage GaN design methods. Specifically, senior director of technical marketing Philip Zuk spoke in the session 'GaN – Design, EMC and Measurement'.

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

GaN Systems sponsors China Power Supply Society competition to design high-efficiency, high-power-density GaN-based inverters

To inspire power design engineers at Chinese universities to advance electronic power technology, GaN Systems Inc of Ottawa, Ontario, Canada — a fabless developer of gallium nitride (GaN)-based power switching semiconductors for power conversion and control applications — is again sponsoring the annual CPSS competition to design high-efficiency, high-power-density GaN-based inverters, which is conducted by the China Power Supply Society (CPSS), the China Power Society Science Popularization Committee, and Nanjing University of Aeronautics and Astronautics.

Choosing GaN instead of legacy silicon transistors allows power systems designers to increase both system efficiency and power density while reducing system size, weight and cost, says GaN Systems. Nowhere is this trend more apparent than in the energy market, where GaN transistors are replacing MOSFETs in applications such as energy storage systems, inverters and AC solar panels, the firm adds.

The theme of the 3rd annual competition is the application of power electronics technology for innovation, energy saving and new energy use. Inverter design entries will be evaluated based on performance criteria, including inverter efficiency, power density and output stability across various load conditions.

The CPSS will announce the finalist teams on 15 September, and the competition winners will be announced and presented with their awards at the 22 November annual meeting. Cash awards of 20,000 yuan, 10,000 yuan, and 5000 yuan will be given to the first, second and third place winners, respectively.

"Design contests like the CPSS competition serve to motivate and excite power system designers to design and build systems with efficiencies and power densities never achieved before," believes GaN Systems' CEO Jim Witham. "The industry saw this firsthand with the Google Little Box Challenge, where GaN-based inverter power densities dramatically exceeded the challenge goals," he adds. "We are proud to provide opportunities for engineers to explore and expand the performance limits of power inverters by leveraging the benefits of GaN transistors in novel inverter designs."

www.cpss.org.cn

GaN Systems' investors receive venture capital awards

GaN Systems Inc of Ottawa, Ontario, Canada says that its funding partners are being recognized for their investment success.

After releasing its 8th annual Global Cleantech 100 list, Cleantech Group (CTG) has honored GaN Systems' investor Crysalix Venture Capital with the 2017 Financial Investor of the Year Award. The Global Cleantech 100 is a peer-reviewed list of the top private companies involved in innovative clean technology, and that have the greatest potential to impact the future of a wide range of industries within a 5–10 year timeframe.

In a parallel development, in its 2016 'Year in Review' report, the CVCA (Canadian Venture Capital and Private Equity Association) reported that GaN Systems' funding partner Cycle Capital Management was recognized for being the most active cleantech venture capital firm in Canada in 2016. Additionally, Cycle Capital was Canada's 2nd most active independent private venture capital firm, consummating 29 deals and investing at total investment of $132m. According to the CVCA report, Canadian cleantech investments for 2016 experienced a 200% increase over the previous year.

Chrysalix Venture Capital was selected from a field of over 11,000 peer-reviewed nominees. They were chosen for having the highest percentage — in excess of 60% — of their qualifying portfolio companies on the 2017 Global Cleantech 100 list. Founded in Vancouver, Canada in 2001, Chrysalix is a technology-focused investment firm that invests in companies that bring disruptive innovation to the world's largest industries. GaN Systems is one of seven such companies in its portfolio that are also included in the Global Cleantech 100 list.

"This award is a great endorsement of our portfolio and validation of Chrysalix's strategy of targeting breakthrough industrial innovations leveraging intelligent systems and components, which we pioneered in our last fund and have made the central focus of our new Chrysalix RoboValley Fund," says Chrysalix's president & CEO Wal van Lierop.

Cycle Capital invests in cleantech entrepreneurial companies that are dedicated to fostering a sustainable future. "It's by investing in globally competitive companies led by great entrepreneurial teams like GaN Systems that we become the leader of the cleantech investment in Canada," comments founder & managing partner Andrée-Lise Méthot.

www.apec-conf.org
www.gansystems.com

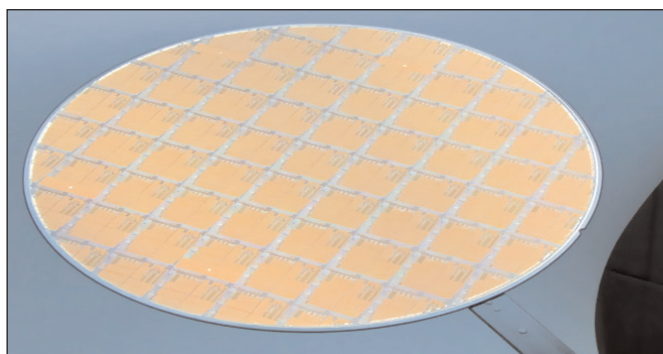
X-FAB and Exagan demonstrate mass production of GaN-on-Si devices on 200mm wafers

Silicon foundry and GaN start-up establish 200mm, fully CMOS-compatible process

X-FAB Silicon Foundries AG of Erfurt, Germany and Exagan of Grenoble, France, a gallium nitride (GaN) technology start-up enabling smaller and more efficient electrical converters, have demonstrated mass-production capability for manufacturing highly efficient high-voltage power devices on 200mm GaN-on-silicon wafers using X-FAB's standard CMOS production facility in Dresden, Germany. The achievement is the result of a joint development agreement launched in 2015, enabling cost/performance advantages that could not be achieved with smaller wafers.

Exagan and X-FAB say that they have resolved many of the challenges related to material stress, defectivity and process integration while using standard fabrication equipment and process recipes. Combined with the use of 200mm wafers, this can significantly lower the cost of mass producing GaN-on-Si devices. By enabling greater power integration than silicon ICs, GaN devices can improve the efficiency and reduce the cost of electrical converters, which is expected to accelerate their adoption in applications including electrical vehicle charging stations, servers, automobiles and industrial systems.

The new GaN-on-Si devices have been built using substrates fabricated at Exagan's 200mm epitaxy manufacturing facility in Grenoble, France. These epiwafers meet the physical and electrical specifications to produce Exagan's 650V G-FET devices as well as the tight requirements for compatibility with CMOS manufacturing lines.



Exagan's G-FET GaN-on-silicon devices on wafer.

GaN industrial production has been limited to 100mm and 150mm wafers due to the challenges of layering GaN films on silicon substrates. Exagan says that its G-Stack technology enables GaN-on-Si devices to be manufactured more cost effectively on 200mm substrates by depositing a unique stack of GaN and strain-management layers that relieves the stress between GaN and silicon layers. The resulting devices have been shown to exhibit high breakdown voltage, low vertical leakage and high-temperature operation.

"This is a major milestone in our company's development as we accelerate product development and qualification," states Exagan's president & CEO Frédéric Dupont. "It demonstrates the combined strengths of our epi material, X-FAB's wafer fab process and our device design capabilities. It also confirms the success of our vertically integrated fab-lite model, with expertise from materials to devices and applications. It is perfect timing to establish GaN technology and products on the most competitive 200mm platform just as GaN power products are getting broad traction in IT server, consumer electronics and automotive markets," he adds.

"Through this productive partnership, X-FAB is leveraging its resources and expertise to bring Exagan's technology into manufacturing and provide the power conversion market with a reliable supply chain," says X-FAB's Rudi De Winter.

Exagan showcased its GaN technology and G-FET transistors at the PCIM (Power Conversion Intelligent Motion) Europe trade show in Nuremberg, Germany (16–18 May).

www.xfab.com
www.exagan.com/en/products/gfet-family

Exagan presents GaN-on-silicon technology

At the PCIM (Power Conversion Intelligent Motion) Europe 2017 trade show in Nuremberg, Germany (16–18 May), founder & CEO Frédéric Dupont of gallium nitride technology start-up Exagan of Grenoble, France was on hand to discuss the development of a cost-efficient, low-risk, 200mm manufacturing process for fast-switching, high-efficiency GaN-on-silicon devices.

The results stem from the joint development partnership Exagan entered into with X-FAB Silicon Foundries AG of Erfurt, Germany in May 2015. Together, the firms have produced Exagan's 650V GaN-on-Si G-FET power transistors using a standard CMOS process flow.

At PCIM Europe, Exagan's senior executives discussed the firm's latest technology advances and provided an update on the strategic partnership with X-FAB.

www.exagan.com

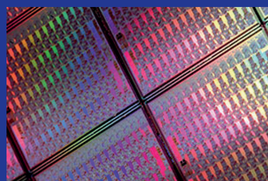
NAsP III/V

Guiding processing forward

Developing III/V integration on Si?

Speeding-up time-to-market with GaP-on-Si integration.

GaP-on-Si templates with high crystalline perfection for high-end applications



For today´s high-end applications we all strive to achieve a supreme performance. The challenging question is this: how to boost the efficiency of Si wafers to get one step ahead?

Our solution for you: NAsP III/V

Our technology has mastered the first challenge for the integration of a variety of III/V semiconductor materials and device heterostructures on 300 mm CMOS compatible (001) Si wafers. For this purpose, we have developed a proprietary nucleation process for the deposition of thin GaP layers on such Si substrates with high crystalline perfection.

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

Nitride Solutions closes $2.75m funding round

Nitride Solutions Inc of Wichita, KS, USA, which makes nitride substrates for LEDs, lasers and power electronics) has closed $2.75m in a new round of funding, led by Nelnet Inc of Lincoln, NE (one of Nitride Solutions' earliest investors) and joined by new investors Leawood Capital Venture Fund of Leawood, KS, and DK Group of Omaha, NE.

"The combination of Nitride Solutions' expertise in the manufacturing space, as well as its advanced technology, made them a great addition to our portfolio," comments Chuck Norris, director at Nelnet, which is involved in loan servicing, payment systems and fiber internet deployment (focusing on new businesses, businesses with strong regional impact, and businesses that provide innovative solutions across a variety of industries).

"When evaluating potential investments, we look for disruptive technologies," says Karl Gemperli, managing director of Leawood Ventures, which manages Leawood Capital Venture Fund (which spans a diverse portfolio of private technology companies). "The aluminum nitride process could be transformative to the electronics industry," he believes. "With massive global export potential, Nitride Solutions has built a production line that can manufacture at scale."

Leawood and DK Group join Nitride Solutions' existing investment group including angel investors from Kansas, Nebraska, Oklahoma, Washington DC, Wisconsin, California, Alaska, and South Korea.

The new funds will be used to ramp up production capacity and staffing to meet rapidly growing demand from the USA and Asia for aluminum nitride (AlN) products. "These customers have clearly indicated that our unique products are enhancing performance in various electronic applications," says CEO Jeremy Jones. "We are investing to be able to continue to meet and exceed their quality and delivery expectations," he adds.

www.nitridesolutions.com

Ammono enters insolvency; liquidator invites offers

Ammono S.A. in Warsaw, Poland, which produces bulk gallium nitride using ammonothermal technology, has entered into insolvency proceedings.

The court-appointed liquidator has invited interested parties to submit written proposals (with a security deposit of 1m zlotys) to purchase the firm via an auction process. The minimum selling price is 20m zlotys.

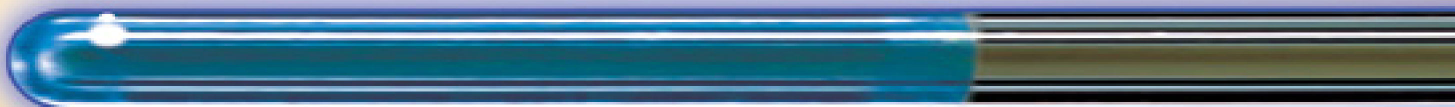
Proposals should be submitted on or before 22 May, and will be reviewed at 1pm on 24 May.

www.ammono.com

University Wafer
https://order.universitywafer.com Ph 800-713-9375 Fx 888-832-0340 chris@universitywafer.com
Your Advantage
Buy one Wafer!
Compare Pricing
Fast Quotes!
Faster Service
Quality Guaranteed
Quick turnaround.
Why buy wafers in volume if you don't have to?
Buy One Wafer!
...ANIUM
...LA GLASS
...PHENE
INGAAS EPI ON INP
ITO GLASS
LINBO3
NITRIDE ON SILICON
SAPPHIRE
SILICON

Qty	ID	Diam	Type
1	1394	25.4mm	P
22	2483	25.4mm	Undoped
500	444	50.8mm	P
267	446	50.8mm	N

Exclusively from Conax...



EtchDefender™
TECHNOLOGY

Coated TCs for the ASM Epsilon® that last up to 3X longer

Conax introduces EtchDefender™ coating—the patent-pending solution for extending the life of quartz sheath thermocouples.

Lab and production tests prove EtchDefender™

- Increases yield and decreases cost of ownership
- Won't flake from the quartz substrate
- Doesn't decompose, out-gas or sublimate under vacuum at high temperature
- Slows devitrification and erosion
- Increases wafer yield and consistency

FIND OUT MORE

Ideas. Solutions. Success.

+1 800 223 2389 | conaxtechnologies.com

Councils in Cardiff Capital Region investing £37.9m to establish compound semiconductor foundry

Signifying the first funding since a £1.2bn City Deal was formally agreed in March with the Welsh and UK governments, ten local councils in the Cardiff Capital Region (CCR) are to invest £37.9m to create a new foundry for compound semiconductor applications development and high-volume manufacturing, as part of what is reckoned to be the world's first compound semiconductor cluster, being established in South Wales.

Owned by the ten councils, the foundry will lease space to compound semiconductor manufacturing and applications development companies. Discussions on site location are on-going, targeting the start of construction in the early summer. The project is expected to leverage up to £365m of private sector investment over the next five years.

"The University has invested millions of pounds in partnership with IQE, and today's announcement is excellent news for innovation, industry and enterprise in South Wales and beyond," comments professor Colin Riordan, vice chancellor of Cardiff University. "It offers a real opportunity to build Europe's first compound semiconductor applications cluster and create a world-class powerhouse to commercialize next-generation technologies."

The CCR City Deal aims to position the region as the European leader in compound semiconductor-enabled applications. In 2016, the UK Government's innovation agency Innovate UK announced a £50m investment to establish a new Compound Semiconductor Applications Catapult in South Wales — located in the CCR — building on existing expertise and investment by Cardiff University, Cardiff-based epiwafer foundry and substrate maker IQE plc, and the Welsh Government.

South Wales supply chain

"The objective of these commitments is to create a complete compound semiconductor eco-system in South Wales to take advantage of the growing prominence of compound semiconductor technologies," says councillor Andrew Morgan, leader of Rhondda Cynon Taf County Borough Council and chair of the City Deal Regional Cabinet. "This requires the development and integration of a compound semiconductor supply chain in South Wales, with the economic and social benefits that will bring," he adds.

"There are semiconductor clusters across Europe, around Eindhoven, Dresden, Leuven and Grenoble," note councillor Peter Fox, leader of Monmouthshire County Council (leading the project) and councillor Anthony Hunt, leader of Torfaen County Borough Council (who co-leads on CCR City Deal's business and innovation portfolio). "However, these are based on silicon technologies, hence this is a unique opportunity for Wales to establish the world's first compound semiconductor cluster," he adds.

"We are very impressed to see council leaders with the vision to make investments like this," says IQE's chief executive Dr Drew Nelson. "IQE already has a very strong presence here, and is looking to invest in building significant additional production capacity as part of this deal over the next 5 years. Our investment will see the next stage of our growth firmly rooted in CCR."

"It is not often that the opportunity presents to be in at the start of something with international credentials," comments Kevin Crofton, chairman of the Compound Semiconductor Applications Catapult.

www.catapult.org.uk

IQE's Infrared division presents invited papers at SPIE DCS

At the SPIE Defense and Commercial Sensing conference (DCS) in Anaheim, CA, USA (9–13 April), the Infrared business unit of IQE presented papers on recent key developments and commercialization of advanced infrared materials.

Complementing papers demonstrating the development of large-diameter antimonide substrates were two presentations covering IQE's five-year contribution to the Vital Infrared Sensor Technology Acceleration (VISTA) program, from which a range of GaSb substrate and epitaxial material technologies has been developed.

Furthermore, IQE's infrared materials portfolio has been now been expanded by adding another industry-critical infrared material, cadmium zinc telluride (CZT). A paper described the development of this material through to commercialization.

Invited papers:

- 'Production manufacturing of 5" diameter gallium antimonide substrates'
- 'MBE growth of advanced Sb-based IR photodetector structures for the VISTA Program'
- 'Bulk growth and surface characterization of epitaxy ready cadmium zinc telluride substrates for use in IR imaging applications'
- 'Large-format multi-wafer production of 5" GaSb-based photodetectors by molecular beam epitaxy'
- 'Standardizing large format 5" GaSb & InSb substrate production'.

Collectively, these developments enable IQE to offer a range of infrared materials, providing full spectrum coverage across a wide and diverse range of detector and sensing applications.

http://spie.org/conferences-and-exhibitions/defense--commercial-sensing
www.iqep.com

info@iqep.com

your partner for EPITAXY

visit www.iqep.com
to see how you can reduce
your costs and gain
competitive advantage
by partnering with
the world's No.1 pure-play
epiwafer specialist
for all your
epitaxial wafer needs

OPTO WIRELESS SOLAR

VCSELs edge-emitting lasers Al-free lasers visible/IR lasers
Visible LEDs APDs PiN detectors long-wavelength PiNs
Multi-junction CPV cells
HBTs pHEMTs BiFET/BiHEMTs

AXT's Q1 revenue exceeds original guidance after faster-than-expected recovery from fire

Growth driven by silicon photonics applications rising to 20–25% of indium phosphide revenue, while demand for PON recovers

For first-quarter 2017, AXT Inc of Fremont, CA, USA — which makes gallium arsenide (GaAs), indium phosphide (InP) and germanium (Ge) substrates and raw materials — has reported revenue of $20.6m, up on $20.3m last quarter and $18.7m a year ago. This is well above the revised guidance of $18–18.5m, and even slightly above the original guidance of $19.5–20.5m.

This was despite a short-circuit electrical fire at the firm's manufacturing facility in Beijing, China on the evening of 15 March that caused no damage to InP crystal growth or wafer production, nor the 6-inch GaAs and Ge crystal growth furnaces, nor the electrical supply supporting them, but affected the electrical power supply supporting 2-inch, 3-inch and 4-inch GaAs and Ge crystal growth. In addition, the critical wastewater pipe that services wafer processing was accidentally damaged by the fire department while locating and suppressing the fire, and that part of the facility was shut down at their request.

Due to the pause in production for those products, AXT lowered its Q1 revenue guidance from $19.5–20.5m to $18–18.5m. However, a faster-than-expected recovery allowed production to be resumed on 20 March (just four days after the fire), due to several factors:

- the wastewater pipe was repaired much faster than expected, allowing AXT to resume wafer processing and orders shipments after just four days (critical to Q1 backlog);
- AXT's custom-designed furnaces enabled it to rotate key furnace hardware between crystal growth diameters, allowing some 6-inch furnace capacity to be used for 2-, 3- and 4-inch GaAs and Ge crystal growth production;
- AXT had sufficient redundancy in its furnaces to relocate some within the plant to an area designated for crystal growth expansion and begin bringing them back online in their new location (AXT expects to be back to full production during Q2/2017).

"Through the adaptability of our equipment and facility and a reserve of stage inventory of smaller-diameter crystalline ingots that we quickly moved to wafer processing, we were able to mitigate the effects of the fire on our production," notes chief financial officer Gary Fischer. "Throughout the process, our primary focus was on supporting the needs of our customers without interruption," he adds. "We succeeded in fulfilling all customer orders."

In Q1, substrate revenue was $16.6m (80.6% of sales), up on $16m last quarter. Revenue from raw material joint ventures was $4m (19.4% of sales), down on $4.3m last quarter.

Despite being down slightly on last quarter, InP sales were again strong. The EPON and GPON passive optical network market (particularly in China) has historically been the key driver of InP demand in application such as fiber-to-the-home and -office. "In the last four quarters [especially second-half 2016], there was a slowdown in purchasing from carriers as well as inventory buildup in the supply chain that constrained market growth," says CEO Morris Young. "Despite some recent mixed signals in the news, we have been encouraged by indications from our customers that suggest improved conditions in key regions," he adds. In addition, the silicon photonics sector has grown and now accounts for 20–25% of AXT's InP revenue (compared with a negligible amount just two years ago), reckons Fischer.

Through the adaptability of our equipment and facility and a reserve of stage inventory of smaller-diameter crystalline ingots that we quickly moved to wafer processing, we were able to mitigate the effects of the fire

GaAs sales were up substantially in Q1. There was particular strength in wireless applications, where demand has stabilized in the wake of the incursion of silicon-on-insulator (SOI) technology into the market. "Certain applications remain best suited for GaAs and are likely to remain so for the foreseeable future," says Young. "Semiconducting GaAs demand was also a bit stronger than expected, with revenue primarily coming from our traditional markets."

Ge substrate sales were roughly flat, but still reflect an improvement in the worldwide satellite market, particularly in China. "Remote sensing, communications and positioning and navigation remains the predominant applications for certain regions like China," notes Young.

Of total revenue, Asia-Pacific comprised 63% (down from 71% last quarter), while North America comprised 10% (up from 6%) and Europe 27% (up from 23%). One customer generated more than 10% of revenue, while the top five generated about 35% of revenue, again reflecting diversification of both products and customers.

Although still up on 28.1% a year ago, gross margin fell more than expected, from 37.1% last quarter (which was particularly strong as a result of yield improvements and other efficiencies) to 30.5% in Q1, due partly to a less favorable product mix and foreign exchange rates but also through prioritizing customer requirements over production efficiency while recovering from the fire.

►

Operating expenses fell $5.2m last quarter to $4.9m. Net income was $0.67m ($0.02 per diluted share), down from $2.2m ($0.06 per diluted share) last quarter but up from just $42,000 (breakeven, $0.00 per diluted share) a year ago.

Depreciation and amortization was $1.1m (down from $1.3m last quarter). Capital expenditure (CapEx) has been cut from $0.9m to $0.7m.

During the quarter, cash, cash equivalents and investments rose by $32.9m from $53.7m to $86.8m. However, this was mainly because on 7 March AXT closed a secondary public offering of 5.3 million shares of common stock (including an overallotment option of 692,307 shares) at a price of $6.50 per share. After deducting underwriting fees and offering expenses, net proceeds were $32.3m.

AXT expects to use the proceeds for general purposes, including capital for expanding operations to meet the requirements of business opportunities across its portfolio, as well as the relocation of its GaAs substrate production line to a new site (the location of which will be decided in the next few weeks), which will occur in stages over the next two years (in response to the China Central Government's re-development plan for the area where AXT's existing GaAs manufacturing facility is located).

For second-quarter 2017, AXT forecasts quarter-to-quarter revenue growth of about 9% to $22–23m (including a record quarter for InP). Gross margin is expected to recover (with the longer-term goal being at or above 35%, driven mainly by growth in InP). Net income should rebound to $0.04–0.06 per share.

"We are seeing encouraging progress in the adoption of several emerging technologies and are continuing to invest in our product development, production capacity, and customer engagement and support capabilities in order to position ourselves for coming business opportunities," says Young.

"Ge substrate sales continue to provide steady profitable revenue, and strengthening market conditions could provide additional opportunity over the coming years," he adds.

"The 3D sensing market can provide a new growth opportunity for high-end substrate manufacture [using GaAs-based vertical-cavity surface-emitting lasers], should the technology enjoy more widespread adoption into a variety of products," says Young. "In mobile phones the technology is likely to be used for augmented reality applications by enhancing camera capability to enable facial recognition, guest data and greater precision and object replacement. Gaming and facial recognition for security are examples of two early applications," he adds. "The technology also has applications outside of the mobile in smart TV, automobiles, industrial and medical devices and gaming consoles, among others. The strict requirement of 3D sensing are likely to provide a strong barrier to entry to new players in the market. Today, only three competitors including AXT are able to provide low-EPD [etch pit density] substrates in sufficient volume for production," reckons Young.

"2017 will likely be an important year for AXT, and I believe we are taking the correct steps to ready our business for our next phase of growth," Young concludes.

www.axt.com

Riber's revenue booms in Q1/2017, driven by Cells & Sources for PV and screen applications

Order book grows 37% year-on-year; full-year revenue growth of at least 30% targeted

For first-quarter 2017, Riber S.A. of Bezons, France, which manufactures molecular beam epitaxy (MBE) systems as well as evaporation sources and effusion cells, has reported revenue of €9.2m, up dramatically from €1.4m a year ago.

This is due mainly to revenue for Cells & Sources booming 18-fold from €0.4m to €7.3m, primarily for the photovoltaic and screen industries. In addition, one MBE research system (worth €0.9m) was delivered, compared with none a year ago. Revenue for Services & Accessories is steady year-on-year at €1m.

By geographic region, 75% revenue came from Asia, 21% from Europe and just 3% from the USA.

The total order book has risen by 37% from €12.4m at end-March 2016 to €17m at the end of Q1/2017. This has been driven mainly by Cells & Sources orders quadrupling from €0.5m to €2m, supplemented by orders for Services & Accessories rising by 88% from €2.4m to €4.5m.

The systems order book has risen by 11% from €9.5m to €10.5m, comprising four production machines (up from two in 2016) and three research systems (down from five in 2016), all for delivery in 2017. This does not include an order from University of California Santa Barbara (UCSB) in the USA (announced on 18 April) for a model C21T MBE system, to be used for research on chalcogenide materials.

Considering its good visibility, Riber is targeting revenue growth of at least 30% for full-year 2017.

The firm's executive board has also implemented the share buy-back program that was authorized by the combined general meeting of 22 June 2016.

www.riber.com

Veeco's Q1 revenue up 21% year-on-year to $94.4m, driven by LED demand

Build up of orders to drive strong second-half 2017

For first-quarter 2017, epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA has reported revenue of $94.4m, rebounding further from $93.6m last quarter and up 21% on $78m a year ago. This is above the seasonal average, reflecting the ongoing recovery in LED industry conditions (as evidence by customer utilization rates rising in recent months).

The Lighting, Display & Power Electronics segment — primarily metal-organic chemical vapor deposition (MOCVD) systems — grew by 39% from last quarter (rebounding from 42% to 58% of total revenue, compared with just 29% a year ago). This was driven mostly by sales of EPIK MOCVD reactors to support ongoing demand for blue LED applications. In addition, demand for red, orange and yellow (R-O-Y) LEDs drove an increase in K475i product sales. Also, sales of Precision Surface Processing (PSP) systems to LED makers represented a record.

The Advanced Packaging, MEMS & RF segment fell back from 17% to 12% of total revenue, reflecting lower sales for advanced packaging applications.

Revenue from Foundational Businesses fell back from last quarter's exceptional $39m to $29m (from 41% of total revenue to 30%). This consisted of the Scientific & Industrial sector falling from 28% of total revenue last quarter (which had been boosted by shipments of MBE systems for high-power laser diode applications) to a more normal 16%, while the Data Storage sector rose slightly from 13% to 15%.

On a geographic basis, China rose to 43% of revenue (driven by demand from LED makers), Europe, the Middle-East & Africa (EMEA) was unchanged at 23%, while the USA declined to 18% and the rest of the world to 16%.

Gross margin has fallen from 39.2% last quarter to 37% (below the targeted 38–40%), impacted 1–1.5 percentage points by a less favorable product mix (shipping an old model MaxBright MOCVD system from inventory for a customer not yet prepared to transition to the EPIK system) plus another 1–1.5 percentage points by temporary duplicate costs associated with manufacturing consolidation efforts (Veeco began renovating its New Jersey facility in second-half 2016 to combine manufacturing operations for ion beam, optical, and other components). "We have been incurring duplicate cost to maintain existing operations and resources until the new facility is fully functional," explains chief financial officer Sam Maheshwari. Veeco expected this to be completed in Q1, but the permit process and construction activities have taken about three months longer than anticipated.

"We maintained strong expense discipline, which helped to offset the temporary gross margin pressure," says Maheshwari. Operating expenses (OpEx) have been cut from $38m a year ago and $33m last quarter to below the projected $31–32m, due to R&D expenses reducing from $17.2m last quarter to $14.6m.

Net income has fallen slightly from $3.8m last quarter to $3.6m ($0.09 per diluted share), but this is still a big improvement on a loss of $5.7m a year ago. It is also above the midpoint of the forecasted $0–6m ($0.00–0.16 per share), despite a $0.05 per share impact due to a pre-tax interest expense from January's public offering of senior convertible notes (due 2023).

Adjusted earnings before interest, taxes, depreciation and amortization (EBITDA) was $7.3m, up from $6.2m last quarter and an improvement on –$2.1m a year ago.

Cash flow generated from operations was $6.3m, up from just $0.4m last quarter and much better than cash burn of $19m a year ago. During the quarter, cash and short-term investments rose by $2m to $682m, excluding the $336m in net proceeds from January's public offering of 2023 convertible notes.

During the quarter, inventory was reduced by $12m as Veeco continued to ship MOCVD systems (including the older MaxBright model). Days of inventory hence improved from 134 days to 107 days.

Order bookings totaled $107m (exceeding $100m for the third consecutive quarter). For a seasonally weak quarter, the drop of $20m from last quarter's $127m was moderate, considering the unusually strong Q4/2016, which included Veeco's largest ever order — of MOCVD and PSP systems for Germany's Osram Opto Semiconductors GmbH (to be shipped mostly in second-half 2017).

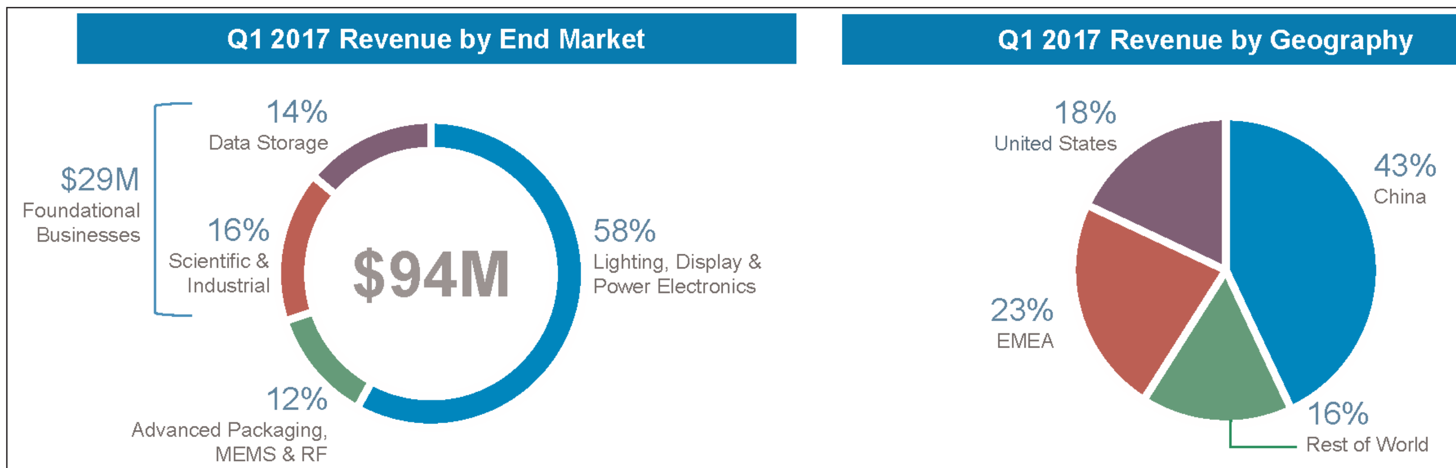
Although bookings for Lighting, Display & Power Electronics correspondingly fell, orders were received for multiple MOCVD systems from Chinese LED makers. "We continue to see positive momentum in the space and have a healthy sales funnel," notes Maheshwari.

Bookings for Advanced Packaging and MEMS rose, offsetting fewer RF capacity orders. "We have continued to see incremental opportunities in advanced packaging supported by the versatility of our PSP products," says Maheshwari.

Bookings for Foundational Businesses were relatively stable quarter-over-quarter, aided by slightly increased orders for Data Storage.

As planned, order backlog has built up further, by $12m to $221m, but a disproportionate amount is not expected to ship until second-half 2017.

For second-quarter 2017, Veeco expects revenue of $85–100m. ►



Gross margin should be 38–40%, after the temporary impact of about 1 percentage point due to manufacturing consolidation activity. OpEx should be $31–33m. Earnings are expected to range between a loss of $2m (–$0.05 per share) and income of $4m (+$0.09 per share), including the impact of a pre-tax interest expense of $2m ($0.06 per share) from the 2023 convertible notes. Adjusted EBITDA should be $4–10m. Order bookings will rebound after the weak first quarter.

"We are continuing to build backlog and see a healthy sales pipeline, which supports top-line growth in the second half of 2017," says chairman & CEO John R. Peeler. "Revenue will be more geographically diverse than the first half as we start to shift down some of the backlog that we continue to build."

Veeco's manufacturing consolidation should be completed in third-quarter 2017. "Our consolidation efforts, combined with sustained cost discipline, will drive positive operating leverage as revenues scale," Peeler believes.

With gross margin expected to scale up with revenue in second-half 2017, Veeco therefore continues to target full-year gross margin of 40% or more. OpEx is still targeted to be $130m annually ($32.5m per quarter). "In the last two quarters and in the Q2 guide as well as Q1, we're a little bit less than that, but I think it's going to go back up to those levels on a go-forward basis [in second-half 2017, as revenue grows]," says Maheshwari.

In the coming months, Veeco plans to launch a new GaN MOCVD system for blue LEDs targeting the lighting market. "This product is based on the EPIK reactor technology [launched in late 2014]," Peeler claims. "We're already seeing strong customer pull for the new system, which is expected to further enhance cost of ownership," he adds. "It will have better economics than older tools, so it will put us one step closer to a more meaningful retirement cycle. Anything that was made before 2008 is really not viable, so we have seen customers taking older units out of service... But it's going to take a little while longer before we get to the real mass-deployment cycle of 2010 and 2011 replacement."

Finally, in early February, Veeco announced an agreement to acquire Ultratech Inc of San Jose, CA, USA (which makes lithography, laser-processing and inspection systems for advanced packaging, semiconductor and LED applications) for $815m. The acquisition "increases our scale, diversifies our revenue, and dramatically expands our presence in the advanced packaging market," comments Peeler. "We are pleased with the progress we've made towards completing the Ultratech acquisition. Our integration planning efforts are well underway, with both teams working closely together to hit the ground running on day one. We've made tremendous progress in developing plans to integrate processes and systems," he adds. "We've already made progress in identifying new opportunities to leverage our complementary technology, market, and geographic strengths," Peeler continues. "We've cleared all regulatory hurdles and expect the transaction to close in late May, with Ultratech's shareholder meeting scheduled for 25 May."

www.veeco.com

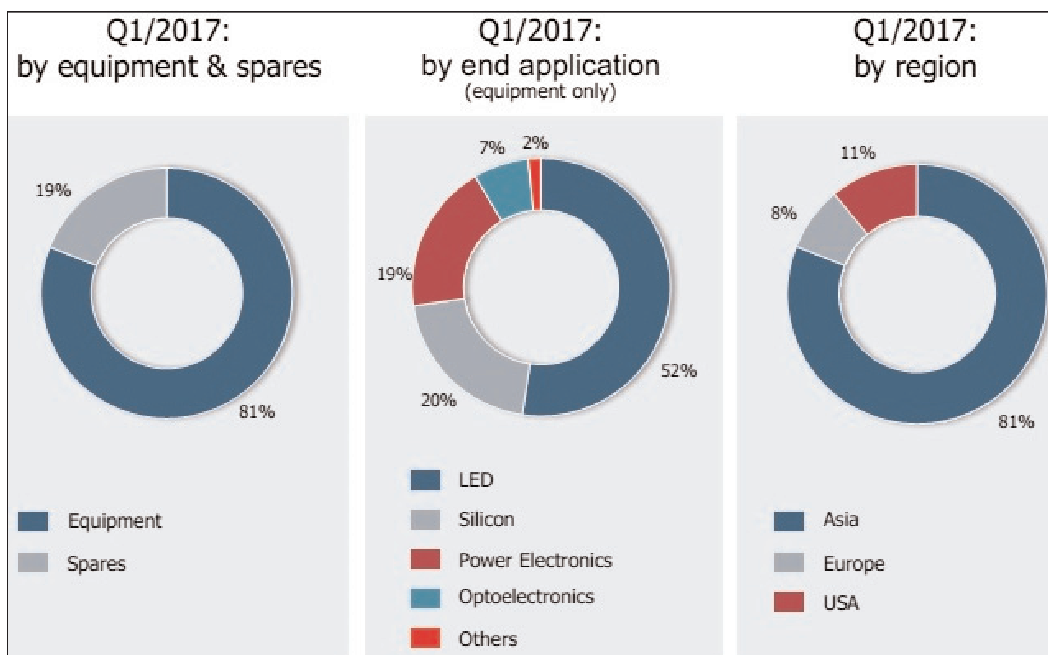
REGISTER
for *Semiconductor Today* free at
www.semiconductor-today.com

Aixtron's Q1 revenue and order intake rise strongly year-on-year

TFOS product development frozen as R&D for future technologies to be focused into independent units financed with technology partners

For first-quarter 2017, deposition equipment maker Aixtron SE of Herzogenrath, near Aachen, Germany has reported revenue of €53.6m, down 40% on last quarter's exceptionally high €89.8m (which comprised about half of full-year 2016 revenue) but up on €21.4m on a year ago (and the highest Q1 revenue since 2011). Based on solid order backlog at the end of 2016, growth was driven mainly by demand for production systems for Optoelectronics, Power Electronics, and LEDs, as well as for Memory applications.

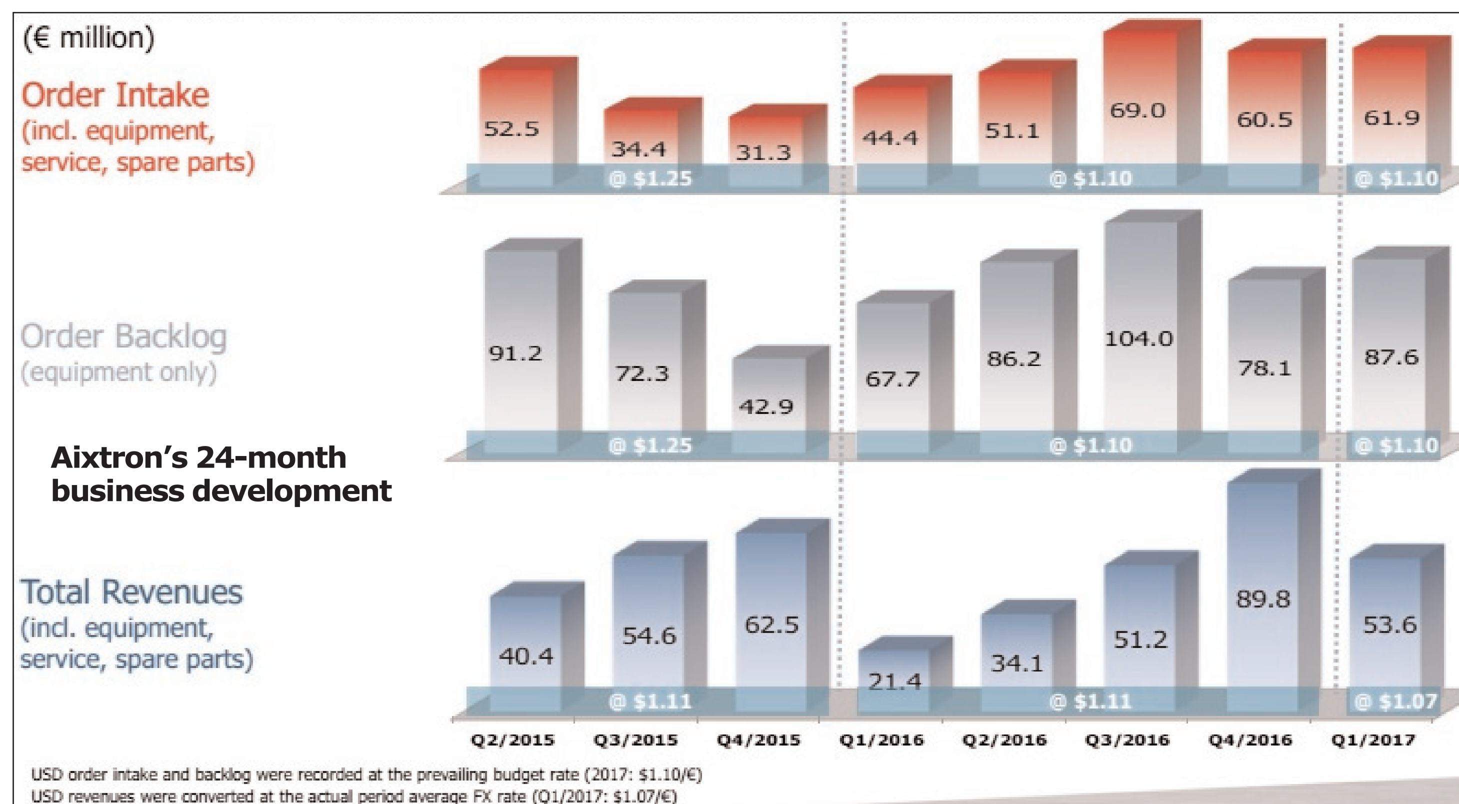
Specifically, equipment revenue was €43.5m (81% of total revenue), up on just €11.9m (56% of total revenue) a year ago. Meanwhile, revenue from spare parts & services has grown by 6% from €9.5m a year ago to €10.1m.



Breakdown of Aixtron's first-quarter 2017 revenue by region, application, and type.

On a regional basis, 81% of revenue came from Asia (continuing to rebound, after dipping from 70% a year ago to just 44% in Q2/2016), 8% came from Europe (down from 15% last quarter), and 11% came from the USA (down from 17%).

Although down on last quarter's



33%, gross margin is still up on 15% a year ago to 25%, or 27% excluding Aixtron's €1m write-down of inventory assets for equipment related to III-V materials for future-generation logic chips (TFOS) — comprising the firm's first measures to focus R&D spending for the development of future technologies by freezing product development for III-V-materials for TFOS.

Operating expenses have risen further, from €17.8m a year ago and €21.4m last quarter to €26.4m, due mainly to higher R&D expenses. However, excluding a €5.6m write-down of assets from freezing the TFOS-related equipment development activities, R&D spending would have been a more normal €14.1m (just 26% of revenue, whereas the €13.3m R&D expenses a year ago equated to 62% of revenue at that time).

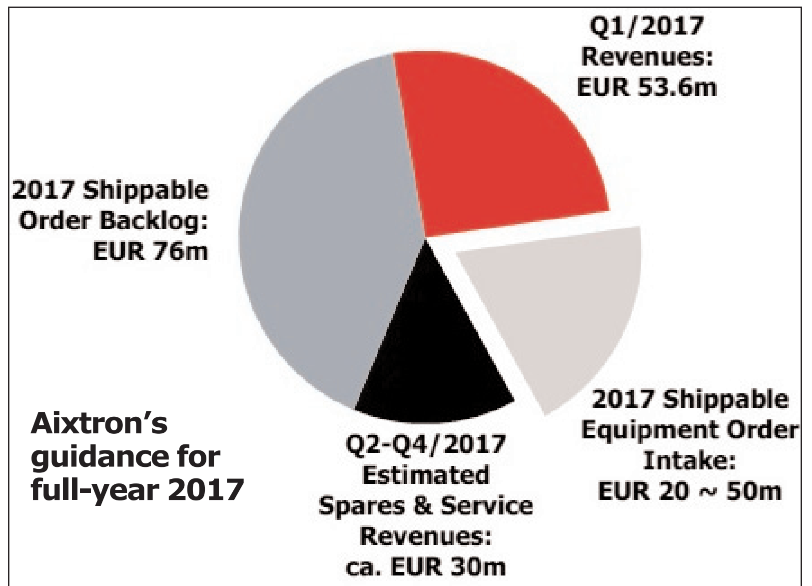
Compared with last quarter's exceptionally high €12.5m, earnings before interest, tax, depreciation and amortization (EBITDA) was –€6m, but this is still an improvement on –€11.7m a year ago.

The gross margin and EBIT were impacted by low-margin sales of AIX R6 metal-organic chemical vapor deposition (MOCVD) systems from inventory.

The net result was –€13.5m. However, excluding the total TFOS-related write-downs of €6.6m, the adjusted net result was –€6.9m, compared with last quarter's exceptionally high €6.4m, but an improvement from –€15.5m a year ago.

"Inventory at €49.9m [cut from €54.2m last quarter] is at its lowest level for 10 years and is a clear reflection of the improvements we've made in inventory management [plus shipments of AIX R6 MOCVD systems from inventory]," says chief accounting officer Charles Russell. "Secondly advance payments from customers increased to €30.5m from €26.1m, reflecting the continued strong order intake in 2017."

Due mainly to the collection of accounts receivable as well as the increase in advance payments from customers for new orders, operating cash flow was €34.6m. Capital expenditure (CapEx) has been cut further, to €1.3m (from €2.2m last quarter and €5.1m a year ago). Overall, free cash flow has hence improved further, from –€20.3m a year ago and -€4.9m last quarter to €33.3m.



During the quarter, cash and cash equivalents (including cash deposits with a maturity of more than 3 months) rose from €160.1m to €193.6m, due mainly to the collection of trade receivables from customers. Aixtron continues to have a healthy balance sheet with equity of €356.7m, cash of €193.6m and no debt.

Order intake was €61.9m in Q1, roughly level with €60.5m last quarter but up 39% on €44.4m a year ago. As of end-March, equipment order backlog was €87.6m, up 12% on €78.1m at the beginning of 2017 and up 29% on €67.7m a year previously.

As in previous quarters, the key driver for the development in revenues and order intake was demand for production systems for specialty LED (red-orange-yellow; UV and IR), telecom and optoelectronics, as well as for NAND and DRAM memory applications. This in turn was mainly attributable to emerging technology trends, such as big data, cloud computing, electro mobility, and the upcoming 5G mobile communication standard.

"Aixtron has a wide portfolio of enabling technologies for highly diversified applications and industries. To better focus R&D costs for the development of future technologies, we will group our portfolio for future technologies and transfer it into clearly defined independent units to be financed with respective technology partners," says CEO Kim Schindelhauer. "In a first step to focus our R&D expenses in the future, we wrote down assets totaling €6.6m resulting from freezing our product development for III-V-Materials for future-generation logic chips (TFOS)," he adds. "We will not spend further R&D until a firm timeline for the introduction of this material application has been set and a partner covers the required developments costs. Then, we are fully committed to support our customers to introduce TFOS materials to the market."

The comparatively high order intake in Q1/2017 supports Aixtron's expectation regarding the development of revenues and order intake during 2017. Consequently, the firm reiterates its full-year 2017 guidance (given in February) for order intake and revenue of €180–210m (consisting of Q1's revenue of €53.6m supplemented by 2017-shippable order backlog of €76m joined by a forecasted €20–50m of further 2017-shippable equipment order intake, plus a forecasted €30m of spares & service revenue). It also continues to expect an improvement in free cash flow from 2016 to 2017 and to achieve a positive EBIT for full-year 2018.

www.aixtron.com

ALD tool maker Picosun extends services portfolio to delivery of precursors

Atomic layer deposition (ALD) thin-film technology firm Picosun Oy of Espoo, Finland has launched a delivery service for ALD precursor chemicals, implemented in cooperation with several well-known chemical manufacturers.

Picosun says that its ALD business continues to expand not only in semiconductor manufacturing but in other fields of industry too. It has therefore developed a comprehensive portfolio of flexible cost-effective services with its industrial partners. As new processes are ramped up for large scale production, an efficient supply chain for ALD-specific services such as chemicals is vital, reckons the firm.

One of the new partners is EpiValence Ltd of Redcar, Cleveland, UK, a manufacturer of specialty chemicals for electronics industries, with whom Picosun now collaborates to offer fast and smooth precursor delivery to all Picosun ALD tool users. The service includes chemicals, and filling and shipping of the precursor containers to the customer site, where they can be directly connected to the ALD tool. Cleaning and refill service for used containers is also available.

"We at Picosun want to ensure first-class customer experience by delivering all-inclusive ALD solutions, combining the equipment and processes with a full-scale service portfolio and centralized supply of all required accessories and consumables. Precursor chemicals are an integral part of this supply," says Picosun's applications & services director Dr Erik Østreng. "We are very happy to deepen our collaboration with EpiValence, which is well known for its top-quality products targeted specifically for the microelectronics sector. Together we can deliver everything our customers need to run successful ALD production," he adds.

"Together we can ensure uninterrupted supply and secure delivery of both ALD chemicals and tools to a worldwide clientele," says EpiValence's commercial director Chris Richards, offering a "complete and united supply chain for ALD technology".

www.picosun.com
www.epivalence.com

CLEANSORB®
EXHAUST GAS ABATEMENT

CS CLEAN SOLUTIONS

For R&D and manufacturing
CVD, ALD, Plasma Etch, Ion Implantation
and many more process applications

- Safe, dry chemical conversion of hazardous gases to stable solids
- Proprietary CLEANSORB® media
- no handling of toxic waste
- Practically maintenance-free
- Local refill service worldwide

www.csclean.com

SPTS wins Queen's Award for Enterprise

SPTS Technologies Ltd of Newport, Wales, UK — an Orbotech Ltd company that manufactures etch, physical vapor deposition (PVD) and chemical vapor deposition (CVD) and thermal wafer processing solutions for the MEMS, advanced packaging, LED, high-speed RF on GaAs, and power management device markets — has been awarded the Queen's Award for Enterprise in International Trade 2017, in recognition of its substantial year-on-year growth in overseas earnings and commercial successes in its global business. In addition to judging outstanding achievement in international trade, the judging panel also assessed SPTS on its corporate responsibility, which included employee affairs, customers and suppliers relationships, and its impact on the environment and society.

The Queen's Awards for Enterprise were introduced in 1966 to acknowledge businesses with outstanding performance in three categories: International Trade, Innovation and Sustainable Development. The annual awards are open to any company operating in the UK and are announced annually on Queen Elizabeth II's birthday (21 April). This is SPTS Technologies' second Queen's Award, after receiving its first in 2013.

"This award belongs to the entire organization — from those involved in the development and manufacture of our industry leading wafer processing solutions to our team outside the UK who sell, install and support our products and customers," comments Kevin Crofton, president of SPTS Technologies and corporate VP at Orbotech. "Our customers are many of the leading device manufacturers in the microelectronics industry... Our growth is a testament to the quality and competitiveness of UK developed technologies and products in the global markets," he adds.

"They [SPTS] are a prominent global business that makes an important contribution to our economy, which is why we have awarded them Anchor status," commented Economy Secretary Ken Skates. "A focus on exporting is more important now than ever before as we transition out of the EU, and success stories such as this show that companies in Wales can more than step up to the challenge."

SPTS exports more than 95% of its products manufactured in the UK and has surpassed the milestone of £1bn in export sales. The firm has manufacturing facilities in Newport (UK), Allentown (USA, Pennsylvania), San Jose (USA, California), and operates across 19 countries in Europe, North America and Asia-Pacific.

www.spts.com

ClassOne's new chamber cuts copper plating costs by 95%

ClassOne Technology of Kalispell, MT, USA has announced its new CopperMax chamber, which is said to offer major copper plating cost reductions for users of ≤200mm wafers.

Citing performance data from a CopperMax pilot installation on a Solstice tool at a Fortune 100 customer, over a six-month period the customer tracked their actual production operating costs while using the new chamber for copper TSV (through-silicon vias), damascene and high-rate copper plating. For the three processes with CopperMax they reported that operating costs were reduced by between 95.8% and 98.4% compared with previously used conventional plating chambers.

"Many of our emerging market customers are starting to do copper plating," says president Kevin Witt. "So we've spent a lot of time on the process, working to reduce customer costs and also increase performance. And the new CopperMax chamber is proving to do both."

Consumables are the largest cost factor in copper plating, notes ClassOne. Optimizing copper plating generally requires the use of expensive organic additives, which are consumed very rapidly and need to be replenished frequently.

"We learned, however, that over 97% of those expensive additives were not being consumed by the actual plating process," says Witt. "Most were being used up simply by contact with the anode throughout the process. So, we designed our new copper chamber specifically to keep additives away from the anode — and the results are pretty dramatic. Significant savings can be realized by high- and medium-volume users with high throughputs as well as by lower-volume and R&D users that have long idle times."

The CopperMax chamber employs a cation-exchange semi-permeable membrane to divide the copper bath into two sections. The upper section contains all of the additives, and it actively plates the wafer. The lower section of the bath contains the anode that supplies elemental copper, which is able to travel through the membrane and into the upper section to ultimately plate the wafer. However, the membrane prevents additives from traveling down to the anode, where they would break down and form process-damaging waste products.

The chamber is designed to use inexpensive bulk anode pellets instead of solid machined Cu material

As a result, the CopperMax bath remains much cleaner, and bath life is extended by over 20x. This increases uptime, enables higher-quality, higher-rate Cu plating, and it reduces cost of ownership very substantially, says ClassOne.

For example, a customer using a Solstice system with six CopperMax chambers and running TSV and high-rate copper plating will save over $300,000 per year just from additive use reductions.

CopperMax also reduces Cu anode expenses. The chamber is designed to use inexpensive bulk anode pellets instead of solid machined Cu material, which cuts anode costs by over 50%. Also, since the pellets have 10x greater surface area, they also increase the allowable plating rates.

"Like the rest of our equipment, this new chamber aims to serve all those smaller wafer users who have limited budgets," says Witt. "Simply stated, CopperMax is going to give them a lot more copper plating performance for a lot less."

ClassOne Technology signs Scientech as representative for China, Taiwan and Southeast Asia

ClassOne Technology of Kalispell, MT, USA, which manufactures wet-chemical processing equipment including Solstice electroplating systems (especially for emerging markets and other cost-conscious users of ≤200mm substrates), has signed Scientech Corp of Taipei, Taiwan as its new representative for China, Taiwan and Southeast Asia.

"Asia is an extremely active and important region for us," says Byron Exarcos, president of the ClassOne Group. "We wanted a respected and thoroughly experienced sales and support operation there, and Scientech filled the bill perfectly. They have all the necessary infrastructure and well-established field service teams, having served the industry for over three and a half decades — including many years representing Semitool," he adds.

"We're very impressed by the rapid success ClassOne has been achieving, bringing high-performance wet processing solutions to the emerging markets — with more than 100 tools already installed across the US and Europe," comments Scientech's president M.T. Hsu. "It's great to represent products that are in high demand, and we're looking forward to helping expand ClassOne's presence in Asia."

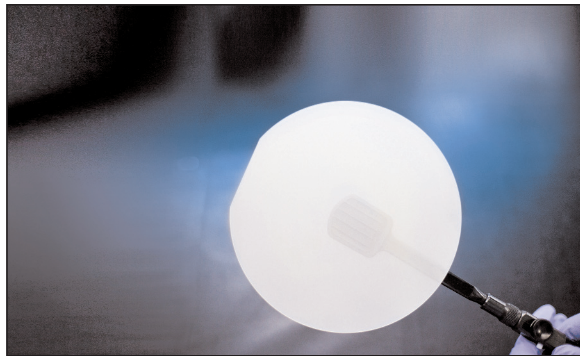
Scientech Corp was established in 1979 and has five offices across Taiwan and Shanghai. It will provide full sales, installation, service, parts, process development assistance and technical support for all ClassOne Technology equipment, including the Solstice family of electroplating systems and the Trident families of Spin Rinse Dryers and Spray Solvent Tools.

www.scientech.com
www.classone.com/products

Monocrystal launches Ultra-Clean sapphire wafers for microLED development

Monocrystal Inc of Stavropol, Russia, which manufactures large-diameter synthetic sapphire substrates and cores for LED, optical product and RFIC applications, has launched Ultra-Clean sapphire wafers, after applying its cleaning technology to achieve the wafer surface quality required by high-precision optoelectronic applications (including microLEDs).

Currently being developed by all leading LED makers as a next-generation light source, the microLED has significant advantages over conventional LEDs in terms of brightness and power consumption, says Monocrystal. The firm's new Ultra-Clean (UC) sapphire wafers have only 20–50 particles of no more than 1μm in size on their surface, so they are designated specifically for microLED production.



Monocrystal's Ultra-Clean sapphire wafer.

"MicroLED is a very promising technology which requires a new approach in many aspects, including sapphire wafer surface preparation," says CEO Oleg Kachalov. "Our UC-wafers with a very low particle count will allow our customers to achieve their target epitaxial yields, which is crucial for microLED successful development and further commercialization," he adds.

"Our new UC-wafers are also compatible with the conventional PSS [patterned sapphire substrate] process," notes VP sales Mikhail Berest. "It is an advanced cost-saving solution, which eliminates the pre-cleaning step and allows PSS makers to increase their yields up to 95–99% after the first pass," he reckons. "We have already received a very positive feedback on the UC-wafers from several long-term customers."

www.monocrystal.com

AP&S tailors metal lift-off process for LED manufacturing

AP&S International GmbH of Donaueschingen, Germany says that, at the beginning of 2017, its metal lift-off process (which was launched in 2012 and is currently running at several key customers sites in Europe) has been further developed to meet the specific requirements of LED production.

"The AP&S range already includes several wet process tools for this industry," says Uwe Müller, director Business Unit Single Wafer. The firm can now meet the sector's key challenges such as automated high-volume production and the prevention of substrate damage.

The AP&S metal lift-off process is a single-wafer spin process offering what is claimed to be three unique features:

- solvent performance that has no impact on the substrate and structures;
- the use of DMSO (dimethyl sulfoxide), which is non-critical in terms of the environment, health and safety (EH&S) in the EU and the USA; and
- an optimized process time with a positive impact on overall throughput.

Common wet chemical lift-off processes work by batch immersion or spray application, which often gives rise to critical residues and cross-contamination (e.g. metal flakes). Another commonly used technology for lift-off is based on single-wafer spin clean, which requires mandatory pre-soak and a high temperature for solvents. A further disadvantage of such equipment technologies is the use of chemicals such as NMP (n-methyl-2-pyrolidone) or acetone. NMP is an EH&S critical substance, which causes severe irritation to the skin, eye area and in the respiratory system, and carries the risk of damaging fertility and harming the unborn child. Acetone is highly flammable, and residues after processing with acetone represent a well-known problem.

By using DMSO at elevated temperatures combined with megasonic agitation, the AP&S metal lift-off process offers safety for workers, the environment and equipment, and guarantees constant solvent performance over an extended period. The process guarantees damage-free lift-off for sensitive applications and sensitive substrates. There are no residues left on the substrate after processing, and DMSO itself is easy to rinse off with deionized (DI) water or a lower solvent. This means lower chemical consumption, cost reduction in the production chain, and enhanced process capability, says the firm.

The AP&S lift-off solution is available for all types of metal layers, alloys and further protection layers used in the semiconductor industry. Interested parties can test the metal lift-off process in the AP&S demonstration center (an in-house application laboratory). "I look forward to welcome customers and potential partners in our demo center and to demonstrate them our unique metal lift-off process.

www.ap-s.de

Toyoda Gosei to begin sales of glass-encapsulated UV LEDs

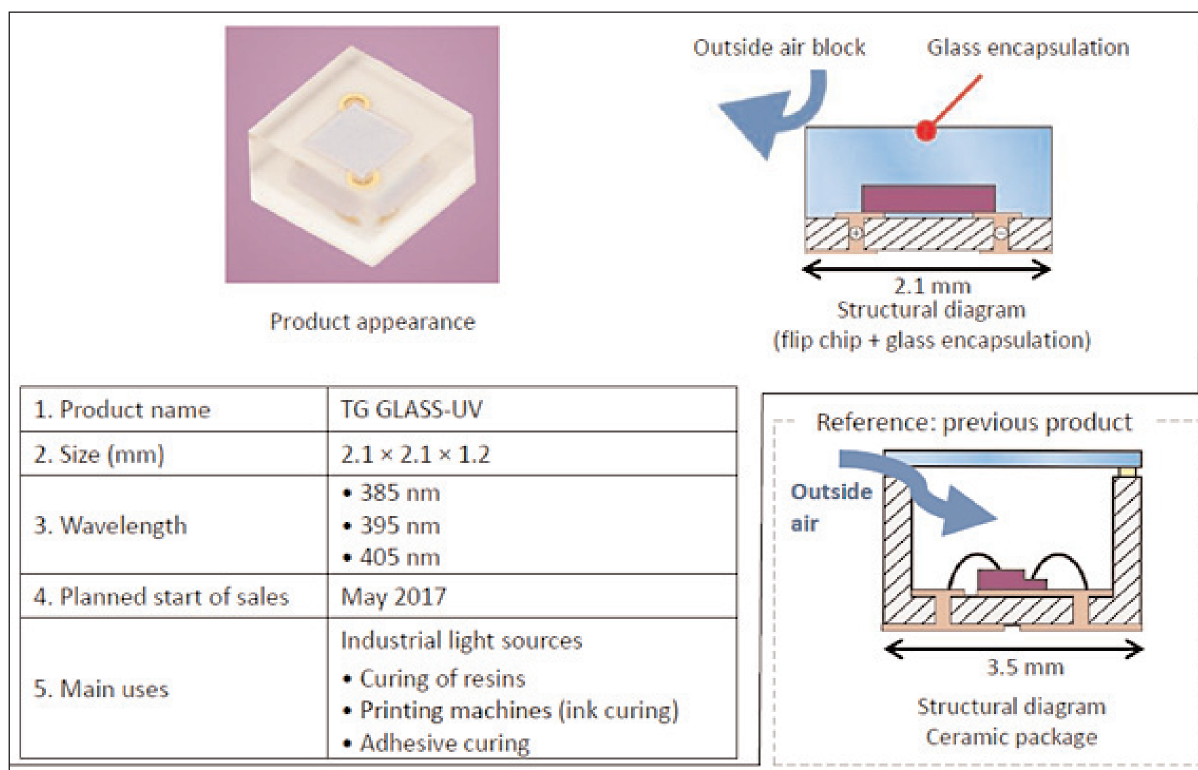
Toyoda Gosei Co Ltd of Kiyosu, Aichi Prefecture, Japan is to begin sales of its glass-encapsulated ultraviolet LED products developed in March 2016 for use as an industrial light source in the curing of resins, ink and adhesives.

The firm says that the new UV LEDs maintain good reliability in high-temperature, high-humidity environments due to complete encapsulation of the LED chip in glass, minimizing the impact of gas penetration and moisture on the die. Also, an improved crystal structure boosts the light output per LED die, while the use of flip-chip technology (directly connecting the LED die to the substrate) results in smaller product size.

With these improvements, the new glass-encapsulated UV-LEDs achieve light output per unit area of 200mW/mm^2, more than twice that of previous products.

The new UV LEDs were displayed at the Optics & Photonics International Exhibition (OPIE '17) in Yokohama, Japan (19–21 April).

www.opie.jp/en



1. Product name	TG GLASS-UV
2. Size (mm)	2.1 × 2.1 × 1.2
3. Wavelength	• 385 nm • 395 nm • 405 nm
4. Planned start of sales	May 2017
5. Main uses	Industrial light sources • Curing of resins • Printing machines (ink curing) • Adhesive curing

LG Innotek launches UV LED module for sterilizing water purifier faucets

Seoul-based LG Innotek (a subsidiary of South Korean electronics company LG Group) says that, since the end of March, it has been mass producing an ultraviolet (UV) LED module that sterilizes the inside of water purifier faucet aerators. The module has been incorporated into LG Electronics' new direct water purifier 'PuriCare Slim Updown', which was launched in March.

A water purifier faucet aerator always holds a small amount of water. This part is prone to contamination due to the growth of germs that enter with the influx of air. However, it has been difficult to install a sterilizer inside a faucet aerator because the space is too narrow. The new module is 1.5cm in width and 3.7cm in length and can be mounted in the small space inside the water purifier.

The UV LED module kills 99.98% of germs when a faucet aerator is exposed to ultraviolet rays (of 278nm wavelength) for 5 minutes. It is also harmless, since it uses only ultraviolet rays for sterilization without any chemicals or heavy metals. In addition, unlike a mercury UV lamp, there is no need to worry about breaking it.

LG Innotek says that the new module is convenient to use as it allows quick and accurate control of ultraviolet rays. As soon as its sterilization function is activated, UV rays are released at peak performance. In contrast, a mercury UV lamp requires about 2 minutes to warm up.

LG Electronics' direct water purifier installed with this module allows instant sterilization of faucets by pressing the 'Self Care' button at any time. It also performs automatic sterilization every hour.

LG Innotek plans to actively expand the application of UV LEDs to various products. It already has a line-up of products that are optimized for different applications, including 365nm, 385nm, 395nm and 405nm UV-A LEDs for general industry and a 305nm UV-B LED for the biomedical field as well as a 280nm UV-C LED for sterilization.

www.lginnotek.com

THE MARK OF

Purity.
Precision.
Performance.

When it comes to ultra high purity gas delivery systems, look for the mark of excellence.

For over 35 years, **SEMI-GAS® has been the semiconductor industry's go-to brand for premier, production-ready, ultra high purity gas delivery systems.** Today, Tier 1 leaders and high-tech innovators all over the world look to SEMI-GAS® for proven solutions that uphold their rigorous application demands.

Learn more at **www.semi-gas.com/mark**

SEMI-GAS® IS POWERED BY

SemiLEDs reduces cash burn, despite revenue falling by a third

Revenue to rebound slightly next quarter

For fiscal second-quarter 2017 (ended 28 February), LED chip and component maker SemiLEDs Corp of Hsinchu, Taiwan has reported revenue of $1.83m, down 32% on $2.7m last quarter and 37% on $2.92m a year ago. However, during the quarter, SemiLEDs shut down its manufacturing production for two weeks due to the Chinese New Year holiday.

Gross margin was breakeven, down from 4% last quarter but still better than –27% a year ago. Total operating expenses have been slightly cut from $1.22m las quarter to $1.14m. Despite this, operating margin has worsened from –41% last quarter to –62%.

On a non-GAAP basis, net loss was $1.06m ($0.30 per diluted share), rising from $0.61m ($0.17 per diluted share) last quarter but better than $2.2m a year ago.

Despite this, net cash used in operating activities has been cut from $1.12m last quarter to $0.64m, while capital expenditure has been cut further, from $68,000 last quarter to just $20,000. Total free cash outflow has hence been almost halved from $1.19m last quarter to $0.66m. During the quarter, cash and cash equivalents fell from $4.83m to $4.07m.

For fiscal Q3/2017 (to 31 May), SemiLEDs expects revenue to rise to $2m±10%.

www.semileds.com

Seoul Semiconductor files LED patent infringement lawsuit in Germany against Mouser

On 31 March, South Korean LED maker Seoul Semiconductor Co Ltd (SSC) filed a patent infringement lawsuit in Germany in the District Court of Düsseldorf against global electronic component distributor Mouser Electronics Inc asserting infringement of an LED patent.

According to the complaint, the accused products include LEDs for high-power light emission. Further investigation suggests that they are manufactured by multiple LED companies, including Everlight Electronics Co Ltd, a global top-10 LED maker. Seoul has sought a permanent injunction, damages, and recall and destruction of the allegedly infringing products.

The asserted patented technology serves to efficiently extract light emitted from the internal LED structure by treating LED chip surfaces, improving light intensity and brightness. This patented technology has been widely used for various high-power LED applications, such as automobile lighting, cellphone flashlights, outdoor lighting, UV LED appliances, etc.

According to market research firm IHS, the LED penetration rate in automobile headlamps will rise sharply from the existing penetration rate of 16.4% to 32.3_% by 2021. This high-power LED technology is already being used for exterior automobile lighting, including headlights and daytime running lights. Furthermore, it is expected to become a significant technology for electric vehicles and autonomous vehicles, which require high-power LED lighting with high heat dissipation for energy efficiency.

In addition, this high-power LED technology also applies to LEDs for mobile phone flashlights, which require higher light intensity. Because margins for flashlight LEDs are higher than those for backlights, the flashlight LED market has still grown steadily despite the overall decline in the IT sector LED market.

Further, the high-power LED technology is widely applicable to general lighting products for outdoor illumination and commercial or industrial use because such technology substantially enhances light efficiency and improves the brightness per unit area obtained from the LED. The technology is also widely used in manufacturing ultraviolet (UV) LEDs for sterilization, purification and curing processes. The UV LED application market is expected to grow rapidly, reaching $800m by 2020.

Beginning with this lawsuit, Seoul says that it plans to actively defend its patent assets against infringing high-power LED technologies. It has already identified infringements of other patents that it possesses related to high-power LEDs and will be considering additional infringement lawsuits.

"The asserted patent is considered an essential technology for manufacturing high-power LEDs and has been widely used in various LED applications," says Ki-bum Nam, VP of Seoul Semiconductor's Lighting Business Department. "However, there are many LED products currently on the market that infringe this patented technology, so we have decided to begin enforcing our patent rights in such cases," he adds. "To create a fair market competition and promote technological innovation, we continuously take any and all actions necessary to deter such infringement and protect our intellectual property."

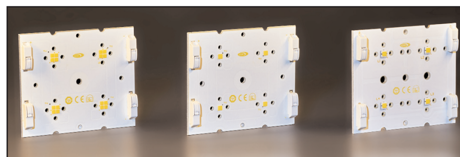
www.SeoulSemicon.com

Seoul Semi introduces reference modules for WICOP

Seoul Semiconductor Europe of Munich, Germany, a subsidiary of South Korean LED maker Seoul Semiconductor Co Ltd, has made available reference modules based on its package-free WICOP LEDs.

"Offering module solutions, based on our highly innovative technologies, will allow our customers to evaluate the technology and its benefits easily, enabling them to realize their solutions faster than by just using LED components," says Andreas Weisl, CEO of Seoul Semiconductor Europe and VP sales. "Resources at our customers are often limited, so they need powerful, reliable and easy-to-handle solutions to meet their requirements. As a solution provider, we help them to be ahead of competition and to achieve a fast time-to-market, also by creating customized modules in our Munich-based lab."

This first release includes reference modules for the WICOP Y19, Y22 and Y22P LEDs. The Y19 module consists of four clusters of 2x2 LEDs with a combined typical flux of 4650lm, while the Y22 and Y22P



New reference modules based on package-free WICOP LEDs.

modules achieve 1268lm with four single LEDs each. They all feature a color rendering index (CRI) of 70 and a color temperature of 4000K.

All modules announced are tailored to common customer needs and follow the outlines given in book 15 of the Zhaga specification, which defines the location and pitch of the LEDs and the position and size of the alignment holes for optical lenses. The boards feature standard power connectors and are easy to assemble and easy to use together with commercially available lenses, like the new Wilma lens-array from LEDiL.

With luminous efficiency of up to 210lm/W at a drive current of 350mA, WICOP LEDs are suitable as light sources for applications such as wall washes or floodlights in the architectural space and lighting in warehouses or production sites in the industrial arena. Outdoor they can be used for street lighting, in tunnels or for the illumination of stadiums, harbors, airports or railway stations, as well as for security applications.

Their compact footprint makes the LEDs several times smaller and much brighter than conventional LEDs, enabling cost savings at the system level, the firm claims. This is achieved through the chip design, with the phosphor film attached directly to the chip surface, rendering obsolete the previously required packaging with frames and gold wires. WICOP LEDs are hence also suitable for applications where a small form factor is needed.

Production quantities of the three new reference modules can be provided on request. If needed, they can also be customized by Seoul Semiconductor's regional labs for specific requirements.

www.seoulsemicon.com/WICOP/WICOP_en.asp

Seoul Semi's Q1 sales growth bucks normal seasonality

Seoul Semiconductor Co Ltd has reported growth in first-quarter revenue to KRW257.5bn (US$228m), due to strong sales in general lighting and strength across all segments in the IT division, with automotive lighting in particular driving profits.

For the lighting division, technologies such as Wicop and Acrich boosted sales, supplemented by newly launched products such as filament LEDs and chip-on-board (COB) products. In addition, automotive exterior lamps such as daytime running lights (DRLs) and headlights maintained rapid growth.

For the IT division, sales growth was driven mainly by existing customers expanding their product line-ups, supplemented by new customers. As a result, overall company revenue rose significantly despite the weak seasonality normally seen in Q1. In particular, the mobile and TV segments of the IT division saw noticeable growth, leading to better-than-expected sales and profitability.

The improving operating profit drove operating margin up by 223% year-on-year, showing how the impact of seasonality has diminished.

To improve share price stability and increase shareholder value, Seoul Semiconductor has launched a KRW10bn share buyback program, to be executed within the next six months through Mirae Asset Daewoo Securities.

Seoul Semiconductor has also been pursuing legal action against companies that infringe on its patent rights. On 31 March, it filed a patent infringement lawsuit in Germany in the District Court of Düsseldorf against global electronic components distributor Mouser Electronics Inc involving an LED product manufactured by Everlight Electronics Co Ltd that allegedly infringes Seoul Semiconductor's patents for Acrich, MJT and Wicop LED technologies. In addition, notices have been sent to companies that have copied Seoul Semiconductor's Wicop chip-scale package (CSP) technology (in which the chip adheres directly on the substrate without requiring the use of packages).

For Q2/2017, Seoul Semiconductor expects revenue of KRW250–270bn. It plans to further strengthen its sales and marketing activities for its proprietary technologies including Acrich and Wicop and to focus on acquiring more new customers in order to boost earnings.

www.SeoulSemicon.com

Lumileds doubles flux of LUXEON CoB Core Range with new High Density option

Lumileds has launched the LUXEON CoB Core Range – High Density, a family of chip-on-board (CoBs) LEDs with double the luminous flux of the CoB Core Range (Gen 3) devices.

Focusing on the most popular light-emitting surface (LES) sizes for spot lighting applications (6mm, 9mm and 11mm), the High Density CoBs can achieve what is claimed to be the highest center-beam candlepower (CBCP, or punch) in narrow-beam (<20º) spotlight applications. "Our customers require the sharpest beams and precise beam control," says Eric Senders, product line director for LUXEON CoB LEDs. "LUXEON CoB Core Range – High Density caters to this market by delivering the highest punch at low beam angles along with exceptional quality of light," he claims.

Light quality of LUXEON CoB Core Range – High Density products is reflected in the 3-step MacAdam Ellipse color definition. Quality of light is also associated with the color over angle (CoA) of LEDs used in spotlight applications. When the CoA is high, a 'halo effect' is created, where a halo or yellowish ring around the spotlight can be seen, especially against a white wall. With the LUXEON CoB Core Range – High Density array, the color differences within the beam are minimal, eliminating the halo effect, says Lumileds.

LUXEON CoB Core Range – High Density offers a maximum flux of 2500lm from a 6mm LES, 5000lm from a 9mm LES, and 6000lm from an 11mm LES (at 3000K, 80 CRI). The arrays are offered over a color temperature range of 2700–5700K and color rendering index (CRI) of 70, 80 or 90. Lumileds claims that the CoBs provide the industry's lowest thermal resistance, enabling smaller heat-sinks and optics for lower overall system cost. The MCPCB substrate is also more robust than ceramic substrates, which are subject to cracking upon assembly or use, adds the firm.

www.lumileds.com/LUXEONCoBCoreRange

Lumileds appoints Ilan Daskal as chief financial officer

LED maker Lumileds of San Jose, CA, USA has appointed Ilan Daskal as chief financial officer (CFO).

Daskal has over 25 years of experience in senior financial roles, including VP of finance at Infineon Technologies NA and CFO at International Rectifier. "His breadth of experience in operations, mergers and acquisitions, and capital markets will help drive Lumileds future growth," comments CEO Mark Adams.

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

"The company's legacy of innovation, customer engagement and performance leadership are all compelling factors that will drive continued success," comments Daskal about Lumileds.

www.lumileds.com

Lumileds' LED lumen maintenance exceeds DLC Premium testing specs in four main product families

Lumileds says it is the only firm to meet the Premium specifications of the DesignLights Consortium (DLC) in four main product families. LUXEON LEDs, within the high-power, color, chip-on-board (CoB) and mid-power families, exceed DLC Premium specifications even at high operating temperatures and drive current conditions.

"Whether your application calls for a high-power, mid-power, chip-scale package (CSP), CoB or color LED, LUXEON LEDs can be used to specify and design a light engine that meets the top-tier specifications of DLC Premium and be assured of the very best lumen maintenance performance," says Shih Shun Mark Chang, global director, Technical Solutions Management at Lumileds.

Lumileds claims that it pioneered the standardization of lumen maintenance testing in 2008 and was the first company to provide LM-80 test report data to customers. Since then, it has improved its manufacturing and testing processes, from epitaxy to new phosphor development to die fabrication and in-situ process control. With over 3 billion device-hours of testing, Lumileds product portfolio includes 23 unique products with data from hundreds of millions of LM-80 device hours proving that LUXEON products far exceed the DLC's Premium targets for efficiency and lumen maintenance — including L90 times surpassing the DLC Premium requirements of 36,000 hours, with many products demonstrating L90 times in excess of over 100,000 hours.

KEEPING AN EYE ON THE **FUTURE**

Evatec brings you advanced thin film production solutions for Advanced Functionality Materials

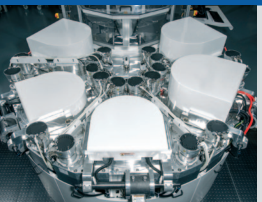
From new high piezoelectric coefficient materials like AlScN to highly aligned NiFe soft magnetic layers or complex optical interference coatings, Evatec sputter platforms and processes help you keep an eye on the future. Advanced Process Control (APC) technologies bring precision and throughput to the deposition of new **Advanced Functionality Materials** in **Wireless**, **MEMS** and **LED** technologies. To find out more about Evatec processes and platforms visit **www.evatecnet.com**

RADIANCE SPUTTER CLUSTER

MSP 1232

LLS EVO II LOAD-LOCK SPUTTER

CLUSTERLINE® 300 II SPUTTER



SOLARIS S380 SPUTTER

MORE INFO

ADVANCED PACKAGING • HP OPTICS • MEMS • OPTOELECTRONICS • POWER DEVICES • WIRELESS • THE THIN FILM POWERHOUSE

www.evatecnet.com

Cree introduces NX technology platform for next generation of lighting-class LEDs

Cree Inc of Durham, NC, USA has announced the NX technology platform, which will power the next generation of its lighting-class LEDs.

The NX technology platform enables the new Extreme Density (XD) LED family to deliver up to four times higher lumen density than the firm's previous generation of high-power LEDs. It makes possible new designs that eliminate existing constraints for a wide spectrum of applications such as color mixing, directional lighting and industrial lighting.

"Our new NX technology platform builds on Cree's advancements in epitaxial structure, chip architecture and light conversion, and leverages Cree's lighting applications expertise," says Dave Emerson, Cree LEDs senior VP & general manager. "Unlike other technology platforms adapted from LCD backlighting applications, our NX technology platform was designed from the beginning to dramatically improve the performance of LEDs in lighting applications."

The new platform embodies advances in a number of components and technologies, including the new Dmax LED chip, a more efficient phosphor system, new package designs and simpler manufacturing processes.

The first product available in the new family of XD LEDs is the XLamp XD16 LED, which delivers a lumen density of up to 264lm/mm^2 (reckoned to be 50% higher than the best LEDs currently available). Specifically optimized for applications that require high light output and high lumens-per-watt (such as street lights and high bays), XD16 LEDs enable higher performance luminaires with better light control. Also, the ceramic-based XD16 LED addresses challenges with assembly, thermal design, optical design and reliability that have been experienced with other competing LED technology platforms, it is claimed.

Engineering samples of XLamp XD16 LED will be available by late spring, with production quantities to be available by the end of summer.

www.cree.com/nx

Cree launches next generation of RSW LED street-light portfolio

Cree has launched the next generation of its RSW LED street-light portfolio with the introduction of 2700K, 5000K and 70 color rendering index (CRI) configurations, giving cities and municipalities the ability to meet the full range of lighting preferences for their communities without sacrificing energy savings, it is claimed.

The enhanced series includes RSW Small and Medium models that offer warm light for residential streets and clean, white illumination for roadways. Both deliver improved performance for superior efficacy with uniform and dark-sky friendly LED lighting, the firm adds.

"Cree's RSW Series enables municipalities to save time, energy and resources with LED street lighting without sacrificing the comfort of residents," says David Elien, Cree senior VP & general manager, lighting. "The additional offerings ensure that community officials can address the unique requirements of each roadway application while using less energy and providing enhanced visual comfort without the glare of street lights spilling into neighborhood properties at night."

The expanded series delivers luminous efficacy of up to 128lm/W, outperforming high-pressure sodium (HPS) solutions with up to 70% more energy savings and replacing HPS fixtures ranging up to 150W.

Utilizing Cree's WaveMax Technology, the RSW Series delivers improved color quality and efficacy while providing enhanced visual comfort with reduced glare and high color contrast, claims the firm. The RSW Series is also smart-city ready, enabled by a standard NEMA 7-pin.

Epistar files US patent infringement lawsuit against Lowe's

LED epiwafer & chip maker Epistar Corp of Taiwan's Hsinchu Science-based Industrial Park has filed a lawsuit in the US District Court for the Central District of California against Lowe's Companies Inc and Lowe's Home Centers LLC.

It alleges that the Kichler Lighting's LED filament bulbs sold by Lowe's — e.g. the Kichler Lighting 60W Equivalent Dimmable Soft White A15 LED Decorative Light Bulb (P/N: YGA16A08-A15C-CL-5W) — infringe claims of Epistar's US patents 6,346,771 'High Power LED Lamp', 7,560,738 'Light-Emitting Diode Array Having An Adhesive Layer', 8,791,467 'Light Emitting Diode And Method Of Making The Same', 8,492,780 'Light-Emitting Device And Manufacturing Method Thereof', and 8,587,020 'LED Lamp'.

It also alleges that Utilitech's LED bulbs sold by Lowe's — e.g. the Utilitech 60W Equivalent Warm White A19 LED Light Fixture Light Bulb (P/N: YGA03A41-A19-9W-830) — infringe one or more claims of Epistar's US patent numbers 8,492,780 'Light-Emitting Device And Manufacturing Method Thereof' and 8,587,020 'LED Lamp'.

www.epistar.com.tw

Pick your size.

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

Temescal
UEFC–4900

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

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

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

FerroTec

© 2015 Ferrotec (USA) Corporation. All rights reserved.
Temescal is a registered trademark and Auratus is a trademark of Ferrotec (USA) Corporation.

Cree's quarterly revenue drops 15% as US commercial lighting sales fall 12% short

Lighting business being right-sized to cut $8m in costs annually

For fiscal third-quarter 2017 (to 26 March), Cree Inc of Durham, NC, USA has reported revenue of $341.5m, down 7% on $366.9m a year ago and 15% on $401m last quarter (and at the low end of the targeted range of $340-370m).

"Our Wolfspeed and LED Products businesses performed at or above their targets for the quarter," notes chairman & CEO Chuck Swoboda.

Revenue for the Wolfspeed business (Power & RF devices and silicon carbide materials) was $56.1m (16% of total revenue), up 3.7% on $54m (13.5% of total revenue) last quarter and 29% on $43.7m (12% of total revenue) a year ago (and above the expected $55m).

Revenue for LED Products (chips and components) was $131.3m (39% of total revenue), above the targeted range due to better-than-expected demand (as well as also reducing distributor inventories). However, this is down 4.9% on $138m last quarter and down 3% on $135.5m a year ago.

Revenue for Lighting Products (mainly LED Lighting systems and bulbs) was $154m (45% of total revenue), down 26% on $208.9m last quarter and down 18% on $187.7m a year ago. This is 12% lower than targeted due to (1) the US commercial lighting market being seasonally slower than forecast (as was also reported by several other manufacturers) and (2) the win rate being lower on quoted projects due primarily to delays related to lingering effects of the third-party supplier driver issue that impacted product quality in fiscal Q2.

The lower commercial lighting revenue also resulted in under-utilization of Cree's factory which, along with the higher warranty reserves, caused a decrease in gross margin.

Lighting Products gross margin was 23%, down from 26% a year ago and 35.8% last quarter. LED Products gross margin has fallen further, from 31.6% a year ago and 29.2% last quarter to 24.7%, due to product mix and costs associated with ramp-up of the new LED chip. Wolfspeed's gross margin was 47%, down from 52.1% a year ago but better than targeted due primarily to improved factory productivity. Overall company gross margin on a non-GAAP basis was 25.9%, down from last quarter's higher-than-normal 32.7% but also down on 30.6% a year ago.

Due mainly to lower variable sales expenses associated with the lower commercial lighting sales, operating expenses were $2m lower than expected, at $94m.

The sale of the Wolfspeed business to Germany's Infineon Technologies for $850m was targeted to close during the quarter, but on 6 March the deal was formally terminated because the Committee on Foreign Investment in the United States (CFIUS) determined that the transaction could not be approved due to national security concerns. Results hence included two consequent items:
(1) Cree was required to record an income tax expense charge of $86m to establish a valuation allowance on its US deferred tax assets and other deferred charges;
(2) Cree recorded an additional $12m in expenses (net of tax), primarily associated with the resumption and catch-up of depreciation and amortization on Wolfspeed's long lived assets, partially offset by the $12.5m termination fee from Infineon.

Net income was $749,000 ($0.01 per diluted share), down from $29.9m ($0.30 per diluted share) and $17.2m ($0.17 per diluted share) a year ago. However, excluding the $10.3m ($0.10 per share) in resumption and catch-up of depreciation and amortization expenses related to the termination of the Wolfspeed deal, net income would have been $11.1m ($0.11 per diluted share), on the lower end of the targeted range of $10–18m ($0.10–0.18 per share).

Cash generated from operations was $43.4m (up from $15m a year ago). Capital expenditure (CapEx) was $24.7m. Free cash flow was hence $18.7m (an improvement on -$6.3m a year ago).

During the quarter, Cree spent $6m to repurchase 200,000 shares (making $104m on repurchasing 4.4 million shares in fiscal 2017 year-to-date). "With the termination of the Wolfspeed transaction, we have limited our stock buyback activity while we update our longer-term capital needs to support the targeted growth in Wolfspeed," says chief financial officer Mike McDevitt.

Overall during the quarter, cash and investments rose by $18m from $421m to $439m. At the end of the quarter, Cree had $153m outstanding on its line of credit.

"The factors that impacted our lighting business are temporary and we target improvement in all three businesses in Q4," says Swoboda.

For fiscal fourth-quarter 2017 (ending 25 June), Cree targets revenue of $340–360m, with sequential growth of 2% in Lighting Products (as growth in commercial lighting is offset by seasonally slower consumer sales) and 4% in LED Products, while Wolfspeed business is expected to be flat to slightly higher. "Our Wolfspeed business is currently limited by factory capacity, which we've already started to address," says McDevitt.

Gross margin should rise to 29%, driven primarily by Lighting (due mainly to a higher mix of commercial sales plus higher factory utilization) aided by incremental improvements in LED and Wolfspeed margins. ►

Operating expenses are expected to rise by $3m to $97m, due mainly to non-recurring costs associated with right-sizing the Lighting Products business plus start-up costs for the new joint venture Cree Venture LED Company Ltd.

"Given the current state of our Lighting business, we have re-evaluated the business to identify spending that is not aligned with our current growth strategy for this business," notes McDevitt. "During Q4, we are taking action to remove certain costs that are targeted to yield an $8m annual benefit [starting from fiscal first-quarter 2018]."

Cree is forming the joint venture Cree Venture LED Company Ltd with San'an Optoelectronics Company Inc of Xiamen, China to produce and deliver to market mid-power lighting-class LEDs in an exclusive arrangement to serve the expanding markets of North and South America, Europe and Japan. "We will be consolidating the joint venture's operations into our results and recording the JV's revenue and gross profit as part of our LED segment," says McDevitt. Also, Cree will receive a royalty for IP licensed to the JV, commissions for its LED sales force selling the JV's products, and reimbursement for administrative services performed on the JV's behalf.

For fiscal Q4, Cree expects an increase in net income to $2–7m ($0.02-0.07 per diluted share).

For full-year fiscal 2017, Cree targets capital spending of $95m, related primarily to infrastructure projects to support longer-term growth and strategic priorities. Target free cash flow is $120m.

"While we are still developing our capital investment and free cash flow targets for our fiscal 2018, we currently estimate the company will be free cash flow positive again in fiscal 2018," says McDevitt. "This is inclusive of the capital required to expand capacity for our Wolfspeed business, which is currently capacity constrained, but excludes capital required to support potential Lighting-related mergers and acquisitions (M&A)," he adds.

During fiscal Q4, the new Dmax LED chip platform will begin ramping into higher-volume production, which should provide some margin improvement in core high-power LED business in fiscal first-half 2018.

"The company is building a solid foundation for growth in all three businesses for fiscal 2018," says Swoboda. "The Wolfspeed business is doing well and is in a unique position to benefit from the market shift to silicon carbide power devices and gallium nitride RF devices as both a substrate and a device supplier. The LED business is making progress with new high-power LED technology and is now positioned to grow revenue by leveraging the new JV to also serve our customers' mid-power product needs. Our Lighting team is strengthening the fundamentals and laying the groundwork to grow revenue and profits in this business," he concludes.

www.cree.com

Cree and San'an forming Hong Kong-based JV to produce mid-power lighting-class packaged LEDs

Exclusive deal to serve North and South America, Europe and Japan, plus China and rest of the world on non-exclusive basis

LED chip, lamp and lighting fixture maker Cree Inc of Durham, NC, USA and Xiamen-based San'an Optoelectronics Co Ltd (China's largest producer of full-color ultra-high-brightness LED epiwafers and chips) are forming a joint venture Cree Venture LED Company Ltd to produce and deliver to market mid-power lighting-class LED packaged products in an exclusive arrangement to serve the expanding markets of North and South America, Europe and Japan, and serve China and the rest of the world on a non-exclusive basis.

Based in Hong Kong, Cree Venture LED Company Ltd will be led by general manager TK Ong (who has extensive experience in the LED market) and will be governed by a board of directors with members from both firms. Cree will own 51% of the JV, and San'an 49%.

Leveraging Cree's portfolio of patents and global sales channels, the JV aims to bring to market a broad portfolio of products to serve the fast-growing $4bn global mid-power LED market. Cree says that its LED business is now able to serve the broader needs of the general illumination (indoor and outdoor lighting), horticultural and other evolving LED markets.

"This joint venture builds on both companies' leading product and channel capabilities to give Cree the ability to provide our LED customers a complete range of high-power and mid-power LED products to serve a broad range of markets and applications," says Cree's president & CEO Chuck Swoboda.

"The addition of the mid-power LED products in this new joint venture to Cree's industry-leading high-power products gives us an unparalleled LED portfolio," reckons Cree LEDs senior VP & general manager Dave Emerson. "With our LED systems expertise, customers are able to work with our existing channels to find the best LEDs for their applications."

Cree and San'an will be working in the coming months to incorporate, fund and commence operations of the joint venture. Initial product sales are targeted for Q3/2017. Cree will receive royalties from the JV on its patent portfolio.

www.sanan-e.com/en

Osram Opto launches Oslon Black Flat S LEDs for adaptive automotive lighting

Osram Opto Semiconductors GmbH of Regensburg, Germany has launched the Oslon Black Flat S series, which is claimed to provide the first single-LED solution for adaptive front-lighting systems (AFS) in vehicles. AFS enables the direction of the light beam to adjust when cornering for example, providing optimal visibility by illuminating the side of the road in addition to in front of the vehicle. This also protects oncoming traffic from glare through the adaptive driving beam (ADB).

The Oslon Black Flat S series is claimed to comprise the first surface-mountable LEDs with up to five individually controllable chips. Switchable light segments enable oncoming traffic and traffic further ahead to be masked out, making driving more comfortable and safer. With improved thermal properties, the high-power LEDs offer system benefits and are suitable as an entry-level ADB solution even for vehicles in the compact class, reckons the firm.

"Increasing visibility and reducing glare, adaptive front-lighting systems like Adaptive Driving Beam enhance safety and comfort for both drivers and traffic participants," says product manager Thomas Christl. "ADB is one of the most advanced AFS developments. Drivers virtually drive with an always-on high-beam light distribution while other drivers on the road only experience low-beam glare," he adds. "With camera integration, ADB detects other vehicles or obstacles and either dynamically shadows out these vehicles in order to prevent glare or illuminates these obstacles to ensure safety."

The Oslon Black Flat S combines benefits from both the Oslon Black Flat package and Osram Ostar Headlamp package. Featuring Osram's new chip technology with notchless chips, optical design can be simplified and further brightness improvements are made possible.

The Oslon Black Flat S has an optimized layout of thermal pads that help to dissipate heat effectively, ensure light homogeneity and further improve second level reliability. As an surface-mount (SMT) package it is possible to integrate these new functionalities and improved features easily and cost-efficiently using standard SMT processes, claims the firm.

www.osram.com

SoraaLaser expands solid-state laser light source range

SoraaLaser of Goleta, CA, USA (a spin-off from LED lighting firm Soraa Inc that is commercializing visible laser light sources for display, automotive and specialty applications) has expanded its solid-state laser light source technologies.

Its new technologies include LaserLight-SMDs, LaserLight MicroSpot modules with various beam-shaped illumination, LaserLight Fiber modules with dynamic illumination, and LaserLight Fiber modules with remote micro luminaires. The light sources are said to provide performance properties and advantages over LED, OLED and legacy sources in specialty lighting applications.

In the last six months, the technology has been a finalist for a 2017 Prism Award, a finalist in the 2017 Sapphire Awards, and was included in the 2016 IES Progress Report as Illumineer of the Year.

The visible laser light sources are based on its patented semi-polar GaN laser diodes, combined with advanced phosphor technology. They are said to provide novel properties compared with other light sources by combining the benefits of solid-state illumination such as minimal power consumption and long lifetime.

SoraaLaser's visible laser light sources are used directly in single-color and RGB applications or integrated into laser pumped phosphor architectures.

www.soraalaser.com

Soraa expands into directional luminaires

Soraa is expanding into the directional luminaire market by launching Arc directional fixtures.

Designed around what is said to be the industry's slimmest-profile die-cast heat sink, Arc is optimized for thermal management.

Arc will initially be offered in track, pendant, downlight and surface-mounted designs as well as with fixture SNAP accessories, including trims, Snoot and wall washes in a variety of color temperatures including 2700K, 3000K and 4000K. All Arc luminaires feature Soraa VIVID COB light engines with full-spectrum 95CRI, R9>95 and Rw 100 typical. The 9°, 10° and 15° beam spreads are compatible with the Soraa SNAP system for further customizing beam and light color.

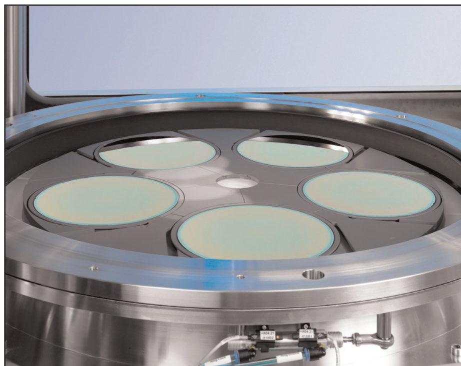
"Because we can now offer our customers a fully integrated, ultra-thin design with the added benefit of guaranteed compatibility and best-in-class dimming, we see specifiers beginning to re-think the way they design, by emphasizing rather than hiding luminaires," says George Stringer, senior VP of sales.

Osram Opto qualifies Aixtron AIX G5 C MOCVD system for GaN LED production

Deposition equipment maker Aixtron SE of Herzogenrath, near Aachen, Germany says that Osram Opto Semiconductors GmbH of Regensburg, Germany has qualified the first of multiple AIX G5 C planetary systems for manufacturing gallium nitride (GaN) LEDs.

Aixtron says that, as market demand for high-quality opto-electronics is increasing due to the continually growing number of applications in the illumination, sensing and visualization sectors (including automotive, communication, display, health and food), Osram Opto is expanding production capacities, for example at its Regensburg facility.

"We have chosen the AIX G5 C as it is one of the best-in-class for high-performance applications. The system offers the lowest defect and particle level to date due to its effective in-situ cleaning system and cassette-to-cassette handler, which is essential for high yields," comments Berthold Hahn, senior director LED Chip at Osram Opto. "Furthermore, Aixtron's advanced production tools allow best wavelength uniformity for reduced binning effort and therefore enables future technologies with very demanding uniformity requirements. Overall, the AIX G5 C provides leading edge blue and green LED processes that are necessary to meet our high quality standards in volume production for various lighting applications," he adds.



Aixtron's AIX G5 C reactor.

"We are looking forward to the further collaboration with one of the world's leading semiconductor manufacturers," says Dr Frank Schulte, vice president of Aixtron Europe. "Our AIX G5 C platform perfectly backs Osram's product strategy since it enables the manufacturing of devices that support future-oriented technology trends in the areas of mobility, communication and energy efficiency."

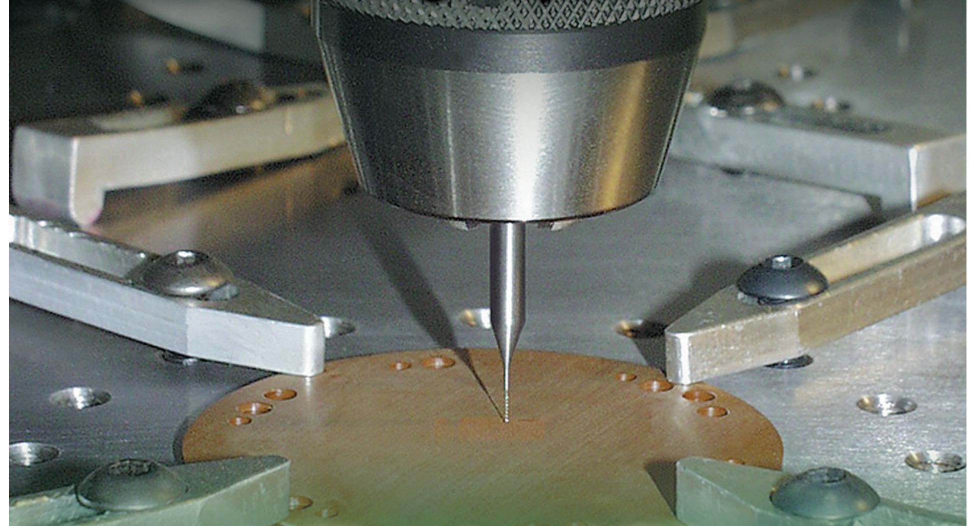
www.osram-os.com

www.aixtron.com

Burr-free

micro drilling

that meets your most demanding requirements.

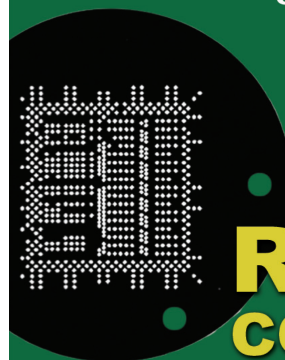


Drilling Capabilities

• all drilling and inspection performed under climate-controlled conditions

• micro drilling down to .0020" dia. and 10 times dia. in depth

• drilling of a wide range of materials, from plastics and ceramics to tool steel, aluminum, copper and brass



RIFF COMPANY, Inc.

1484 Highland Avenue • Cheshire, CT 06410 USA

Tel +1 203 272 4899 • micro-drilling@riff-co.com

www.riff-co.com

Sivers IMA acquiring CST Global

Wireless component supplier gains opto portfolio

Sivers IMA Holding AB of Kista, north of Stockholm in Sweden (a fabless supplier and developer of microwave and millimeter-wave components for WiGig/5G wireless and radio-frequency network applications) has agreed to acquire Compound Semiconductor Technologies Global Ltd (CST Global) of Hamilton (near Glasgow), Scotland, UK, a privately held company that designs and makes lasers and other semiconductor-based optical products.

CST Global was formed in 1999 by the universities of Strathclyde and Glasgow (together with Scottish Enterprise), specializing in the design, development and manufacture of III-V optoelectronic wafers and chips for the telecom, fiber, industry, defense and health sectors.

With the acquisition of CST Global, Sivers IMA's portfolio gains direct fiber-optic network products, including lasers used in data-center, cloud and 'fibre-to-the-subscriber' markets.

"Data usage and bandwidth needs are constantly increasing and, with this acquisition, Sivers IMA is now able to offer basic components in these growth areas," says Sivers IMA's CEO Anders Storm.

"Sivers IMA can now supply photonic, microwave and millimeter wave solutions for the rapidly expanding data-center, cloud and telecommunications markets in China, Europe and America," comments CST Global's CEO Neil Martin.

Sivers IMA intends to continue growing CST Global's product portfolio and customer base. In addition to XPON/GPON products focused on broadband, over the last year CST Global has developed datacoms products based on 100Gbps optical lasers, for the data-center and metro haul markets.

The acquisition is "an important part of our strategic plan to establish Sivers IMA as a leading global electronics component supplier within data and telecommunications," says Sivers IMA's chairman Björn Norrbom. "This is the first step in a larger plan in which we initially intend to apply for listing at Nasdaq First North, with the objective in the next step to transfer to the Nasdaq Stockholm main list," he adds.

The acquisition is an important part of our strategic plan to establish Sivers IMA as a leading global electronics component supplier within data-communications and tele-communications

"CST Global is delighted to be part of a growing company group focusing on microelectronics, microwaves and photonics," comments Martin. "This combination will give us a unique position on a rapidly growing and evolving market, in particular for data- and telecoms."

The purchase price consists of 27,924,998 newly issued shares in Sivers IMA to be delivered at closing. In addition, if CST Global's 2017 revenue exceeds £6.5m, an earn-out payment of up to 13,962,499 new shares will be issued (making 41,887,497 shares in total, corresponding to 50% of all shares in the company after the transaction). The volume-weighted average price per share of Sivers IMA during the last ten trading days prior to the agreement was SEK5.40, so the initial purchase price will amount to about SEK151m.

The acquisition is contingent on approval by more than half of the votes casted at Sivers IMA's extraordinary general meeting (EGM) and the authorization for the board to issue the new shares constituting the initial purchase price, that all shareholders loans to CST Global have been converted into shares, that certain undertakings regarding a 12 month lock-up period for the shares received in Sivers IMA have been given, that certain approvals from third parties has been obtained and that the CST Global's cash available will be at least £400,000.

For fiscal 2016 (to end-June 2016), CST Global generated revenues of about SEK40m, with a negative EBIT of about SEK8m. As a division within the Sivers IMA group, CST Global is expected to achieve a positive EBIT for full-year 2017. Preliminary revenues for first-quarter 2017 show year-on-year growth of 47% for CST Global, and 45% for Sivers IMA (albeit at negative EBIT).

Even if it is not yet profitable, the strong growth is a contributing factor to the additional need for funding, says Sivers IMA. Its board has therefore identified the need to add working capital and capital for investments for the joint entity, to meet an expected increase in demand and to support the goal of achieving profitability. The firm therefore intends to conduct a rights issue of about SEK80m as soon as possible after the transaction is completed.

www.cstglobal.uk

CST Global leads CoolBlue research project to develop next-generation GaN laser technology

III-V optoelectronic foundry Compound Semiconductor Technologies Global Ltd of Hamilton, Scotland, UK is taking the commercial lead on the 14-month research project 'Quantum Cooling using Mode Controlled Blue Lasers' (CoolBlue) — which started in April and is funded through the UK government's Engineering and Physical Sciences Research Council (EPSRC) — with Glasgow and Aston Universities as academic partners.

CoolBlue aims to develop next-generation GaN laser technology for use in atomic-cooled, quantum sensors. "Traditional laser sources have proven too complex and inefficient to produce commercially, in this application," says Thomas Slight, development engineer at CST Global and project lead. "However, direct blue laser diode sources offer increased power and simplicity, with the opportunity to miniaturize quantum sensor formats and produce them in a robust format. The CoolBlue project funds two cycles of laser design, fabrication and test, which we will do at CST Global, optimizing key laser parameters, including power," he adds.

Expertise generated during this project will allow CST Global to develop new products for the emerging GaN laser markets

"Expertise generated during this project will allow CST Global to develop new products for the emerging GaN laser markets," continues Slight. "The successful introduction of these products will create jobs. The additional revenues will be re-invested by CST Global into further, aligned, research projects. Commercialization of academic research by the Universities of Glasgow and Aston should also have a positive impact on further, similar, research opportunities and funding."

CST Global appoints vice president of operations

CST Global has appointed Gary Palmer as VP operations. He joins from Huawei-CIP.

Following a BEng(Hons) in Microelectronics from Glasgow Caledonian University, Palmer has held senior management and director roles during his 25 years working in the UK semiconductor industry (including for Intense, IQE Europe, NEC Semiconductors, Samsung Semiconductors and Anadigics Inc). He has worked in quality & reliability engineering, product engineering, project management and operations disciplines covering CMOS, III-V RF and III-V photonics and silicon, gallium arsenide and indium phosphide devices. He also has experience of supply into demanding consumer, automotive, aerospace, defence and telecoms markets.

Gary Palmer.

"As VP operations, I have responsibility for all of CST Global's foundry services, from epitaxial growth and fabrication, through to assembly and packaging," says Palmer, who highlights the challenge of taking III-V optoelectronic products from R&D into volume production, using lean manufacturing practice in a ISO 9001:2015 environment.

CST Global attains ISO 9001:2015 for the design, development and manufacture of optical devices

CST Global has attained ISO 9001:2015 accreditation for Quality Management Systems applicable to the design, development and manufacture of optical devices. The accreditation's scope adds exacting management processes and procedures to all 3" and 4" wafer fabrication and test processes.

"ISO 9001: 2015 demands that all management, production and test processes are measured and maintained. Responsibility for this is assigned to the CST Global management team," says quality control manager Gerald O'Connor. "We operate in a potentially hazardous environment, using many toxic materials. Validated risk assessments are essential, with continuous measurement of all processes a requirement. This includes the new MOCVD machine and the automatic bar stacker machine for 4" wafers. Many of our suppliers meet equivalent standards and, ultimately, it gives our customers total confidence in the quality of our products," he adds.

"ISO 9001: 2015 accreditation impacts every aspect of the company," notes CEO Neil Martin. "For its successful implementation, staff across the entire company must take responsibility for their individual part of the quality process," he adds. "CST Global can now supply market-leading companies in the data center, cloud and telecommunications markets, who expect this level of quality control."

www.cstglobal.uk

AIM Photonics strikes IP licensing deal with new consortium member IBM

IBM joins initiative to enable advanced packaging designs and manufacturing of photonic integrated circuits

The Rochester-based consortium AIM Photonics (American Institute for Manufacturing Photonics), an industry-driven public–private partnership advancing the USA's photonics manufacturing capabilities, has announced a patent and intellectual property licensing agreement with IBM, which has also joined the consortium.

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

AIM Photonics views this as another significant step in the advancement of the silicon photonics industry in upstate New York. AIM Photonics is part of the overall Finger Lakes Forward revitalization effort — the region's strategic plan for economic growth, which places an emphasis on the industry cluster of optics, photonics and imaging to realize the region's full potential and act as a core driver of jobs and output growth.

The collaboration between IBM and AIM Photonics is expected to provide a path for the development of new technologies and products that will solidify the consortium's position in the integrated photonics manufacturing ecosystem.

Also, the intellectual property licensing agreement with IBM should help AIM Photonics to establish standard processes in the development of silicon photonics assemblies, such as couplings for communication signals and light sources. Industry and academic AIM Photonics members will access these technologies through a process design kit (PDK) and prototype development at the Rochester Test Assembly and Packaging (TAP) facility and the 300mm chip facility at SUNY Poly's campus at Albany, NY.

One of AIM Photonics' primary goals is to make Rochester a technology hub for silicon photonics manufacturing and packaging, generating both growth and job opportunities for the city of Rochester, Monroe County, and the State as a whole.

"Adding IBM as a member of AIM Photonics not only significantly strengthens this outstanding institute, but highlights the momentum the Finger Lakes region is experiencing in the high-tech sector," comments John Maggiore, New York State photonics board of officers chairman.

Through its membership, IBM will contribute to the development of AIM Photonics' advanced integrated silicon photonics technology, packaging services, and other future offerings to make advanced technology available to AIM Photonics members and the wider technical community. Together with the other industry partners and the affiliated universities, IBM will help to direct advanced research activities of AIM Photonics towards new products.

"Working side by side with IBM photonic PIC and packaging experts is a significant milestone for AIM Photonics as we continue to advance our capabilities and prepare the TAP facility," states Dr Michael Liehr, AIM Photonics' CEO and SUNY Poly executive VP of Innovation & Technology and VP of Research.

Recently, at an AIM Photonics Technology summit during the Optical Networking and Communication Conference & Exhibition (OFC 2017) in Los Angeles (1–15 March), IBM's Dr Wilfried Haensch gave the presentation 'Advanced optical packaging for Integrated Silicon Photonics' to more than 100 conference attendees.

www.research.ibm.com/photonics
www.aimphotonics.com

REGISTER
for *Semiconductor Today*
free at
www.semiconductor-today.com

Kaiam acquires Compound Photonics fab in UK

Kaiam Corp of Newark, CA, USA — a private company founded in 2009 commercializing hybrid photonic integrated circuit (PIC) technology for pluggable optical transceivers in data-centers — has completed its acquisition of the manufacturing facilities of Compound Photonics Group Ltd (CP) in Newton Aycliffe, UK. The acquisition includes investment by CP into Kaiam to further develop the facility.

The Newton Aycliffe facility will enable Kaiam to significantly increase its manufacturing capacity for silica-on-silicon planar lightwave circuits (PLCs) and 40 and 100Gb/s transceivers, and adds both electronic and optoelectronic compound semiconductor devices to the firm's product line. The acquisition brings new space, tooling and an experienced team to complement and expand on Kaiam's existing large-scale manufacturing facility in Livingston, Scotland, UK. The new facility also allows Kaiam to produce indium phosphide (InP) photonic integrated circuits that will be needed for advanced transceivers in the future. This continues Kaiam's strategy of vertical integration that began with its acquisition of the PLC fab of Gemfire in Livingston in 2013.

The Newton Aycliffe facility is 300,000ft^2 and includes a fully operational wafer fab with 100,000ft^2 of cleanroom space for processing, packaging, and testing III-V devices. The factory currently ships gallium arsenide devices and circuits, and has the capability for InP optoelectronics. Originally built as silicon fab for DRAM memory chips, the plant was converted to III-V materials by subsequent acquirers and now has both 3" and 6" lines for III-V devices.

"The Newton Aycliffe facility is a strategic acquisition that gives us both increased manufacturing scale and vertical integration. We already fabricate our MEMS and PLC devices on silicon, and purchase discrete modulated lasers and detectors as sources and receivers," says CEO Bardia Pezeshki. "However, future transceivers that run at higher speed and use complex modulation formats will require integrated photonic elements that are highly differentiated, and will not be readily available in the market. This new facility will give us this essential PIC capability, positioning us well to meet our customers' needs for continuously improving speed, cost, power, density, and manufacturing scale," he adds.

"We welcome Kaiam, an international corporation that has already found success in the UK," comments Dr Simon Goon, managing director of economic development company Business Durham. "I am pleased that this semiconductor manufacturing capability is to be retained in County Durham, and that it will continue to grow the photonics industry in the UK."

www.kaiam.com
www.compoundphotonics.com

TowerJazz announces silicon photonic foundry process

Specialty foundry TowerJazz has announced a new silicon photonic process (SiPho) that complements its silicon germanium (SiGe) BiCMOS processes utilized for manufacturing optical transceiver electronics.

TowerJazz is also collaborating with PhoeniX Software B.V. of Enschede, The Netherlands — a vendor of photonic design automation (PDA) software used to synthesize integrated photonic circuits — to provide process design kits (PDKs) for customers developing optical networking and data-center interconnect applications. Silicon photonics holds the potential to become a cost-effective, scalable technology for the production of photonic integrated circuits (PICs) and addresses the high-performance requirements of these applications, says TowerJazz.

The firm's foundry SiPho process is built to enable a wide range of optical fiber interconnect Tx and Rx front-end optical ICs. The process includes several versions of single-mode silicon waveguides, high-speed germanium photodetectors, p-n junction modulators and enablement for edge and grating couplers.

PhoeniX's OptoDesigner 5.1 PIC design solution uses a unique 'photonic synthesis' process to map design intent into a design-rule clean circuit layout targeted to TowerJazz's SiPho process. Designers can use OptoDesigner's parametric object oriented scripting environment and its integrated photonic simulators to optimize their designs to achieve an optimal layout that meets their performance and design requirements while also ensuring robust design manufacturability.

"We are excited to be entering the silicon photonics foundry space in order to provide solutions to a greater portion of the optical transceiver market for our customers," says Dr Marco Racanelli, senior VP & general manager of TowerJazz's RF & High Performance Analog business unit. "As a pure-play foundry, design enablement plays a critical and complementary role to the manufacturing process… PhoeniX Software has extensive experience in the silicon photonics space to bring high-value PDKs to our customers," he adds.

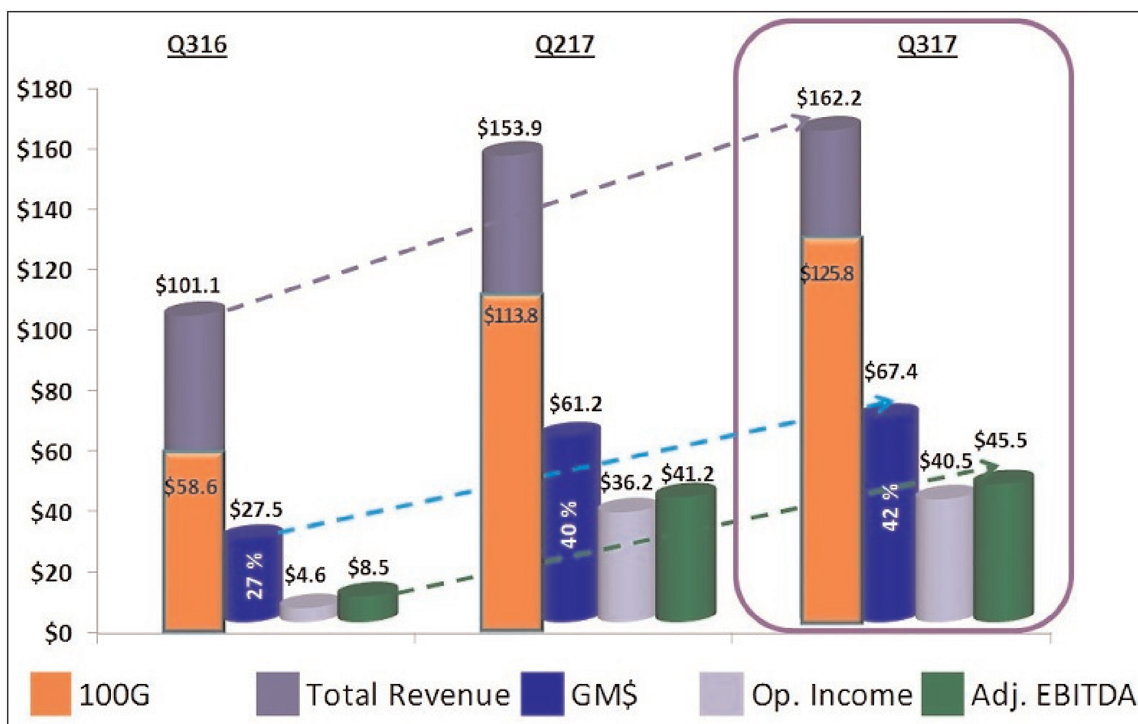
"PDK-based design is key to achieving greater designer productivity and we are very excited to be working with TowerJazz to make their SiGe BiCMOS PDKs available to the datacom market," says PhoeniX's CEO Twan Korthorst. TowerJazz offers "world-class production capabilities to our mutual customers in the integrated photonics market." PDKs for SiPho will be available in third-quarter 2017.

www.towerjazz.com
www.phoenixbv.com

Oclaro quarterly revenue up 60% year-on-year, yielding record gross margin and operating income

China slowdown to drive June-quarter revenue down 10%, before September-quarter return to growth

For its fiscal third-quarter 2017 (to 1 April), Oclaro Inc of San Jose, CA, USA (which provides components, modules and subsystems for optical communications) has reported revenue of $162.2m, up 5% on $153.9m last quarter and up 60% on $101.1m a year ago. There was growth in all areas of business (especially 100G-and-beyond products) in what is normally a seasonally weak period.



Oclaro's revenue, gross margin, operating income and adjusted EBTDA for fiscal Q3/2017.

Sales for 100G-and-beyond products were $125.8m (78% of total revenue), up 11% on last quarter's $113.8m (74% of total revenue) and up 115% on $58.6m (58% of total revenue) a year ago, driven by newer line-side and client-side products such as shipments of the CFP2-ACO transceiver and the emerging QSFP28 transceiver product family into the metro and data-center markets.

Sales for 40G-and-below products were $36.4m (22% of total revenue), down 9% on last quarter's $40.1m (26% of total revenue) and $42.5m (42% of total revenue), due to the expected reduction in legacy 10G product shipments. However, there was good sales growth of 10G tunable transceivers (for which demand is expected to remain strong).

Datacom (client-side) sales rose by 9% sequentially (to $76m, of which $18m was 40G-and-below and $58m was 100G-and-above), driven by the continuing ramp-up of QSFP28 products, supplementing the mostly CFP-based product sales. Telecom (line-side) sales grew by 3% sequentially as metro and data-center interconnect (DCI) sales continue to expand.

"We also achieved further customer and regional diversification, driven by sales growth in North America and Europe," says CEO Greg Dougherty. Oclaro's 10%-or-greater customers represented 59% of sales compared to 68% last quarter, with the same top four customers contributing 18%, 17%, 12% and 12% respectively. Of total revenue, China comprised 36% (down from 42%, as sales fell by 9%) and Southeast Asia 22% (down from 26%), while the Americas comprised 28% (up from 21%) and Europe, Middle East & Africa (EMEA) 12% (up from 10%).

Gross margin and operating income were both records, despite the impact of annual price negotiations (since price reductions were towards the more favorable end of the usual 10–15% range).

On a non-GAAP basis, gross margin has risen further, from 27.2% a year ago and 39.8% last quarter to a record 41.6% (above the 36–39% guidance), due to a richer 100G product mix (more new products and less from CFP) and greater scale as Oclaro further leveraged its manufacturing overhead.

Operating expenses have risen from $22.9m a year ago and $25m last quarter to $27m (although this has been cut from 23% to just 17% as a proportion of sales).

Operating income has risen further, from just $4.6m (5% of sales) a year ago and a record $36.2m (24% of sales) last quarter to $40.5m (25% of sales), exceeding the $32-36m guidance.

Likewise, net income has risen from just $3.3m ($0.03 per diluted share) a year ago and $36.3m ($0.21 per diluted share) last quarter to $39.9m ($0.23 per diluted share).

Adjusted EBITDA (earnings before interest, taxes, depreciation and amortization) was $45.5m (up from ►

$41.2m last quarter and $8.5m a year ago). Hence, after subtracting capital expenditure (CapEx) of $21.7m (up further, from $17.2m last quarter) and working capital (including prepaid expenses) of $12.5m (up from $9.8m), overall cash, cash equivalents, restricted cash, and short-term investments rose by $11.3m during the quarter, from $243.5m to $254.8m.

For fiscal fourth-quarter 2017 (to 1 July), Oclaro expects revenue to fall by about 10% to $144–152m. Despite the lower revenue, gross margin should be 38–41%, although operating income is expected to fall to $27–31m.

The drop in revenue is due to:
(1) a significant slowing of demand in China seen in April;
(2) an accelerated transition from the 100G CFP transceiver family to the smaller QSFP28 form-factor platform for client-side optics; and
(3) an expected 20-25% decline ($7–9m) in 40G-and-below business.

"In April, we were informed by both of our major Chinese customers that demand would be even slower than previously anticipated for Q4," notes Dougherty. "The majority of the projected Q4 impact is coming from one customer. This customer cited both the reduction in demand for the Chinese market as well as an inventory correction… due in part to the corporate mandate for better cash flow. Most of the 10G and 100G products that we ship to this customer are expected to be impacted," he adds. "The reductions were smaller at the other customer and primarily involved just two product codes. We have very good visibility with this customer, based on a supply agreement that runs through the end of this calendar year."

Demand for client-side CFP transceivers peaked in the March quarter. "We are seeing a significant falloff for these products in Q4 [of about 20% sequentially]," notes Dougherty. "This is again mainly caused by China, but we are seeing a similar impact in select router customers in North America," he adds. "This transition is driving the demand for QSFP28 LR4, where we are well positioned and ramping our capacity. We currently expect our QSFP28 sales to double in Q4 and continue to grow throughout this calendar year."

The drop in 40G-and-below business comprises:
(1) the slowdown in China; and
(2) the planned end of life of the firm's 40G telecom products (with the ending of shipments in the March quarter leading to an expected $3m reduction in revenue in the June quarter).

"The fundamental demand drivers in China remain intact. We anticipate growth from the region to return again later this year from metro and provincial networks deployment," Dougherty says. "Another future growth driver for China will be the deployment of 5G wireless technology. China is driving to be the first country to deploy 5G and is targeting 2019 to do so. 5G will require extensive 100G plus coherent networks as well as new higher-speed back-haul and front-haul connection," he adds. "In addition to the higher speeds, these networks will require the transceivers to operate over industrial temperature ranges because they will be held outdoors in uncontrolled environments." At the Optical Fiber Communications conference & exhibition (OFC 2017) in Los Angeles in late March, Oclaro announced the availability of its industrial-temperature 25G and tunable transceivers for this application. "We are uniquely positioned to be successful in this new very large emerging market," Dougherty believes.

"We have become less reliant on China as we have diversified our customer base," stresses Dougherty. "While China will likely not recover until later in this year, we do believe that the strength in the metro and data-center markets [which are driven rather by North America and now also Europe] will allow us to resume our growth in the September quarter… driven by increases in our CFP2 ACO and QSFP28 sales. The ACO continues to be the platform of choice for metro and data-center interconnects and, as a result, we have significantly diversified our customer base. We continue to be the market leader and have numerous multi-year supply agreements in place. Inside the data center, we are experiencing success with our QSFP28 family. One key aspect is that our products are able to interoperate with other companies' QSFP28 products as well as the installed base of CFP products. Customers are valuing this intra-operability more and more, strengthening Oclaro's market position," he adds.

Regarding near-term CapEx, Oclaro expects to invest $20–25m per quarter to expand manufacturing capacity for QSFP28, CFP2-ACO and tunable laser production, leading to additional depreciation of about $1m per quarter over the calendar year.

"As we look at the evolution of optics within the data center, we see a strong push for higher speeds," says Dougherty. Oclaro demonstrated its 400G data-center product at March's OFC 2017, and is currently shipping its CFP8 PAM4 transceiver and developing next-generation 400G PAM4 small-form-factor solutions such as the QSFP 56 double density and the OSFP (octal small-form-factor pluggable) transceivers. "These products are all enabled by our industry-leading 56G InP laser technology. Higher and higher speeds play very well to Oclaro strength, and we expect to be a leader in 400G optic," he adds. "Despite the near-term headwinds, given our technology leadership in 100G and beyond, we remain bullish about the prospects for future growth in the markets that we serve."

For calendar full-year 2017, Oclaro expects revenue growth of about 20% on 2016, and gross margin to remain in the upper 30s to 40% range. Coupled with 18–20% operating expenses, this should yield sustainable operating income as a percentage of sales in the high teens to low-20s.

www.oclaro.com

Emcore's quarterly revenue grows by 8% to $32.6m, driven by greater-than-seasonal CATV sales

End of Beijing facility transition to lower break-even and boost margins

For its fiscal second-quarter 2017 (to end-March), Emcore Corp of Alhambra, CA, USA — which provides indium phosphide (InP)-based optical chips, components, subsystems and systems for the broadband and specialty fiber-optics markets — has reported revenue of $32.6m, up (in what is normally the seasonally softest quarter) by 8% on $30.2m last quarter and by 51% on $21.5m a year ago (and above the guidance of $29–31m).

Of total revenue, cable TV comprised 80–85%, chips 5–10%, Satcom 5–10%, and fiber-optic gyro products (FOG) about 2.5%.

Cable television revenue grew 9% quarter-on quarter and 107% year-on-year. Of this, RF-over-glass (RFoG) product shipments grew more than expected from a small base, while DOCSIS 3.1 product revenue held steady relative to fiscal Q1 in what is normally a seasonally low quarter, countering the typical seasonal softness usually seen in the cable business.

Emcore also saw nominal growth for its Satcom & video product line. Fiber-optic gyro revenue fell, driven by the timing of customer orders.

Merchant chip revenue rose as much as 51% quarter-on-quarter (continuing the strongest sector performance over the past four quarters), contributing solid gross margins.

On a non-GAAP basis, gross margin has risen from 33.2% a year ago and 33.6% last quarter to 34.4%. This was despite the adverse impact of a heavier one-time mix towards the low-margin end of the RFoG product family (marking the end of a model changeover) plus $340,000 in expenses from the relocation of the firm's Beijing manufacturing operations from the existing facility to a new automated facility.

"While Q2's RFoG heavy mix created an incremental headwind to the gross margins, we kept our operating expenses for those products below the corporate average, allowing them to contribute to operating profit and margin," notes president & CEO Jeff Rittichier.

Operating income has risen further, from just $0.6m a year ago and $3.5m last quarter to $3.7m (operating margin of 11.4%, at the high end of the 9.5–11.5% guidance), despite the Beijing transition costs plus heavy R&D investment. Without these, operating income would have been closer to $4m (12.4% of revenue), near to the fiscal Q4/2017 operating margin target of 12.5%.

Pre-tax income was $3.7m ($0.14 per diluted share), up from $3.5m ($0.13 per diluted share) last quarter and $0.02 per diluted share a year ago.

Capital expenditure (CapEx) has been cut back from last quarter's $3.2m to a more normal $1.3m as the Beijing facility transition nears completion. Depreciation was $0.9m. Free cash flow was strong, at $5.2m. During the quarter, cash and cash equivalents rose from $62.2m to $68.6m.

"We transitioned production to our new Beijing facility; opening the door to even more efficient operations going forward," says Rittichier. "The combination of strength in the CATV market, a more efficient manufacturing platform and growth in other high-profit-margin products gives us confidence that we will exceed our target of 12.5% non-GAAP operating margin commitment."

The combination of strength in the CATV market, a more efficient manufacturing platform and growth in other high-profit-margin products gives us confidence that we will exceed our target of 12.5% non-GAAP operating margin

For fiscal third-quarter 2017 (to end-June), Emcore expects revenue to fall to $29–31m (without the one-off $3m in low-end RFoG units in fiscal Q2), despite continued strength in the infrastructure side of cable TV business (driven by a resumption in growth for DOCSIS 3.1 products). Operating margin should be 11–13% (en route to the target of 15% exiting fiscal 2018). Going forward, RFoG shipments will primarily consist of more sophisticated, higher-margin products.

Within the Satcom and video market, Emcore started restructuring its product line over a year ago and is starting to see the benefits from those actions. "We just completed the discontinuation of our video products, which carried excessive engineering costs, and cut out over 60% of the product options for our Satcom product line as well," notes Rittichier. With the introduction of new low-cost L-band links, technologies for 5G radio over Fiber DAS are focused on larger Satcom systems. "We expect profits to grow faster than revenue in these product areas," says Rittichier. "With all that final testing transitioned to our EMS [electronics manufacturing services] partners in the US complete, we believe we are in a good position to realize incremental operating leverage in these product lines," he adds.

All captive CATV-related manufacturing has now been shifted to the new Emcore Asia automated facility (inside the 5th Ring in Beijing). Over the next 3 months or so, the remaining automation equipment will be installed (reducing direct headcount from a peak of 370 last ►

December to about 100). This may cause some additional transition cost in the quarter (about half the level of fiscal Q2). "Even as our Chinese facilities are being transformed, our US operations shifted postcode simulation test and sort operations as well as chip-on-block assembly to EMS providers as well," says Rittichier. "Combined with the changes in our Satcom manufacturing strategy, these actions will result in our breakeven point declining by $1–1.5m per quarter. We should see some impact from these changes in our numbers this quarter, but will fully realize the benefits in Q4," he adds.

"This manufacturing transformation is not really the end point," Rittichier continues. "Over the past year, two of our Six Sigma Green Belt projects have given us the ability to automatically tune CATV transmitters with high accuracy and minimal touch time. The deep learning project was particularly insightful in raising our understanding of profit dynamics. When combined with new automation techniques, we've achieved 90%+ reduction in touch time per unit. We are going to move transmitter tuning to the EMS providers to eliminate transportation, inventory, carrying cost and to further improve cycle time," he adds. "Over the next year, we expect to devote a majority of our Six Sigma Green and Black Belt projects to wafer fab operations, where we will not only improve our standard process controls but build the process nodes that will launch new generations of chip products for both captive and emerging markets. We see the fab as a key area for investments in both in terms of capital and the world-class technologist we need as we work to improve our ability to both execute and invent."

Regarding merchant chip business, for GPON, Emcore is only going to supply 2.5G products (mainly from inventory) to customers that are multi-generational. "It's really the 10G targets that are going to get 2.5G attention from us when and if they need it… We are not going to be running around in China selling small amounts of this and that," says Rittichier. "Early indications from our customers remain very positive for our 10G parts, while we continue product development work on parts to address data-center markets," he adds. "With our OFC announcements, we marked the availability of 6.5GHz 5G wireless devices, and expect to continue the development of those products," continues Rittichier. "We also received additional customer orders in the GPON market, which we can fill from stock, in Q3 and Q4. At a high-level, we expect our penetration into these markets will drive a higher blended margin for both our chip business and for the company overall."

www.emcore.com

Emcore launches 10G laser and photodiode chips for next-gen PON

At the Optical Fiber Communications trade show (OFC 2017) in Los Angeles (21-23 March), Emcore Corp of Alhambra, CA, USA — which provides indium phosphide (InP)-based optical chips, components, subsystems and systems for the broadband and specialty fiber-optics markets — showcased a variety of new 10Gbps distributed feedback (DFB) laser and avalanche photodiode (APD) chips designed for XG-PON, XG-EPON and NG-PON2 passive optical networks. The firm expects its new chips to represent a price/performance breakthrough for OLT (Optical Line Terminal) and ONU (Optical Networking Unit) applications.

The latest G1013 series of 10Gbps top- and bottom-illuminated APD and PIN photodiode chips have high responsivity, low capacitance, low dark current and are designed for low-cost, high-speed data communication receiving in fiber-optic networks. The top-illuminated models are available as tested die. The bottom-illuminated coplanar APD and PIN photodiodes are tested to be mounted on a chip-on-block (COB) for ease of assembly into receiver modules. Emcore will soon introduce companion 10G laser chips with wavelength options of 1270nm, 1310nm and 1550nm. The firm's 10G chips feature advanced digital chip design, a wide operating temperature range of –40ºC to +85ºC, high optical output power, and are Telcordia Technologies 468 and RoHS-compliant.

"With these latest advancements in our 10G chip product line, we are poised to continue our growth as a merchant supplier of high-performance chips for a wide range of applications in the telecom market and beyond," says president & CEO Jeffrey Rittichier. "In addition to next-gen PON applications, these latest chip offerings have application in 4G LTE+ and emerging 5G wireless networks."

Emcore's chip-level devices are designed and manufactured at its InP wafer fabrication facility in Alhambra, which features metal-organic chemical vapor deposition (MOCVD) reactors for 3x3" or 6x2" wafers, plus stepper, wafer track, RIE (reactive ion etching), diffusion, metal and dielectric deposition, and cleaving and dicing equipment in a class 1000 cleanroom.

The firm claims to be the only chip supplier with a complete product portfolio of laser, avalanche photodiode and PIN photodiodes with an in-house wafer fab. The facility also functions as the firm's anchor for vertically integrated manufacturing of its laser, transmitter and receiver products.

www.ofcconference.org
www.emcore.com

Manz sells CIGS PV research subsidiary for €50m to partners Shanghai Electric and Shenhua, forming NICE PV Research JV

Manz to begin work on major orders following €79m downpayment

Equipment maker Manz AG of Reutlingen, Germany (which has three Solar, Electronics and Energy Storage strategic business units, and supplies integrated production lines for solar cells and modules) has received €50m for its subsidiary Manz CIGS Technology GmbH. Until April, Manz CIGS Technology GmbH operated as an independent research company in copper indium gallium diselenide (CIGS) thin-film solar technology within Manz AG.

Last November, as part of a strategic cooperation deal, Manz and its partners Shanghai Electric Group (one of China's largest equipment manufacturing conglomerates, and Manz's anchor investor) and Shenhua Group Corporation Ltd (reckoned to be the world's largest coal supplier, which in 2015 adapted itself to China's strategic focus on clean energy development) decided to establish a joint research company. The agreement specified that Manz's research company would be incorporated into the new firm. The corresponding contracts were signed in January. The deal also included orders totaling €263m placed at Manz AG. The transaction was approved by Chinese authorities in mid-April. Manz CIGS Technology GmbH has now been incorporated into the newly created company NICE PV Research Ltd, in exchange for €50m from Shanghai Electric and Shenhua.

NICE PV Research began its research operations as planned in April. Its aim is to speed the development of CIGS technology in order to leverage the potential for further increases in photovoltaic efficiency and further reductions in manufacturing costs.

Finalizing the transaction means that Manz will soon begin work on the major orders that it has received. The agreed downpayment of €79m is expected to be made in May.

www.manz.com

Midsummer launches CIGS BIPV metal roof systems

Together with Swedish metal roofing firm Clix Steel Profile AB, Midsummer AB of Järfälla, near Stockholm, Sweden — a provider of turnkey production lines for manufacturing flexible, lightweight copper indium gallium diselenide (CIGS) thin-film photovoltaic (PV) solar cells — has launched a complete solution for building-integrated photovoltaic (BIPV) metal roof systems.

Midsummer has developed a rapid process for the production of flexible thin-film solar cells using sputtering of all layers of the solar cell, allowing scalable and cost-effective manufacturing of thin film solar cells.

Midsummer has teamed up with Clix Steel Profile, which has developed a metal roof system that is certified for slopes as low as 5°. The system has a unique fixing principle for its steel sheets and pricing that is reckoned to be competitive for both DIY and professional use.

"The roof plates are produced with integrated lightweight flexible panels using any type of coated steel," says Midsummer's CEO Sven Lindström. "The lightweight, flexible panel from Midsummer is integrated already at the factory, thereby reducing installation time and cost," he adds.

Each panel is mounted on the roof plates using a high-performance elastomeric butyl adhesive tape designed to provide excellent tack and adhesion under outside condition in the field. The standing seam roof is then installed by linking the roof plates together in one step. Finally, the PV modules are connected to a system with standard connectors. All connectors and junction boxes are hidden under the ridge capping and well protected for snow and ice. It can easily be accessible if necessary. There are no visible connectors, cables or junction boxes when the roof installation is complete.

Midsummer says that it continues to develop its unique method for manufacturing flexible thin-film CIGS solar cells on individual stainless-steel substrates. Its versatile DUO deposition tool is now a proven commercial product and its R&D focus has been on increased cell efficiency, lightweight flexible modules, and integration of these modules into roofing elements.

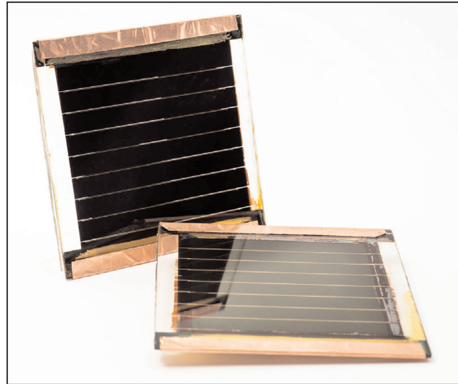
www.midsummer.se
www.clix.se

Imec and Solliance boost efficiency for 4cm x 4cm perovskite PV module to 12.4%

Eight cells connected in series using low-area-loss interconnection

As a partner in Solliance — a cross-border Dutch–Flemish–German thin-film photovoltaic (TFPV) solar energy R&D consortium in the ELAT (Eindhoven–Leuven–Aachen) region — nanoelectronics research center imec of Leuven, Belgium has improved its 4cm x 4cm perovskite PV module, achieving a certified solar energy conversion efficiency of 12.4% (amongst the highest for this size of perovskite module). The module efficiency was measured under long-term maximum power point (MPP) tracking, testifying to its stability. At Solliance, this perovskite technology is developed with industrially applicable processes and with a view towards rapid market introduction.

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



The perovskite modules were made at imec using an advanced recipe for the active layer and a process that achieves a very high aperture-area efficiency in combination with high operational device stability. In the existing design, eight cells are connected in series by using a low-area-loss interconnection technology based on laser and mechanical patterning. Due to this optimization, about 90% of the designated illumination area of 16cm^2 contributes to energy generation. The device stability and performance is exhibited by the 12.4% power conversion efficiency under more than 10 minutes maximum power point tracking, as certified by Fraunhofer ISE.

"This breakthrough achievement confirms that we are able to steadily improve the conversion efficiency of perovskite solar modules," says Tom Aernouts, Solliance program manager and group leader for thin-film photovoltaics at imec. "In a few years time, we have made rapid progress not only on conversion efficiencies for single cells but are now also consolidating this at module level for this type of thin-film photovoltaics," he adds. "Looking ahead, within Solliance we've set an aggressive roadmap for larger-area low-cost processing and long-term stability that will advance this technology beyond the lab."

Imec is developing its industrial R&D platform for perovskite modules in the framework of Solliance, which conducts research on the development of perovskite-based PV modules and its applications, with industrial partners Solartek Ltd of Troitsk, Moscow, Russia, Dyesol Ltd of Sydney, Australia and Panasonic of Japan.

Imec showcased its silicon and perovskite photovoltaic technologies at the SNEC 11th International Photovoltaic Power Generation events (PV Power 2017) in Shanghai, China (19–21 April).

www.snec.org.cn
www.imec.be
www.solliance.eu
www.dyesol.com

Solar Frontier's CIS solar panels installed at Shell headquarters buildings in Thailand

Tokyo-based Solar Frontier — the largest manufacturer of CIS (copper indium selenium) thin-film photovoltaic (PV) solar modules — says its CIS thin-film solar panels have been installed at two buildings at the Shell headquarters in Thailand. The project was constructed by Energy Pro Corporation Ltd, a Thai solar power engineering, procurement & construction (EPC) specialist that has worked with Solar Frontier on multiple other projects.

Solar Frontier's CIS thin-film solar panels are 119.68kW in size and are installed on two rooftops of Shell House HQ in Bangkok. Expected annual power generation is 179,479kWh and all power generated will be for self-consumption, leading to an expected level of CO_2 reduction of 104 tons over the first year.

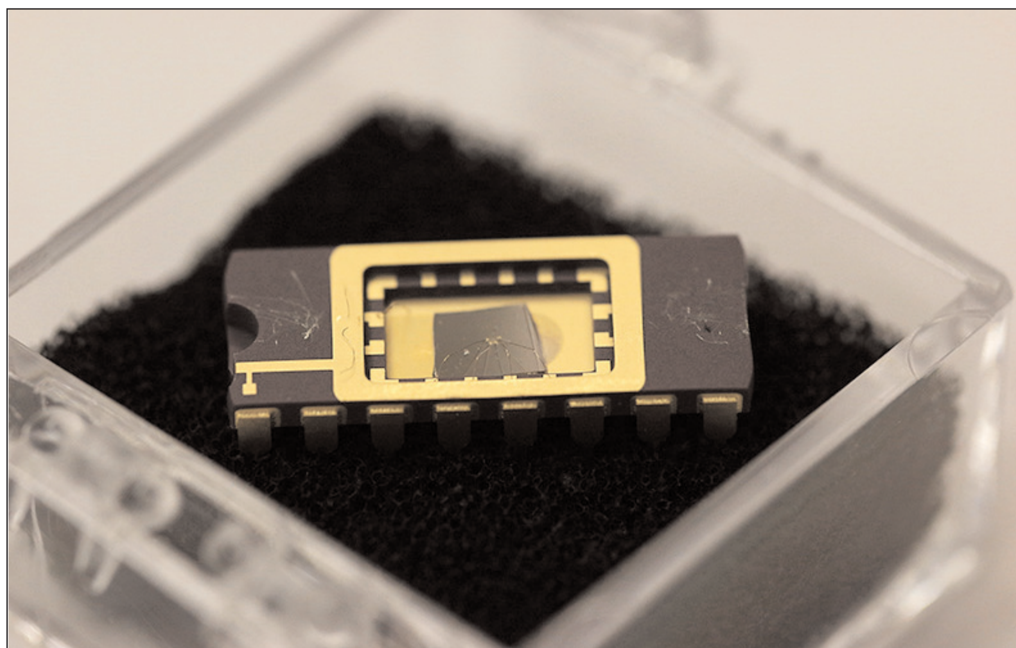
"This initiative follows from a similar program last year where we had solar panels installed on the roofs of two of our Shell retail stations in Thailand," says Asada Harinsuit, chairman, The Shell Companies of Thailand, and VP, Retail East. "We see our efforts here as helping to contribute to Thailand's renewable energy goals as well as to reducing Shell's CO_2 levels across our organization."

www.solar-frontier.com

Graphene phototransistor promises high-performance optoelectronics

Position-dependent and millimeter-range photodetection has been achieved using micron-scale graphene on SiC.

A team of researchers at Purdue University, the University of Michigan and Pennsylvania State University claims to have solved a problem hindering the development of highly sensitive optical devices made of graphene, which could enable applications ranging from imaging and displays to sensors and high-speed communications (Biddut K. Sarker et al, 'Position dependent and millimeter-range photodetection in phototransistors with micron-scale graphene on SiC', Nature Nanotechnology; published online 10 April 2017, DOI: 10.1038/nnano.2017.46).



Graphene field-effect transistor (GFET) developed at Purdue University. (Purdue University image/Erin Easterling.)

As an extremely thin layer of carbon with extraordinary optical and electronic properties, graphene is a promising material for high-performance optoelectronics. However, typical graphene-based photodetectors have only a small area that is sensitive to light, limiting their performance.

The problem has now been solved by combining graphene with a comparatively much larger silicon carbide (SiC) substrate, creating graphene field-effect transistors (GFETs), which can be activated by light, says Yong Chen, a Purdue University professor of physics & astronomy and electrical & computer engineering, and director of the Purdue Quantum Center.

High-performance photodetectors might be useful for applications including high-speed communications and ultra-sensitive cameras for astrophysics, as well as sensing applications and wearable electronics. Arrays of the graphene-based transistors might enable high-resolution imaging and displays.

"In most cameras you need lots of pixels," says Igor Jovanovic, a professor of nuclear engineering and radiological sciences at the University of Michigan. "However, our approach could make possible a very sensitive camera where you have relatively few pixels but still have high resolution," he adds.

"In typical graphene-based photodetectors demonstrated so far, the photoresponse only comes from specific locations near graphene over an area much smaller than the device size," says Jovanovic. "However, for many optoelectronic device applications, it is desirable to obtain photoresponse and positional sensitivity over a much larger area."

The new findings show that the device is responsive to light on a non-local scale, even when the SiC substrate is illuminated at distances greater than 500μm from the graphene. The photoresponsivity and photocurrent can be increased by as much as 10 times, depending on which part of the material is illuminated. The new photo-transistor is also position-sensitive, so it can determine the location from which the light is coming (important for imaging applications and for detectors).

"This is the first time anyone has demonstrated the

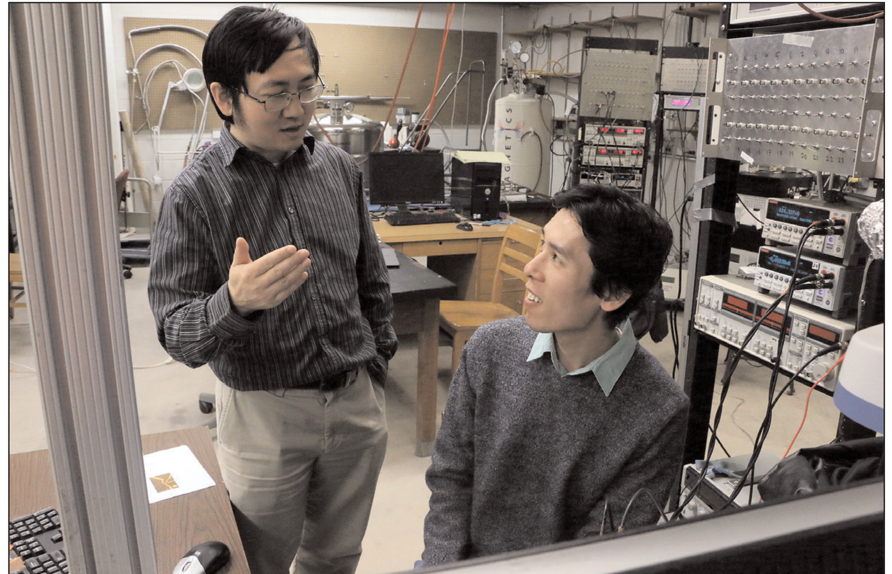
use of a small piece of graphene on a large wafer of silicon carbide to achieve non-local photodetection, so the light doesn't have to hit the graphene itself," Chen says. "The light can be incident on a much larger area, almost a millimeter, which has not been done before."

A voltage is applied between the back side of the silicon carbide and the graphene, setting up an electric field in the silicon carbide. Incoming light generates photo-carriers in the SiC.

The research is related to work to develop new graphene-based sensors designed to detect radiation, and was funded with a joint grant from the US National Science Foundation (NSF) and the US Department of Homeland Security plus another grant from the Defense Threat Reduction Agency.

"This particular paper is about a sensor to detect photons, but the principles are the same for other types of radiation," Chen notes. "We are using the sensitive graphene transistor to detect the changed electric field caused by photons — light in this case — interacting with a silicon carbide substrate."

Light detectors can be used in scintillators, which are used to detect radiation. Ionizing radiation creates brief flashes of light, which in scintillators are detected by photo-multiplier tubes (a roughly century-old technology). "So there is a lot of interest in developing advanced semiconductor-based devices that can achieve the same function," Jovanovic says.



Yong Chen (left) a Purdue University professor of physics and astronomy and electrical and computer engineering, and graduate student Ting-Fung Chung. (Purdue University image/Erin Easterling).

The team also explains their findings with a computational model. The transistors were fabricated at the Birck Nanotechnology Center in Purdue's Discovery Park.

Future research will include work to explore applications such as scintillators, imaging technologies for astrophysics, and sensors for high-energy radiation. ■

www.nature.com/nnano/journal/vaop/ncurrent/abs/nnano.2017.46.html
www.physics.purdue.edu/people/faculty/yongchen.php
www.engin.umich.edu/college/about/people/profiles/f-to-j/igor-jovanovic

REGISTER
for *Semiconductor Today*
free at
www.semiconductor-today.com

Monolithic III-V transistors and laser diodes integrated on germanium

Researchers see work as a milestone on the path towards enabling low-power and high-speed optoelectronic integrated circuits.

Researchers based in Singapore and USA claim to have developed the first monolithic integration of indium gallium arsenide (InGaAs) field-effect transistors (FETs) and electrically pumped InGaAs/GaAs multiple quantum well (MQW) laser diodes on germanium (Ge) substrate using direct epitaxial growth [Annie Kumar et al, Optics Express, vol25, p5146, 2017].

The team from National University of Singapore (NUS) and Nanyang Technological University (NTU) in Singapore and Massachusetts Institute of Technology (MIT) in the USA sees its work as a milestone on the path towards enabling low-power and high-speed optoelectronic integrated circuits (OEICs).

The researchers hope for potential applications in on-chip optical interconnects, giving higher speed, lower interconnect energy, and higher interconnect density than is possible through metal electron conduction.

Molecular beam epitaxy (MBE) was carried out on 6°-offcut Ge. The use of germanium substrates

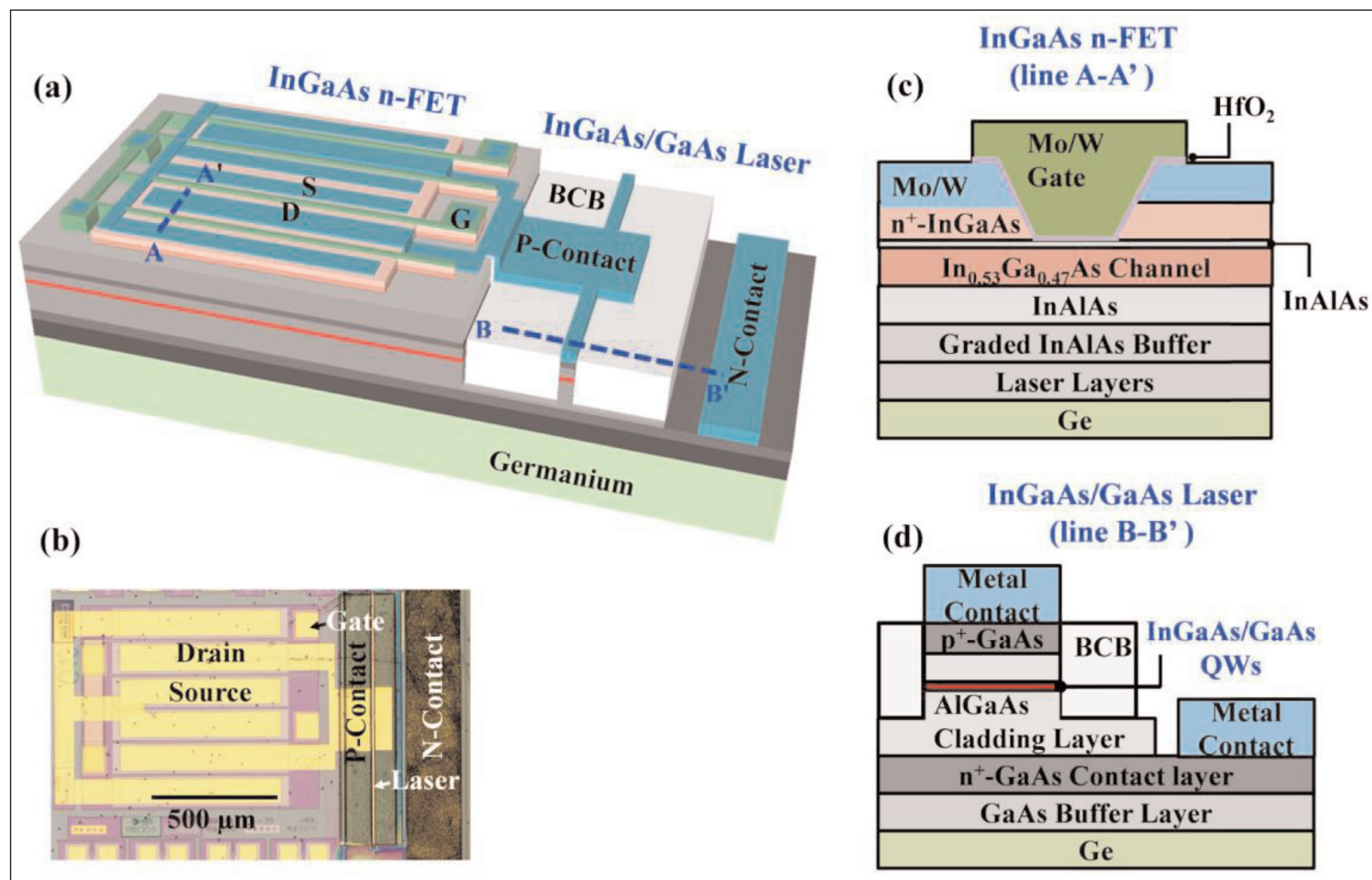


Figure 1. (a) Schematic of monolithic integration of InGaAs n-FETs with lasers. (b) Optical microscope image of optoelectronic integrated circuit with multiple finger InGaAs FETs driving laser.(c) Cross-sectional schematic of fabricated InGaAs FET along line A-A′ in (a). (d) Cross-sectional schematic of fabricated InGaAs/GaAs laser along line B-B′ in (a).

reduces lattice mismatch with GaAs, compared with silicon, reducing threading dislocations and defects. The first III-V deposition was 10 monolayers of 300°C migration-enhanced epitaxy (MEE) GaAs. The initial deposition was designed to reduce defects related to anti-phase boundaries in the crystal structure.

Next, 500nm of 580°C n^+-GaAs was deposited as the n-contact layer, followed by three GaAs/AlGaAs superlattice layers applied with the aim of suppressing threading dislocations propagating into the laser heterostructure, which began with 1.7μm aluminium gallium arsenide ($Al_{0.4}Ga_{0.6}As$) bottom cladding.

The MQW active region consisted of three 8nm $In_{0.2}Ga_{0.8}As$ wells and 20nm GaAs barriers. The waveguide region consisted of AlGaAs graded-index separate-confinement heterostructures above and below the MQW with the aluminium content ranging from 0.05 and 0.40. The top cladding was 1.2μm of $Al_{0.4}Ga_{0.6}As$. The p-contact consisted of 400nm p^+-GaAs.

Subsequent transistor layers were a 800nm graded InAlAs buffer with indium content ranging from 0.1 to 0.52, a 15nm $In_{0.53}Ga_{0.47}As$ channel, a 2nm $In_{0.52}Al_{0.48}As$ etch-stop layer, and 30nm of a n^+-$In_{0.53}Ga_{0.47}As$ cap. The graded InAlAs buffer was designed to bridge between the lattice constants of the laser and transistor layers.

Transistors were fabricated metal-first with molybdenum source–drain electrodes. Tungsten was used to protect the molybdenum from oxidation during dry etch of the channel region with a silicon dioxide hard mask. After removal of the tungsten and molybdenum, the channel was wet etched down to the 2nm InAlAs stop layer.

The gate stack consisted of 6nm atomic layer deposition (ALD) hafnium dioxide dielectric insulator and sputtered molybdenum and tungsten metal electrode. The gate was patterned and dry etched. Electrical isolation was achieved with a mesa wet etch. The transistor was protected during laser fabrication with a layer of plasma-enhanced chemical vapor deposition (PECVD) silicon dioxide.

For the laser diode, the waveguide ridge was wet etched while the facets were formed with dry etch. The n-contact was formed from annealed gold/nickel/gold/germanium/nickel layers. The device was passivated and planarized with benzocyclobutene (BCB). The p-contact metal was gold/titanium.

The researchers hope for potential applications in on-chip optical interconnects, giving higher speed, lower interconnect energy, and higher interconnect density than is possible through metal electron conduction

The researchers report on the low thermal budget silicon CMOS-compatible fabrication: "The highest temperature used in the entire process flow was 400°C to maintain the high quality of QWs and reduce the possible inter-diffusion of the QW layers."

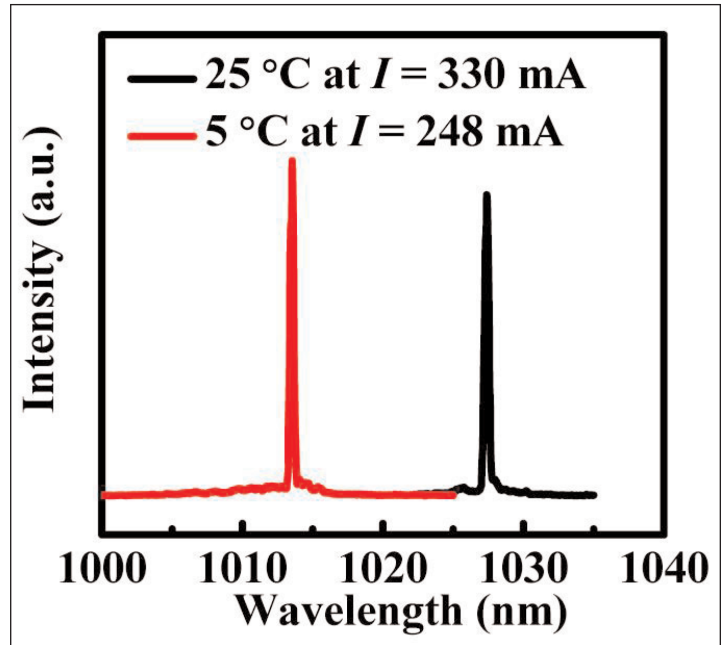


Figure 2. Lasing spectra of diode at 5°C and 25°C.

A 4.5μm-channel nFET had a subthreshold swing of 93mV/decade and an on/off current ratio of more than four orders of magnitude (i.e. 10^4). The drive current at 1.5V gate potential above threshold (overdrive) was 200μA/μm at 1.5V drain bias.

The capacitance equivalent thickness of the gate insulator was 2nm. A negative impact on the device performance was a large source–drain series resistance of 4.7kΩ-μm, which the researchers believe can be reduced by boosting doping of the n^+-InGaAs layer and reducing contact metal sheet resistances.

A device with 21μm-long channel had a peak effective field mobility greater than 2000cm^2/V-s, according to split capacitance-voltage measurements. When the inversion carrier density was $10^{13}/cm^2$, the mobility was 900cm^2/V-s.

The laser diode had an on/off current ratio of more than seven orders of magnitude. The lasing threshold current for a 1mmx24μm laser diode was 210mA (875A/cm^2) at 5°C, under pulsed operation. The room-temperature threshold was 1.25kA/cm^2.

At room temperature, the laser peak wavelength was 1027nm at 330mA injection. This represents a red-shift on photoluminescence emission at 978nm. The researchers suggest that heating during laser operation reduces the bandgap and hence increases the wavelength. The linewidth of the laser peak was 1.7nm. The 5°C measurements gave a short laser wavelength around 1014nm at 248mA with the same linewidth. ■

www.osapublishing.org/oe/abstract.cfm?uri=oe-25-5-5146

Author: Mike Cooke

Semi-polar InGaN laser diode/ waveguide photodiode combination

Researchers see integrated device as leading to on-chip power monitoring, visible light communication, and photonics platform

Researchers based in Saudi Arabia and USA have integrated a waveguide photodetector (WPD) with a 405nm laser diode (LD) using free-standing semi-polar gallium nitride (GaN) technology [Chao Shen et al, Appl. Phys. Express vol10, p042201, 2017]. The semi-polar material reduces electric fields in aluminium indium gallium nitride (AlInGaN) heterostructures that arise from differences in charge polarization of the chemical bonds between the elements. Reducing these fields avoids the detuning between InGaN multiple quantum wells (MQW) laser diode emission and photodetector absorption spectra seen with polar c-plane heterostructures.

The team from King Abdullah University of Science and Technology (KAUST) in Saudi Arabia, University of California Santa Barbara (UCSB) in the USA, and King Abdulaziz City for Science and Technology (KACST) in Saudi Arabia see the integrated device as leading to on-chip power monitoring, visible light communication (VLC), and the implementation of III-nitrides as a photonics platform. Using laser diodes, rather than light-emitting diodes (LEDs), gives benefits in terms of efficiency droop and modulation bandwidth for solid-state lighting and VLC applications.

The epitaxial structure (see Figure 1) was grown on $(20\bar{2}\bar{1})$ GaN by metal-organic chemical vapor deposition (MOCVD). The MQW structure was four periods of 3.6nm/7nm $In_{0.1}Ga_{0.9}N$/GaN wells/barriers. The electron-blocking layer (EBL) was 18nm p-type aluminium gallium nitride (p-$Al_{0.18}Ga_{0.82}N$). The separate-confinement heterostructures (SCHs) were 120nm p/n-InGaN. The cladding layers were 600nm p-GaN and 350nm n-GaN. The contact layers were heavily doped p- and n-type to give ohmic contacts with the palladium/gold and titanium/aluminium/nickel/gold respective contact metallization.

The material was structured into a 505μm-long laser diode with a 90μm-long WPD at its rear facet. The

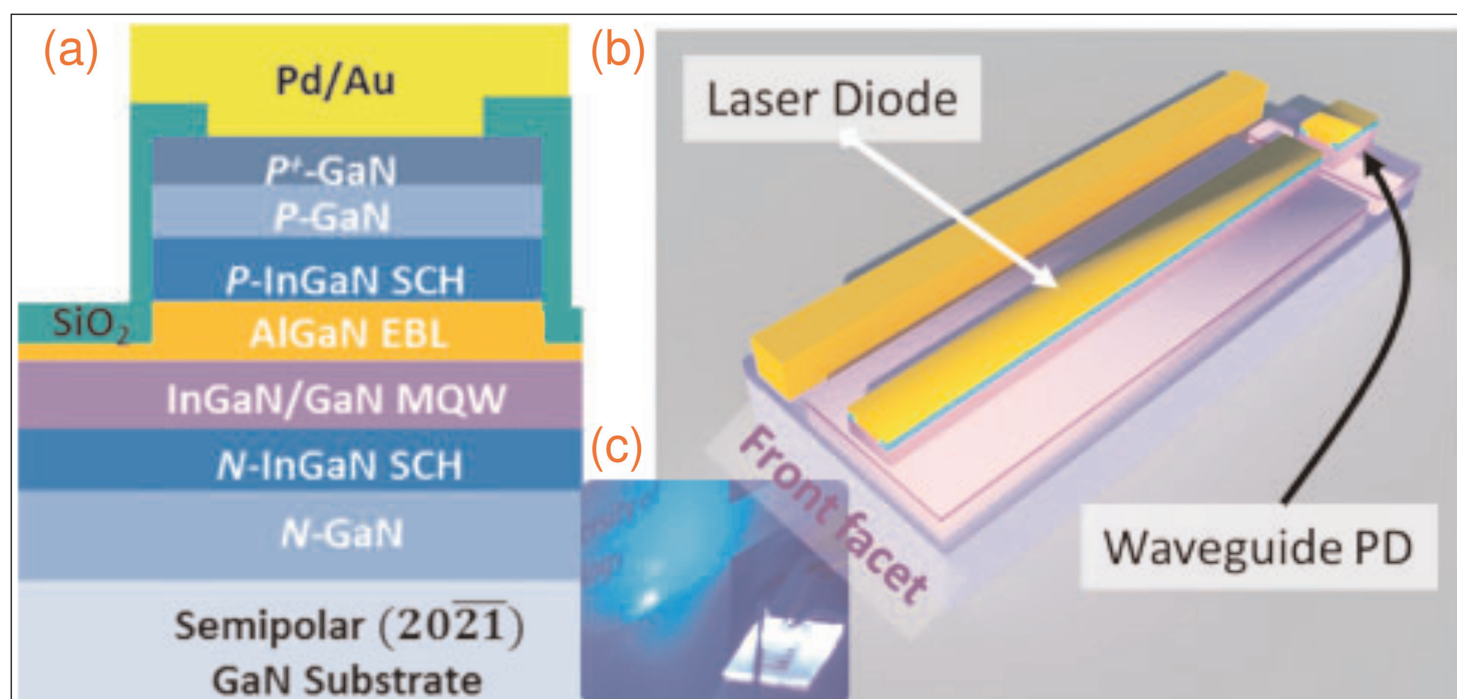


Figure 1. (a) Epitaxial layer structure, (b) schematic of InGaN/GaN MQW based WPD-LD, and (c) photo of laser emission from front facet of WPD-LD.

device separation was 5µm. The etched ridge waveguide was 2µm wide. An isolation trench was fabricated by focused ion-beam milling. The facets were uncoated. The electrical isolation of the devices was around 1MΩ, "more than five orders of magnitude higher than the junction series resistance, enabling the independent operation of the two components," according to the researchers.

The laser diode had a 130mA threshold and 0.4W/A slope efficiency, as determined by a standard calibrated silicon photodetector, with continuous wave (CW) operation at room temperature. The output from the WPD at zero bias followed the performance of the laser diode closely, allowing its use as an on-chip power monitor.

Reverse biasing the WPD resulted in increased response by increasing the depletion region where photons were absorbed, generating a photocurrent. Tests were carried out with pulsed currents on the laser diode to avoid self-heating. At 200mA injection, the laser diode produced WPD currents of 63.5µA, 80.7µA, 112.3µA and 130.4µA under respective reverse biases of 0V, 2V, 4V and 6V. The photocurrent/optical input power responsivity of the WPD increased from 0.018A/W to 0.051A/W as the reverse bias increased from 0V to 10V.

The researchers comment: "Considering the fact that the WPD and LD share the same active layer design without the need of epitaxial re-growth, the presented WPD outperforms other PDs utilizing InGaN/GaN QWs on c-plane-orientated substrates (0.001–0.01A/W at 450nm) for simultaneous light emission and detection. The high responsivity of the WPD is attributed to the enhanced overlap between the absorption peak of the WPD and the emission peak of the LD. The enhancement in the overlap originates from a reduced polarization field in QWs grown on a semi-polar GaN substrate."

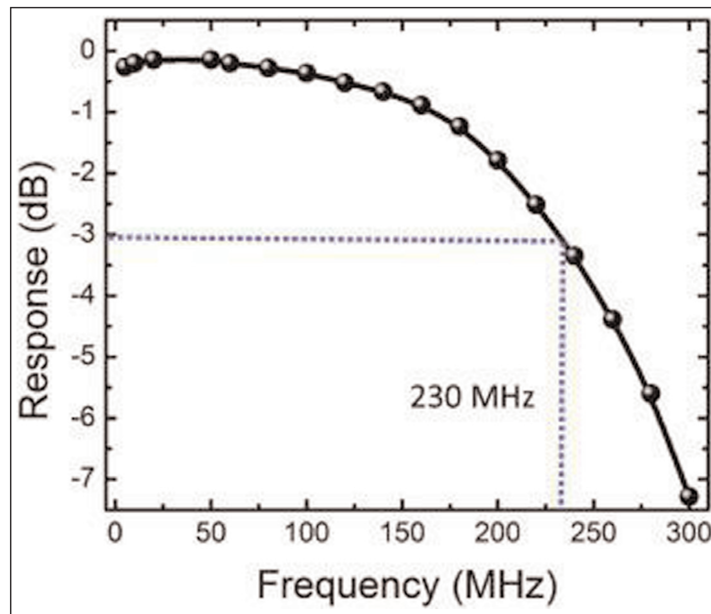


Figure 2. Modulation response of WPD at zero bias.

The frequency response of the system with unbiased WPD was also measured (Figure 2). The 3dB bandwidth was 230MHz. The researchers attribute the bandwidth to the WPD, since laser diode bandwidth was known to be above 1GHz. Despite this, the waveguide photodetector bandwidth improves on values reported for GaN Schottky barrier photodiodes (5.4MHz) and GaN p–i–n photodiodes (10–20MHz).

The team comments: "The increased cutoff frequency of the WPD is associated with the reduced device size owing to the narrow ridge design and the improved responsivity of the semi-polar plane WPDs. The high-speed WPD suggests its potential as an integrated receiver for on-chip communication and VLC applications." ■

https://doi.org/10.7567/APEX.10.042201

Author: Mike Cooke

REGISTER
for *Semiconductor Today*
free at
www.semiconductor-today.com

Towards polarized white light with tunnel junctions and hybrid growth

UCSB has fabricated a semi-polar InGaN device emitting blue and yellow light from electroluminescence and optical pumping.

University of California Santa Barbara (UCSB) has used a combination of metal-organic chemical vapor deposition (MOCVD) and molecular beam epitaxy (MBE) to produce semi-polar indium gallium nitride (InGaN) devices that emit polarized blue and yellow light [Stacy J Kowsz et al, Optics Express, vol25, p3841, 2017].

The researchers hope that developing these concepts could lead to white light sources with polarized emissions that would reduce power consumption in liquid crystal displays (LCDs). Presently, LCDs use unpolarized backlighting that must be filtered by a polarizer, cutting the energy throughput by more than a half. The use of semi-polar InGaN material can lead to polarized light emission.

The UCSB device consisted of two sequences of multiple quantum wells (MQWs). The bottom sequence comprised a blue light-emitting diode (LED) that optically pumped the top MQW structure to give an added yellow component to the spectrum.

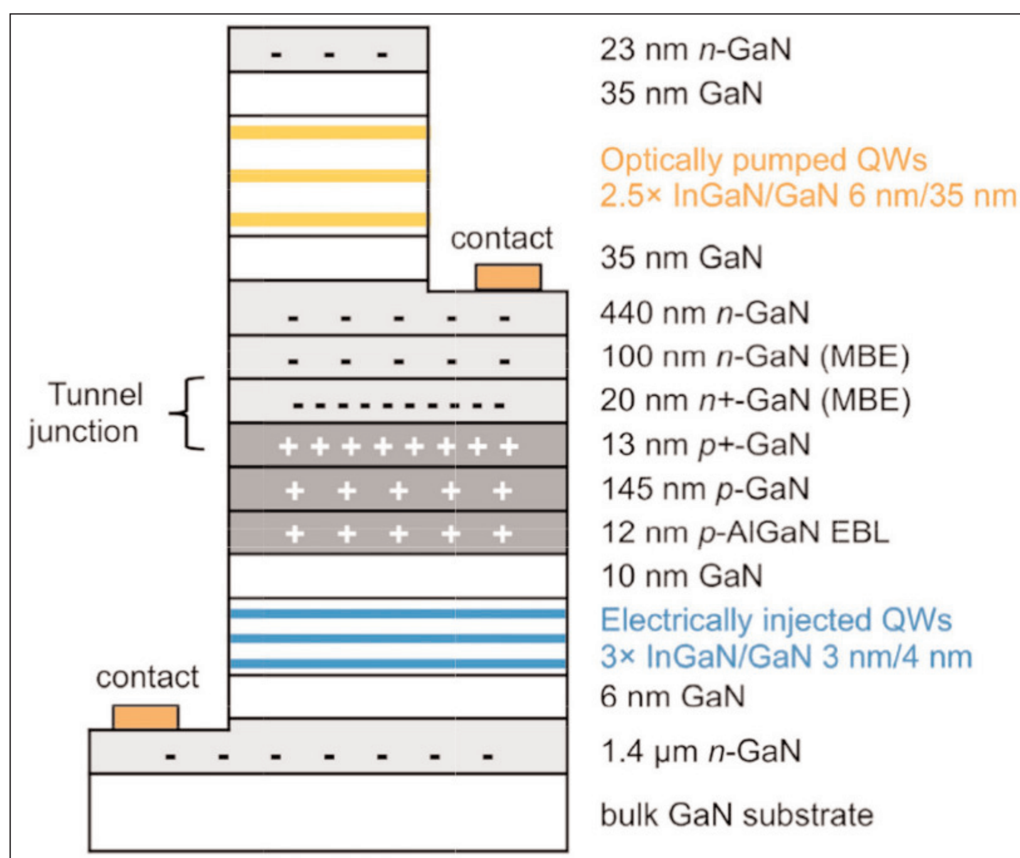


Figure 1. Cross-sectional schematic of device with optically pumped QWs on top of electrically injected QWs.

The LED structure also had a tunnel junction (TJ) layer that was designed to improve current spreading, giving a more uniform current density through the device. "Metal-organic chemical vapor deposition enabled the growth of InGaN QWs with high radiative efficiency, while molecular beam epitaxy was leveraged to achieve activated buried p-type GaN and the TJ," the team comments.

Current spreading is often achieved with transparent conductive oxides or thin metal layers. However, these options absorb more light than the n-GaN used in the TJ.

The use of a tunnel junction allows the high indium-content InGaN QWs needed for the longer-wavelength yellow emission to be grown at lower temperature, after the high-temperature processes needed for good electrical performance of the blue LED section.

The LED layers were grown by MOCVD. Activation of the p-GaN magnesium doping involved annealing to remove hydrogen that forms a complex with magnesium. Ammonia-assisted MBE was used to create tunnel junctions with sharp p^+/n^+ interfaces. The MBE n-GaN also blocks hydrogen diffusion from the subsequent MOCVD QWs into the p-GaN layers.

For pure MOCVD, there is a memory effect where growing n-GaN layers after p-GaN results in the silicon-

doped n-GaN being contaminated with Mg. Also, oxygen has been found to be beneficial in tunnel junctions — it is thought that the oxygen donates electrons, reducing tunneling distance.

The 600°C Mg-activation annealing was carried out in air, resulting in residual surface oxidation, before transport to the MBE reactor for growth of the tunnel junction. The optically pumped MQWs were grown by MOCVD after exposing the structure again to air. The second MOCVD sequence was carried out at relatively low temperature except for the first 200nm of n-GaN. Mitsubishi Chemical Corp supplied the 7.5mmx7.5mm free-standing semi-polar (20$\bar{2}$1) bulk GaN substrates for the devices.

LEDs were fabricated with a 1.8μm-high 0.1mm^2-area circular mesa and a ring injection area for the bottom n-GaN contact layer. The tunnel junction was contacted with a separate 300nm etch of a 3.2μm-radius circular hole at the 0.1mm^2 mesa's center. The contact metals were 450°C-annealed titanium/aluminium/nickel/gold. The backside of the wafer was polished to prevent scattering and to preserve the optical polarization of the light emitted from the strained semi-polar InGaN QWs.

The turn-on voltage for the devices was higher than for LEDs and pn diodes with tunnel junctions produced by UCSB previously using similar techniques. "We expect that improved electrical characteristics for optically pumped and electrically injected TJ devices can be achieved by optimizing the TJ and n-contacts," the team comments.

The emission consisted of a relatively narrow blue peak at 450nm and a broader peak around 560nm. The mix of components depended on the position of the microscope used to gather emissions. Optical polarization measurements gave an overall ratio of 0.28 along the directions [1$\bar{2}$10] and [10$\bar{1}\bar{4}$]. The blue LED polarization ratio was 0.2 and the yellow optically pumped MQW ratio was 0.36.

The researchers report: "The polarization ratio of the yellow QWs is greater than the polarization of blue QWs because increasing the InGaN indium content

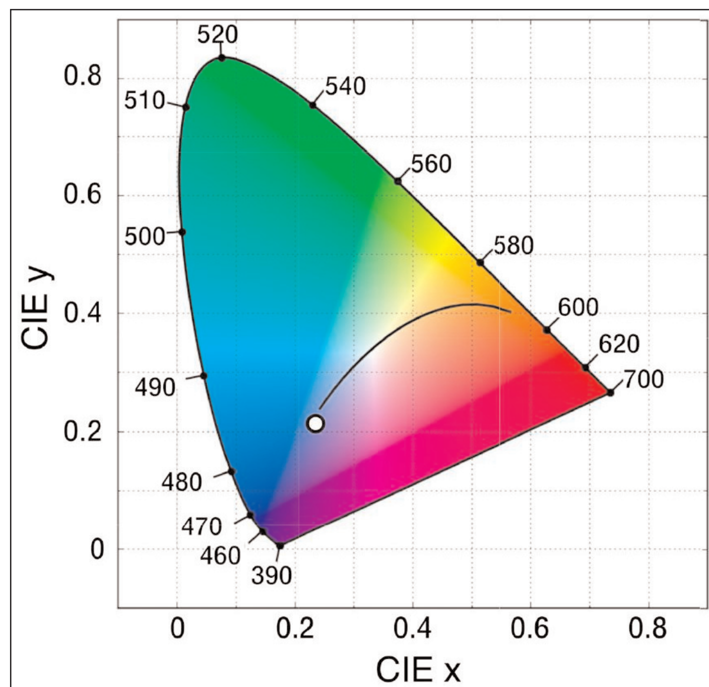


Figure 2. CIE x, y chromaticity diagram with coordinates corresponding to UCSB device spectrum.

increases strain, which results in separation of the valence bands."

The light output from the device has a similar spectral profile as that from 'white' LEDs that use a blue light emitter combined with yellow phosphors. On the chromaticity diagram, the 1931 CIE x,y coordinate standard value, (0.23,0.21), lies at the end of the Planckian locus (Figure 2).

The researchers comment: "Increasing the ratio of yellow to blue emission in future devices should enable spatially uniform phosphor-free polarized white light. Moreover, increasing the absorbance, radiative efficiency, and/or number of optically pumped QWs will increase the ratio of yellow to blue emission. Incorporating a dichroic coating with high blue reflectance and high yellow transmittance also will allow for control over the ratio of yellow to blue emission." ■

https://doi.org/10.1364/OE.25.003841

Author: Mike Cooke

REGISTER
for *Semiconductor Today*
free at
www.semiconductor-today.com

Getting the best cost and performance out of GaN-on-silicon devices

Mike Cooke looks at recent research to realize better-performing and more complex transistors and diodes.

Gallium nitride (GaN) transistors and diodes are being developed for power electronics applications with a view to replacing the present pure silicon components. The wide bandgap of GaN offers opportunities to increase carrier saturation velocities, mobility and density, along with higher critical electric field for higher breakdown voltages. However, these opportunities will only be realized if GaN-based devices can be produced at sufficiently low cost to compete with silicon alternatives.

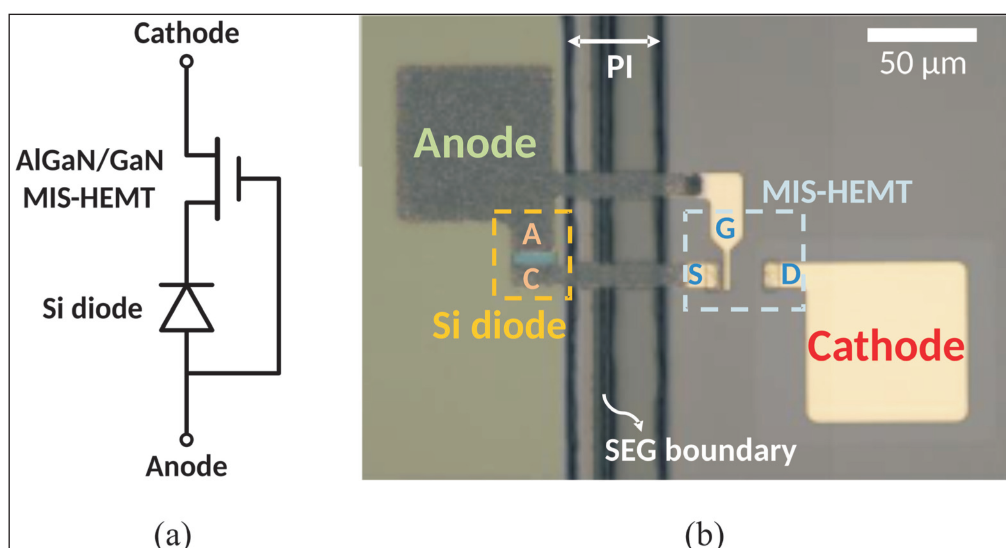


Figure 1. (a) Circuit schematic and (b) top-view image of cascoded diode.

An obvious route to less expensive devices is to use III-nitride materials grown on large-diameter silicon substrates, which costs a fraction of the amount needed to buy more conventional — and smaller-diameter — substrates such as sapphire, silicon carbide (SiC) or free-standing GaN. Another cost-cutting technique is to increase device density, improving wafer utilization efficiency.

Here, we look at some recent research to realize better-performing and more complex GaN power electronics on silicon substrates.

Cascode diode

Hong Kong University of Science and Technology (HKUST) has developed a high-voltage monolithic cascode diode combination (Figure 1) of silicon (Si) pn diode and normally-on aluminium gallium nitride (AlGaN) barrier metal-insulator-semiconductor high-electron-mobility transistor (MIS-HEMT) [Jie Ren et al, IEEE Electron Device Letters, vol38, p501, 2017].

"Compared with conventional AlGaN/GaN [Schottky barrier diodes (SBDs)], the cascoded diode can provide much lower reverse leakage current due to the superior voltage-blocking capability of the MIS-HEMT and the low leakage of the Si diode," the researchers comment.

The researchers also see the monolithic integration work as leading to smaller effects from parasitic inductance, resistance or capacitance compared with systems assembled from a number of discrete parts. "Large parasitics will cause circuit ringing during fast switching, resulting in system instability," they add. Further potential advantages include reduced system size and production cost.

The devices were fabricated on 4-inch (111) Si substrates (Figure 2). A 300nm layer of silicon dioxide was formed, which was etched to form a mask for the recessed window. Further etching created a 4mm-deep region for selective epitaxial growth (SEG). More silicon dioxide was deposited as a sacrificial layer that was then removed to smooth the bottom silicon surface in the recessed windows.

A new 1.5mm SiO_2 SEG mask was applied before metal-organic chemical vapor deposition (MOCVD) of a 280nm AlN nucleation layer, a 1.1µm step-graded AlGaN buffer, a 2.7µm GaN buffer, a 100nm GaN channel, a 1nm AlN spacer, 20nm $Al_{0.3}Ga_{0.7}N$ barriers, and a 8nm in-situ silicon nitride cap.

Polycrystalline GaN on the SiO_2 mask was removed

with dry etching that stopped at the SiO_2. Removing the SEG mask then resulted in a near-planar surface, which enabled fine-pattern lithography.

The p- and n-type regions of the silicon pn diode were formed by implantation of boron/boron difluoride (BF_2) and phosphorus, respectively. Plasma-enhanced chemical vapor deposition (PECVD) was used to create a 350nm SiO_2 passivation layer for the diode.

The AlGaN/GaN HEMT was fabricated by argon implantation defining the active region, selective etch of source-drain windows in the silicon nitride cap, titanium/aluminium/nickel/gold source-drain metal deposition, 830°C annealing to activate the Si diode doping and alloy the HEMT source-drain metal stacks, atomic layer deposition (ALD) of aluminium oxide as part of the gate insulator with the silicon nitride cap, and nickel/gold evaporation of the gate electrode.

The devices were connected using sputtered aluminium. A 2.5μm imide layer at the periphery of the SEG window improved the step coverage of the aluminium interconnect. The sputtered aluminium was also used to create the silicon pn diode contacts.

The silicon pn diode had a 50μm^2 active region with a drift region 2.5μm long and 20μm wide. The active MIS-HEMT area was 190μm^2 with 2μm-long 10μm-wide gate. The gate-source and gate-drain distances were 2μm and 15μm, respectively.

The interconnect distance of 70μm reduces the parasitic inductance to around 0.03nH, compared with the ~2nH typical for conventional ~2mm wirebonding.

Individual characterization of the silicon diode gave a forward voltage of 0.8V at 500A/cm^2 current density. Breakdown occurred at 22V. Meanwhile, the MIS-HEMT had an on/off current ratio of 10^8 and 613mA/mm drive current at 2V gate potential and 10V drain bias. The threshold voltage was –5.2V. Breakdown with 1mA/mm current density was 550V.

The cascode circuit had a turn-on voltage of 0.6V for a current density of 1A/cm^2, normalized by the sum of the active areas (240μm^2 = 50μm^2 + 190μm^2) of the component parts. At 500A/cm^2, the specific on-resistance was 5.4mΩ-cm^2 (differential, 2.8mΩ-cm^2).

A conventional AlGaN/GaN Schottky barrier diode on the same wafer had a 0.7V turn-on and 3.7mΩ-cm^2 specific on-resistance (1.8mΩ-cm^2, differential). The higher on-resistance of the cascode diode is blamed on "series resistance and the additional device area needed for the Si diode".

By contrast, the reverse bias leakage was two orders of magnitude lower for the cascode diode than for the SBD. In fact, the large reverse leakage of the SBD makes it impractical for applications, according to the researchers. In numbers, the cascode diode reverse leakage was 5.6x10^{-5}mA/mm (1.9x10^{-4}mA/cm^2) at 300V. The 300V reverse bias is a typical bus voltage for applications using 500–600V-class diodes, according to the team.

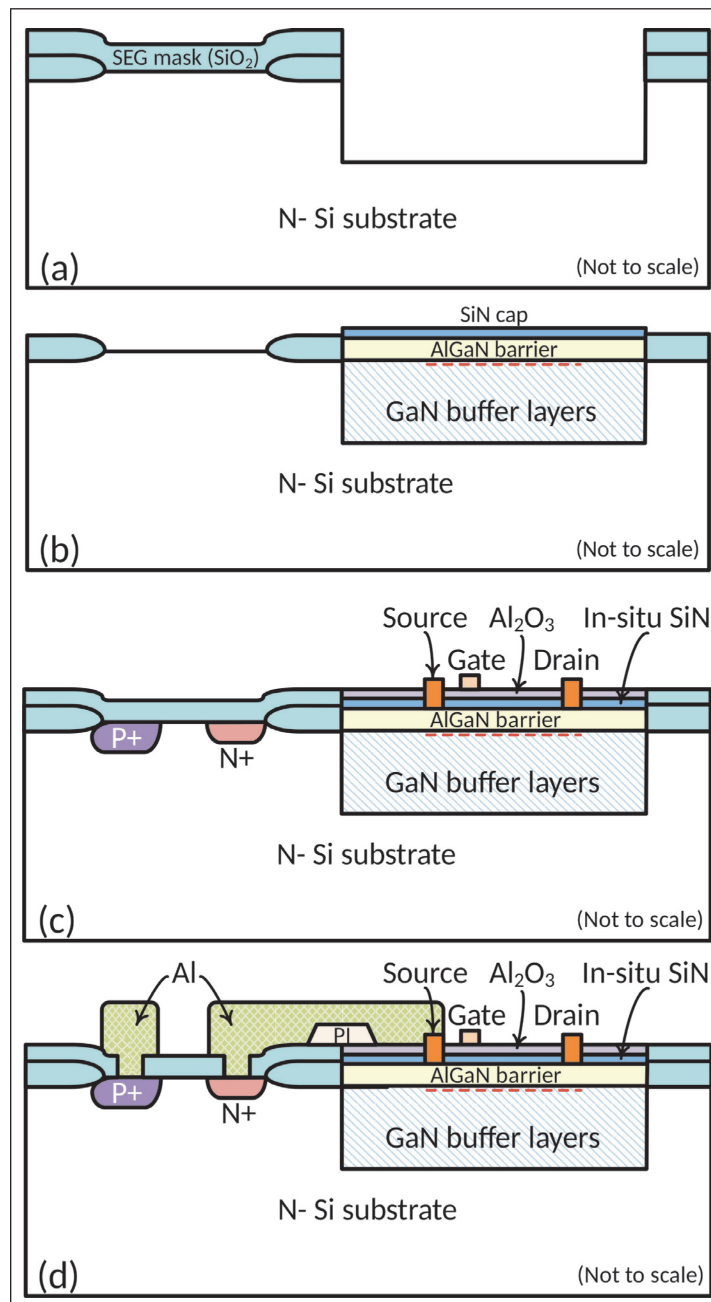


Figure 2. Schematic cross sections: (a) after recessed window formation, (b) after AlGaN/GaN epitaxial structure growth, (c) after Si and GaN fabrication, (d) after metal-line interconnection deposition.

The cascode diode reverse leakage performance was "smaller than most of the state-of-the-art AlGaN/GaN SBDs," the researchers say. They attribute the small leakage to "the superior voltage blocking capability of the MIS-HEMT and the low leakage current of the Si diode".

The cascode diode on/off current ratio was 3x10^6 with 1A/cm^2 breakdown of 557V, which the researchers claim is 62V greater than that of the conventional AlGaN/GaN Schottky barrier diode.

Another area where the cascode diode improves on the AlGaN/GaN SBD is in having a low ideality factor of 1.4, compared with 2.7, indicating a sharper turn-on behavior.

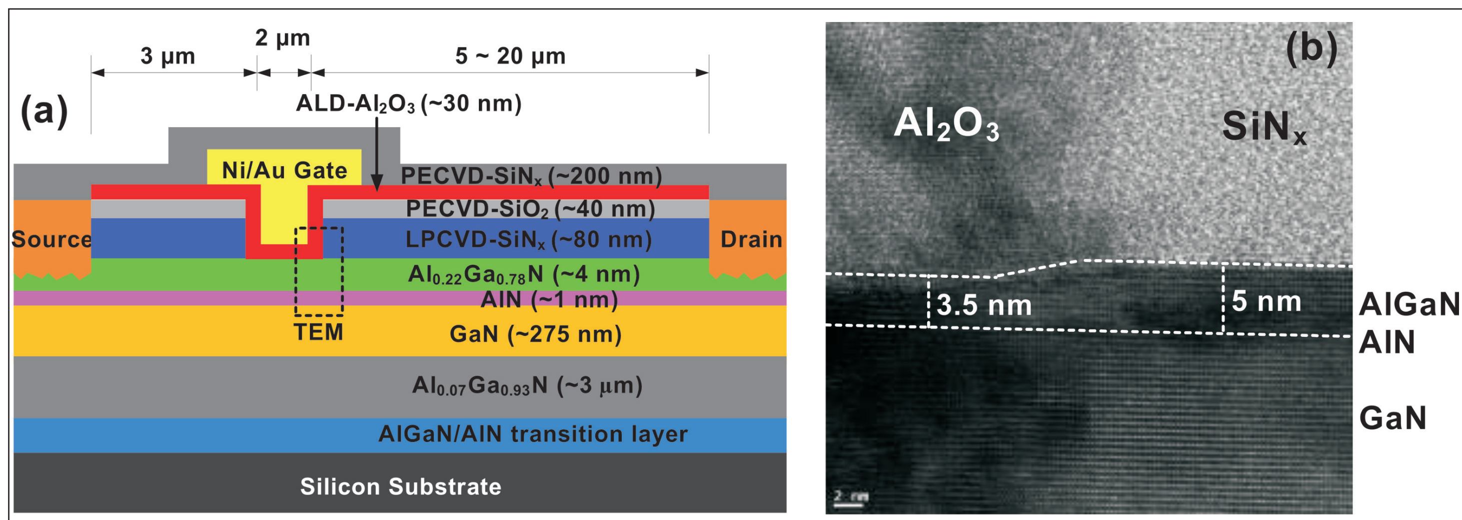


Figure 3. (a) Schematic device structure of normally-off Al_2O_3/AlGaN/GaN MIS-HEMTs fabricated on UTB AlGaN/GaN heterostructures. (b) Transmission electron microscope cross-sectional view of device's gate corner.

Varying the temperature between 25°C and 200°C, the reverse leakage of the cascode diode increased by two orders of magnitude, but this change was smaller than that of the AlGaN/GaN SBDs.

Ultra-thin-barrier

Researchers in China and Hong Kong have fabricated ultra-thin barrier (UTB) aluminium gallium nitride (AlGaN) on gallium nitride normally-off MIS-HEMTs with silicon nitride (SiNx) passivation [Sen Huang et al, IEEE Electron Device Letters, vol37, p1617, 2016]. The passivation reduced sheet resistance in the conducting two-dimensional electron gas (2DEG) near the AlGaN/GaN interface by almost an order of magnitude.

The team from the Institute of Microelectronics of the Chinese Academy of Sciences (CAS), the Suzhou Institute of Nano-Tech and Nano-Bionics in China, and the Hong Kong University of Science and Technology (HKUST) sees potential application in next-generation normally-off power-switching devices. Rather than using recess etch of thick AlGaN layers to achieve normally-off behavior, the researchers used a combination of ultra-thin barrier layers and passivation in the access regions (Figure 3).

The epitaxial material was grown by MOCVD on 4-inch silicon substrate. The ultra-thin AlGaN barrier on an AlN interface enhancement layer resulted in a 2DEG with $2.7x10^{12}/cm^2$ carrier density and 2570Ω/square sheet resistance.

Passivation with low-pressure chemical vapor deposition (LPCVD) of 80nm silicon nitride increased the sheet carrier density to $9.5x10^{12}/cm^2$. At the same time, the sheet resistance was reduced to 334Ω/square. The 2DEG mobility was increased to $1980cm^2/V$-s from the $869cm^2/V$-s value without passivation. The high mobility is taken as indicating insignificant interface roughness scattering.

The researchers calculated a positive surface charge of $4.56x10^{12}/cm^2$ at the silicon nitride/III-nitride interface from capacitance-voltage measurements. The team further estimates a reduction in the AlGaN surface potential from 1.35eV to 0.49eV. They comment: "The reduction of surface potential of AlGaN barrier by LPCVD-SiN_x contributes to an effectively enhanced 2DEG density in UTB AlGaN/GaN heterostructures."

To fabricate devices, the source-drain regions of the silicon nitride were etched using an inductively coupled plasma (ICP) mix of fluorform (CHF_3) and sulfur hexafluoride (SF_6). The exposed AlGaN was treated with hydrochloric acid. Titanium/aluminium/nickel gold ohmic contacts were deposited and annealed at 830ºC in nitrogen.

The gate region was also defined by fluorine-based ICP etch. Aluminium oxide (Al_2O_3) gate dielectric was applied using atomic layer deposition. Remote plasma pre-treatment of the Al_2O_3 deposition surface was used to suppress deep states at the Al_2O_3/AlGaN interface. The gate electrode was nickel/gold.

The maximum drain current of a MIS-HEMT with 2µm gate length was 661mA/mm at 12V gate potential. The specific on-resistance was 9.0Ω-mm. The gate–drain distance was 10µm. With 1V drain bias, the gate threshold (V_{TH}) for 1µA/mm current was +0.27V. Across a sample of 30 devices, the threshold standard deviation was 0.15V.

The researchers comment: "Owing to the as-grown ultra-thin AlGaN barrier, intentional recess etching of the AlGaN barrier is eliminated, contributing to improved V_{TH} controllability and uniformity."

The vertical breakdown voltage was 695V. Three-terminal breakdown occurred at 1089V, according to a leakage criterion of 1µA/mm with substrate floating. The breakdown path was source to drain. The three-terminal breakdown voltage reduced to 617V with a 5µm gate-to-drain distance.

Operation with 200ns pulses at 10μs period increased dynamic on-resistance by 10% (Figure 4), indicating some current collapse. The researchers suggest that the increased resistance could be due to oxidation during transfer between AlGaN barrier surface cleaning and growth of the silicon nitride passivation. Alternatively, border/bulk traps could be present in the passivation.

Devices with 20mm gate width achieved normally-off operation with 0.75Ω on-resistance and maximum drain current of 6.5A.

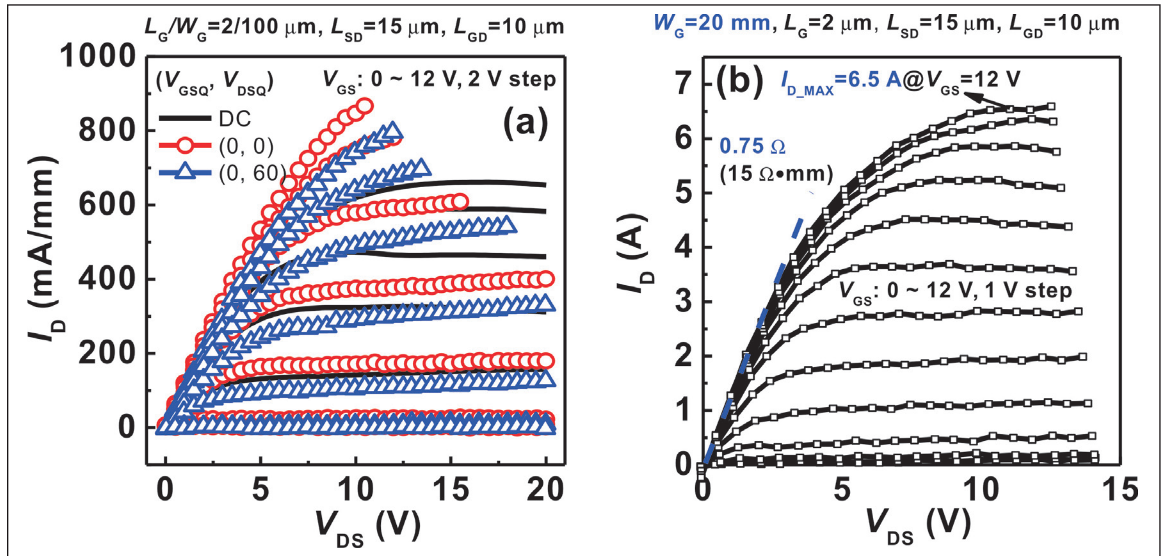


Figure 4. (a) Pulsed drain current (I_D) versus drain bias (V_{DS}) characteristics of fabricated normally-off Al_2O_3/AlGaN/GaN MIS-HEMTs from various quiescent gate, drain bias points (V_{GSQ},V_{DSQ}). (b) Characteristics of fabricated 20mm-gate-width devices.

Multi-level metalization

Researchers based in USA and Korea have used multi-level metalization to improve the performance and density of aluminium gallium nitride/gallium nitride (AlGaN/GaN) heterostructure field-effect transistors (HFETs) on silicon [Seung Kyu Oh et al, Appl. Phys. Express, vol10, p016502, 2017].

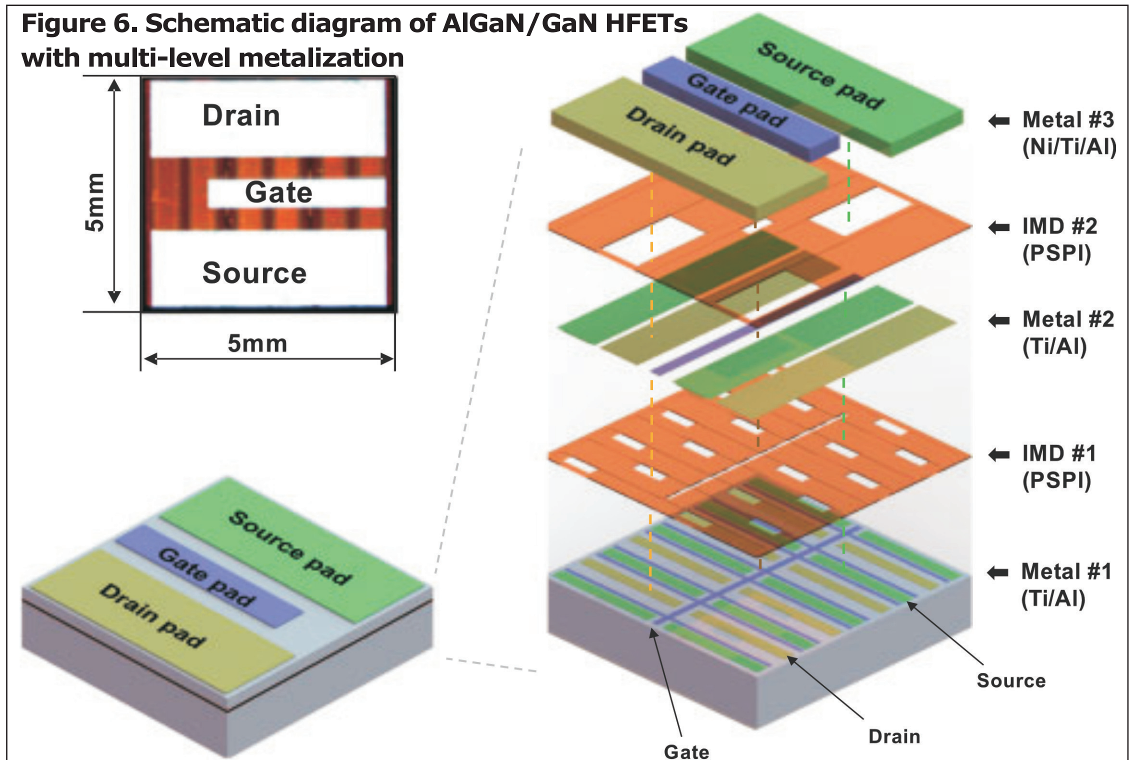
The devices achieved higher drain currents and lower fall off in current at high drain bias, compared with conventional single-metal-layer HFETs of the same device area. The team from the University of Houston in the USA and Sunchon National University, Chonbuk National University and LG Electronics in South Korea comments: "Multi-level metalization schemes, which are well developed in the Si-based semiconductor industry, are an effective way to increase the number of dies per wafer."

The III-nitride heterostructure (Figure 5) was grown on 150mm-diameter (111) silicon by MOCVD. The top p-GaN layer was removed by

Cap	Magnesium-doped p-GaN	100nm
Cap	GaN	30nm
Barrier	AlGaN	20nm
Channel	Undoped GaN	1μm
Buffer	Carbon-doped GaN	2μm
Buffer	AlGaN/GaN superlattice	1μm
Seed	AlN	
Substrate	Silicon (111)	150mm diameter

Figure 5. III-nitride hetero-structure.

Figure 6. Schematic diagram of AlGaN/GaN HFETs with multi-level metalization



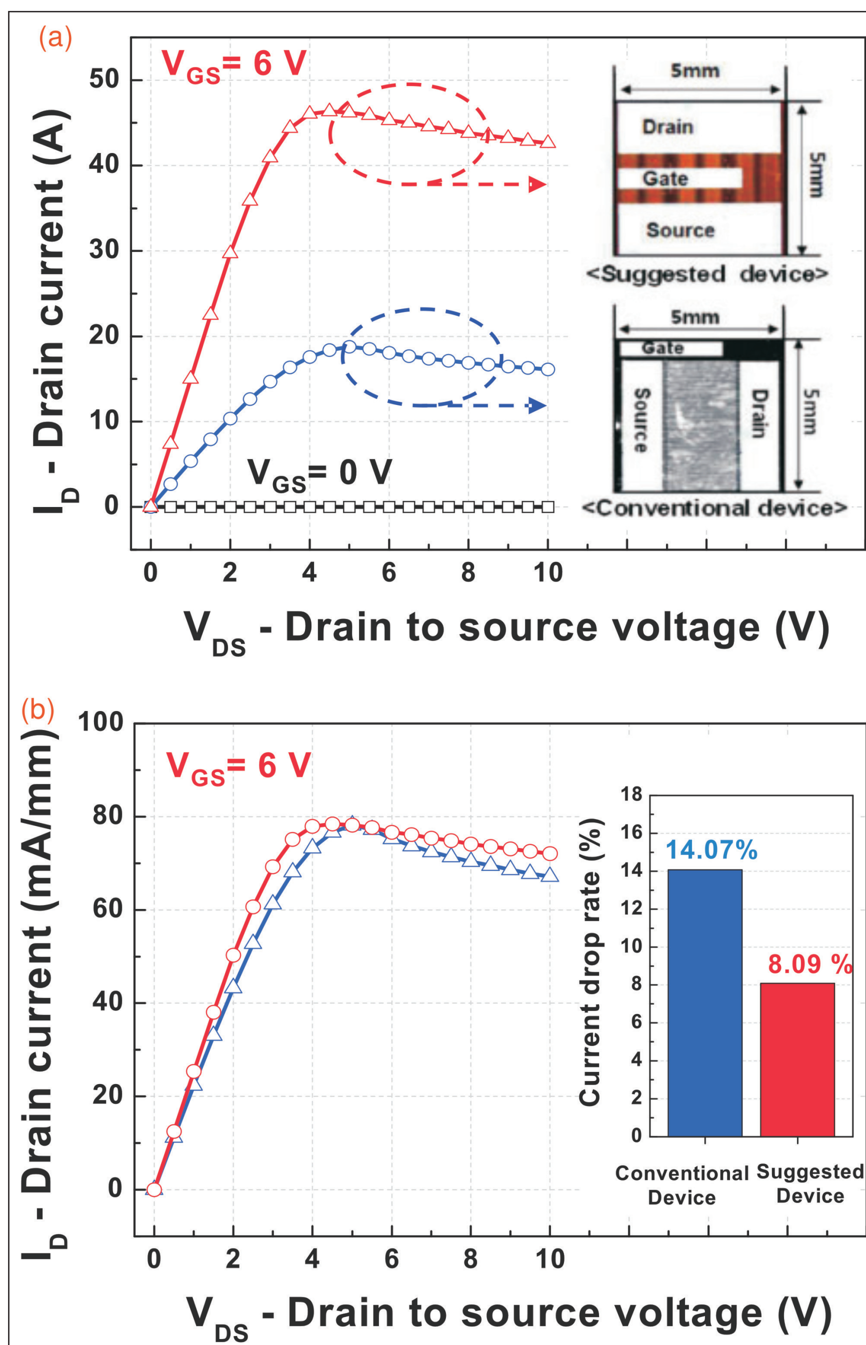


Figure 7. (a) Output power characteristics and (b) current drop ratio of AlGaN/GaN HFETs with multi-level metalization in comparison with conventional HFETs having same chip size.

selective inductively coupled plasma reactive-ion etch except in the gate region of the device. Further etching created device-isolation mesas. Ohmic source/drain electrodes consisted of annealed titanium/aluminium/palladium/gold (Ti/Al/Pd/Au). The gate electrode was nickel/gold (Ni/Au). PECVD silicon nitride was used to passivate surface states.

The first metal layer consisted of Ti/Al lines, deposited after etching via holes in the silicon nitride to make contact with the devices (Figure 6). Further metal layers were separated by photosensitive polyimide (PSPI). The intermetal dielectric (IMD) was spin-coated onto the wafer at 3000 rotations per minute and soft-baked at 120°C for 3 minutes. The material was patterned with via holes using mercury lamp 365nm i-line UV light and development, followed by hard-baking at 140°C for 3 minutes. Curing was carried out at 320°C for 100 minutes in nitrogen atmosphere.

The second metal layer of Ti/Al lines was deposited on the IMD with contacts through the via holes. A further layer of IMD was applied and patterned with via holes. This final IMD layer was treated with oxygen plasma to improve the adhesion between the IMD and the final Ni/Ti/Au source, gate and drain bonding pads.

The researchers comment: "In this structure, the size of the chip is significantly smaller than those of conventional devices due to the location of the bonding pad region directly on top of the active device area."

The normally-off transistors had a threshold of +0.8V. With 6V gate and 4V drain bias, the maximum drain current was 46.3A (Figure 7). With 0V gate, the current leakage was 92μA at 600V drain bias. The breakdown voltage for 500μA leakage was 635V. This was slightly lower than the 670V breakdown of a conventional HFET of the same area.

The gate width of the 5mmx5mm multi-level HFET device was 590806μm (4409μmx134), while the 5mmx5mm conventional HFET gate width was 250800μm (2200μmx114).

The maximum drain current of the conventional HFET was 18.4A with the same biasing as for the multi-level device. The researchers explain: "The maximum drain current, which is related to the output power, for the multi-level-metalization-structured HFETs is 240% higher because the multi-level metalization structure can increase the size of the active area for the same chip size."

As drain bias increased to 10V, self-heating effects reduced the drain current with 6V gate potential 14.07% in the conventional device and 8.09% in the multi-level structure. Self-heating increases phonon scattering and hence reduces carrier mobility in the two-dimensional electron gas channel. The reduced drain current fall off at 10V in the multi-level HFET thus indicates improved heat dissipation. The researchers suggest that this was due to generated heat being transferred from the active area to the surface through the conductive Al via-holes. ■

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

2017 International Conference on Compound Semiconductor Manufacturing Technology

May 22nd – 25th , 2017
Hyatt Regency Indian Wells
Indian Wells, California, USA

www.csmantech.org

Conference and Exhibitor Registration is Open

This years conference includes papers on:

Producibility
Wafer & Device Processing
Process Control & Yield
Epitaxy & Material
RF & Power Devices
Optical Devices & LED
Emerging Technologies
Test & Reliability
Packaging & Heterogeneous Integration
Business Outlook
Equipment

GaN, GaAs, InP, SiC, Diamond, Sb Compounds, SiGe, & other related materials

Conference Chair
Celicia Della-Morrow
chairman@csmantech.org

Technical Program Chair
Drew Hanser
tpcchair@csmantech.org

Exhibits Chair
Patrick Fay
exhibitor@csmantech.org

Workshop Chair
David Meyer
workshops@csmantech.org

University Liaison
Martin Kuball
Student.aid@csmantech.org

Sponsorship Chair
Kelli Rivers
sponsorship@csmantech.org

Publication Chair
Jansen Uyeda
publication@csmantech.org

For more information please visit www.csmantech.org

Benefits and advantages of silicon carbide power devices over their silicon counterparts

Giuseppe Vacca outlines the advantages of silicon carbide compared with traditional silicon and the benefits attainable for fabricating power devices.

Silicon carbide power devices allow us to leverage many important advantages over traditional silicon technology, which has already reached intrinsic limitations due to material characteristics: silicon's physical-electrical properties are precluding further performance improvement, while research activity requires such great effort that it is too expensive and uneconomic in terms of cost of investment.

To overcome these constraints from silicon performances limitation, major semiconductor companies have understood that it has become necessary to make use of new compound materials like silicon germanium (SiGe) and gallium arsenide (GaAs). For some applications it is even better to turn to wide-bandgap semiconductors such as silicon carbide (SiC) and gallium nitride (GaN). Among these, 4H-type SiC is the most currently cited, and many researchers believe that it will play a very important role in the future of electronics because it shows great potential in power electronics devices.

Interest in silicon carbide has increased greatly over the last several years, since this novel semiconductor can boost power handling capability, and its behavior is achieved through the combination of higher power density together with better efficiency. These qualities are coupled with the possibility of handling operating temperature above 150°C (the maximum operating temperature for counterpart silicon-based devices).

Silicon carbide is now the semiconductor material used for manufacturing innovative power devices, accounting for the biggest share of investment in R&D, in both microelectronics design centers and foundries. SiC devices are opening up advanced applications in the most important fields of electronics, and its properties allow the performance of existing semiconductor technology to be extended.

As a binary compound containing equal amount of silicon and carbon atoms in a hexagonal crystal structure, there are two principal kinds of polytypes of silicon carbide: 6H-SiC and 4H-SiC. Before the introduction of 4H-SiC, the dominant polytype was 6H-SiC. Both types have been used for some years for manufacturing electronic devices, although recently 4H-SiC has become dominant. They have similar electrical properties, but 4H-SiC is preferred because its electron mobility is identical along both the horizontal and vertical planes of the crystal, whereas 6H has anisotropic behavior.

Introduction

As a result of silicon carbide's favorable features, SiC power devices and power integrated systems can handle much higher power density compared with traditional silicon counterparts.

This happens because SiC-based devices combine higher breakdown voltage with wider frequency bandwidth signals, allowing significant performance improvement in many applications such as radio-frequency, microwave and power electronics, with plenty of advantages offered by silicon carbide devices over silicon diodes, MOSFETs and other type of transistors currently on the market.

Silicon carbide's larger bandgap energy (3.2eV, about three times higher than silicon's 1.1eV) — in conjunction with the high breakdown voltage and a typical critical electric field at least one order of magnitude greater than silicon's — are properties that can be conveniently exploited to fabricate new power devices with very good performance.

The main advantage of a SiC MOSFET is the low drain-to-source ON-resistance (R_{DS-ON}) — about 300–400 times lower than that of silicon devices with a comparable breakdown voltage — presenting a key desirable feature for designing extraordinarily efficient power electronics equipment and related systems.

Based on these advantages and potential future development, silicon carbide technology is attracting the most important semiconductor players thanks to the possibility of providing higher power levels in an extremely effective and efficient way, minimizing power loss and hence improving average efficiency up to 10% while diminishing die size by about five-fold.

On the other hand, it means that silicon carbide can manage higher power levels than silicon devices utilizing the same active area. Fabricating devices with the same performance level yet reduced dimensions is then achievable (see Figure 1).

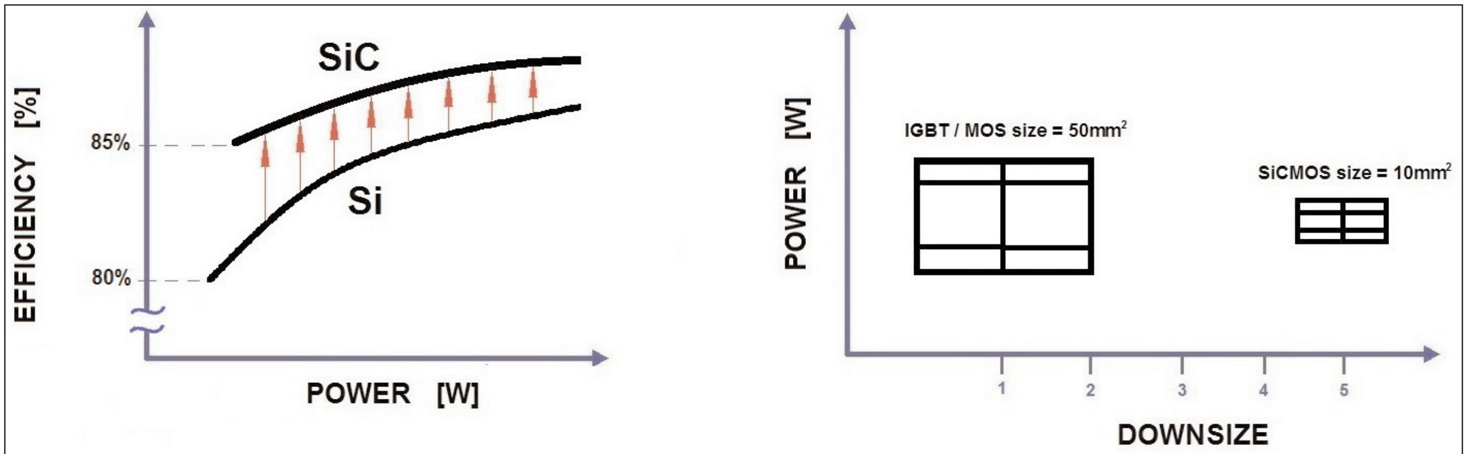


Figure 1. Estimated efficiency improvement and downsizing for SiC versus silicon devices.

Electro-thermal characteristics

Silicon carbide devices can exhibit simultaneously high electro-thermal conductivity and extremely fast switching.

Indeed, the lower output capacitance and R_{DS-ON} make SiC MOS suitable for switching designs such as digital power supplies, three-phase inverters and many kinds of electronic converters (AC to DC and DC to DC).

This happens because SiC components are capable of handling high energy levels while operating at much higher switching frequencies.

Using SiC devices hence enables significant cost saving and downsizing of magnetic parts (transformers, chokes, inductors) used in all switching mode design systems.

Note that achievable R_{DS-ON} values for SiC MOS are much lower than for silicon MOSFETs with a comparable drain-to-source voltage, so SiC MOS devices can reduce conduction loss and frequency-switching loss at the same time.

Thermal conductivity is a key additional feature because it represents how easy it is to remove heat caused by power loss, avoiding any temperature rise in the device.

Note that electron mobility and breakdown electric field are dependent on the dopant concentration — nitrogen is used as an n-type dopant and aluminium as a p-type dopant.

It is quite difficult to cool down devices made from semiconductor material characterized by low thermal conductivity. In this case, a de-rating factor arises, causing partial performance degradation when devices are operating at high temperatures. In contrast, high thermal conductivity means that power devices can be cooled in the best way without any performance degradation.

Additionally, silicon carbide exhibits an operating temperature of at least 200°C, i.e. 50°C higher than the absolute maximum rating of silicon MOS devices. Sometimes this temperature can go up to 400°C or more.

Properties @ 300K	Si	SiC (4H)
Band Gap Energy [eV]	1.1	3.2
Electronic Mobility [cm²/V·s]	1400	900
Breakdown electric field [KV / cm]	300	2400
Thermal conductivity [W / cm·K]	1.5	4

Figure 2. SiC versus silicon properties.

This advantage allows SiC power devices to work well in hot and hostile environments, avoiding performance de-rating and related problems regarding reductions in mean time to failure (MTTF) and life time, and enabling appreciable gains in quality and reliability.

As a summary of the benefits obtainable by using SiC devices and systems already on the market, a simple comparison between different technologies can be seen from the Johnson figure of merit (see Figure 3).

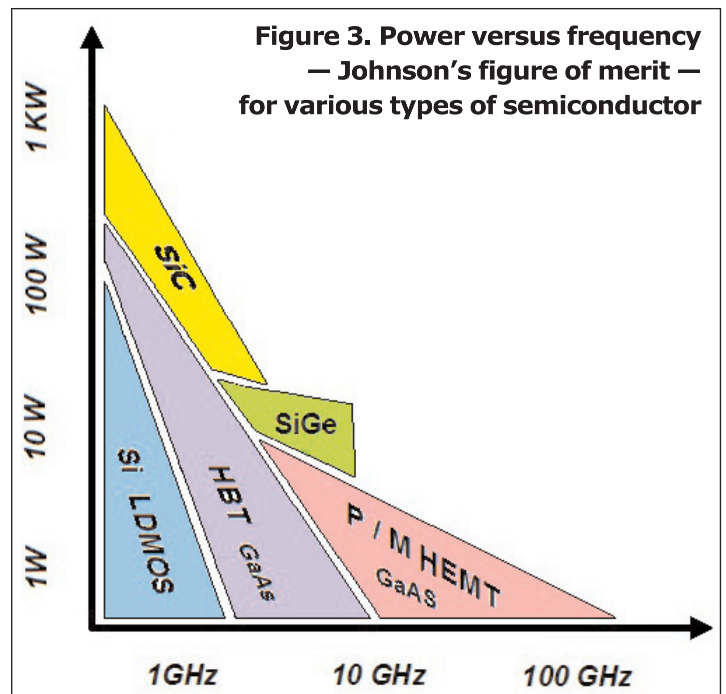


Figure 3. Power versus frequency — Johnson's figure of merit — for various types of semiconductor

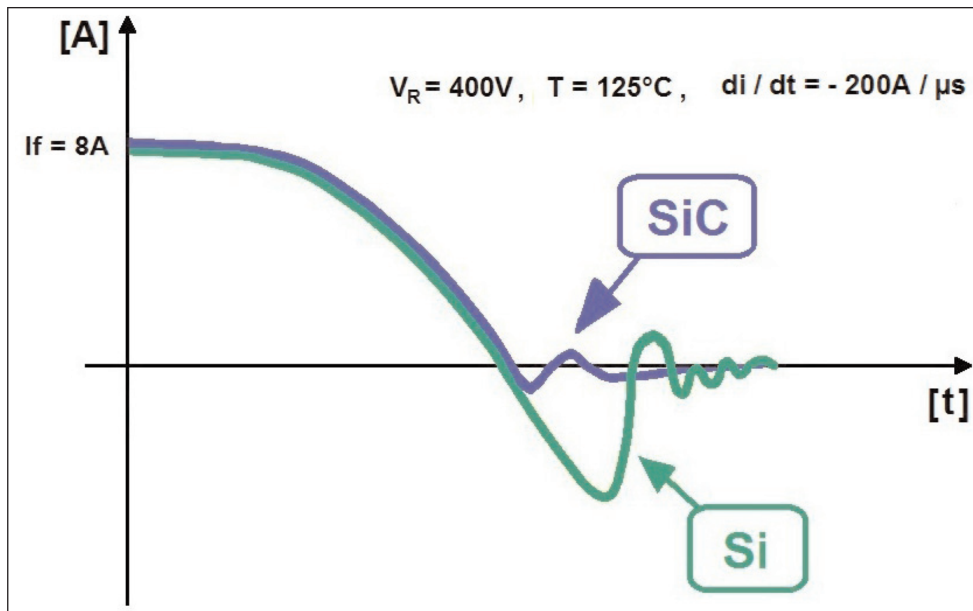


Figure 4. Reverse recovery time comparison of SiC Schottky diode versus silicon fast recovery diode.

Available devices

Silicon carbide power electronic devices can be classified in two main categories:
(1) power devices grown on semiconducting substrates, e.g. SiC Schottky barrier power rectifiers (diodes) and power switches (SiC MOSFETs);
(2) devices grown on semi-insulating substrates, i.e. high-power, high-frequency metal-semiconductor field-effect transistors (MESFETs).

Using homoepitaxial growth on SiC makes it possible to fabricate both kinds of devices with lateral and vertical structures.

Lateral devices — basically SiC MESFETs — are popular in high-frequency applications because they are utilized in RF and microwave amplifiers working in the S-band (up to 4GHz), and they can also be used for satellite applications. These devices can work at a maximum operating temperature of 250°C.

Vertical geometry devices comprise mainly high-voltage Schottky barriers and SiC MOSFETs. Both are already present in the portfolios of most key semiconductor players. The first devices demonstrate the remarkable advantages for Schottky diodes compared with silicon fast recovery diodes because SiC devices exhibit smaller reverse recovery current together with a shorter recovery time. These factors allow a significant reduction in switching loss accompanied by a low level of radiated emission. Furthermore, these positive effects deteriorate very little when temperature rises.

In contrast, traditional silicon diodes suffer performance degradation when the ambient temperature rises. This is due to switching loss, and the main effect is that electromagnetic interference increases.

PN junction silicon diodes exhibit a long transient and high current spikes when the junction polarization changes from forward voltage to reverse voltage. SiC Schottky barrier diodes (SBDs) have good behavior because they are unipolar devices, so they employ only majority carriers (and no minority carriers) to fulfill the conduction state. Based on this fact, the reverse recovery time of SiC SBDs is smaller and shorter than silicon fast recovery devices.

Thanks to these better characteristics, the deployment of SiC diodes is going ahead and they are replacing silicon counterparts, particularly in critical application operating at 600–1200V with current rating up to 50A, such us active PFC (power factor correction) and other kinds of boost converters, UPS (uninterruptible power supplies), motor drives, solar inverters, DC-to-DC primary stages, electronic welding machines, etc.

Automotive applications benefit from these new devices because they can be inserted into hybrid solutions and fast battery recharging equipment at charging stations for electric cars and industrial vehicles. Also, devices with a 1700V maximum voltage are already available.

The typical forward voltage of silicon carbide power Schottky diodes is around 1V, with the feature that V_f has a positive temperature coefficient (increasing with a rise in temperature), avoiding any thermal runway and facilitating easy parallel connection of more SiC diodes. So, they can perform automatic current sharing due to self-regulation, ensuring more stable operation compared with conventional silicon diodes (which have a negative temperature coefficient).

The most popular silicon power devices for switching applications are insulated-gate bipolar transistors (IGBTs). MOSFETs are used if the switching frequency overcomes 20MHz.

To achieve low $R_{CE\text{-}ON}$ (IGBT resistance in the conduction state) minority carrier injection is required, but their presence requires a longer switch-off time since they need to recombine. This kind of process is accompanied by power loss, because minority carriers cause a current tail and this effect has to be dissipated.

MOSFETs are unipolar devices, so they don't produce any current tails. Furthermore, if they are fabricated using silicon carbide, they can exhibit good performance in switching applications, adding to their great potential for withstanding high-temperature operating conditions.

The elimination of the tail current of silicon IGBTs is a considerable benefit in SiC MOS. But be aware that an additional ringing with overshoot can be observed when replacing IGBTs with SiC-based devices.

Three-phase inverters for high-power motor control intelligent power modules (IPM) represent an emerging market. These modules incorporate a gate driver, current monitor and overcurrent protection circuit, temperature feedback and other features. In this kind of power module, the six power devices are made using SiC MOS, replacing conventional IGBT or MOS.

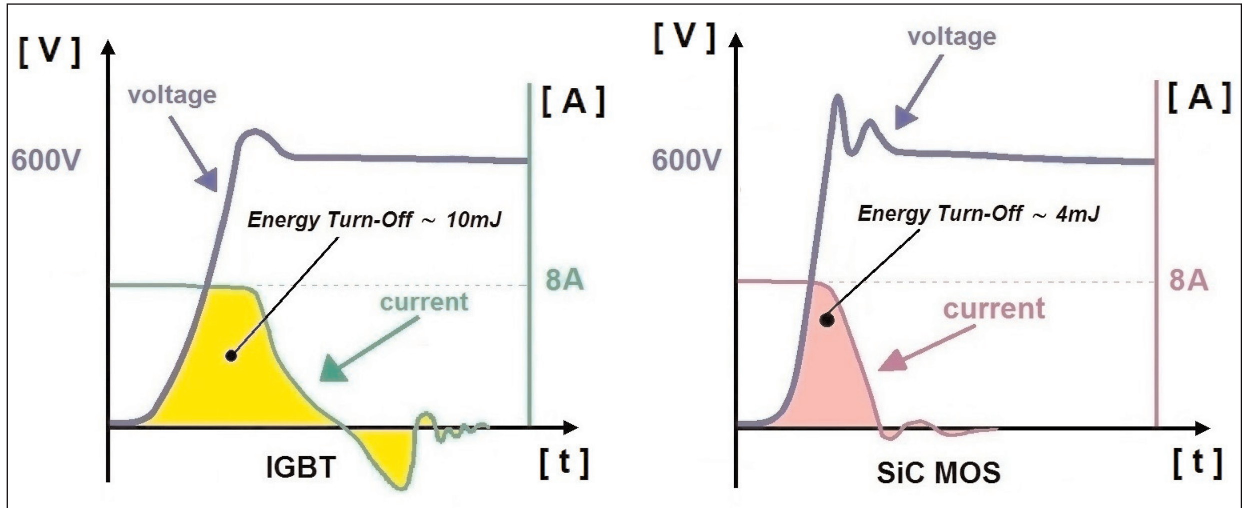


Figure 5. Comparison of energy loss during turn-off.

This important evolution allows the handling of very high current values (up to 150A at 1200V and 250°C) in small packages. An appropriate study of power packaging and heat-sinks is required.

The particular application will define the standard of performance, size, power density and weight, especially for sensitive application such as electric aircraft.

Although many advantages are offered by SiC in terms of electrical and thermal properties, there are some aspects that are currently still limiting development and mass production because there are remaining material processing problems such as micropipes and screw dislocations, which have the effect of limiting die size. However, these problems have not halted the deployment of SiC power devices for some years now.

SiC wafer production for the microelectronic and optoelectronic industries is increasing greatly because demand is rising. Using chemical vapor deposition (CVD), it is possible to grow and produce epitaxial wafers with diameters of 3-inches (76.2mm), 4-inches (100mm) and 6-inches (150mm) for manufacturing vertically integrated structures.

An increase in wafer diameter helps to improve productivity and to reduce the production costs for power device manufacturers.

CVD equipment can be applied to SiC wafers of all sizes, and this tool contributes to reducing device production costs because, by using CVD, SiC epiwafers have fewer surface defects. Consequently, an improvement in yield is achieved. ■

References

[1] Mietek Bakoswsky, Adolf Schoner, Per Ericsson, Helena Stromberg, Hiroyuky Nagasawa and Masayuki Abe, 'Development of 3C-SiC MOSFETs', Journal of Telecommunication and Information Technology 2/2007.

[2] W. Wondrak, E. Niemann, R. Held and U. Schmid, 'SiC Devices for Advanced Power and High Temperature Application', IEEE Transaction on Industrial Electronic, vol 48, 2.

[3] M. Bhatnagar, PK McLarty and B.J. Baliga, 'Silicon Carbide High Voltage (400V) Schottky barrier diodes', IEEE Electron Devices, August 2002.

[4] Khaterine Tweed, 'Silicon Carbide Power Electronics for Making Silicon', IEEE Spectrum 03/2015.

[5] Ajay Kumar and M S Aspalli 'SiC : an advanced Semiconductor Material for Power Devices', International Journal of Research in Engineering and Technology, May 2014.

[6] Robert Callanan, 'Application of Silicon Carbide MOSFETs', Power Electronics Europe, Issue 3 2011.

Giuseppe Vacca PhD, senior design engineer, Electronics & Electrical Systems, Whirlpool Corp.
E-mail: giuseppe_vacca@whirlpool.com
www.whirlpool.com

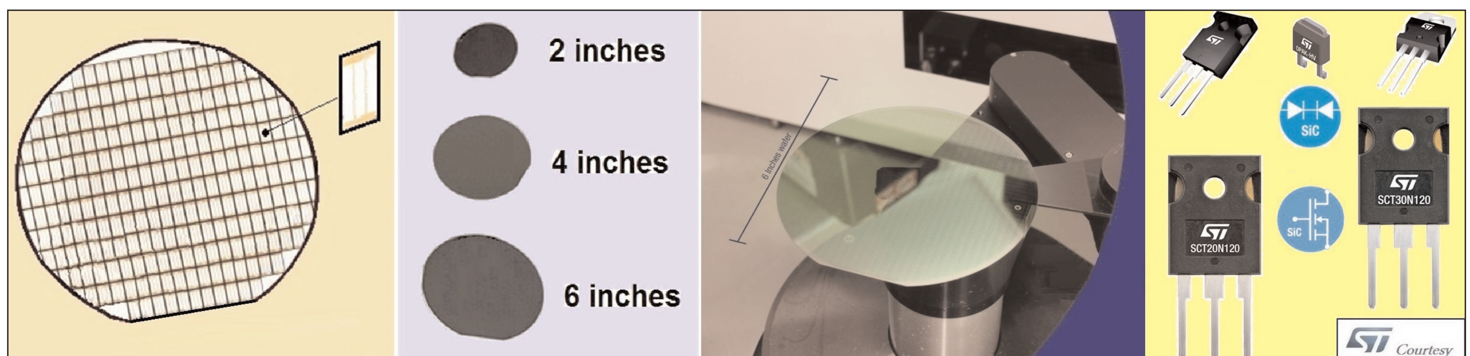


Figure 6. Examples of 2-, 4- and 6-inch 4H-SiC wafers and devices.

suppliers' directory

Index

1 Bulk crystal source materials p76
2 Bulk crystal growth equipment p76
3 Substrates p76
4 Epiwafer foundry p77
5 Deposition materials p77
6 Deposition equipment p78
7 Wafer processing materials p78
8 Wafer processing equipment p79
9 Materials and metals p79
10 Gas & liquid handling equipment p79
11 Process monitoring and control p79
12 Inspection equipment p80
13 Characterization equipment p80
14 Chip test equipment p80
15 Assembly/packaging materials p80
16 Assembly/packaging equipment p80
17 Assembly/packaging foundry p80
18 Chip foundry p80
19 Facility equipment p80
20 Facility consumables p80
21 Computer hardware & software p81
22 Used equipment p81
23 Services p81
24 Consulting p81
25 Resources p81

To have your company listed in this directory, e-mail details (including categories) to mark@semiconductor-today.com
Note: advertisers receive a free listing. For all other companies, a charge is applicable.

1 Bulk crystal source materials

Mining & Chemical Products Ltd (part of 5N Plus, Inc)
1-4, Nielson Road,
Finedon Road Industrial Estate,
Wellingborough,
Northants NN8 4PE,
UK
Tel: +44 1933 220626
Fax: +44 1933 227814
www.MCP-group.com

Umicore Indium Products
50 Simms Avenue,
Providence, RI 02902,
USA
Tel: +1 401 456 0800
Fax: +1 401 421 2419
www.thinfilmproducts.umicore.com

United Mineral & Chemical Corp
1100 Valley Brook Avenue,
Lyndhurst, NJ 07071,
USA
Tel: +1 201 507 3300
Fax: +1 201 507 1506
www.umccorp.com

2 Bulk crystal growth equipment

MR Semicon Inc
PO Box 91687,
Albuquerque,
NM 87199-1687,
USA
Tel: +1 505 899 8183
Fax: +1 505 899 8172
www.mrsemicon.com

3 Substrates

AXT Inc
4281 Technology Drive,
Fremont,
CA 94538,
USA
Tel: +1 510 438 4700
Fax: +1 510 683 5901
www.axt.com

Supplies GaAs, InP, and Ge wafers using VGF technology with manufacturing facilities in Beijing and five joint ventures in China producing raw materials, including Ga, As, Ge, pBN, B_2O_3.

CrystAl-N GmbH
Dr.-Mack-Straße 77,
D-90762
Fürth,
Germany
Tel: +49 (0)911 650 78 650 90
Fax: +49 (0)911 650 78 650 93
E-mail: info@crystal-n.com
www.crystal-n.com

Crystal IS Inc
70 Cohoes Avenue
Green Island, NY 12183, USA
Tel: +1 518 271 7375
Fax: +1 518 271 7394
www.crystal-is.com

Freiberger Compound Materials
Am Junger Loewe Schacht 5,
Freiberg, 09599, Germany
Tel: +49 3731 280 0
Fax: +49 3731 280 106
www.fcm-germany.com

Kyma Technologies Inc
8829 Midway West Road,
Raleigh, NC, USA
Tel: +1 919 789 8880
Fax: +1 919 789 8881
www.kymatech.com

MARUWA CO LTD
3-83, Minamihonjigahara-cho,
Owariasahi, Aichi 488-0044,
Japan
Tel: +81 572 52 2317
www.maruwa-g.com/e/products/ceramic

MARUWA is a global supplier of ceramic substrates and wafers made of aluminium nitride (AlN), alumina (Al_2O_3), ZTA and silicon nitride (Si_3N_4). Products meet required properties such as high thermal conductivity and bending strength for power devices, especially wafers are suitable as a bonding wafer (GaN, SOI) for epi wafers.

sp3 Diamond Technologies
2220 Martin Avenue,
Santa Clara, CA 95050, USA
Tel: +1 877 773 9940
Fax: +1 408 492 0633
www.sp3inc.com

Sumitomo Electric Semiconductor Materials Inc
7230 NW Evergreen Parkway,
Hillsboro, OR 97124,
USA
Tel: +1 503 693 3100 x207
Fax: +1 503 693 8275
www.sesmi.com

III/V-Reclaim
Wald 10,
84568 Pleiskirchen, Germany
Tel: +49 8728 911 093
Fax: +49 8728 911 156
www.35reclaim.de
III/V-Reclaim offers reclaim (recycling) of GaAs and InP wafers, removing all kinds of layers and structures from customers' wafers. All formats and sizes can be handled. The firm offers single-side and double-side-polishing and ready-to-use surface treatment.

Umicore Electro-Optic Materials
Watertorenstraat 33,
B-2250 Olen, Belgium
Tel: +32-14 24 53 67
Fax: +32-14 24 58 00
www.substrates.umicore.com

Wafer World Inc
1100 Technology Place, Suite 104,
West Palm Beach, FL 33407,
USA
Tel: +1-561-842-4441
Fax: +1-561-842-2677
E-mail: sales@waferworld.com
www.waferworld.com

4 Epiwafer foundry

Spire Semiconductor LLC
25 Sagamore Park Drive,
Hudson, NH 03051,
USA
Tel: +1 603 595 8900
Fax: +1 603 595 0975
www.spirecorp.com

Albemarle Cambridge Chemical Ltd
Unit 5 Chesterton Mills,
French's Road, Cambridge CB4 3NP,
UK
Tel: +44 (0)1223 352244
Fax: +44 (0)1223 352444
www.camchem.co.uk

Intelligent Epitaxy Technology Inc
1250 E Collins Blvd,
Richardson,
TX 75081-2401,
USA
Tel: +1 972 234 0068
Fax: +1 972 234 0069
www.intelliepi.com

IQE
Cypress Drive,
St Mellons, Cardiff
CF3 0EG,
UK
Tel: +44 29 2083 9400
Fax: +44 29 2083 9401
www.iqep.com

IQE is a leading global supplier of advanced epiwafers, with products covering a diverse range of applications within the wireless, optoelectronic, photovoltaic and electronic markets.

OMMIC
2, Chemin du Moulin B.P. 11,
Limeil-Brevannes, 94453,
France
Tel: +33 1 45 10 67 31
Fax: +33 1 45 10 69 53
www.ommic.fr

Soitec
Place Marcel Rebuffat, Parc de Villejust, 91971 Courtabouef, France
Tel: +33 (0)1 69 31 61 30
Fax: +33 (0)1 69 31 61 79
www.picogiga.com

5 Deposition materials

Akzo Nobel High Purity Metalorganics
www.akzonobel.com/hpmo
Asia Pacific:
Akzo Nobel (Asia) Co Ltd,
Shanghai,
China
Tel. +86 21 2216 3600
Fax: +86 21 3360 7739
metalorganicsAP@akzonobel.com
Americas:
AkzoNobel Functional Chemicals,
Chicago,
USA
Tel. +31 800 828 7929 (US only)
Tel: +1 312 544 7000
Fax: +1 312 544 7188
metalorganicsNA@akzonobel.com
Europe, Middle East and Africa:
AkzoNobel Functional Chemicals,
Amersfoort, The Netherlands
Tel. +31 33 467 6656
Fax: +31 33 467 6101
metalorganicsEU@akzonobel.com

Cambridge Chemical Company Ltd
Unit 5 Chesterton Mills,
French's Road,
Cambridge CB4 3NP,
UK
Tel: +44 (0)1223 352244
Fax: +44 (0)1223 352444
www.camchem.co.uk

Dow Electronic Materials
60 Willow Street,
North Andover, MA 01845,
USA
Tel: +1 978 557 1700
Fax: +1 978 557 1701
www.metalorganics.com

Matheson Tri-Gas
6775 Central Avenue,
Newark, CA 94560,
USA

Tel: +1 510 793 2559
Fax: +1 510 790 6241
www.mathesontrigas.com

Mining & Chemical Products Ltd
(see section 1 for full contact details)

Praxair Electronics
542 Route 303, Orangeburg,
NY 10962,
USA
Tel: +1 845 398 8242
Fax: +1 845 398 8304
www.praxair.com/electronics

SAFC Hitech
Power Road, Bromborough,
Wirral, Merseyside CH62 3QF,
UK
Tel: +44 151 334 2774
Fax: +44 151 334 6422
www.safchitech.com

Materion Advanced Materials Group
2978 Main Street,
Buffalo, NY 14214,
USA
Tel: +1 716 837 1000
Fax: +1 716 833 2926
www.williams-adv.com

6 Deposition equipment

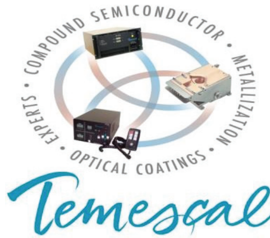
AIXTRON SE
Dornkaulstr. 2,
52134 Herzogenrath,
Germany
Tel: +49 2407 9030 0
Fax: +49 2407 9030 40
www.aixtron.com

AIXTRON

AIXTRON is a leading provider of deposition equipment to the semiconductor industry. The company's technology solutions are used by a diverse range of customers worldwide to build advanced components for electronic and optoelectronic applications (photonic) based on compound, silicon, or organic semiconductor materials and, more recently, carbon nanotubes (CNT), graphene and other nanomaterials.

Evatec AG
Hauptstrasse 1a,
CH-9477 Trübbach, Switzerland
Tel: +41 81 403 8000
Fax: +41 81 403 8001
www.evatecnet.com

Ferrotec-Temescal
4569-C Las Positas Rd,
Livermore,
CA 94551,
USA



Tel: +1 925 245 5817
Fax: +1 925 449-4096
www.temescal.net

Temescal, the expert in metallization systems for the processing of compound semiconductor-based substrates, provides the finest evaporation systems available. Multi-layer coatings of materials such as Ti, Pt, Au, Pd, Ag, NiCr, Al, Cr, Cu, Mo, Nb, SiO_2, with high uniformity are guaranteed. Today the world's most sophisticated handsets, optical, wireless and telecom systems rely on millions of devices that are made using Temescal deposition systems and components.

Oxford Instruments Plasma Technology
North End, Yatton,
Bristol, Avon BS49 4AP, UK
Tel: +44 1934 837 000
Fax: +44 1934 837 001
www.oxford-instruments.co.uk

We provide flexible tools and processes for precise materials deposition, etching and controlled nanostructure growth. Core technologies include plasma and ion-beam deposition and etch and ALD.

Plasma-Therm LLC
10050 16th Street North,
St. Petersburg, FL 33716, USA
Tel: +1 727 577 4999
Fax: +1 727 577 7035
www.plasmatherm.com

Plasma-Therm, LLC is an established leading provider of advanced plasma processing equipment for the semiconductor industry and related specialty markets.

Riber
31 rue Casimir Périer, BP 70083,
95873 Bezons Cedex, France
Tel: +33 (0) 1 39 96 65 00
Fax: +33 (0) 1 39 47 45 62
www.riber.com

SVT Associates Inc
7620 Executive Drive,
Eden Prairie, MN 55344, USA
Tel: +1 952 934 2100
Fax: +1 952 934 2737
www.svta.com

Veeco Instruments Inc
100 Sunnyside Blvd.,
Woodbury, NY 11797,
USA
Tel: +1 516 677 0200
Fax: +1 516 714 1231
www.veeco.com

Veeco is a world-leading supplier of compound semiconductor equipment, and the only company offering both MOCVD and MBE solutions. With complementary AFM technology and the industry's most advanced Process Integration Center, Veeco tools help grow and measure nanoscale devices in worldwide LED/wireless, data storage, semiconductor and scientific research markets—offering important choices, delivering ideal solutions.

7 Wafer processing materials

Air Products and Chemicals Inc
7201 Hamilton Blvd.,
Allentown, PA 18195, USA
Tel: +1 610 481 4911
www.airproducts.com/compound

MicroChem Corp
1254 Chestnut St. Newton,
MA 02464, USA
Tel: +1 617 965 5511
Fax: +1 617 965 5818
www.microchem.com

Praxair Electronics
(see section 5 for full contact details)

8 Wafer processing equipment

EV Group
DI Erich Thallner Strasse 1,
St. Florian/Inn, 4782,
Austria
Tel: +43 7712 5311 0
Fax: +43 7712 5311 4600
www.EVGroup.com

Technology and market leader for wafer processing equipment. Worldwide industry standards for aligned wafer bonding, resist processing for the MEMS, nano and semiconductor industry.

Logitech Ltd
Erskine Ferry Road,
Old Kilpatrick,
near Glasgow G60 5EU,
Scotland, UK
Tel: +44 (0) 1389 875 444
Fax: +44 (0) 1389 879 042
www.logitech.uk.com

Oxford Instruments Plasma Technology
(see section 6 for full contact details)

Plasma-Therm LLC
(see section 6 for full contact details)

SAMCO International Inc
532 Weddell Drive,
Sunnyvale,
CA,
USA
Tel: +1 408 734 0459
Fax: +1 408 734 0961
www.samcointl.com

SPTS Technology Ltd
Ringland Way,
Newport NP18 2TA,
UK
Tel: +44 (0)1633 414000
Fax: +44 (0)1633 414141
www.spts.com

SUSS MicroTec AG
Schleißheimer Strasse 90,
85748 Garching,
Germany
Tel: +49 89 32007 0
Fax: +49 89 32007 162
www.suss.com

Veeco Instruments Inc
(see section 6 for full contact details)

9 Materials & metals

Goodfellow Cambridge Ltd
Ermine Business Park,
Huntingdon,
Cambridgeshire
PE29 6WR,
UK
Tel: +44 (0) 1480 424800
Fax: +44 (0) 1480 424900
www.goodfellow.com

Goodfellow

Goodfellow supplies small quantities of metals and materials for research, development, prototyping and specialised manufacturing operations.

10 Gas and liquid handling equipment

Air Products and Chemicals Inc
(see section 7 for full contact details)

Cambridge Fluid Systems
12 Trafalgar Way, Bar Hill,
Cambridge CB3 8SQ,
UK
Tel: +44 (0)1954 786800
Fax: +44 (0)1954 786818
www.cambridge-fluid.com

CS CLEAN SOLUTIONS AG
Fraunhoferstrasse 4,
Ismaning, 85737,
Germany
Tel: +49 89 96 24000
Fax: +49 89 96 2400122
www.csclean.com

SAES Pure Gas Inc
4175 Santa Fe Road,
San Luis Obispo,
CA 93401,
USA
Tel: +1 805 541 9299
Fax: +1 805 541 9399
www.saesgetters.com

11 Process monitoring and control

Conax Technologies
2300 Walden Avenue,
Buffalo, NY 14225, USA
Tel: +1 800 223 2389
Tel: +1 716 684 4500
E-mail: conax@conaxtechnologies.com
www.conaxtechnologies.com

Ideas. Solutions. Success.

Conax Technologies is a designer and manufacturer of standard and custom-engineered temperature sensors, compression seal fittings and feedthroughs, probes, wires, electrodes and fiber-optic cables. The company is headquartered in Buffalo, New York, with locations on the US West Coast, Canada, Europe and Asia.

k-Space Associates Inc
2182 Bishop Circle
East, Dexter,
MI 48130,
USA
Tel: +1 734 426 7977
Fax: +1 734 426 7955
www.k-space.com

k-Space Associates Inc specializes in in-situ, real-time thin-film process monitoring tools for MBE, MOCVD, PVD, and thermal evaporation. Applications and materials include the research and production line monitoring of compound semiconductor-based electronic, optoelectronic, and photovoltaic devices.

KLA-Tencor
One Technology Dr,
1-2221I, Milpitas, CA 95035, USA
Tel: +1 408 875 3000
Fax: +1 408 875 4144
www.kla-tencor.com

LayTec AG
Seesener Str.
10–13,
10709 Berlin,
Germany
Tel: +49 30 89 00 55 0
Fax: +49 30 89 00 180
www.laytec.de

LayTec develops and manufactures optical in-situ and in-line metrology systems for thin-film processes with particular focus on compound semiconductor and photovoltaic applications. Its know-how is based on optical techniques: reflectometry, emissivity corrected pyrometry, curvature measurements and reflectance anisotropy spectroscopy.

WEP (Ingenieurbüro Wolff für Elektronik- und Programmentwicklungen)
Bregstrasse 90, D-78120
Furtwangen im Schwarzwald,
Germany
Tel: +49 7723 9197 0
Fax: +49 7723 9197 22
www.wepcontrol.com

12 Inspection equipment

Bruker AXS GmbH
Oestliche Rheinbrueckenstrasse 49,
Karlsruhe, 76187, Germany
Tel: +49 (0)721 595 2888
Fax: +49 (0)721 595 4587
www.bruker-axs.de

13 Characterization equipment

J.A. Woollam Co. Inc.
645 M Street Suite 102,
Lincoln, NE 68508, USA
Tel: +1 402 477 7501
Fax: +1 402 477 8214
www.jawoollam.com

Lake Shore Cryotronics Inc
575 McCorkle Boulevard,
Westerville, OH 43082, USA
Tel: +1 614 891 2244
Fax: +1 614 818 1600
www.lakeshore.com

14 Chip test equipment

Keithley Instruments Inc
28775 Aurora Road,
Cleveland, OH 44139, USA
Tel: +1 440.248.0400
Fax: +1 440.248.6168
www.keithley.com

15 Assembly/packaging materials

ePAK International Inc
4926 Spicewood Springs Road,
Austin, TX 78759,
USA
Tel: +1 512 231 8083
Fax: +1 512 231 8183
www.epak.com

Gel-Pak
31398 Huntwood Avenue,
Hayward, CA 94544, USA
Tel: +1 510 576 2220
Fax: +1 510 576 2282
www.gelpak.com

Wafer World Inc
(see section 3 for full contact details)

Materion Advanced Materials Group
2978 Main Street,
Buffalo, NY 14214,
USA
Tel: +1 716 837 1000
Fax: +1 716 833 2926
www.williams-adv.com

16 Assembly/packaging equipment

Ismeca Europe Semiconductor SA
Helvetie 283, La Chaux-de-Fonds,
2301, Switzerland
Tel: +41 329257111
Fax: +41 329257115
www.ismeca.com

Kulicke & Soffa Industries
1005 Virginia Drive,
Fort Washington,
PA 19034,
USA
Tel: +1 215 784 6000
Fax: +1 215 784 6001
www.kns.com

Palomar Technologies Inc
2728 Loker Avenue West,
Carlsbad, CA 92010,
USA
Tel: +1 760 931 3600
Fax: +1 760 931 5191
www.PalomarTechnologies.com

TECDIA Inc
2700 Augustine Drive, Suite 110,
Santa Clara, CA 95054,
USA
Tel: +1 408 748 0100
Fax: +1 408 748 0111
www.tecdia.com

17 Assembly/packaging foundry

Quik-Pak
10987 Via Frontera,
San Diego, CA 92127, USA
Tel: +1 858 674 4676
Fax: +1 8586 74 4681
www.quikicpak.com

18 Chip foundry

Compound Semiconductor Technologies Ltd
Block 7, Kelvin Campus,
West of Scotland, Glasgow,
Scotland G20 0TH, UK
Tel: +44 141 579 3000
Fax: +44 141 579 3040
www.compoundsemi.co.uk

United Monolithic Semiconductors
Route departementale 128,
BP46, Orsay, 91401,
France
Tel: +33 1 69 33 04 72
Fax: +33 169 33 02 92
www.ums-gaas.com

19 Facility equipment

MEI, LLC
3474 18th Avenue SE,
Albany, OR 97322-7014,
USA
Tel: +1 541 917 3626
Fax: +1 541 917 3623
www.marlerenterprises.net

20 Facility consumables

W.L. Gore & Associates
401 Airport Rd, Elkton,
MD 21921-4236,
USA
Tel: +1 410 392 4440
Fax: +1 410 506 8749
www.gore.com

21 Computer hardware & software

Ansoft Corp
4 Station Square,
Suite 200,
Pittsburgh, PA 15219,
USA
Tel: +1 412 261 3200
Fax: +1 412 471 9427
www.ansoft.com

Crosslight Software Inc
121-3989 Henning Dr.,
Burnaby,
BC, V5C 6P8,
Canada
Tel: +1 604 320 1704
Fax: +1 604 320 1734
www.crosslight.com

Semiconductor Technology Research Inc
10404 Patterson Ave.,
Suite 108, Richmond, VA 23238,
USA
Tel: +1 804 740 8314
Fax: +1 804 740 3814
www.semitech.us

22 Used equipment

Class One Equipment Inc
5302 Snapfinger Woods Drive,
Decatur,
GA 30035,
USA
Tel: +1 770 808 8708
Fax: +1 770 808 8308
www.ClassOneEquipment.com

23 Services

Henry Butcher International
Brownlow House, 50–51
High Holborn,
London WC1V 6EG,
UK
Tel: +44 (0)20 7405 8411
Fax: +44 (0)20 7405 9772
www.henrybutcher.com

M+W Zander Holding AG
Lotterbergstrasse 30,
Stuttgart,
Germany
Tel: +49 711 8804 1141
Fax: +49 711 8804 1950
www.mw-zander.com

24 Consulting

Fishbone Consulting SARL
8 Rue de la Grange aux Moines,
78460 Choisel, France
Tel: + 33 (0)1 30 47 29 03
E-mail: jean-luc.ledys@neuf.fr

25 Resources

Al Shultz Advertising Marketing for Advanced Technology Companies
1346 The Alameda,
7140 San Jose, CA 95126, USA
Tel: +1 408 289 9555
www.alshuktz.com

SEMI Global Headquarters
3081 Zanker Road,
San Jose, CA 95134, USA
Tel: +1 408 943 6900
Fax: +1 408 428 9600
www.semi.org

Yole Développement
45 rue Sainte Geneviève,
69006 Lyon, France
Tel: +33 472 83 01 86
www.yole.fr

REGISTER

for *Semiconductor Today*

free at

www.semiconductor-today.com

event calendar

If you would like your event listed in *Semiconductor Today*'s Event Calendar, then please e-mail all details to the Editor at mark@semiconductor-today.com

14–18 May 2017
Compound Semiconductor Week (CS Week 2017), including:
44th International Symposium on Compound Semiconductors (ISCS 2017)
29th International Conference on Indium Phosphide and Related Materials (IPRM 2017)
Berlin, Germany
E-mail: info@csw2017.org
www.csw2017.org

14–19 May 2017
Conference on Lasers and Electro-Optics (CLEO 2017)
San Jose Convention Center, San Jose, CA, USA
E-mail: CLEO@compusystems.com
www.cleoconference.org

16–17 May 2017
ITF Belgium (Imec Technology Forum 2017)
Antwerp, Belgium
E-mail: Olfa.Marzouk@imec.be
www2.imec.be/be_en/events.html

16–18 May 2017
PCIM Europe (Power conversion and Intelligent Motion) 2017
Nuremberg Messe, Germany
www.mesago.de/en/PCIM/main.htm

21–23 May 2017
International Wide Bandgap Materials Power Electronics Applications Workshop (IWBGPEAW 2017)
Stockholm, Sweden
E-mail: veyrier@yole.fr
www.b2match.eu/iwbgpeaw2017

22–25 May 2017
2017 CS ManTech: International Conference on Compound Semiconductor Manufacturing Technology
Hyatt Regency Indian Wells Resort & Spa, CA, USA
E-mail: lynn_fincher@msn.com
www.csmantech.org

28 May – 1 June 2017
29th International Symposium on Power Semiconductor Devices and ICs (ISPSD 2017)
Sapporo, Japan
E-mail: ispsd2017reg@ech.co.jp
http://eds.ieee.org/eds-meetings-calendars.html

30 May – 2 June 2017
Intersolar Europe Exhibition and Conference (ISE 2017)
Messe München, Munich, Germany
E-mail: info@intersolar.de
www.intersolar.de

4–6 June 2017
IEEE Radio Frequency Integrated Circuits Symposium (RFIC 2017)
Hawaii Convention Center, Honolulu, HI, USA
http://rfic-ieee.org

advertisers' index

Advertiser	Page no.
Aixtron SE	5
Conax Technologies	23
CS Clean Solutions	32
CS Mantech	71
Evatec	41
Ferrotec-Temescal	43
Fuji Electric	17
III/V-Reclaim	33
IQE	25
$NAsP_{III/V}$	21
RIFF Company	47
SEMI-GAS	37
University Wafer	22
Veeco Instruments — MBE	7
Veeco Instruments — MOCVD	2

4–9 June 2017
IEEE MTT-S International Microwave Symposium (IMS 2017)
Hawai'i Convention Center, Honolulu, HI, USA
E-mail: ims2017.info@gmail.com
www.ims2017.org

5–8 June 2017
2017 Symposia on VLSI Technology and Circuits
Rihga Royal Hotel, Kyoto, Japan
E-mail: vlsi@vlsisymposium.org
www.vlsisymposium.org

11–14 June 2017
Joint EuroCVD21 – Baltic ALD 15
Linköping, Sweden
E-mail: henrik.pedersen@liu.se
www.eurocvd-balticald2017.se

25–29 June 2017
CLEO/Europe-EQEC 2017: Conference on Lasers and Electro-Optics/Europe & the European Quantum Electronics Conference
Munich, Germany
E-mail: info@cleoconference.org
www.cleoeurope.org

25–30 June 2017
44th IEEE Photovoltaic Specialists Conference (PVSC 2017)
Marriot Wardman Park Hotel, Washington DC, USA
E-mail: info@ieee-pvsc.org
www.ieee-pvsc.org/PVSC44

26–29 June 2017
LASER World of PHOTONICS 2017 (23rd International Trade Fair and Congress for Photonics Components, Systems and Applications)
Messe München, Munich, Germany
E-mail: info@world-of-photonics.com
www.world-of-photonics.com

10–12 July 2017
IEEE Photonics Society's 2017 Summer Topicals Meeting Series
San Juan, Puerto Rico
E-mail: i.donnelly@ieee.org
www.sum-ieee.org

10–12 July 2017
Intersolar North America
San Francisco, CA, USA
E-mail: info@intersolar.de
www.intersolar.us

15–18 July 2017
ALD 2017: 17th International Conference on Atomic Layer Deposition, featuring the 4th International Atomic Layer Etching Workshop (ALE2017)
Sheraton Denver, CO, USA
E-mail: della@avs.org
www.ald-avs.org

31 July – 4 August 2017
Conference on Lasers and Electro-Optics – Pacific Rim (CLEO – Pacific Rim 2017)
Opto-Electronics and Communications Conference (OECC)
Photonics Global Conference (PGC)
Sands Expo and Convention Centre, Singapore
E-mail: admin@photonics2017.org
http://photonics2017.org/orgcleo.php

6–10 August 2017
SPIE Optics + Photonics 2017
San Diego Convention Center, CA, USA
E-mail: customerservice@spie.org
http://spie.org/optics-photonics1

23–25 August 2017
IEEE 14th International Conference on Group IV Photonics (GFP 2017)
Berlin, Germany
E-mail: m.figueroa@ieee.org
www.gfp-ieee.org

17–22 September 2017
ICSCRM 2017: International Conference on Silicon Carbide and Related Materials
Wardman Park Marriott, Washington DC, USA
E-mail: info@mrs.org
www.mrs.org/icscrm-2017

17–21 September 2017
ECOC 2017: 43rd European Conference on Optical Communication
Svenska Mässan (The Swedish Exhibition & Congress Centre), Gothenburg, Sweden
E-mail: ecoc2017@meetx.se
http://ecoc2017.org

1–5 October 2017
2017 IEEE Photonics Conference (IPC), 30th Annual Conference of the IEEE Photonics Society
Orlando, FL, USA
E-mail: i.donnelly@ieee.org
www.ipc-ieee.org

semiconductorTODAY

COMPOUNDS & ADVANCED SILICON

www.semiconductor-today.com

Join our LinkedIn group: Semiconductor Today

Follow us on Twitter: Semiconductor_T

Choose *Semiconductor Today* for . . .

ISSN 1752-2935 (online)

semiconductorTODAY

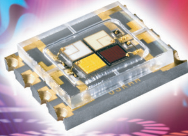
COMPOUNDS & ADVANCED SILICON

Vol. 7 • Issue 2 • March/April 2012

www.semiconductor-today.com

Efficiency droop in nitride & phosphide LEDs

First single-crystal gallium oxide FET



Graphensic spun off • Emcore sells VCSEL range to Sumitomo

Masimo buys Spire Semiconductor • Oclaro and Opnext merge

MAGAZINE

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

Targeted 82,000+ international circulation

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

WEB SITE

Average of over 26,000 unique visitors to the site each month

Daily news updates and regular feature articles

Google-listed news source

E-BRIEF

Weekly round-up of key business and technical news

E-mail delivery to entire circulation

Banner and text marketing opportunities available