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COMPOUNDS & ADVANCED SILICON

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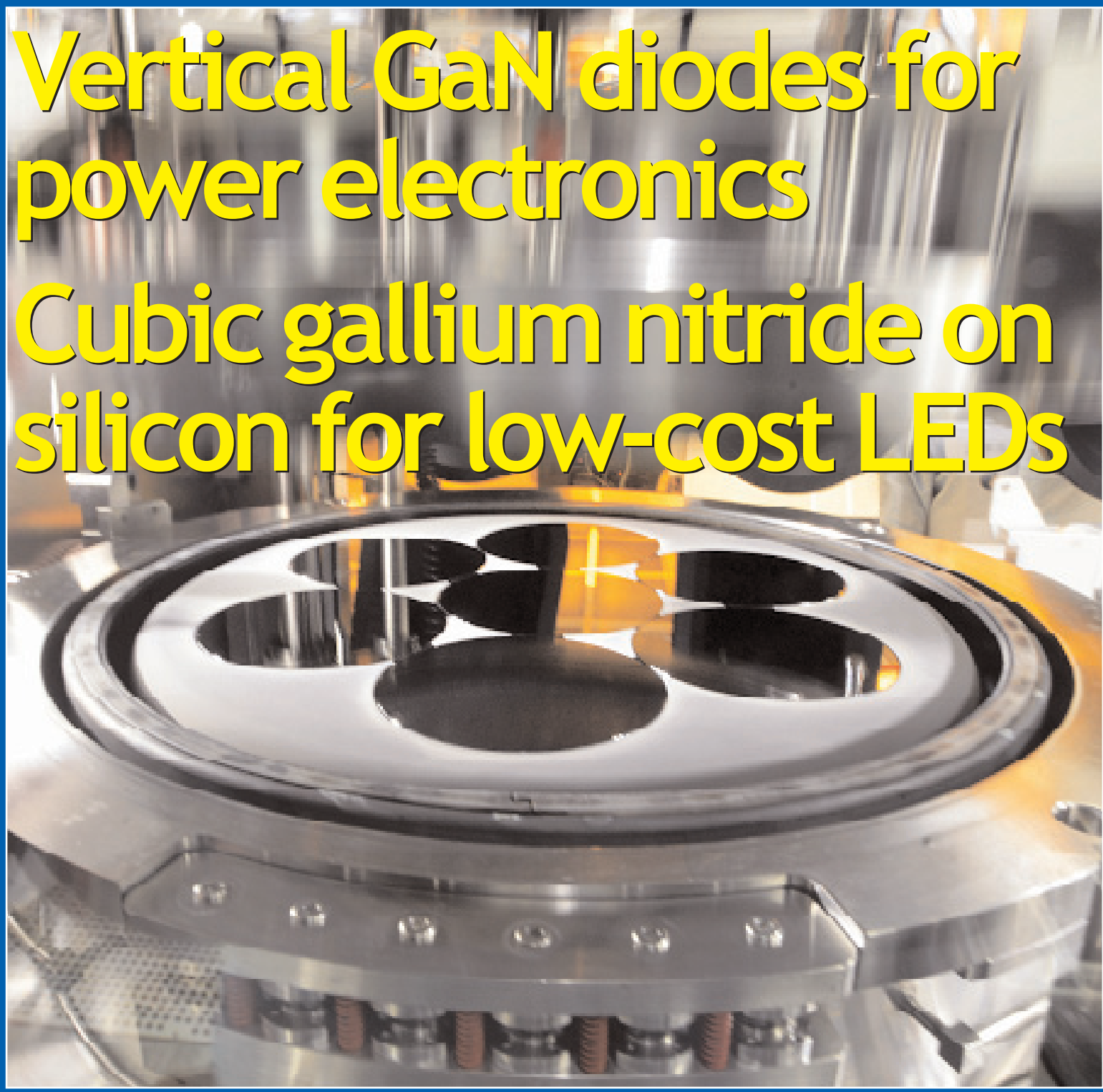


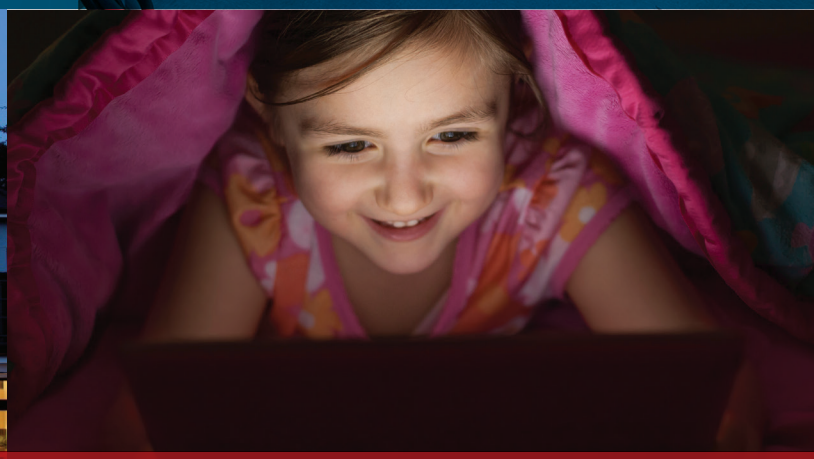
Vertical GaN diodes for power electronics

Cubic gallium nitride on silicon for low-cost LEDs

Veeco & imec team on GaN power devices • POET using Wavetek

Fraunhofer ISE boosts CPV module efficiency to 43.4%

Lower Cost LEDs



Faster LED Adoption

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

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

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

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

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

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

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

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

Veeco's New TurboDisc EPIK700 GaN MOCVD System

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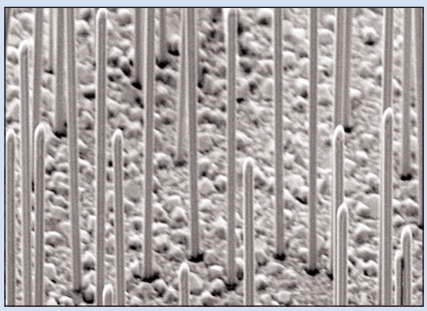
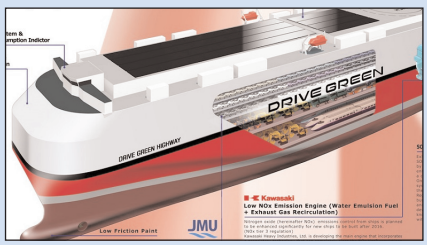
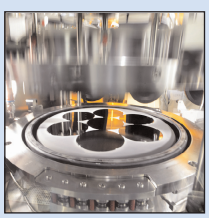
p37 Veeco's new TurboDisc K475i As/P MOCVD system for the production of red, orange, yellow LEDs as well as multi-junction III-V solar cells, laser diodes and transistors.



p56 TU Munich has developed III-V nanowire lasers grown directly on silicon, targeting cost-effective production of high-performance photonic components.



p73 Solar Frontier's CIS thin-film PV solar panels have been installed by Japanese shipping firm K Line on its new environmentally friendly transport ship.



Cover: Interior of a GaN MOCVD reactor at Plessey: UK-based Plessey, Anvil Semiconductors and the University of Cambridge are working together to fabricate high-efficiency LEDs in cubic GaN grown on Anvil's 3C-SiC/Si (silicon carbide on silicon) substrates. **p46**

editorial

Focus on power electronics

This issue (on pages 88–93) we report work by the universities of Cornell and Notre Dame on developing gallium nitride devices with vertical structures (on either bulk or free-standing GaN substrates) rather than the lateral structures of established high-electron-mobility transistors (HEMTs) and other unipolar transistors (which suffer from field and current crowding that can lead to breakdown via gate leakage etc). This allows vertical GaN p–n junction diodes to get nearer to the theoretical high critical field of such a wide-bandgap material, allowing a high breakdown voltage for power electronics applications.

Furthermore, pages 94–96 covers work by Peking University researchers on high-mobility GaN heterostructures using a low-aluminium-content AlGaN buffer layer, which could lead to reduced stress when grown on silicon substrates. This offers the prospect of low-cost vertical GaN-on-Si high-performance electronic devices.

Also, through its industrial affiliation program on GaN-on-Si, Belgium-based nano-electronics research center imec has been collaborating with metal-organic chemical vapor deposition (MOCVD) system maker Veeco over the last four years to improve the epi quality of GaN layers deposited on silicon substrates. Now, a joint development project has been agreed that aims to accelerate the development of GaN power electronic devices using epiwafers created using Veeco's Propel Power GaN MOCVD system (see page 36).

Commercial prospects are highlighted by Technavio forecasting that the MOCVD market for power electronics is rising at a compound annual growth rate (CAGR) of over 40% to more than $205m in 2019 (see page 9). The report also forecasts that the Asia-Pacific's already large 91% share of this market will grow further, at the expense of North America, while Europe will grow in revenue terms, aided by being the hub of the automotive industry (drawing Canada-based GaN Systems to collaborate with Germany-based automotive electronics specialist HELLA in developing a 97%-efficient electric vehicle charger, for example — see page 29). GaN Systems has also — together with the Centre for Power Electronics of the UK's EPSRC (Engineering and Physical Sciences Research Council) — launched a Future Power Challenge, open to UK electronics postgraduates (page 28).

As well as GaN, Europe is also a focus for silicon carbide power electronics, particularly Sweden, Germany and the UK (where US firm Raytheon has its SiC foundry in Glenrothes, Scotland). A grant from UK government agency Innovate UK will aid the UK's Manufacturing Technology Centre (MTC) and 3C-SiC device developer Anvil Semiconductors in developing a power conversion module using cubic silicon carbide — which can be grown on silicon substrates — rather than the more costly 4H-SiC (see page 20).

Anvil's 3C-SiC-on-silicon technology is also being used in a collaboration with the University of Cambridge and UK-based Plessey Semiconductors to fabricate LEDs in cubic GaN grown on Anvil's 3C-SiC/Si substrates (see page 46). In addition to the lower costs of using silicon, using cubic SiC avoids the strong internal electric fields in conventional LEDs that impair carrier recombination and contribute to droop in luminous efficiency at high drive currents, particularly for green LEDs (for which the internal electric fields are stronger).

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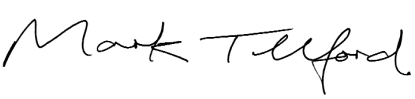

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***Semiconductor Today* covers the R&D and manufacturing of compound semiconductor and advanced silicon materials and devices** (e.g. GaAs, InP and SiGe wafers, chips and modules for microelectronic and optoelectronic devices such as RFICs, lasers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

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

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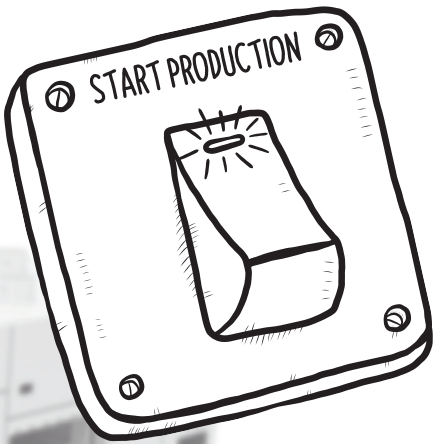

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news

LED production equipment market to grow at CAGR of over 5% to $1.5bn in 2019

Asia-Pacific rising from 86% to 88% of market; back-end equipment segment to grow at 9%

The global LED production equipment market will rise at a compound annual growth rate (CAGR) of more than 5% to $1.5bn in 2019, forecasts a report by analysts at Technavio. Demand for LED production equipment is currently being heavily influenced by the increasing number of fabrication plants being established in the Asia-Pacific region (APAC).

"The market witnessed strong growth in 2014 due to the increasing number of LED fab establishments in Taiwan and China because of increasing demand for LEDs in APAC. However, the growth during the forecast period will not witness much fluctuation," notes lead semiconductor equipment research analyst Sunil Kumar in the report 'Global LED Production Equipment Market 2015–2019'. "The key factors contributing to the minimal fluctuations in the market are the product life cycle of front-end equipment, which is 5–7 years, and the reduced rate of new LED fab establishments globally," Sunil adds.

Of the front-end and back-end sectors of the LED production equipment market, the back-end segment is the largest, representing 62% of the market. This segment is expected to grow at a CAGR of 9% during the forecast period due to the rising number of LED manufacturers globally.

APAC accounted for an 86% share of the global LED production equipment market in 2014. This region is expected to continue to dominate the market during the forecast period, increasing its market share to over 88% in 2019.

APAC is a manufacturing hub for LEDs and LED panel manufacturers and has high growth potential as most of the LED manufacturing companies are located in this region, notes the report. Most of the market growth in this region comes from countries such as Taiwan, South Korea, Japan and China.

High costs are a major barrier for LED market growth. Key to achieving low-cost LEDs is low-cost manufacturing and the adoption of advanced manufacturing processes

Technavio's hardware and semiconductor research analysts have identified the following three market growth factors: increasing demand for LEDs; strengthening supply chain; and increasing focus on cost reduction.

Increasing demand for LEDs

LEDs are emerging as potential substitutes for traditional lighting sources such as incandescent, fluorescent, and halogen lighting. Their high luminous efficacy and lower power consumption compared with traditional lighting sources is driving demand for LEDs in general lighting applications. Additionally, LCD displays are employing LEDs in backlight units, significantly contributing to the market. The market is also seeing high demand from the automotive sector, with the integration of LEDs in automobiles.

Strengthening supply chain

Since its inception the LED supply chain has undergone drastic changes, but since 2010 restructuring has taken place, involving the strengthening of the upstream, midstream and downstream supply chains, says the report. One of the factors for a strong and established supply chain is the vertical integration of some of the major vendors such as Cree, Philips and Osram, which control most of the value chain.

"Strong supply chain establishments will tend to increase the profitability of vendors as the inventory levels will be low and the cost of manufacturing can be controlled," says Kumar. "This will facilitate LED manufacturers to reduce the cost of LEDs, which in turn fuels the adoption of LEDs in several application sectors," he adds.

Increasing focus on cost reduction

High costs are a major barrier for LED market growth, forcing most vendors to focus on reducing the cost of LEDs. Key to achieving low-cost LEDs is low-cost manufacturing and the adoption of advanced manufacturing processes, states the report. The need for advances in manufacturing processes is driving the need for advances in LED production equipment too. In profiling key gallium nitride (GaN) metal-organic chemical vapor deposition (MOCVD) system vendors Aixtron, Veeco Instruments and Taiyo Nippon Sanso, the report notes that, for example, Veeco's TurboDisc MaxBright MHP GaN MOCVD multi-reactor system can improve production yield by 20% and increase footprint efficiency by 15%. Another example for cost reduction is increasing the size of LED epitaxial wafers, concludes Technavio.

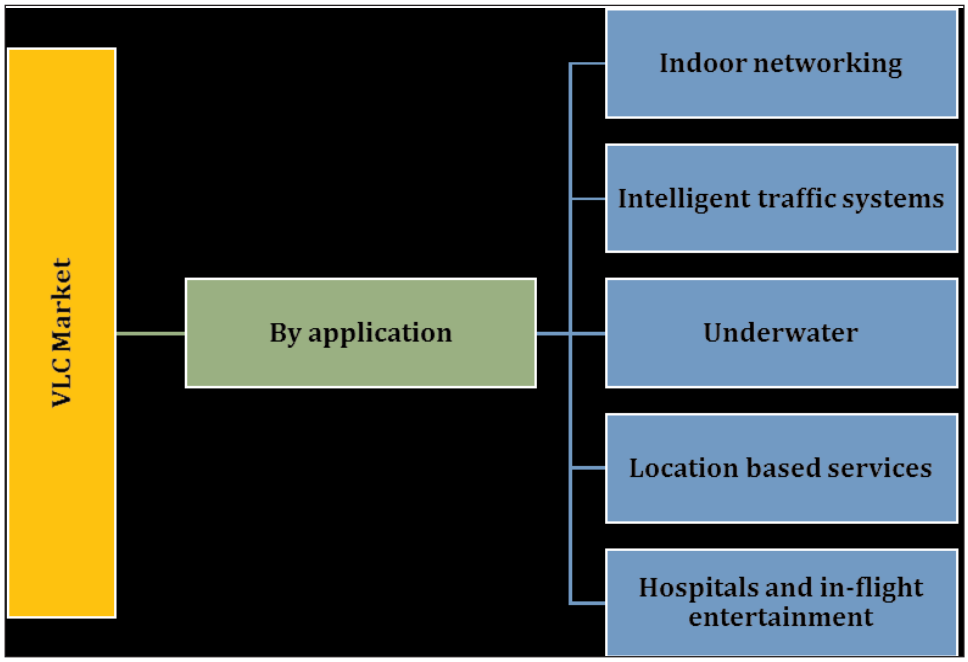
www.technavio.com/report/global-semiconductor-equipment-led-production-market

Visible light communication market to grow at 64% CAGR to more than $8bn in 2019

Indoor networking market to drive growth

The global visible light communication (VLC) market will post a remarkable compound annual growth rate (CAGR) of close to 64% to more than $8bn in 2019, according to the report 'Global Visible Light Communication Market 2015-2019' by Technavio.

The report segments the visible light communication market by application as: indoor networking, location-based services, intelligent traffic systems, in-flight communication and entertainment, and underwater communication



Indoor networking market

The global indoor networking market using VLC is expected to approach $6bn by 2019, growing at a CAGR of almost 65% during the forecast period.

Retailers can use VLC technology to enhance the shopping experience of customers, and improve the value delivered. About 60% of customers use mobile phones in retail stores, and around 70% of sales are made in the aisle. The use of this technology can further ensure that shoppers looking for specific goods on their shopping list will be directed to them easily.

"The adoption of this technology, along with indoor position apps, will improve the targeted advertising of retailers and enhance their sales," says Technavio's lead semiconductor equipment industry analyst Asif Gani. "Moreover, low data rates and existing infrastructure will reduce costs considerably."

Location-based services market

As GPS does not work in an indoor environment, the accepted technology for identifying location in such environment is the deployment of Wi-Fi AP. VLC can be used as an alternative to Wi-Fi due to its ability to offer accurate indoor locations, as numerous LED luminaires are generally installed in a building. A typical building has 10 times more LEDs than Wi-Fi APs. The higher density of LEDs can ensure precise pinpointing of mobile devices, resulting in improved accuracy. The adoption of LED lighting networks for their energy efficiency will add to the growth of the location-based services segment, says Technavio.

Intelligent traffic systems market

The use of VLC technology in traffic systems will allow drivers to use smart devices or car headlights to connect and generate information such as traffic updates, shortest estimated time of arrival to a specific location (taking into account traffic congestion), and even for Internet access. This information can be transmitted to other cars using tail lights.

"Efficiency of these intelligent traffic systems may be affected due to noise, but such interference can be avoided by using specific colored lighting to transmit information, and programming the receivers to recognize specific wavelengths," notes Gani.

In-flight communication and entertainment market

VLC technology can be used in flights for entertainment or for providing Internet access, as this technology does not interfere with flight avionics or any other electrical equipment in the surrounding area. Also, the use of VLC will reduce the amount of cabling required, which will ultimately reduce the weight of the aircraft, increasing fuel efficiency and adding flexibility to seating layouts in the aircraft cabin, notes the report.

Underwater communication

The use of radio frequency (RF) in water is impractical because of strong signal absorption, and the low bandwidth of acoustic waves disturbs marine life. Therefore, VLC technology can be incorporated in the headlights of underwater devices or divers to facilitate communication. At present, underwater devices such as remotely operated underwater vehicles (ROV) are powered by wires. However, if VLC is used, these devices will be able to roam freely, and transmit and receive data from the surface.

The top vendors of VLC systems highlighted in the report are: pureLiFi, Oledcomm-France LiFi, Nakagawa Laboratories, Outstanding Technology, LightPointe Communications, and fSONA Networks.

www.technavio.com/report/global-semiconductor-equipment-visible-light-communication-market

Silicon photonics-based optical communications component market to reach $1bn by 2020

Replacement of InP and GaAs technology requires development of wafer-scale optical manufacturing, packaging and testing technologies, compatible with 3D wafer stacking

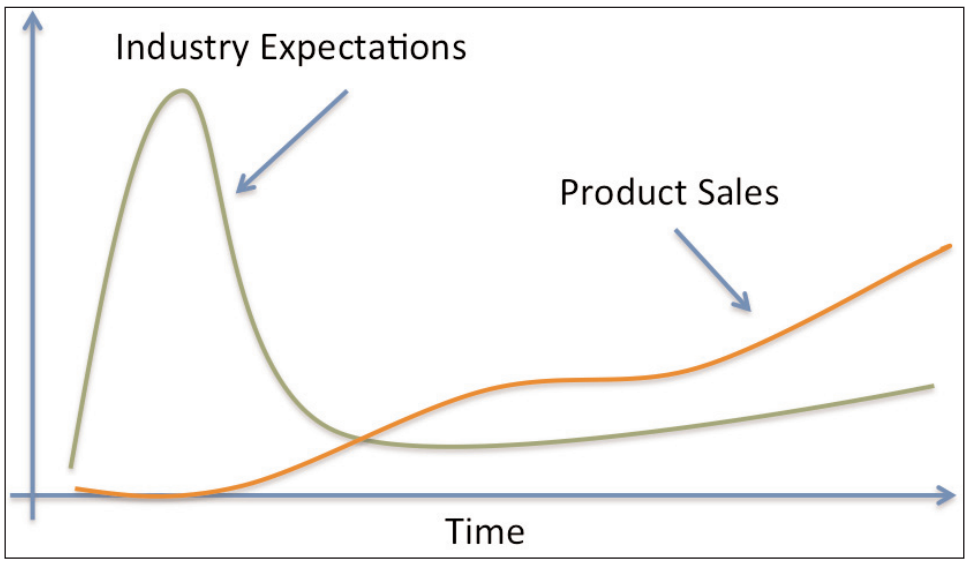
LightCounting has released a report 'Market Opportunity for Optical Integration Technologies, Including Silicon Photonics' giving an analysis of the potential impact of integration technologies on the market for optical transceiver module and related components used in data centers and other networking systems.

The potential impact of photonic integration on the optical communications market has captivated the imagination of the industry for the last two decades. Recent successes by vendors developing integrated products using silicon photonics (SiP) has led to several mergers and high-value acquisitions in 2012–2013, and shipments of SiP-based products increased in 2014–2015.

It seems clear that several SiP suppliers demonstrated that the technology works, notes the report. However, it is up to the manufacturing engineers and business managers of these suppliers to show that SiP products can be made in high volume at a competitive cost and generate profits to fund development of next-generation products. As often happens with new technologies, product sales are starting to ramp up just as industry expectations start to fade (see Figure).

The key question now is how much of an impact optical integration technologies will have on the market in 2016–2021, says LightCounting. Will SiP replace more mature indium phosphide (InP) and gallium arsenide (GaAs) technologies, which dominated the market over the last decade and already enabled a variety of integrated products?

Segmented by primary application, including Ethernet, WDM, and active optical cables (AOCs) and embedded optical modules (EOMs), the report presents data on advances made by optical integration technologies during 2010–2015 and gives a forecast for shipments and sales of discrete and integrated products based on InP, GaAs and SiP technologies for 2016–2021.



Typical trend for cross-correlation between industry expectation for new technologies and product sales.

Competition from more established InP and GaAs technologies will be fierce in 2016–2021, predicts the report. There is not a single SiP-based product on the market that does not have an alternative made using InP and GaAs optics.

"Many in the industry have predicted that silicon photonics (SiP) will enable inexpensive, mass-produced optical connectivity, radically changing the optical components and modules industry," comments LightCounting's CEO & founder Vladimir Kozlov. "Our analysis suggests this will not happen in the next 5 years, but sales of SiP-based optical products may reach $1bn by 2020, accounting for about 10% of the market."

If SiP-based products can weather the fierce competition from more established technologies and gain a beach-head in this market by 2020, it may disrupt the market over the next decade. Such a disruption will require development of wafer-scale optical manufacturing, packaging and testing technologies, compatible with 3D wafer stacking for integration with electronics, says LightCounting.

Nevertheless, even a distant possibility of a technological disruption has justified investment into SiP technology by Cisco, which was then followed by many other equipment suppliers. Optical integration start-ups continue to raise funding and all established suppliers of components and modules have SiP technology on their roadmap. The chances for success are still low and distant, but no vendor can afford to ignore the possibility of a disruption, concludes the LightCounting.

www.LightCounting.com/Silicon.cfm

Power electronics MOCVD market growing at 40% CAGR to over $205m in 2019

APAC the main market, but Europe revenue driven by automotive hub

The metal-organic chemical vapor phase deposition (MOCVD) market for power electronics is rising at a compound annual growth rate (CAGR) of over 40% to more than $205m in 2019, according to the report 'Global MOCVD Market in Power Electronics 2015–2019' by Technavio.

APAC region the largest market

With a huge share of 91% in 2014, APAC became the largest market for MOCVD in power electronics and will remain the lead market over the next five years. The high concentration of original equipment manufacturers (OEMs) and original design manufacturers (ODMs) in the region is driving market growth, the report notes.

Growing demand for power electronic devices in renewable and utility applications in APAC is another factor that is expected to fuel the demand for power electronics. The availability of raw materials, low establishment and labor costs, and the business-friendly government policies of various countries have encouraged many companies to set up manufacturing sites in the region. Technological advances in MOCVD and power electronics, such as gallium nitride (GaN) power devices and GaN-on-silicon (GaN-on-Si) platforms are also adding to the market growth in the region.

"Rapid growth of the MOCVD market in the APAC is also because countries such as China, Japan, Taiwan and South Korea have many firms with a strong presence in the electronics manufacturing industry," says Asif Gani, Technavio's lead semiconductor equipment industry analyst.

Key vendors in the global MOCVD market in power electronics highlighted in the report are US-based Veeco Instruments Inc, Germany-based Aixtron SE, and Japan-based Taiyo Nippon Sanso Corp (although there are also a few small emerging players, mostly in China, making MOCVD tools for power electronics).

Americas

Due to the rise in demand and procurement of MOCVD equipment used for power electronics in APAC, the market share of the Americas is expected to fall gradually during the forecast period, says Technavio. The Americas (especially the USA and Canada) represent mature markets for technology products, as the consumers in this region are early adopters of any emerging technology, the firm adds. The shifting and development of existing and new manufacturing units and their expansion to APAC is affecting the market share of the Americas.

Europe

The MOCVD market for power electronics in Europe is expected to grow steadily in terms of revenue during the forecast period, with countries such as Germany (home to Aixtron, the world's second largest MOCVD equipment supplier), France and the UK playing pivotal roles. Europe is the hub of the automotive industry, in which demand for energy-efficient power electronics is increasing significantly.

"EMEA, like the Americas, will see a decrease in its global market share due to high demand and manufacturing of power electronics in APAC. However, the decrease is only from a global market share perspective and not in terms of revenue," says Gani.

www.technavio.com/report/global-semiconductor-equipment-mocvd-power-electronics-market

GaN power device market to grow at 24.5% to 2022

The gallium nitride power device market will rise at a compound annual growth rate (CAGR) of 24.5% from 2016 to $2.6bn in 2022, according to the report 'GaN Power Devices Market — Global Forecast to 2022' from MarketsandMarkets.

Major growth segments are satellite communication, radar and wireless applications due to the launches of new GaN power devices for these applications and developments to boost power handling capacity and switching frequency.

ICT and consumer electronics contribute most market share

The technical evolution of GaN devices is accelerating usage in the information communication technology (ICT) end-user sector (including RF, satellite and telecom), due mainly to increased demand and the extensive focus on various types of RF and wireless applications.

Consumer electronics is one of the main revenue-contributing end-user sectors, with significant revenue for GaN opto-semiconductor devices. Revenue growth is also slowly gaining pace with the gradual penetration of GaN power semiconductor devices into various consumer electronics applications.

Japan to dominate GaN wafer market

Japan is expected to take the largest market share and dominate the GaN wafer market from 2016 to 2022. The Japan market is driven by the rise in applications in this region and continuous developments in the semiconductor industry. In terms of the distribution of key players, Japan ranks second of all the geographical regions, with several players being headquartered in the country.

Some of the major players in Japan in the GaN power device market include Renesas Electronics, Rohm Co Ltd, Nichia Corp, Toshiba Corp, and Toyoda Gosei Ltd.

www.marketsandmarkets.com/Market-Reports/gallium-nitride-wafer-market-93870461.html

Qorvo's quarterly revenue falls 12% after demand pause from largest Mobile Products customer

Wireless infrastructure growth heralds recovery in China base-station market

For its fiscal third-quarter 2016 (to 2 January), Qorvo Inc (which provides core technologies and RF solutions for mobile, infrastructure and defense applications) has reported revenue of $620.7m (well below the original guidance of $720–730m), down 12% on $708.3m last quarter and 16% on $742m a year ago for the combined December 2014 quarter revenues of RF Micro Devices Inc of Greensboro, NC and TriQuint Semiconductor Inc of Hillsboro, OR, USA (following the merger of the two firms on 1 January 2015). Nevertheless, in Qorvo's first full year, compared to calendar 2014, revenue grew 12%.

Qorvo had two 10%-or-more customers: the larger at about 42% of revenue (representing the collective demand of multiple subcontractors for this end-customer); and China-based telecoms equipment maker Huawei Technologies Co Ltd (a customer for both Mobile Products and Infrastructure & Defense Products) at 10%.

Mobile Products revenue fell 15% from $578m last quarter to $489m, due to a late reduction in demand from Qorvo's largest customer. "Customers are building less phones than what we expected just a month ago even," notes president & CEO Bob Bruggeworth.

Infrastructure & Defense Products (IDP) revenue grew slightly from $129m last quarter to $130m, with 18% growth in Wireless Infrastructure (indicating an initial recovery in the China base-station market). This is driving further recovery from the low of $122m in the June 2015 quarter (which followed a sharp drop for wireless infrastructure due to a pause in LTE base-station deployment).

On a non-GAAP basis, gross margin has fallen from 49.7% last quarter to 47.9% (below the expected 50%). This is due mainly to lower yields but also to $4m worth of inventory adjustments (since December tends to be a higher quarter for writing off excess and obsolete inventory, as Mobile customers separate their winners from the losers, notes Buhaly), leading to a one-off hit of 200 basis point to margins. However, for Qorvo's first full year, compared to calendar 2014, gross margin rose more than 400 basis points.

Operating expenses (OpEx) fell $17m from $156.8m last quarter to $139.8m, reflecting a significant reduction in variable compensation expense (accruals for bonus expense) and seasonally lower spending.

Net income has fallen from $183.3m ($1.22 per diluted share) last quarter to $148m ($1.03 per diluted share, well below the initial guidance of $1.25–1.30).

Nevertheless, cash flow from operations has risen again, from $168.8m last quarter to $218m. Capital expenditure (CapEx) was $61.5m (down from $80.3m), primarily to address growth in demand for premium filters. Free cash flow was hence $156.5m.

Total cash and investments at the end of the December quarter exceeded $1bn. During the quarter, Qorvo repurchased 4.6 million shares of common stock at a total cost of $250m. The firm has $750m remaining in its one-year $1bn share repurchase program (approved in November 2015 and expiring on 4 November 2016). "Our balance sheet and strong cash flow provide the opportunity to create value for our shareholders through share repurchases while continuing to invest in internal and external opportunities to drive long-term diversified growth," says chief financial officer Steve Buhaly.

Massive MIMO active antenna systems are driving a 10x increase in RF content in next-generation base-stations

"The Qorvo team executed extremely well in our first full year versus calendar 2014, growing annual revenue 12%, expanding gross margin more than 400 basis points and achieving more than 40% growth in operating income," says Bruggeworth.

"Qorvo is leveraging our comprehensive portfolio of tightly integrated, world-class RF solutions, rapidly introducing new products and technologies, expanding into the new serviceable markets, and enjoying very favorable design-win activity," says Bruggeworth. "We are growing our dollar content at our three largest mobile customers in the most highly anticipated marquee smartphones being released this year [starting to ramp later this quarter], and we anticipate strong growth in IDP," he adds.

In December, Qorvo released the industry's first 6-inch temperature-compensated surface acoustic wave (TC-SAW) filter wafers in its Florida fab, qualified 6" SAW wafers in its fab in Greensboro, and demonstrated its first 8" bulk acoustic wave (BAW) wafers in its Texas fab. Qorvo has begun shipping its recently launched BAW-based quadplexers for FDD bands 1 and 3 (an industry first, it is claimed) enabling carrier aggregation in 4G LTE devices, and demonstrated BAW-based hexaplexer prototypes.

Qorvo has also been selected to support a number of key cellular platforms with its next-generation envelope-tracking (ET) power management integrated circuit (PMIC) and begun shipment to a large global smartphone OEM, and has landed a number of large-scale wins for later this year.

Qorvo has also recently expanded its shipments of antenna control solutions into the China smartphone market. Previously, the firm's antenna tuners and impedance tuners had been highly concentrated within a small number of high-volume marquee devices, but Qorvo has now increased its addressable market in China as these customers add RF functionality to support their expanding presence in the worldwide market.

In IDP, the December quarter was an exceptionally strong design-wins. Qorvo captured multiple key design wins for macro- and small-cell base-station applications. "Network capacity constraints will accelerate the adoption of small-cell base-stations and massive MIMO active antennas," believes Bruggeworth. "Massive MIMO active antenna systems are driving a 10x increase in RF content in next-generation base-stations," he adds. "We continue to work on capturing new design wins as the market shifts from 4G LTE to LTE-A, LTE-Pro and eventually 5G." At January's 2016 Consumer Electronics Show (CES) in Las Vegas, Qorvo supplied a suite of critical microwave components (including phase shifters, power amplifiers and switches) for a 5G 'massive MIMO' demonstration performed by a major base-station OEM.

Qorvo also expanded its presence in the connected home with key design wins in gateways and access points, highlighted by design wins in flagship products at both NETGEAR and LINKSYS. "The rapidly increasing number of connected devices represented by the Internet of Things will be IDP's largest growth engine," believes Bruggeworth.

In defense, continued strong growth in gallium nitride (GaN)-based products included securing a multi-year win on a next-generation electronic warfare system using Qorvo's patented Spatium solid-state RF power technology incorporating GaN MMICs (with hundreds of system installations anticipated over the life of the contract).

"March-quarter revenue expectations are slightly below our pre-announcement [stated in early January, for revenue to be flat sequentially], reflecting an overall conservative posture [in Mobile, not IDP], given the cautious environment, as well as the timing of new product ramps," says Buhaly. For fiscal fourth-quarter 2016 (ending 2 April), Qorvo expects revenue to fall to $600m. Gross margin should rise back to about 50%. OpEx should be almost $150m.

Over the next few quarters, CapEx should be $60–70m per quarter, believes Buhaly. Most of that will be for filter capacity expansion; some of the wafer size increases where Qorvo is moving SAW and TC-SAW from 4" wafers to 6"; BAW from 6" to 8"; and expanding SAW footprint into the factory in North Carolina. "We see our 6" SAW capacity contributing to growth and profitability in the current year, and we see our 8" BAW capacity doing the same in 2017," says Bruggeworth.

Infrastructure & Defense Products revenue is expected to recover further in the near-term, reinforcing top-line growth opportunities in calendar 2016. "Our IDP team continues to sharpen its focus on the highest-growth segments in its diversified business portfolio," says Bruggeworth. "This focus drives alignment with the growth markets of the Internet of Things, connected home, connected car and the high-growth segments within aerospace & defense," he adds. "By leveraging Qorvo's comprehensive product and technology portfolio, we are providing customers highly differentiated solutions, especially exciting in the growth rate of gallium nitride solutions into many of IDP's key market segments, driving a compound annual growth rate of about 25% for the next few years. We expect growth rates in 2016 to be well above IDP's underlying markets and significantly above the legacy growth rates of our pre-merger multi-market organizations," Bruggeworth states.

"We think calendar 2016 will be a strong year for Qorvo, during which we will continue to make progress on our target operating model," says Buhaly. "Our long-term goal is to move margins up to 55%, and we are hard at work at both developing and implementing parts of our manufacturing cost reduction roadmap, including some significant changes in filter wafer sizes and significant activities there," he adds.

"We are uniquely positioned to reduce cost and enhance our operating model," believes Bruggeworth. After exceeding its target of $75m in annual synergies in its first year (boosting gross margin in second-half calendar 2015), Qorvo is on track for the cumulative $150m by the end of calendar 2016, due mostly to consolidation of the former TriQuint mobile product portfolio into Qorvo's China-based assembly & test facilities (including increased in-sourcing of module assembly and SAW filters).

Qorvo announces $500m accelerated share repurchase

Qorvo has entered an accelerated share repurchase program (ASR) with Bank of America N.A. (BofA) to repurchase $500m of its stock.

Of this, $250m will be subject to a maximum and minimum share price. The final number of shares to be repurchased will be based generally on Qorvo's volume-weighted average stock price (minus a discount) during the term of the ASR. The ASR is expected to be completed in Qorvo's fiscal first-quarter 2017.

The ASR is part of Qorvo's existing $1bn share repurchase program, approved by its board of directors in November. After giving effect to the ASR, about $250m will remain authorized for future repurchases.

www.qorvo.com

Skyworks' quarterly revenue grows by 5% to new record of $926.8m

March quarter to be hit by inventory adjustments at a top customer, but revenue still growing year-on-year

For fiscal first-quarter 2016 (ending 1 January), Skyworks Solutions Inc of Woburn, MA, USA (which manufactures analog and mixed-signal semiconductors) has reported revenue of $926.8m, up 5% on the record $880.8m last quarter and up 15% on $805.5m a year ago.

As a proportion of total revenue, power amplifiers (PAs) have fallen further, from 31% a year ago and 20% last quarter to 16%, as the market shifts toward higher-value integrated solutions. Integrated mobile systems (IMS) have risen further, from 47% a year ago and 59% last quarter to 64%. Broad markets comprised 20%, down from 22% both last quarter and a year ago, although revenue grew healthily.

On a non-GAAP basis, gross margin has grown further, from 46.7% a year ago and 50% last quarter to 51.4% (above the expected 51%).

Operating expenses have risen further, from $94.4m a year ago and $104.9m last quarter to $109.5m (above the expected $108m), driven by ongoing investments in engineering and development teams as Skyworks expands its footprint within new verticals and further enhances its integration capabilities.

Operating income has grown again, from $282m (operating margin of 35%) a year ago and $335.2m (margin of 38.1%) last quarter to $366.6m (margin of 39.6%, exceeding the expected 39%).

Likewise, net income has grown further, from $244.8m ($1.26 per diluted share) a year ago and $296.1m ($1.52 per diluted share) last quarter to $311.2m ($1.60 per diluted share).

Cash flow generated from operations was $345m (up from $230m last quarter), although this includes a $88.5m fee paid by PMC-Sierra Inc on 24 November for terminating their merger agreement (in favor of an acquisition proposal from Microsemi Corp). Capital expenditure was $79.5m (cut from $151m last quarter). Depreciation was $51.5m.

During the quarter, cash and cash equivalents hence rose from $1044m to $1233m (while the firm also has no debt). Skyworks' board of directors declared a cash dividend of $0.26 per share (payable on 3 March to stockholders of record at the close of business on 11 February).

"Skyworks delivered solid financial results in the first fiscal quarter of 2016, driven by our diversification across customers, markets and applications," says chairman & CEO David J. Aldrich. "Leveraging our proprietary and highly integrated system solutions, we continue to increase our addressable content, gain market share and capitalize on global demand for ubiquitous network access."

Business highlights cited for fiscal first-quarter 2016 include the following:

- commencing volume shipments of telematics solutions at Volkswagen;
- securing the first mass production of vehicle-to-vehicle communications sockets at GM;
- supporting Google Chromecast and Roku set-top boxes for streaming applications;
- winning multiple sockets in flagship smartphone platforms at Samsung and other OEMs;
- ramping microcell radio subsystems at a leading infrastructure OEM;
- launching an IP security camera solutions at Nest;
- powering Huawei's Mate 8 flagship LTE platform;
- enabling the DJI Phantom 3 drone with a suite of 14 semiconductors;
- leveraging ZigBee and Bluetooth capabilities for temperature control and garage door applications in the connected home; and
- capturing key smart fitness watch design wins at Fitbit.

"The March quarter, which is normally a seasonally soft period, has been impacted by above-normal forecast reductions and inventory adjustments at one of our top customers," notes Aldrich. "After closely analyzing the market environment, we have adopted an appropriately conservative outlook for our Q2 revenue guidance." Hence, for fiscal second-quarter 2016, Skyworks expects revenue to fall by 16% to $775m (though still up on $762.1m a year ago).

"Despite the current market environment, we expect to deliver earnings growth in the March quarter driven by strong gross margin performance and a disciplined approach with expenses," says executive VP & chief financial officer Donald W. Palette. Although gross margin should fall slightly from fiscal Q1 to 50.5–51%, this is still up year-on-year from 46.7%. Operating expenses are expected to be level sequentially (staying at about $109.5m for the next few quarters). "Through strong gross margin performance and a disciplined focus on cost, the overall impact to EPS is relatively small," says Aldrich. Diluted earnings per share should be $1.24, down sequentially but still representing high single-digit percentage growth year-on-year (from $1.15).

"Our strong gross margin outlook in the face of current market dynamics highlights the benefits of our higher-value integrated systems, along with our scale, and flexible manufacturing operations," says Palette. "Our Q2 margin and EPS guidance highlights the robustness ►

of our business model within the context of challenging market conditions," he adds.

"Looking ahead, we see continued opportunity for margin improvement, as we leverage our recent capital investments and ramp our custom integrated solutions and precision analog products," Palette continues. "We are targeting a goal of at least 53% gross margin for the company and have a number of initiatives in place to accelerate our progress toward achieving this goal," he adds.

"We are well-positioned for a strong second half of calendar 2016 based on clear visibility into design wins across our flagship smartphone customers," says Aldrich. "We are highly confident in our prospect for gaining dollar content within upcoming generations, putting us on track to continue delivering above-market revenue growth with expanding profit margins and earnings leverage," he adds.

"For the second half of calendar 2016, we see momentum building off of this baseline. Many of the drivers supporting this are already in place," notes Palette. "We remain on track toward our mid-term goal of $8 in annualized EPS."

● Skyworks recently agreed for Kyocera to buy (for about $42m) its small subsidiary Trans-Tech, which produces ceramic substrates and materials for broad market applications but had become non-critical to Skyworks' corporate strategy. The transaction is expected to close in early April. Skyworks estimates an impact to revenue of about $14m per quarter (starting in the June quarter) with no impact to EPS. "This transaction helps to improve the financial returns of our business, while sharpening focus on our core strategy," says Palette.

www.skyworksinc.com

Skyworks launches low-power Bluetooth low-energy front-end modules for connected home, wearable and industrial applications

Skyworks has launched two low-power Bluetooth low-energy (BLE) front-end modules (FEMs) for connected home, wearable and industrial applications.

The SKY66110-11 and 66111-11 FEMs operate at 2.4–2.485GHz, with power consumption of only 10mA in transmit mode, and are suitable for products operating from coin cell batteries including sensors, beacons, smart watches, thermostats, smoke and carbon dioxide detectors, wireless cameras and audio headphones, hearing aids and medical pendants.

Packaged in a small-footprint 3mm x 3mm x 0.8mm, 16-pin multi-chip module, the front-end modules more than double the range when compared to a standalone system-on-chip solution. The SKY66111-11 in particular features adjustable output power.

Skyworks unveils SkyBlue technology for LTE amplifiers & front-ends

Skyworks has launched SkyBlue technology to enhance both the power capability and efficiency in LTE amplifiers and front-ends.

With SkyBlue, Skyworks targets a new high-efficiency system that could capitalize on recent co-developments in voltage management and power amplifiers. In addition to eliminating the complex calibration required for envelope tracking systems, SkyBlue maintains efficiency at several backed-off power levels with no significant impact to efficiency, even when compensating for varying losses in multiband devices. Further, SkyBlue has demonstrated Class 2 operation (26dBm antenna power compared to 23dBm in Class 3 operation), which results in much wider cell coverage within existing networks. Skyworks reckons that SkyBlue will be particularly critical in helping to meet emerging requirements for additional front-end output power demanded by carrier aggregation and high-power user equipment (HPUE) demands for cell edge improvements by TDD carriers.

Designs utilizing SkyBlue technology are said to not only deliver twice the power of envelope and average power tracking systems available on the market currently, but across much broader power ranges. These efficiencies can be more than 15–20% in medium to high power ranges where an LTE system operates. Further, these efficiency and power enhancements are achieved with a much simpler implementation compared to envelope tracking, making it easier for OEMs worldwide to deploy. The end result is envelope-tracking-like system efficiency with the simplicity of average power tracking, says the firm. In first-half 2016, Skyworks will begin shipments of products leveraging SkyBlue with a tier-one customer.

"While average power tracking is currently the most popular method to achieve higher power and efficiency gains in LTE amplifiers, Skyworks believes SkyBlue will quickly replace this technology as it delivers industry-leading performance in a straightforward design," claims chief technology officer Peter L. Gammel. "Customers and OEMs can use their existing infrastructure to implement SkyBlue, enabling some of the highest-performing platforms with the shortest times to market when compared to competing envelope tracking alternatives which are more difficult to calibrate," he adds.

Skyworks plans to leverage SkyBlue throughout its next generation of highly integrated SkyOne, SkyOne-Ultra and SkyLiTE product families, as well as its multimode, multiband power amplifiers (MMPAs) covering all application segments.

www.skyworksinc.com/Products_SkyBlue.aspx

TowerJazz closes acquisition of Maxim's Texas fab, adding 28,000 wafers per month capacity

15-year foundry supply agreement to allow gradual ramp of third-party products

Specialty foundry TowerJazz (which has fabrication plants at Tower Semiconductor Ltd in Migdal Haemek, Israel, and at its subsidiaries Jazz Semiconductor Inc in Newport Beach, CA, USA and TowerJazz Japan Ltd) has completed its acquisition of an 8" wafer fab in San Antonio, Texas from Maxim Integrated Products Inc of San Jose, CA, USA (which provides analog integration to automotive, cloud data-center, mobile consumer, and industrial applications). Maxim received $40m and 3.3 million shares of Tower Semiconductor stock (3% of its fully diluted share count).

The acquisition will expand TowerJazz's global manufacturing capacity, increasing its production by about 28,000 wafers per month. The availability of capacity is needed to serve current and forecasted customer demand, the firm says.

As part of the transaction, the firms signed a 15-year supply agreement under which TowerJazz will make products for Maxim in San Antonio, in quantities that will allow a gradual ramp of third-party products.

"We already performed first qualifications of our high-demand and high-volume flows, with Maxim's approval, confirming the outstanding engineering and manufacturing capabilities of the San Antonio fab personnel," comments TowerJazz's CEO Russell Ellwanger.

"We needed a trusted partner to manage our proprietary process technology who also shared our commitment to the employees in San Antonio," says Vivek Jain, senior VP of Maxim Integrated's Technology and Manufacturing Group. "TowerJazz has a proven track record with Maxim and similar beliefs about employees… I look forward to our continued partnership over the coming years," he adds. "With this arrangement, we will continue to support our customers for years to come, improve utilization in our Oregon fab, and advance our manufacturing flexibility."

www.maximintegrated.com
www.towerjazz.com

e2v to be global strategic re-seller of Peregrine's high-reliability RF products for space market

e2v Inc of Milpitas, CA, USA (which provides solutions, sub-systems and components to the medical & science, aerospace & defense and commercial & industrial markets) has signed a strategic re-seller agreement to be the sole provider to the worldwide space market of high-reliability integrated circuits (ICs) made by Peregrine Semiconductor Corp of San Diego, CA, USA, a fabless provider of radio-frequency integrated circuits (RFICs) based on silicon-on-insulator (SOI).

The strategic RF relationship combines Peregrine's expertise and track record in high-reliability RF and power management products with e2v's position in aerospace & defense-qualified semiconductor products. The result is said to be a broad e2v product offering that spans the signal chain from RF to back-end, including data converters, memory and high-performance data processing.

Peregrine is an MIL-PRF-38535 Qualified Manufacturers List (QML) certified supplier with a high-reliability standard catalog portfolio that includes RF switches, digital step attenuators (DSAs), pre-scalers, phase-locked loops (PLLs) and DC–DC converters. These UltraCMOS products, along with newly introduced Peregrine QML RFIC products, will be sold exclusively through e2v.

"For over 15 years, Peregrine's high-reliability RF solutions have provided reliable communications to hundreds of satellite systems and in missions to seven planets and several asteroids," says Duncan Pilgrim, VP & general manager of Peregrine's high-performance analog (HPA) business unit. "This strategic RF relationship enables our space customers to benefit from e2v's expertise in the aerospace and defense market, while continuing to achieve the high performance standards they expect from Peregrine's UltraCMOS products," he adds.

For over 30 years, e2v has supported aerospace & defense customers worldwide and currently offers over 3600 QML-approved products. Leveraging established relationships with the major prime defense contractors, e2v provides global sales support and customer care in avionics, defense and space.

e2v will support Peregrine's high-reliability, radiation-tolerant RFICs and DC-DC power management products, along with e2v's existing space-grade product offering of broadband data converters and microprocessors, says e2v's general manager Brad Little. "This strategic agreement leverages the technology strengths of both companies and will provide our customers with a complete data-processing solution."

www.psemi.com
www.e2v-us.com/products/semiconductors/peregrinerf

TowerJazz Panasonic agrees further 5-year loan of $70m

Specialty foundry TowerJazz (which has fabrication plants at Tower Semiconductor Ltd in Migdal Haemek, Israel, and at its subsidiaries Jazz Semiconductor Inc in Newport Beach, CA, USA and TowerJazz Japan Ltd) has signed a definitive five-year term loan agreement with Japanese banks JA Mitsui Leasing Ltd, Sumitomo Mitsui Trust Bank Ltd and Showa Leasing Co Ltd to provide its Japan-based joint venture TowerJazz Panasonic Semiconductor Company (TPSCo) with an additional long-term loan of ¥8.5bn ($70m).

The term loan will carry an annual interest of the TIBOR rate plus 2% per annum, will mature by fourth-quarter 2020, and be repaid in seven equal semi-annual installments starting on the second anniversary of the signing of the agreement.

The new loan is in addition to the initial 8.8bn Yen loan announced in June 2014, which will be repaid commencing in 2016, with 2.5bn Yen to be paid during that year.

TPSCo was established by Panasonic Corp, 51% of which was acquired by Tower Semiconductor Ltd in early 2014 and 49% of which is now held by Panasonic Semiconductor Solutions Co Ltd. TPSCo has three manufacturing facilities in Hokuriku, Japan which have been producing large-scale integrated circuits for over 30 years. Areas of process technology focus include: high-dynamic-range image sensors (CIS and CCD) and integrated power devices (BCD, SOI, LDMOS) plus high-frequency silicon RF-CMOS.

"We are excited to see the great progress and growth that TowerJazz Panasonic Semiconductor Company made since its establishment, and its future forecasts, all well ahead of its original business plan submitted to us nearly two years ago," says Kiyoshi Doi, division director, Global Business Division, JA Mitsui Leasing.

"This agreement is a strong enabler for our ongoing business and operational growth strategy and will support our plans to further expand our capabilities and customer base, while strengthening our financial results," believes TPSCo's chief financial officer Amit Mappa.

www.tpsemico.com

RFaxis launches family of sub-gigahertz CMOS RF front-end ICs for Internet of Things

Fabless semiconductor firm RFaxis Inc of Irvine, CA, USA, which designs RF semiconductors and embedded antenna solutions for wireless connectivity and cellular mobility, has unveiled a new family of ultra-miniature sub-GHz RF front-end IC (RFeIC) products for the high-growth Internet of Things (IoT)/M2M (machine-to-machine) market. The RFX15xx-series of products bolsters RFaxis' portfolio of RF front-end ICs for IoT with these additional high-power RF front-end options for sub-GHz applications.

The RFX15xx-series is a family of sub-GHz RFeICs in an ultra-miniature 2.5mm x 2.5mm QFN package (a smaller-size option to the existing RFX10xx-series of products). This series is intended for use in the 700/800/900MHz spectrum for high-power industrial, scientific & medical (ISM) frequency-band applications, including IEEE 802.15.4/4g, Wireless M-Bus, Smart Utility Network (SUN), IEEE 802.11ah Wi-Fi HaLow, and other low-power wide-area networking (LP-WAN) connectivity technologies, e.g. LoRa, SigFox, Weightless, and Narrowband Cellular IoT (NB-CIoT).

The RFX15xx family consists of the RFX1510, RFX1530 and upcoming product derivatives (to be unveiled soon). The RFX1510 is integrated with a high-power high-efficiency linear power amplifier (PA) with 27dBm saturated power, low-noise amplifier (LNA), and Transmit/Receive switching circuitry. Similarly, the RFX1530 comes integrated with a high-power high-efficiency linear PA with 30dBm saturated output power, LNA, and T/R switch.

Both come with an integrated directional power detector circuitry, associated matching networks, RF decoupling and harmonic filters, all in single-die, single-chip bulk CMOS technology. They share a common pin-out in a 16-lead plastic QFN package. Like all RFaxis' RFeICs, they are available in bare die form for ultra-compact designs such as system-in-package (SIP) modules. The devices are rated up to 125°C ambient temperature, as required by most wireless sensor networks applications at high temperature and in harsh outdoor environments.

As wireless connectivity for IoT and M2M continues to grow, the need for high-performance yet simple and cost-effective RF front-end solutions is becoming increasingly critical, says RFaxis. The total IoT/M2M wireless connectivity market for fixed, short-range radios as well as LP-WAN is estimated to be 20 billion connected devices by 2025 (according to Machina Research in May 2015).

"There is tremendous opportunity for RF front-ends in the high-growth smart home, smart office, smart building, smart city segments," reckons RFaxis' chief technical officer Oleksandr Gorbachov. "Our expanded IoT portfolio helps enable a wide range of ultra-compact, high-performance and cost-competitive designs," he adds. "We continue to gain strong traction among chipset partners and end-customers as they recognize performance and cost benefits of our innovative, single-die, single-chip RF front-end ICs in pure CMOS."

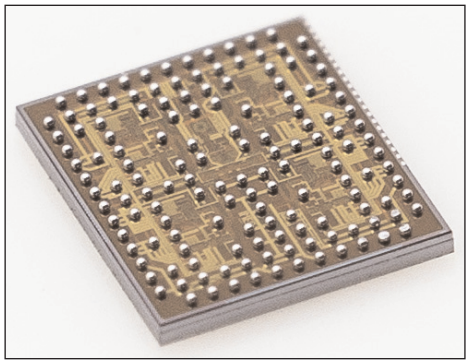
www.rfaxis.com

Imec and VUB present small, low-cost and low-power chip for multi-gigabit 60GHz communication

Four-antenna path beam-forming transceiver uses 28nm CMOS

At the 2016 IEEE International Solid-State Circuits Conference (ISSCC) in San Francisco (31 January — 4 February), nanoelectronics research center imec of Leuven, Belgium and Vrije Universiteit Brussel (VUB) have presented a four-antenna path beam-forming transceiver for 60GHz multi Gb/s communication in 28nm CMOS technology. The transceiver is claimed to be a breakthrough in developing a small, low-cost and low-power solution for multi-gigabit communication targeting WiGig as well as 60GHz wireless backhaul applications.

Due to the tremendous growth in mobile data traffic, display and audio applications, new spectral resources in the millimeter-wave frequency bands are needed to support user demand for high data rates. One way to realize this is through mm-wave wireless networks based on small outdoor cells featuring beam-forming, a signal processing technique using phased antenna arrays for directional transmission or reception. The beam-forming steers the radiation in the desired direction while achieving a good link budget that supports high spectral efficiency.



The beam-forming transceiver chip.

The 60GHz transceiver architecture developed by Imec and VUB features direct conversion and analog baseband beam-forming with four antennas. The architecture is inherently simple and is not affected by image frequency interference. Also, a 24GHz phase-locked loop (PLL) that subharmonically locks a 60GHz quadrature oscillator is inherently immune to the pulling disturbance of the 60GHz power amplifier.

Implemented in 28nm CMOS, the 7.9mm^2 prototype transceiver chip integrates a four-antenna array. The chip was validated with an IEEE 802.11ad standard wireless link of 1m. The transmitter consumes 670mW and the receiver 431mW at 0.9V power supply. The transmitter-to-receiver EVM (error vector magnitude) was better than –20dB in all the four WiGig frequency channels (58.32, 60.48, 62.64 and 64.8 GHz), with a transmitter equivalent isotropic radiated power (EIRP) of 24dBm. This allows for QPSK as well as 16QAM modulations according to the IEEE 802.11ad standard, achieving very high data rates up to 4.62Gbps.

Interested companies are invited to join imec's 60GHz R&D as a research partner and benefit from collaboration in imec's Industrial Affiliation Program, development-on-demand, academic partnerships, or access to the technology for further development through licensing programs.

www.isscc.org
www.imec.be
www.vub.ac.be/en

Custom MMIC launches 2-20GHz distributed low-noise amplifier

Monolithic microwave integrated circuit (MMIC) developer Custom MMIC of Westford, MA, USA has added to its growing product line with the CMD233, a 2–20GHz gallium arsenide (GaAs) MMIC distributed low-noise amplifier (LNA) that offers wide bandwidth, a single positive supply voltage, low noise figure, and a small die size. The new device is suitable for military, space and communications systems, where small size and low noise figure are needed over a wide bandwidth.

Operating from a supply of +3V to +6V, at 10GHz the CMD233 delivers more than 9dB of gain with a corresponding noise figure of 4.5dB and a P1dB (output power at 1dB compression point) of +20.5dBm.

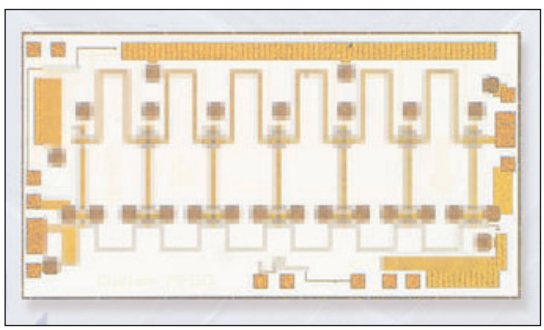


Image of die of Custom MMIC's CMD233 GaAs distributed low-noise amplifier.

The CMD233 is a 50Ω matched design, which eliminates the need for external DC blocks and RF port matching. The device also offers full passivation for increased reliability and moisture protection.

Applications for the CMD233 include military electronic warfare (EW), wideband communication systems, and test instrumentation. The MMIC amplifier is a CMM4000 replacement (pin compatible and performance compatible).

www.custommmic.com/CMD233DistributedAmplifier

Anokiwave extends family of X-band quad core ICs for commercial active electronically scanned array markets

Anokiwave Inc of San Diego, CA, USA, a provider of highly integrated silicon core chips and III-V front-end integrated circuits for millimeter-wave (mmW) and active electronically scanned array (AESA) markets, has extended its family of X-band quad core ICs for commercial AESAs with two new ICs for single-beam Rx and Tx. The launch completes the family of X-band silicon radar quad core IC solutions for commercial radar and 5G communications markets.

Each IC architecture in the family includes an integrated 4-channel beam-former, low-noise amplifier (LNA) and power amplifier (PA) supporting four radiating elements. The ICs feature either a low noise figure or a high input linearity, and are further divided by dual-beam Rx/single-beam Tx or single-beam Rx/single-beam Tx. The AWS-0101 features a low noise figure, dual-beam Rx and single-beam Tx. The AWS-0103 features high input linearity, dual-beam Rx and single-beam Tx. The AWS-0104 is a single-beam Rx, single-beam Tx IC with low noise figure, and the AWS-0105 is a single-beam Rx, single-beam Tx IC with high input linearity.

The devices also include 6-bit phase and 6-bit gain control with either a low noise figure or high input linearity in Rx mode. Additional features include gain compensation over temperature, temperature reporting, forward power telemetry with programmable delay power sampling, and fast beam switching using on-chip beam weight storage registers that can be accessed via direct address lines. Silicon technology enables very high integration of functionality, enabling planar antenna design at X-band with reduced system size, weight and cost.

Commercial AESAs are the future of radar and 5G systems; highly integrated silicon solutions will enable the market to transition from expensive traditional military AESA technology to a commercial arena that requires very low cost

"Commercial AESAs are the future of radar and 5G systems; highly integrated silicon solutions will enable the market to transition from expensive traditional military AESA technology to a commercial arena that requires very low cost," says CEO Robert Donahue.

The X-band family of ICs comprises highly integrated TDD (time-division duplex) transmit–receive ICs in a commercial QFN-style surface-mount plastic package with dimensions of 7mm x 7mm x 0.9mm, easily fitting within the typical 15mm lattice spacing at 10GHz. The ICs are controlled though a 5-wire serial-to-parallel interface (SPI) bus.

Anokiwave offers innovator kits and evaluation kits to customers for early access to the technology. The kits include boards with the X-band IC, USB-SPI Interface module with drivers, and all required cables. Pilot production deliveries are available now, with full production quantities available in June.

Anokiwave achieves ISO 9001 Quality Management System

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) and active electronically scanned array (AESA) markets, has achieved ISO 9001:2008 certification after a thorough analysis of its management and organizational processes by independent, third-party registrar NQA.

As the internationally recognized standard for quality management systems, ISO 9001 provides a framework and set of principles that ensure a common-sense approach to the management of an organization to consistently satisfy customers and other stakeholders. The ISO 9001:2008 standard provides requirements that must be met in order to receive certification, including:

- a set of procedures that cover all key processes in the business;
- monitoring processes to ensure that they are effective;
- maintaining adequate records;
- checking output for defects (with appropriate corrective action where necessary);
- regularly reviewing individual processes and the quality system itself for effectiveness; and
- facilitating continual improvement.

By receiving certification from an industry-recognized, third-party registrar, Anokiwave says that it assures customers that it is committed to delivering world-class service and products. Attaining the ISO 9001:2008 certification involved a self-evaluation process undertaken over the course of nine months during which Anokiwave fully assessed its quality system and procedures. These processes were then validated through an audit conducted by the external, accredited organization NQA. Anokiwave has committed to continuously assess and improve its systems and processes and undergo follow-up audits annually.

www.anokiwave.com

NCSU discovers new phase of boron nitride and new way to create pure c-BN

Wide-bandgap cubic BN targeted at transistors & high-power devices

North Carolina State University (NCSU) has discovered a new phase of boron nitride (Q-BN) that has potential applications for both manufacturing tools and electronic displays. The researchers have also developed a new technique for creating cubic boron nitride (c-BN, with a cubic crystalline structure, analogous to diamond) at ambient temperatures and air pressure, which has applications including the development of advanced power grid technologies.

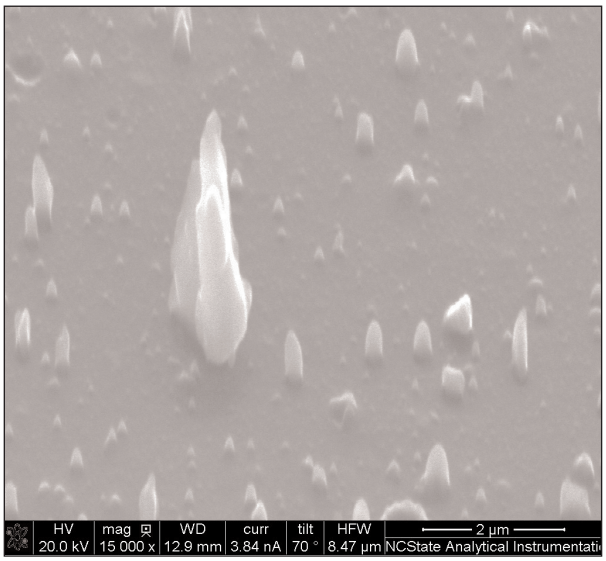
"We have bypassed what were thought to be the limits of boron nitride's thermodynamics with the help of kinetics and time control to create this new phase of boron nitride," says Jay Narayan, the John C. Fan Distinguished Chair Professor of Materials Science and Engineering and lead author of the paper (Jagdish Narayan and Anagh Bhaumik, 'Direct conversion of h-BN into pure c-BN at ambient temperatures and pressures in air', APL Materials, 4, 020701 (2016) DOI: 10.1063/1.4941095).

"We have also developed a faster, less expensive way to create c-BN, making the material more viable for applications such as high-power electronics, transistors and solid-state devices," Narayan says. "c-BN nanoneedles and microneedles, which can be made using our technique, also have potential for use in biomedical devices."

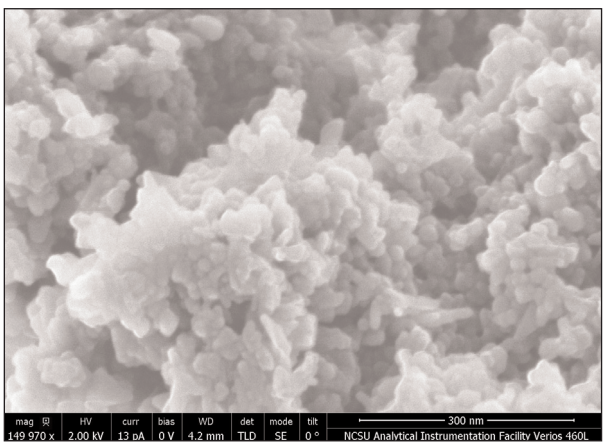
The Q-BN has a low work function and negative electron affinity, which effectively means that it glows in the dark when exposed to very low levels of electrical fields. These characteristics make it a promising material for energy-efficient display technologies.

To make Q-BN, researchers begin with a layer of thermodynamically stable hexagonal boron nitride (h-BN), which can be up to 500–1000nm thick. The material is placed on a substrate and researchers then use high-power laser pulses to rapidly heat the h-BN to 2800K. The material is then quenched, using a substrate that quickly absorbs the heat. The whole process takes about 0.2μs and is done at ambient air pressure.

By manipulating the seeding substrate beneath the material and the time it takes to cool the material, researchers can control whether the h-BN is converted to Q-BN or c-BN. These same variables can be used to determine whether the c-BN forms into microneedles, nanoneedles, nanodots, microcrystals or a film.



Scanning electron micrograph of c-BN nanoneedles and microneedles up to 3μm long. Image credit: Anagh Bhaumik.



Nanocrystallites of cubic boron nitride. Image credit: Anagh Bhaumik.

"Using this technique, we are able to create up to a 100- to 200-square-inch film of Q-BN or c-BN in one second," Narayan says. By comparison, previous techniques for creating c-BN required heating hexagonal boron nitride to 3500K and applying 95,000 atmospheres of pressure.

c-BN has similar properties to diamond, but has several advantages over diamond: it has a higher bandgap (attractive for use in high-power devices); it can be doped to give it positively and negatively charged layers (so it could be used to make transistors); and it forms a stable oxide layer on its surface when exposed to oxygen (making it stable at high temperatures). This last characteristic means that it could be used to make both solid-state devices and protective coatings for high-speed machining tools used in oxygen-ambient environments.

"We're optimistic that our discovery will be used to develop c-BN-based transistors and high-powered devices to replace bulky transformers and help create the next generation of the power grid," Narayan says.

The work was supported by the National Science Foundation under grant DMR-1304607.

http://scitation.aip.org/content/aip/journal/aplmater/4/2/10.1063/1.4941095

www.mse.ncsu.edu/profile/narayan

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Anvil working with UK Manufacturing Technology Centre to develop low-cost hybrid power module

3C-SiC devices and low-cost packaging to allow close coupling of devices & ancillaries, reduce inductance and 100kHz switching speeds

Assisted by a grant from UK Government agency Innovate UK (formerly the Technology Strategy Board), 3C-SiC device developer Anvil Semiconductors Ltd of Coventry, UK, and the UK's Manufacturing Technology Centre (MTC) — which houses equipment for the demonstration (in partnership with industry, academia and other institutions) of new industrial-scale manufacturing processes and technologies — are developing a low-cost hydrid module to take advantage of the benefits of 3C-SiC (silicon carbide) in a close-coupled low-inductance module that enables high-efficiency power conversion.

Driven by competition, demand and legislation, designers of products are striving for increased efficiency, smaller size and weight, and lower cost, but they are squeezed between the efficiency constraints of silicon and the high costs of 4H-SiC devices.

Anvil was spun off in 2010 from the University of Warwick's School of Engineering by its technology commercialization subsidiary Warwick Ventures Ltd in order to exploit patented developments in SiC power semiconductor technology. The firm's technology enables the growth of device-quality 3C-SiC epitaxy on 100mm-diameter silicon wafers to thicknesses that permit the fabrication of vertical power devices. The proprietary process is said to overcome mismatches in lattice parameter and thermal coefficient of expansion, and can be migrated onto 150mm wafers and maybe beyond.

Anvil's SiC technology is hence claimed to enable the development of devices with the efficiency and size benefits of SiC but at the cost of silicon. However, the benefits that can be delivered through using SiC devices are limited by the switching speeds that are often restricted by the inductances introduced by non-close coupling of discrete devices and ancillaries.

Anvil and MTC are using 3C-SiC devices and the most recent low-cost packaging techniques to develop a low-cost hybrid module to allow close coupling of devices and ancillaries, reduce inductances and achieve switching speeds of 100kHz. The use of 3C-SiC is said to provide reduced resistive losses and low sensitivity of device characteristics to temperature, enabling close coupling of components. This delivers increased efficiencies and reduced size and weight by removing the need for some ancillary components and heat sinks. Market opportunities for such a module exist across a wide range of applications including LED lighting, photovoltaic converters, general power supplies, electric car charging and electric vehicles/hybrid electric vehicles (EV/HEV), says Anvil.

www.the-mtc.org
www.anvil-semi.co.uk

Littelfuse invests $3.5m in Monolith Semiconductor

Power semiconductor expertise to supplement circuit protection technology for power control and sensing

As part of its shift into power semiconductors for industrial and automotive markets, Littelfuse Inc of Chicago, IL, USA has invested $3.5m in silicon carbide diode and MOSFET supplier Monolith Semiconductor Inc of Round Rock, TX, USA.

Monolith notes that SiC enables power devices to operate at higher switching frequencies and temperatures versus conventional silicon technology, allowing inverters and other energy conversion systems to be built with much improved power density, energy efficiency and cost.

Founded in 1927, Littelfuse provides circuit protection technologies (fuses, semiconductors, polymers, ceramics, relays and sensors) to the electronics, automotive and industrial markets, with growing global platforms in power control and sensing. The firm has over 8000 staff in more than 35 locations worldwide.

"Investing in and partnering with Monolith's experienced team of SiC and power semiconductor experts allows us to quickly evolve our portfolio with strategically relevant and innovative technology," says Ian Highley, Littelfuse's senior VP & general manager, Semiconductor Products, and chief technology officer. "SiC power technology is among the most promising advancements in the semiconductor market today. It will be an important tool in helping us solve complex problems," he adds.

"Forming this strategic partnership with Littelfuse accelerates development and helps bring silicon carbide technology to the market," comments Monolith's CEO Sujit Banerjee PhD. "Littelfuse is an ideal partner for us. We are excited to dramatically increase our customer reach, gain access to global channels, and benefit from their sales and marketing depth and expertise."

Littelfuse has committed to add to its investment after Monolith has achieved certain milestones. The investment is not expected to have any material financial impact on Littelfuse in 2015 or 2016.

www.littelfuse.com
www.monolithsemi.com

Wolfspeed's SiC MOSFETs enabling faster industrial battery charging while consuming less energy

Wolfspeed of Raleigh, NC, USA, a Cree Company that makes silicon carbide (SiC) and gallium nitride (GaN) wide-bandgap semiconductor devices, says that Italy-based industrial battery charger manufacturer Gruppo PBM is using Wolfspeed's SiC MOSFETs in its new HF9 battery charger family to enable higher efficiency and power density at a lower overall system cost.

Demand for safe, efficient, and fast-charging industrial batteries has increased exponentially along with the proliferation of power electronics. The HF9 product family is designed to provide the highest possible efficiency while achieving easy scalability for power ranging from 6kW to 16kW. Wolfspeed says that these benefits are made possible in part by its 1200V SiC MOSFET technology.

"We selected Wolfspeed SiC planar MOSFETs for our new HF9 battery charger family because they enabled us to improve our battery chargers while achieving operational savings, increased productivity and increased safety. This was not possible with the best IGBTs in the market," say both Marco Mazzanti and Giancarlo Ceo, who respectively serve as chief technology officer and R&D engineer at Gruppo PBM.

Gruppo PBM specializes in rugged high-frequency battery chargers, dischargers and testers. By using SiC MOSFETs in its latest HF9 family, Gruppo PBM achieves not only improved efficiency but also a reduction in component count, improving the overall reliability in the system by lowering the operating temperatures and — most importantly — reducing overall system cost, says Wolfspeed.

"Wolfspeed's SiC MOSFETs, especially our new C3M 900V family, are enjoying rapid adoption in the growing battery charger market segment," says Edgar Ayerbe, Wolfspeed's power MOSFET marketing manager. "Our products increase power density and dramatically lower switching losses, making it possible to introduce smaller, cooler and lower-cost chargers for the automotive and industrial markets."

Wolfspeed's SiC MOSFETs are commercially available in 900V, 1200V and 1700V versions in TO-247 and SMD package options. The new surface-mount package, specifically designed for high-voltage MOSFETs, has a small footprint with a wide creepage distance of 7mm between its drain and source. The new package also includes a separate driver-source connection, which reduces gate ringing and provides clean gate signals, says Wolfspeed.

www.wolfspeed.com

Fujitsu develops GaN power amplifier with record output for W-band wireless transmission

Output boosted 1.8-fold, increasing reach by over 30%

Japan's Fujitsu Ltd and Fujitsu Laboratories Ltd have developed a gallium nitride (GaN) high-electron-mobility transistor (HEMT) power amplifier with record output performance for W-band (75–110GHz) transmission by using a proprietary structure (Figure 1). This can be used in a high-capacity wireless network with coverage over a radius of several kilometers.

Compared to today's mobile phones, which use frequencies in the 0.8–2.0GHz range, the W-band uses a frequency band more than 50 times as broad with 50 times the speed, making it is well suited to high-capacity wireless communications. High-frequency wireless communications using W-band frequencies are drawing increasing interest, both as a way to temporarily set up high-capacity communications channels for handling special events where large numbers of people gather, or for responding to disasters, and also as a way to bring communications to remote areas where fiber-optic cables are difficult to lay.

In areas where fiber-optic cable is difficult to lay, in order to achieve high-speed wireless communications of several gigabits per second, one promising approach is to use high-frequencies, such as the W-band, which uses a wide frequency band.

However, to transmit wireless signals over a distance of several kilometers, the transmission antenna needs a power amplifier capable of a high output, on the order of several watts. Existing power amplifiers for high-frequency transmissions in the millimeter-wave band (30–300GHz), built using GaAs or CMOS semiconductors, are limited by their operating voltage to output of 0.1W, and it has not been possible to increase this.

GaN-HEMT power amplifiers have achieved high output performance in the microwave range (3–30GHz), but the problem up until now was that their output performance declined in the W-band.

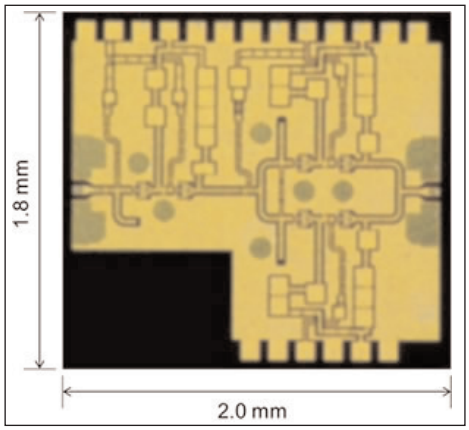


Figure 1: Chip containing the new W-band GaN-HEMT power amplifier.

To design a power amplifier with high output performance, Fujitsu developed a GaN-HEMT device with a unique structure — presented at the 2015 IEEE International Electron Devices Meeting (IEDM) in December — capable of increasing output in the millimeter band (Figure 2).

This uses an of indium aluminium gallium nitride (InAlGaN) layer and a double-layer silicon nitride (SiN) passivation film to increase current density by a factor of about 1.4, resulting in 3W of output power from a transistor per mm of gate width, at a high frequency of 100GHz. In developing this transistor, Fujitsu collaborated with the Tokyo Institute of Technology's professor Yasuyuki Miyamoto in developing device simulation technology.

Fujitsu precisely measured and modeled the characteristics of the GaN-HEMT during high-frequency operation. Based on that, a circuit was designed where pairs of GaN-HEMTs were grouped together into compact, high-gain units with low power loss. In order to maximize the power from these units, the GaN-HEMTs were connected in a series by the inter-stage circuit where the signal lines and the device layouts were carefully laid out.

Using a model of these compact, high-gain units, Fujitsu conducted simulations to optimize the distributor and combiner matching circuits between the units, and their layouts and signal lines, resulting in a high-amplitude power amplifier (Figure 3). A prototype power amplifier had amplitude that multiplied its input by a factor of 80, producing 1.15W of output power. Power output per transistor (a measure of power-amplifier performance) was 3.6W per mm of gate width (claimed to be a record).

Evaluation of the new power amplifier confirmed that it achieved a 1.8 times increase in output over previous W-band power amplifiers (Figure 4). This translates to an improvement of over 30% in transmission range for high-speed wireless communications networks ►

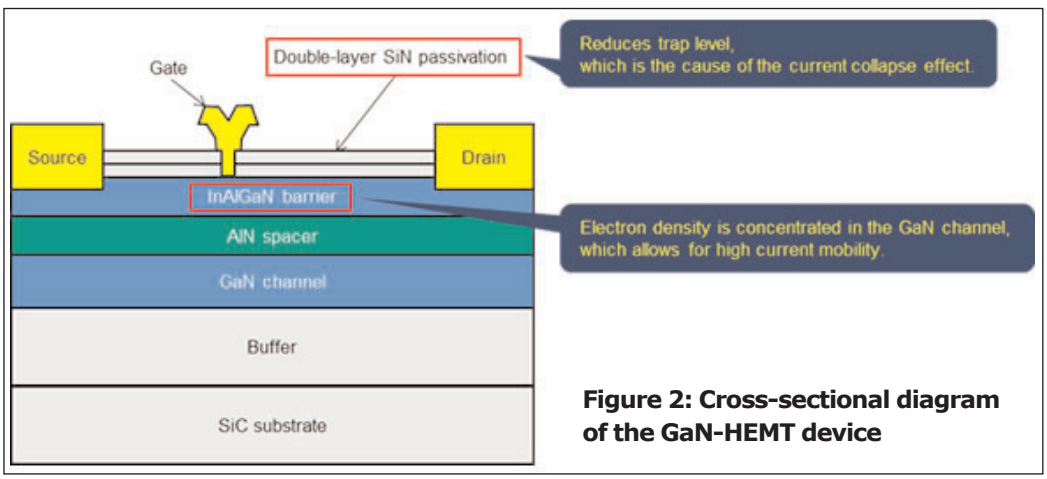


Figure 2: Cross-sectional diagram of the GaN-HEMT device

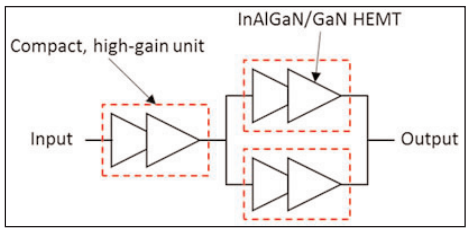


Figure 3: Compact, high-gain circuit.

operating at speeds of several gigabits per second.

Fujitsu plans to apply this power amplifier technology to high-capacity long-range wireless communications and implement high-speed wireless communications systems that can be used for high-expediency temporary communications infrastructure for use during special events and when fiber-optic links have been broken in the event of disasters.

Some of the research was conducted as part of a project of Japan's National Institute of Information and Communications Technology (NICT) on 'Agile Deployment Capability of Highly Resilient Optical and Radio Seamless Communication Systems'. Details were given at the IEEE Topical Conference on RF/Microwave Power Amplifiers for Wireless and Radio Applications (PAWR2016) in Austin, Texas (24–27 January).

http://jp.fujitsu.com/fsl/en
www.radiowirelessweek.org

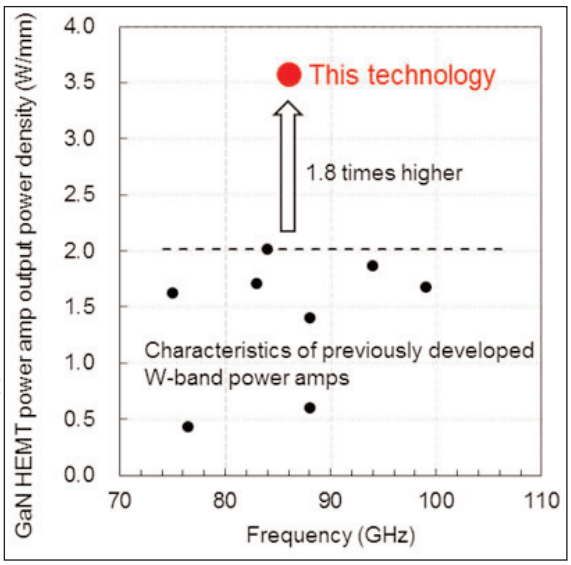


Figure 4: Performance index of GaN-HEMT power amplifiers.

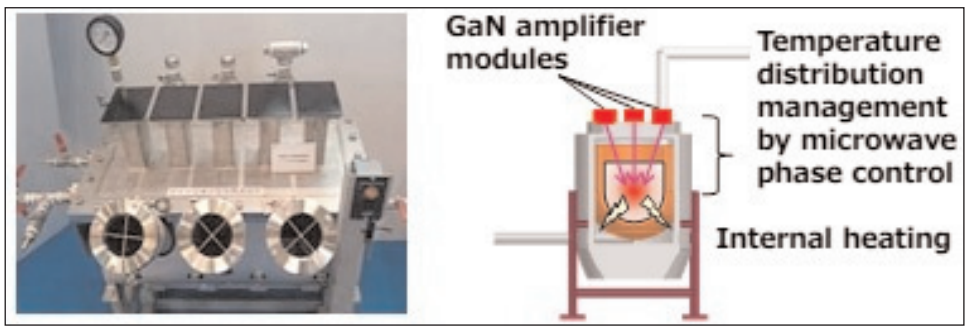
Japanese project develops microwave heating system using GaN amplifier module heaters

Mitsubishi Electric Corp, Tokyo Institute of Technology, Ryukoku University and Microwave Chemical Co Ltd have jointly developed a microwave heating system that uses 500W-output gallium nitride (GaN) amplifier modules as heat sources.

The modules consume 70% less energy than conventional external heating systems that use fossil fuel and improve chemical-reaction productivity three-fold compared with dispersed heating systems. Practical uses will now be developed for high-level energy saving in the chemical industry.

Whereas external heating systems consume high amounts of energy because they need to heat both the equipment and the chemicals inside, the new internal heating system saves energy consumption by heating the chemicals only. In addition, the system adopts a new method that controls the microwave phases generated by the modules and hence manages temperature distribution, leading to greater productivity in chemical reaction.

GaN devices offer more power density and power efficiency than silicon or gallium arsenide devices. GaN amplifier modules are expected to help reduce the size of communication equipment, radars and other equipment for general industry.



Microwave heating equipment using GaN amplifier modules as heat source.

Mitsubishi Electric is responsible for production of the GaN devices and development of the microwave GaN amplifier modules.

Tokyo Institute of Technology is responsible for selection of the sample chemicals, the verification of chemical-reaction productivity and fundamental evaluation for improvements, and standardization.

Ryukoku University is responsible for designing the microwave GaN amplifier modules and fundamental research to improve microwave heating system efficiency.

Microwave Chemical is responsible for increasing the size of the testing reactor containing the microwave heating system employing GaN amplifier modules as heat sources, and for evaluation of energy-saving outcomes.

Development was conducted under the Clean Device Promotion Project 'High efficiency High Power Microwave GaN Amplifiers Realizing Energy-Saving Society', which aims to facilitate novel applications of innovative electronic devices through demonstration and standardization. The project was commissioned by the New Energy and Industrial Technology Development Organization (NEDO), an independent administrative agency of Japan.

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www.nedo.go.jp/library/seika/shosai

Raytheon's GaN-based AESA Patriot air & missile defense radar completes key milestones

Raytheon Company of Waltham, MA, USA recently completed a series of company-funded milestones to upgrade the combat-proven Patriot Air and Missile Defense System. The projected upgrade delivers 360° capability, aiming to keep Patriot ahead of increasingly more sophisticated threats, such as aircraft, drones and cruise and ballistic missiles.

The Patriot radar main array was enhanced with gallium nitride (GaN)-based active electronically scanned array (AESA) technology. The same Raytheon engineers who completed those milestones are currently constructing a GaN-based AESA, full-size, main panel radar array (on track to have a full-scale main array prototype operational in early 2016 — just 24 months after the firm began building it).

"Raytheon has invested more than $150m in GaN technology and learned invaluable lessons while building our GaN-based AESA full-scale prototype," says Ralph Acaba, VP of Integrated Air and Missile Defense at Raytheon's Integrated Defense Systems business (based in Andover, MA). "This ensures Raytheon is able to rapidly develop, build, test and deliver a combat-ready GaN-based AESA radar that gives Patriot 360° capability," he adds.

The Raytheon-built GaN-based AESA radar uses three antenna arrays mounted on a mobile radar shelter to provide 360° of radar coverage. The main AESA array is a bolt-on replacement for the existing gallium arsenide (GaAs)-based Patriot antenna. The GaN-based AESA array measures roughly 9' wide x 13' tall, and is oriented toward the primary threat. Patriot's new rear panel arrays are a quarter the size of the main array, and let the system look behind and to the sides of the main array to offer Patriot the ability to engage threats in all directions.

Artist's rendering of Raytheon's 360° capable Patriot radar array enhanced with GaN-based AESA technology. Raytheon's Patriot is owned by 13 nations, and has more than 200 combat engagements, 1400 flight tests, and 3000 ground tests.

In 2015, Raytheon built a GaN-based AESA rear-panel array and integrated it with a radar for potential use in Patriot, using existing and recently modernized back-end processing hardware and software. The radar then tracked targets of opportunity, leveraging a seamless 360° view.

Raytheon has invested more than $150m in GaN technology and learned invaluable lessons while building our GaN-based AESA full-scale prototype. This ensures Raytheon is able to rapidly develop, build, test and deliver a combat-ready GaN-based AESA radar that gives Patriot 360° capability

"Raytheon's GaN-based AESA radar will outmatch future threats for the same reason today's Patriot is able to outmatch current threats — because it is designed to be upgraded and we have a growth path for the system," says Tim Glaeser, VP of Integrated Air and Missile Defense Business Development at Raytheon's Integrated Defense Systems business.

The recently accomplished AESA GaN milestones include:

- completing construction of the AESA main array structure;
- constructing the AESA arrays' radar shelter;
- integrating receivers and a radar digital processor into the radar shelter;
- delivering the shelter to Raytheon's test facility in Pelham, NH; and
- testing the radar's cooling subsystem.

Raytheon's GaN-based AESA radar will work with future open architecture (such as the Integrated Air and Missile Defense Battle Command System) and retains backwards compatibility with the existing Patriot Engagement Control Station. It will also be fully interoperable with NATO.

Raytheon's Global Patriot Solutions portfolio of air & missile defense technologies provides protection against a range of threats including aircraft, tactical ballistic missiles, cruise missiles and unmanned aerial vehicles (UAVs). Upgraded and enhanced to leverage the latest technology, 13 nations depend on Patriot as the foundation for their defense.

www.raytheon.com/capabilities/products/patriot

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EPC posts video series on how to design with GaN power devices for power conversion

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 expanded its video library on GaN technology by adding a nine-part educational video series to provide power system design engineers with technical information and application examples on how to design more efficient power conversion systems using GaN-based transistors and integrated circuits.

Beyond giving the design basics for using GaN transistors and reliability information, the video series provides direction on converting development boards into working prototypes. Further, it offers practical examples on the use of GaN transistors in widely used power electronics applications such as DC-DC conversion for telecom and datacom systems, as well as two videos on the use of GaN devices in wireless charging systems.

The 'Gallium Nitride Advanced Learning' video series comprises the following:

- **GAL01: What is GaN?** — GaN has emerged as a displacement technology to silicon solutions. GaN's superior performance can be implemented at the price of silicon, makes it suitable for power conversion system.
- **GAL02: Design Basics** — Gate drive requirements for use with eGaN FET and current power conversion circuit designs.
- **GAL03: GaN is Reliable** — EPC reliability testing has demonstrated that GaN technology is ready for commercial use, and this video describes the reliability tests and the results achieved.
- **GAL04: 500W Isolated DC-DC Converter with GaN** — The Power of a Quarter Brick in the Size of an Eight Brick - Presentation of a fully regulated, fully isolated 500W 1/8th brick using eGaN transistors enabling a 60% increase in power in the industry-standard DOSA footprint.
- **GAL05: Cut the Cord! Wireless Power with GaN** — Demonstrations of the benefits of GaN technology in resonant wireless power transfer systems. Both AirFuel Alliance's class 2 and class 3 system designs are showcased as examples.
- **GAL06: eGaN ICs — Integrate for Even Higher Efficiency in Wireless Power and DC–DC Conversion** — Integration further widens the efficiency gap between eGaN technology and traditional silicon. Integrated devices save space, improve efficiency, and lower system costs.
- **GAL07: Increase Power Density with GaN** — Discussion of techniques (including thermal management) for obtaining the most benefit from using GaN technology in power conversion applications.
- **GAL08: How to Turn a Development Board into a Working Prototype** — A practical guide on turning a standard EPC half-bridge development board into a working prototype system.
- **GAL09: Where is GaN Going?** — CEO & co-founder Alex Lidow discusses the wide variety of applications enabled by GaN technology (including emerging applications such as autonomous vehicles, wireless power transfer, augmented reality, and envelope tracking).

"This series of short, less-than-ten-minute-each videos will assist designers of power conversion systems increase their understanding of state-of-the-art in power conversion as well as the role played by GaN technology," notes Lidow. "These videos will accelerate their learning curve and increase their ability to take maximum advantage of the high switching frequency and high performance of GaN power transistors."

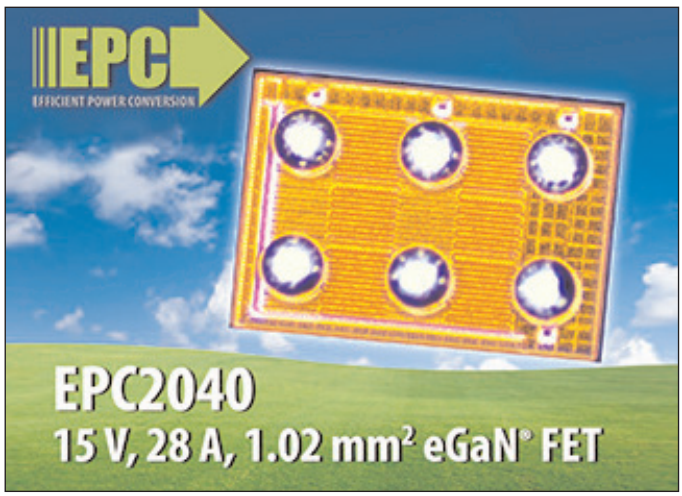
The new GaN Advanced Learning video series is accessible on the EPC video library or on the EPC YouTube Video Channel.

http://epc-co.com/epc/DesignSupport/TrainingVideos.aspx
https://www.youtube.com/user/EPCCorporation

EPC launches eGaN power transistor enabling higher resolution in augmented reality and autonomous vehicle applications

Efficient Power Conversion Corp (EPC) of El Segundo, CA, USA, which makes enhancement-mode gallium nitride on silicon (eGaN) power field-effect transistors (FETs) for power management applications, has launched the EPC2040 power transistor, an extremely small, fast-switching GaN power transistor that enables superior resolution, faster response time, and greater accuracy for high-speed end-use applications.

High stability of the threshold over temperature ensures the high stability as the laser heats up. For example, the product is suitable for pulsed laser drivers used in LiDAR technology (the technology at the heart of 3D sensing in augmented reality platforms as well as collision avoidance and guidance systems in autonomous vehicles). The end result of the EPC2040's performance is increased accuracy and higher resolution in these systems.



The low temperature coefficient of the gate threshold of the EPC2040 eGaN FET contributes to enhanced end-use system performance. This feature gives consistent results, enabling lower laser diode power and high-quality system operation over its entire operating temperature range, says EPC.

Benefits of using eGaN FETs in augmented reality systems include lower laser diode heat resulting from narrower pulse widths, high efficiency due to lower laser diode driver heat, more compact systems because of the small eGaN FET footprint, and consistent operation because the EPC2040 is stable with temperature.

"The EPC2040 was designed specifically for applications requiring high-frequency, narrow-pulse-width capabilities," notes Steve Colino, VP strategic technical sales. "These are the requirements that are critical to improving resolution in LiDAR."

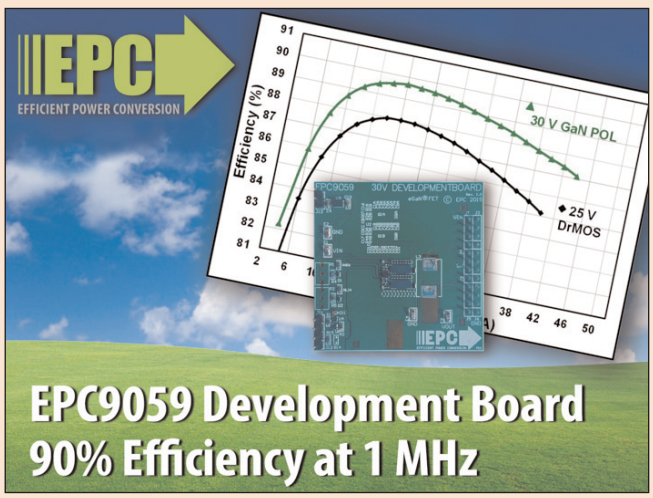
Pricing for the EPC2040 is $0.65 each in 1000-unit quantities.

http://epc-co.com/epc/Products/eGaNFETs/EPC2040.aspx

EPC launches development board with 50A, 1MHz capability to reduce size in point-of-load applications

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 introduced the EPC9059 half-bridge development board for high-current, high-frequency point-of-load (POL) applications using eGaN ICs to reduce power conversion size.

The EPC9059 development board has a 30V maximum device voltage with a 50A maximum output current. In this application, two 30V EPC2100 eGaN ICs operate in parallel with a single onboard gate driver to achieve higher output currents. EPC says that GaN devices have superior current-sharing capability compared to silicon MOSFETs, making them more attractive for parallel operation.



The total system efficiency of the board, operating with 12V input to 1V output with a switching frequency of 1MHz, peaks near 90%. It runs with natural convection and no heat-sink up to 32A, and at heavy load condition of 40A showed a 2.5% efficiency advantage over silicon-based DrMOS solutions, which translates to an almost 20% reduction in total system power loss.

EPC says that the board demonstrates how eGaN technology enables smaller size, higher efficiency and higher power density at the higher frequencies and higher currents required in next-generation point-of-load converters.

EPC9059 development boards are priced at $137.75 each and are available now from distributor Digi-Key Corp.

http://digikey.com/Suppliers/us/Efficient-Power-Conversion.page
http://epc-co.com/epc/Products/DemoBoards.aspx

UK's EPSRC Centre for Power Electronics and GaN Systems launch Future Power Challenge, targeting effective power conversion or control

GaN Systems Inc of Ottawa, Ontario, Canada, a fabless developer of gallium nitride (GaN)-based power switching semiconductors for power conversion and control applications, together with the Centre for Power Electronics of the UK's Engineering and Physical Sciences Research Council (EPSRC), have launched the Geoff Haynes Future Power Challenge, a new competition open to all UK power electronics postgraduates.

The annual award will be worth £2000 for the research paper or poster that makes the strongest contribution to accelerating the use of GaN transistors in future power conversion or control applications. The prize is established to mark the occasion of Geoff Haynes' recent retirement as a founder & vice president of GaN Systems and is in recognition of his contribution to the firm and the formative gallium nitride power industry.

In the last year GaN Systems has introduced to production two families of GaN*PX* normally-off transistors housed in embedded, almost chip-scale packages, optimized for low inductance and low thermal resistance. Now, to achieve their full value in production systems, key enabling issues still need to be addressed.

Papers or posters submitted to the Centre for Power Electronics' 2016 Postgraduate Summer School (to be held at the National College, Nottingham, UK on 1–2 June) will qualify for entry to the competition if they clearly identify research relevant to accelerating the use of GaN components in applications with performance that cannot be achieved using existing silicon technology. Entries will be judged by a panel of academic and industrial experts and the prize will be awarded at the EPSRC Centre of Power Electronics' annual conference on 5–6 July.

In view of the limited timescale and in order not to restrict the entry of relevant work in pre-existing projects using SiC technology, that work will also qualify for entry where demonstration or simulation shows its relevance to a future GaN-based solution. The judges will select a shortlist of projects for presentation at the event, from which the winner will be chosen.

Projects including elements of study of any of the following or related issues will qualify for entry:

- new or improved circuit configurations enabled by the unique operating characteristics of these transistors, leading to system-level benefits;
- new or improved digital control solutions for high-frequency converters;
- thermal management and packaging design for high-density power converters;
- improved inductor and capacitor technologies for energy storage in fast, high-operating-temperature converters;
- study of failure mechanisms in GaN transistors, their control and their impact on system performance and reliability;
- management of EMI in higher-switching-speed converters;
- component choice, board layout and circuit design for fast-switching systems;
- measurement of currents and voltages in fast-switching cells (even the introduction of a scope probe at a critical node can distort performance);
- modeling of the transistors and the new systems that they enable;
- advances in device fabrication technology or device design;
- design of drivers for wide-bandwidth switches; and
- exploring the impact of GaN device characteristics on electrical machines able to benefit from faster switching.

See device characteristics and models for the GaN*PX* family at:
www.gansystems.com/trans-temp.php
www.powerelectronics.ac.uk

Israel distribution and support agreement signed with Eastronics

GaN Systems has extended its global product sales coverage and added technical expertise and customer support in Israel by entering into an agreement with Eastronics (said to be Israel's largest distributor of high-tech products).

"Eastronics provides GaN Systems' with a first-class supply chain, including a sales operation, warehouses, an integration center, service laboratories, demonstration centers and training facilities," says Tony Astley, director of GaN Systems' EMEA sales operation. "Our customers benefit from the extensive experience of Eastronics' professional application engineers, who support them by offering design-in activities from the early stage of project definition through production. They also offer our customers a broad range of solutions and building blocks that range from components to embedded systems supplied by over 30 premier international brands," he adds.

"High-power gallium nitride transistors have been the missing link in our portfolio of power products," says Eastronics' group VP Arie Eitan. "GaN Systems further strengthen Eastronics' position as the 'The Vendor of Choice' for power solutions in Israel's high-tech market."
www.easx.co.il

HELLA, GaN Systems and Kettering University develop 2.6kW/l, 97%-efficient electric vehicle charger

Germany-based automotive electronics specialist HELLA, in collaboration with GaN Systems Inc of Ottawa, Ontario, Canada (a fabless developer of gallium nitride-based power switching semiconductors for power conversion and control applications) and charging technology researchers at the Advanced Power Electronics Lab of Kettering University in Flint, MI, USA have developed a Level-2 electric vehicle (EV) charger prototype with efficiencies exceeding 97% at what is claimed to be an unprecedented 2.6kW/l power density. Prior to this, Level-2 EV chargers reached maximum efficiencies of 94%.

Using GaN Systems' 60A, 650V GS66516T switches in a two-stage architecture, the Kettering University team — led by associate professor of electrical engineering Dr Kevin Bai and known for collaborating with companies to help advance their charging technology — were able to increase the wall-to-battery efficiency to more than 3% greater than that previously obtained.

The power density of more than 2.6kW/l is "a significant milestone with important implications for charging electric vehicles, among other charging applications," states Bai, who characterizes the development as a 'game changer' for the EV charging industry.

"The results of this collaboration are equally gratifying and commercially important, because they provide HELLA with a path to ultra-compact and lighter EV charger designs," comments Matt McAmmond, HELLA's manager of advanced engineering. "In addition to benefiting HELLA and our customers, this development also has a positive environmental impact, as it represents another step toward the global effort to reduce power consumption," he adds.

"HELLA and Kettering University's ultra-compact, ultra-efficient EV chargers clearly demonstrate how the performance of gallium nitride contributes to the development of important new designs," comments Julian Styles, GaN Systems' director of sales & marketing for the Americas.

www.gansystems.com
www.kettering.edu
www.hella.com

Advantech Wireless sees substantial growth in orders for GaN-based solid-state power amplifiers

Advantech Wireless Inc of Montreal, Canada (which makes satellite, RF equipment and microwave systems) has seen a substantial increase in bookings for its line of GaN-based solid-state power amplifiers (SSPAs) in fiscal first-half 2016.

"We rolled out GaN-based power amplifiers and block-up converters [BUCs] because our customers needed more efficient, longer-life components," says VP of business development Cristi Damian. "The market has responded even faster than we had planned, and we will continue to roll out this technology in commercial and military markets through our research and development pipeline."

Advantech claims to be the first company to commercialize GaN SSPAs for satellite communications, and its second generation is a result of R&D investment to increase efficiency and linearity. The second-generation GaN-based SSPAs/BUCs provide high linearity with what is said to be the highest power density and smallest size on the market.

Advantech says that introducing its second generation of GaN-based units has opened new opportunities in market segments that traditionally relied on traveling wave tube (TWT)-based amplifiers. The vast reductions in size, weight and power consumption — along with the enhanced linearity of the GaN-based technology — make possible new applications in tactical troposcattering communications and scientific research facilities. Gallium nitride technology also continues to offer dramatic cost reductions for teleport operators in the broadcast industry, the firm notes.

www.advantechwireless.com

Lighter block upconverter launched for SatCom manpack terminals

Advantech has released a lightweight, more powerful GaN-based block upconverter for SatCom manpack defense & security deployments.

Integrating power supply, phase-locked oscillator, mixer, filter and cooling mechanism but weighing less than 2.6kg (5.5lb), the 16W/20W BUC covers both the standard 14.0–14.5GHz Ku-band or the 13.75–14.5GHz extended Ku-band. The weatherproof hub-mounted units are claimed to be the smallest fully integrated units on the market, achieving a 40% reduction in size and energy consumption compared with the firm's previous-generation Ku-band BUC.

The BUC can support manpack and fly-away terminals for tactical and ruggedized industrial applications.

Epiluvac and SAMCO collaborate to offer processing equipment for WBG materials in Nordic countries

Epiluvac AB of Lund, Sweden — which was founded in 2013 and produces silicon carbide (SiC) chemical vapour deposition (CVD) systems used in power device research — has entered into a collaboration to introduce semiconductor process equipment maker SAMCO Inc of Kyoto, Japan, to new clients in Sweden, Norway, Finland and Denmark.

SAMCO offers systems and services based on three major technologies: (1) thin-film deposition with plasma-enhanced chemical vapor deposition (PECVD), metal-organic chemical vapor deposition (MOCVD) and atomic layer deposition (ALD) systems; (2) microfabrication with inductively coupled plasma (ICP) etching, reactive ion etching (RIE) and deep reactive ion etching (DRIE) systems; and (3) surface treatment with plasma cleaning and ultraviolet (UV) ozone cleaning systems.

"With this collaboration, Epiluvac and SAMCO are both acting as a one-stop solution," says Epiluvac's managing director Bo Hammarlund. "We offer our expertise to help customers decide upon the best combinations in terms of processing equipment for WBG [wide-bandgap] materials, including both SiC and GaN materials."

Founded in 1979, in order to continue serving the needs of its customers in Europe, in 2014 SAMCO acquired Liechtenstein-based UCP to form Samco-UCP Ltd, which now offers services and support for the firm's European customer base.

In addition to its main European office in Liechtenstein, SAMCO also operates from several locations in North America and across Asia. The firm works with research institutions and manufacturers around the world and offers customizable systems designed to meet the unique needs of its clients.

"Both companies, Epiluvac and SAMCO, have long-standing relations with major players in the quickly growing market for power electronics," says Hammarlund. "Many of the processes have to be more efficient in terms of improved yield." He highlights the additional need to handle larger wafers during the coming years, pointing to the fact that 8-inch protoypes of SiC wafers are already on the market. "This rapid development results in a strong request for new, improved equipment and processes, which Epiluvac and SAMCO together can offer their customers," Hammarlund adds.

To meet customer demand, new equipment and processes made by Epiluvac and SAMCO include "not just standard solutions, but also custom-designed equipment," Hammarlund notes.

www.epiluvac.com
www.samcointl.com
www.samco-ucp.com

Advanced Energy highlighting high-speed pyrometer

At SEMICON Korea 2016 in Seoul (27–29 January), Advanced Energy Industries Inc of Fort Collins, CO, USA highlighted its power and control technologies. Among its process power, high-voltage power and thermal products on display, the firm featured its new, floating, high-voltage bipolar power supply and next-generation high-speed pyrometer.

The UltraVolt FLHV series provides high-voltage power for the strong force of electrostatic chucks (ESC) and elevates system performance with advanced controls and monitoring as well as floating (isolated) unipolar/bipolar high-voltage outputs with high stability and reliability. The Sekidenko MXE G2 pyrometer provides high-speed temperature and reflectance measurement for deposition processes including metal-organic chemical vapor deposition (MOCVD) applications for high-brightness light-emitting diode (HBLED) production and emerging III-V materials.

"We offer exceptional temperature and reflectance measurement with the MXE G2 product for processes requiring high-speed acquisition, such as high susceptor rotation speeds commonly used for HBLED production," claims president & CEO Yuval Wasserman.

Advanced Energy is showcasing its full product portfolio for semiconductor and thin-film processing applications, including:

- RF power with multi-level pulsing, enabling a wide variety of semiconductor applications and providing flexibility and adaptability for 3D, IC, VNAND and next-generation device structures;
- source technology uniquely suited to operate in ultra-clean semiconductor applications, enabling critical plasma-based processes with lower device damage, higher throughput and higher yields;
- high-voltage modules and systems for e-beam, e-chuck and other semiconductor, analytical and industrial processes that require energy density, flexibility and modularity;
- DC power for PVD processes used in semiconductor and display manufacturing for copper, aluminum, tantalum, titanium and newer exotic materials;
- thermal products (including pyrometers, optical fiber thermometers and SCR thyristor power controllers) that offer precise thermal profiles and advanced process control solutions for increased productivity, yield and throughput.

www.advanced-energy.com/en/sck2016.html

RASIRC's water-free anhydrous hydrogen peroxide demonstrates five-fold increase in hydroxyl density

Dry peroxide gas delivery for ALD oxide growth on SiGe substrates

In the white paper 'Anhydrous Hydrogen Peroxide Gas Delivery for Atomic Layer Deposition', RASIRC Inc of San Diego, CA, USA (whose products purify and deliver ultra-pure liquids and gases) has released research results showing that anhydrous hydrogen peroxide gas enables a five-fold increase in surface hydroxyl density compared to water in studies involving ALD nucleation on silicon germanium (SiGe) substrates.

Hydroxyl density is an important factor in minimizing interfacial defects, increasing uniformity and improving next-generation semiconductor device performance, says RASIRC. BRUTE Peroxide provides a stable, reliable flow of anhydrous hydrogen peroxide for atomic layer deposition (ALD) and atomic layer etch (ALE), adds the firm, whose products generate specialty gases from liquid sources.

Next-generation devices are moving from silicon to silicon germanium channels, says RASIRC. It is critical to form stable uniform oxides without Si or Ge dangling bonds on the interface grown by ALD at low temperatures. "Research proves conclusively that the presence of water in some ALD and ALE processes negatively affects interfacial layer uniformity, leading to higher defect density, slower initiation, and degraded performance," says president & founder Jeffrey Spiegelman. "Tests of BRUTE hydrogen peroxide confirm that removing the water during processing with dry H_2O_2 enabled a three-fold improvement in hydroxyl density compared to 30% H_2O_2 and water source," he adds.

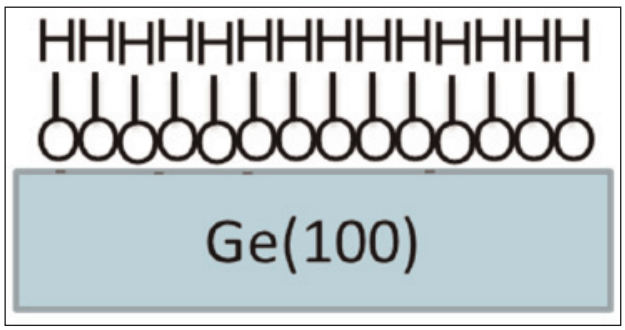


Figure 1: Ideal ALD nucleation of hydroxyl –OH groups depicted on Ge surface.

New market requirements

Semiconductor devices driven by Moore's law are continuously becoming faster, smaller and more power efficient. Integration of new materials makes this possible, but requires new process steps for high-k dielectrics in gate stacks and finFET devices, says RASIRC. High aspect ratios limit the use of traditional oxidants. Plasma processing requires a line of sight, which is often not available. Ozone can burn and damage delicate surfaces. Water is sluggish. Anhydrous hydrogen peroxide provides an alternative for functionalizing the surface with a dense layer of hydroxyl groups prior to deposition, says the firm.

"As thermal budgets are reduced, water fails to chemically react at the interface and physically adsorbs on the surface, blocking active binding sites," says Spiegelman. "Without the interference of water, anhydrous hydrogen peroxide can chemically react at the interface layer, reducing the number of cycles needed to begin ALD growth at the surface," he adds. "Until now a safe method for storage, transport and delivery of anhydrous hydrogen peroxide has not been available. BRUTE Peroxide changes all that."

Research summary

Studies show that hydrogen peroxide is well suited for surface functionalization, because it is highly susceptible to splitting into two hydroxyl radicals on contact with surfaces. In contrast, water splits into one hydroxyl group and one hydrogen site on Ge surfaces, and may desorb, leading to vacant dangling bonds. Ozone is also problematic, where bridging metal-oxides and surface damage are typical.

Tests with SiGe(110) surfaces contrast the relative effectiveness of water, H_2O/H_2O_2 solution and anhydrous hydrogen peroxide. The results show that hydroxyl density increases as the proportion of water decreases. Hydroxyl density with anhydrous hydrogen peroxide is five-fold that for water and three times more dense than for 30% H_2O_2/ H_2O solution, concludes RASIRC.

www.rasirc.com/lp/resources/paper-RASIRC-BRUTE-Peroxide.pdf

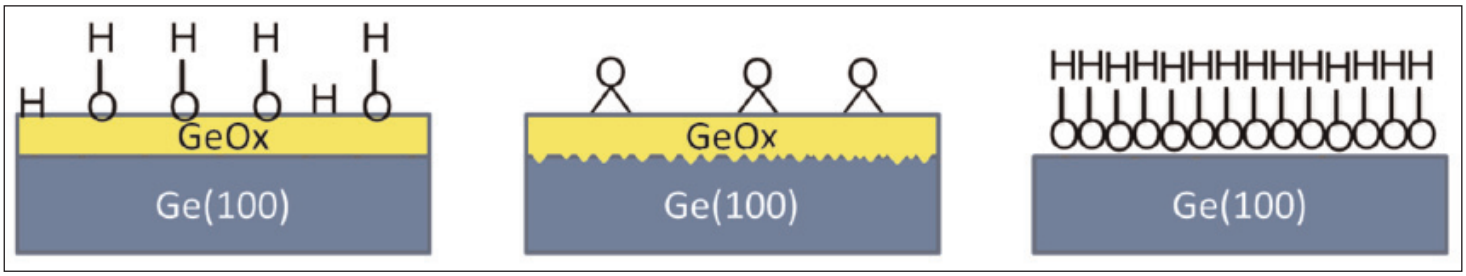


Figure 2: Theoretical nucleation of Ge surfaces is depicted for various oxidants: (a) H_2O, (b) O_2 plasma or ozone, and (c) H_2O_2.

FormFactor to acquire Cascade Microtech for $352m

Merger to combine complementary semiconductor test, measurement and characterization applications, from engineering to production

FormFactor Inc of Livermore, CA, USA (which provides wafer test technologies and expertise) has agreed to acquire Cascade Microtech Inc of Beaverton, OR, USA (which provides equipment enabling precision contact, electrical measurement and test of wafers, ICs, IC packages, circuit boards and modules as well as MEMS, 3D TSV and LED devices) in a cash and stock transaction.

For each share of Cascade stock held, stockholders will be entitled to receive $16 in cash and 0.6534 of a share of FormFactor common stock. The transaction values Cascade at $21.13 per share, or $352m in equity value, i.e. $270m in cash (including about $15m to cash out vested equity awards) plus about 10.4 million shares of FormFactor common stock, valued at $7.85 per share as of 3 February. At closing, Cascade common stockholders should own about 15% of the combined firm. FormFactor intends to fund the cash consideration for the transaction using about $120m of cash on hand plus about $150m in debt financing.

The combination is said to create significant scale by combining complementary market leadership positions in semiconductor test, measurement and characterization applications. By leveraging combined global support and channel investments across a product line that spans from engineering to production test applications, the combined firm is reckoned to be uniquely positioned to solve the most difficult test challenges from engineering to production.

Revenue of the combined company on a pro forma basis for 2015 would be over $426m. The transaction is expected to be immediately accretive to FormFactor's non-GAAP earnings per share and free cash flow. The combined firm expects to realize $10–12m in annualized cost synergies within 18–24 months of closing, and to accelerate the tax benefit of monetizing FormFactor's approximately $300m in net operating losses (NOLs).

The combined company will use the name FormFactor Inc, and continue to trade on the Nasdaq Global Select Market under the symbol 'FORM'. FormFactor's president & CEO Mike Slessor will lead the combined company and FormFactor's chairman Tom St. Dennis will remain in that role. FormFactor expects to add one new board member from Cascade's existing board after closing of the transaction.

"The combination of our products, technologies, and addressable markets enables us to rapidly take the next step in achieving FormFactor's strategic growth objectives," says Slessor. "At the same time, we are able to realize significant financial synergies that the two companies would not be able to realize on their own," he adds. Annualized cost synergies are reckoned to be equivalent to over 25% of the combined companies' non-GAAP operating income.

"As a combined entity, FormFactor and Cascade will be the leader in the production probe card and engineering systems markets," says Cascade's president & CEO Mike Burger. "The combination of Cascade and FormFactor creates a larger, stronger company that will drive long-term value for our customers, employees, partners, and shareholders."

The merger is reckoned to expand the estimated addressable market from $1bn to $1.4bn by enabling entry into engineering systems business, providing a platform for future expansion in test, measurement and yield.

By combining financial, R&D and manufacturing resources to serve a larger, more diversified customer base, the combined companies' top 10 customers will representing 62% of combined revenue (down from 83%).

"With the rapid changes taking place in the semiconductor industry, we are confident that this combination will place us in a strong position to continue to profitably grow our capabilities to serve a global and diverse customer base, while substantially improving our operational and financial metrics," concludes Slessor.

Having been unanimously approved by both companies' boards of directors, the transaction is expected to close in mid-2016 (pending the receipt of customary regulatory approvals). It is also subject to customary closing conditions, including approval by Cascade's stockholders.

www.formfactor.com
www.cascademicrotech.com

Lam's acquisition of KLA-Tencor approved by stockholders

At respective meetings for both firms (on 19 February), stockholders of deposition, etch and wafer-cleaning equipment maker Lam Research Corp of Fremont, CA, USA approved the issuance of shares required to complete the acquisition of KLA-Tencor (agreed on 20 October 2015), while stockholders of process control and yield management solutions provider KLA-Tencor Corp of Milpitas, CA, USA approved adoption of the merger.

"We can secure approvals necessary to complete the transaction in mid-2016," believes Lam's president & CEO Martin Anstice.

www.kla-tencor.com
www.lamresearch.com

IQE's wireless business unit renews major contract with tier-1 customer

Epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK has renegotiated its long-term supply contract with its premier tier-1 customer for the supply of wafer products used in wireless applications. IQE estimates that the contract will contribute more than $55m of revenue during 2016.

The new supply contract guarantees IQE at least 75% of the customer's demand for epiwafers that are produced using its metal-organic chemical vapor deposition (MOCVD) platform. It will also see expansion in terms of additional products from its molecular beam epitaxy (MBE) platforms. IQE says that the contract renewal underlines the strength of the long-term customer relationship that it has developed over many years, having consistently been recognized as one of the customer's best-performing suppliers.

IQE's Wireless business unit continues to leverage its global manufacturing facilities to fulfill the supply contract from its North American facilities in Massachusetts and Pennsylvania as well as its manufacturing site in Taiwan.

The contract covers epiwafer products for radio frequency (RF) applications including power amplifiers (PAs), low-noise amplifiers (LNAs) and switches used in connected devices such as smartphones, tablets, PCs, routers, satcoms, and other Internet of Things (IoT) devices.

"Wireless products continue to represent a key part of IQE's core business," notes IQE's CEO & president Dr Drew Nelson. "This tier-1 customer is a global leader in wireless connectivity solutions, and our long-term supply contract demonstrates a strong commitment to IQE," he adds.

"Global adoption of 4G/LTE and WiFi systems continues, and this majority supply contract is testimony to the world-leading performance which IQE products provide for current and next-generation wireless applications," says Daily Hill, head of IQE's Wireless business unit.

IQE makes final $15m payment for Kopin's III-V product line

Kopin Corp of Westborough, MA, USA has received $15m from IQE as the final payment from the sale of its III-V Product line. Under the terms of the sale (completed in January 2013), Kopin sold its integrated circuit business for a total of about $70m in cash.

Kopin has used the proceeds from the sale to invest in the development of wearables components, and it now provides components to enterprise and consumer developers of head-mounted displays, along with the military. At the 2016 International Consumer Electronics Show (CES) in Las Vegas earlier in January, Kopin demonstrated Solos (its smart eyewear for elite cyclists); launched Whisper Voice Chip (its voice extraction technology); announced Pupil (the world's smallest glass display); and was featured in 13 different companies that demonstrated products at the show.

www.kopin.com

IQE's Infrared business wins $3.7m order for InP materials

IQE has received a new purchase order agreement from a leading global substrate manufacturer (an existing long-term customer) for indium phosphide (InP) materials worth $3.7m.

"The scale of this commitment reflects our status in the semiconductor industry for the supply of a diverse range of semiconductor materials in addition to substrates and epiwafers," says Dr Mark Furlong, VP of IQE's Infrared business unit. "We continue to see growing demand for products with optoelectronic properties and it also confirms our position as a technology leader for advanced semiconductor products for photonics applications."

Produced by IQE's Infrared business unit based in Milton Keynes, UK, high-purity InP is the source material for manufacturing InP wafers used in the production of high-performance photonic components for a wide range of applications in infrared sensing and telecommunications, with a particular trend towards high-definition imaging applications enabled by InP materials.

Demand for photonics products is continuing to grow as new and emerging technologies increasingly rely on the properties of light for a growing range of technological applications, says IQE. InP is the material of choice due to its advantageous photonic properties particularly in the short-wavelength infrared (SWIR) range, complementing IQE's position in indium antimonide (InSb) and gallium antimonide (GaSb) substrate materials which form the key enabling technology base for multiple imaging technologies found in defence, security, medical and industrial applications.

IQE Infrared offers a range of IR materials, from substrates to epiwafers, with a secure, dual-sourced supply of InP, InSb and GaSb, with IQE's US (Galaxy) and UK (Wafer Technology) operations collectively meeting customer requirements.

www.iqep.com

Riber's annual revenue falls 23% to €12.8m in 2015

Doubling of order book during 2015 promises pick up in 2016

Riber S.A. of Bezons, France, which manufactures molecular beam epitaxy (MBE) systems as well as evaporation sources and effusion cells, has reported a second consecutive year of reduced revenue (€12.8m for 2015, down 23% on 2014's €16.6m), linked mainly to the MBE market's contraction over the past two years during a cyclical low.

The majority of orders were booked in second-half 2015, yielding revenue of €7.1m (€5.1m in Q4 plus €2m in Q3) compared with €5.7m in first-half 2015 (€3m in Q2 plus €2.7m in Q1), as the year was marked by significant fluctuations in MBE system sales. System revenue specifically was €6.1m for 2015, down 35% on €9.3m for 2014.

Nevertheless, in the current environment, and despite very strong competitive pressure, Riber has maintained its market shares by focusing its commercial activities on R&D customers (the firm's traditional core business). Over the full year, nine R&D systems were delivered and invoiced, including four in Q4/2015, compared with a total of 11 for the whole year in 2014.

Revenue for Services & Accessories was €4.2m, down 31% on 2014's €6.1m which included a major sale (of €1.2m) for the full reconfiguration of a production system in France (restated for this order, revenue would be down 13% on 2014). The contraction in volumes has been mitigated by redeployment of the range of services & accessories on the firm's leading customers, as well as diversification and strengthening of the range of solutions offered following the acquisition in March of MBE Control Solutions of Santa Barbara, CA, USA (which operates maintenance and refurbishment services for all types of MBE systems).

Sales of Cells & Sources are growing strongly (up 123% from €1.1m in 2014 to €2.5m in 2015), due to the development efforts made, allowing further strengthening and diversification of the range of cells.

The geographic breakdown of Riber's revenue in 2015 was as follows: 45% for Europe, 35% for Asia, 10% for North America, and 10% for other continents (primarily South Africa and New Zealand).

In Q4/2015, Riber's order levels continued to improve, due to two research MBE systems ordered in Germany and the USA (plus a MBE49 multi-wafer production system for China, announced on 18 January).

At the end of 2015, the order book was €12.1m, more than doubling from €6m at the end of 2014. This includes seven systems to be delivered in 2016 (including two production systems) totalling €9.1m (up 125% on €4m in 2014), as well as orders for Cells & Sources and Services & Accessories of €3m (up 58% on €1.9m in 2014), comprising Cells & Sources orders of €0.6m (down from €0.7m) and Services & Accessories of €2.4m (doubling from €1.2m).

Riber expects 2015 earnings to be lower than in 2014. Net cash at end-2015 was positive, at €0.1m, which is down from €2m at the end of 2014 but an improvement from –€0.1m at the end of June 2015. Full-year earnings for 2015 will be released on 31 March.

Due to the recovery in second-half 2015, business should rise in 2016.

www.riber.com

Compound Semiconductor Centre appoints chair

The Compound Semiconductor Centre (CSC) — a joint venture formed last August between epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK and Cardiff University — has appointed professor Colin Whitehouse FREng, FInstP, FIMMM, as its chair.

An expert in compound semiconductor materials, nano-devices and nanotechnology, Whitehouse has experience in both managing and directing research as well as the commercial exploitation of research. "His unparalleled reputation and experience coupled with his extensive network within industry, academia and government will be absolutely invaluable in guiding the development of the centre through its set up and early growth phase," says CSC director Dr Wyn Meredith.

Lately, Whitehouse was deputy chief executive of The Science and Technology Facilities Council (STFC, one of the UK's Research Councils). He was also director of the STFC Daresbury Laboratory in Cheshire and responsible for initiating formation of the National Science and Innovation Campuses at Daresbury and Harwell.

Prior roles include board membership of Sheffield Innovations Ltd (the commercialization arm of the University of Sheffield), commercial exploitation firm STFC Innovations, the Oxfordshire Local Enterprise Partnership (LEP), STEMNET, and chair of the UK's R&D Society. He is also an elected Fellow of the Royal Academy of Engineering, the Institute of Physics, and the Institute of Materials, Mining and Mineralogy.

"The rapidly growing dependence on compound semiconductors that enable all key technology markets will create exciting opportunities for the recently formed Compound Semiconductor Centre, IQE and Cardiff University," says Whitehouse. "The CSC is uniquely positioned to perform the extremely important intermediate role between university-based research, particularly through Cardiff University's Institute of Compound Semiconductors (ICS), and the very recently announced CS Applications Catapult Centre, also to be based in South Wales."

www.compoundsemiconductorcentre.com

Veeco collaborating with imec to improve GaN-based power device yield and reliability

Single-wafer MOCVD system being used to speed GaN epilayer development

Epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA has signed a joint development project (JDP) agreement with Belgium-based nano-electronics research center imec. The collaboration is expected to accelerate the development of highly efficient gallium nitride (GaN)-based power electronic devices using epitaxial wafers created using Veeco's Propel Power GaN metal-organic chemical vapor deposition (MOCVD) system.

Featuring a single-wafer 200mm reactor platform capable of processing 6- and 8-inch wafers and designed specifically for the power electronics industry, the Propel Power GaN MOCVD system (launched in November 2014) deposits GaN films for the production of highly efficient power electronic devices. The single-wafer reactor is based on Veeco's TurboDisc MOCVD design and includes the new IsoFlange and SymmHeat technologies that provide homogeneous laminar flow and a uniform temperature profile across the entire wafer. Users can easily transfer processes from Veeco's K465i and MaxBright MOCVD systems to the Propel Power GaN platform.

Imec has already demonstrated significant gains in GaN layer uniformity and run-to-run repeatability with the Propel system, resulting in significantly improved power device yields. The single-wafer reactor incorporates Veeco's proprietary TurboDisc technology, which is said to deliver superior film uniformity, run-to-run control and defect levels compared to batch reactors.

"Within the framework of our industrial affiliation program on GaN-on-Si, Veeco and imec have collaborated over the last four years to improve the epi quality of GaN layers deposited on silicon wafer substrates," says Rudi Cartuyvels, senior VP Smart Systems and Energy Technologies at imec. "The ultimate goal is to produce the next generation of highly efficient power switching devices," he adds. "We have set very high GaN device yield and reliability targets for 2016, and we look forward to partnering with Veeco to achieve these targets."

According to market research by IHS, industry requirements are growing and requiring smaller, more energy-efficient power ICs. This, in turn, is driving the need for improved power devices using advanced materials. GaN-on-Si coupled with improved process solutions, such as single-wafer GaN MOCVD, is critical to the development of these improved power devices.

"Global demand for advanced power electronics with greater energy efficiency, a smaller form factor and greater reliability is rapidly accelerating," notes Jim Jenson, senior VP & general manager, Veeco MOCVD Operations. "We believe that the technology in our Propel single-wafer system will enable imec to achieve their power device targets and help to bring these advanced devices to market faster."

www.veeco.com/Propel

Aixtron receives 'Innovation Award for Automation'

At the 13th Innovationsforum for Automation in Dresden, Germany (21–22 January), deposition equipment maker Aixtron SE of Herzogenrath, near Aachen, Germany received the 'Innovations Award for Automation, which is awarded annually by organizer Automation Network Dresden (AND) to honor the development of innovative system automation software concepts.

The AND is an initiative of the five Dresden-based automation specialists HAP GmbH, Roth & Rau – Ortner GmbH, AIS Automation Dresden GmbH, SYSTEMA GmbH, and XENON Automatisierungstechnik GmbH.

The jury awarded Aixtron for its user-oriented operation system for deposition systems that the firm has been supplying for over 30 years to the global semiconductor industry for the production of light-emitting diodes (LED), lasers, power electronics, organic light-emitting diodes (OLED), memory and logic chips, and carbon nanomaterials.

The jury highlighted that — with its new ATO (Aixtron Tool Orchestrator) operation solution — Aixtron had overcome the apparent contradiction between high automatization levels and manual operation. In enhancing the user interface, the firm's engineers had also made system users the key focus of their considerations, the jury added.

The award "recognizes Aixtron's power of innovation in an important aspect of system construction," says Dr Christian Geng, Aixtron's director of technology. "We aim to make it as easy as possible for our customers to operate our systems and thus enhance their production efficiency," he adds. "Given increasing automation of all production processes, operation software and the user interface are playing an ever greater and more decisive role."

www.automation-dresden.de

Veeco launches K475i As/P MOCVD system

New system accepted by red-orange-yellow LED maker Changelight

Epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA has launched the TurboDisc K475i arsenic phosphide (As/P) metal-organic chemical vapor deposition (MOCVD) system for the production of red, orange, yellow (R/O/Y) light-emitting diodes, as well as multi-junction III-V solar cells, laser diodes and transistors.

"Veeco continues to drive innovation with MOCVD technology that enables us to lower manufacturing costs and increase production with systems that are reliable, flexible and easy to use," comments Shuangxiang Zhang, general manager of Yangzhou Changelight Co Ltd. "The K475i quickly achieved unparalleled yield and brightness that will allow us to meet the growing demand for red, orange and yellow LEDs as well as other As/P-based devices," he adds.

According to market research firm Strategies Unlimited, R/O/Y LED demand is expected to grow at a 10% compound annual rate through 2023. This demand for red, orange and yellow LEDs is being driven by signage, automotive, display and general lighting applications, as well as the emergence of new applications such as wearable smart devices.

Incorporating proprietary TurboDisc and Uniform FlowFlange MOCVD technologies, the new K475i system enables users to reduce LED cost per wafer by up to 20% compared with alternative systems through what is reckoned to be higher productivity, best-in-class yields and reduced operating expenses.

"The new K475i is built upon production proven technologies that are incorporated into all of our industry-leading MOCVD systems," says James T. Jenson, senior VP & general manager, Veeco MOCVD Operations, who highlights Changelight's rapid qualification of the beta system. "We have already seen strong industry interest in the K475i," he adds.

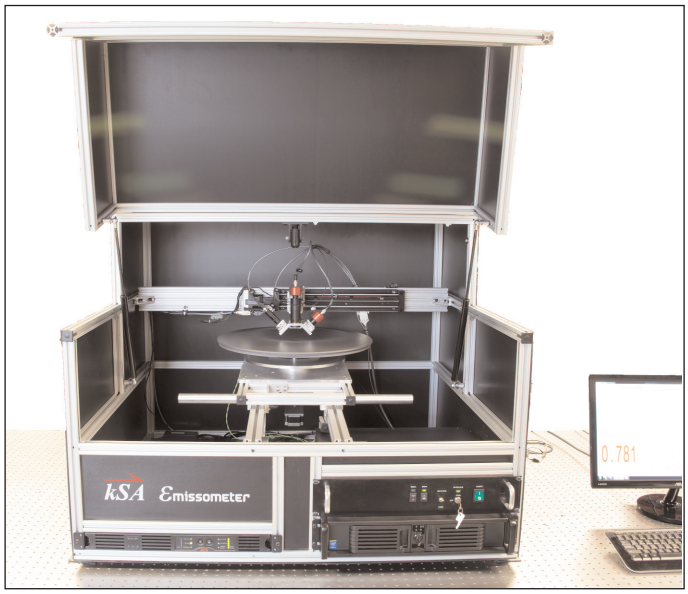
Veeco says its proprietary Uniform FlowFlange technology produces films with very high uniformity and improved within-wafer and wafer-to-wafer repeatability resulting in what is reckoned to be the industry's lowest cost of ownership. The patented technology is said to provide ease-of-tuning for fast process optimization and fast tool recovery time after maintenance, enabling the highest productivity for applications such as lighting, display, solar, laser diodes, pseudomorphic high-electron-mobility transistors (pHEMTs) and heterojunction bipolar transistors (HBTs).

www.veeco.com

k-Space launches emissometer for characterization of MOCVD wafer carriers

k-Space Associates Inc of Dexter, MI, USA (which supplies thin-film metrology tools for the semiconductor, compound semiconductor and solar markets) has launched the kSA Emissometer. The ex-situ tool provides metal-organic chemical vapor deposition (MOCVD) fabs with essential wafer carrier characterization, including emissivity uniformity and defect identification.

Traditionally, MOCVD fabs rely on subjective human tests to inspect the quality of wafer carriers after bakes and between runs, and then they rely on empirical data to adjust carrier temperatures from growth to growth, says k-Space. The kSA Emissometer is said to put the science back in carrier evaluation with high-resolution carrier emissivity mapping and the detection of defects and micro-cracks that are not visible to the human eye. The tool is designed to be used by operators and engineers and provides full quantitative carrier maps in 10 minutes.



The new kSA Emissometer.

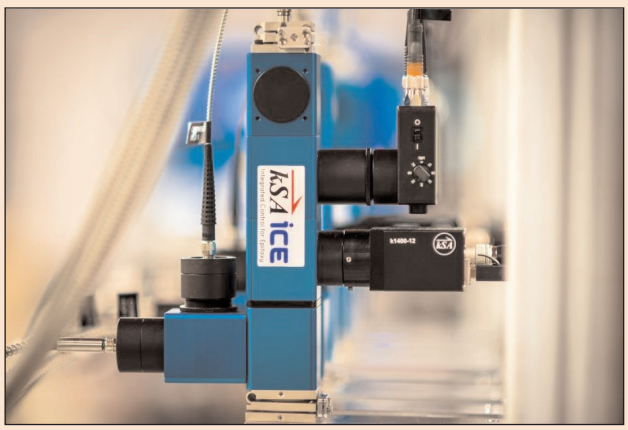
"The real advantage of the kSA Emissometer is that it provides fabs with systematic carrier data that can be integrated into their quality control processes," says CEO Darryl Barlett. "It also provides a go-no-go decision on carrier use and quantitative determination of the carrier emissivity, allowing for temperature set-point adjustments for individual carriers," he adds. "In the end, this will lead to lower production costs and better device yields."

www.k-space.com

k-Space's ICE metrology tools installed on NuFlare's GaN-on-silicon MOCVD reactors

k-Space says that semiconductor equipment maker NuFlare Technology Inc of Kanagawa, Japan has installed multiple kSA ICE (Integrated Control for Epitaxy) in-situ metrology tools for process monitoring and control. The kSA ICE tools measure real-time wafer temperature, curvature and reflectance for NuFlare's custom multi-chamber metal-organic chemical vapor deposition (MOCVD) reactors, focused on the growth of gallium nitride (GaN) on 200mm silicon substrates.

The NuFlare MOCVD system can be configured with up to four, single-wafer 200mm MOCVD process modules. k-Space worked with NuFlare to develop a custom kSA ICE tool that allows for simultaneous real-time measurement from multiple measurement heads on each process module from a single controller. This helped to reduce the total system costs while maintaining full monitoring and control capabilities, says k-Space.



A kSA ICE head mounted on a reactor.

The ICE tools perform patented curvature measurements that are critical to GaN-on-Si integration. Moreover, by measuring the temperature of the wafer via emissivity-corrected pyrometry (ECP) at two positions on the wafer, users obtain temperature control to better than 1°C. This kSA ICE multi-chamber design allows measurement heads to be easily added as a user moves from one process module up to four 200mm process modules, adds the firm.

"NuFlare worked side-by-side with us to help develop a kSA metrology tool tailored to the needs of this growing market," comments k-Space's head of product development Dr Chuck Taylor. "The modular capability of this custom kSA ICE tool is an ideal cost-effective solution for a multi-module MOCVD system," he adds.

www.nuflare.co.jp
www.k-space.com/products/ksa-ice

LayTec's Gen3 tool offers new features for UV LED epitaxy

After unveiling its third generation of in-situ metrology tools last October, LayTec AG of Berlin, Germany says the EpiTT Gen3 is now available as the first representative of this Gen3 product class.

The backbone of the metrology's hardware and software is modularity. LayTec says that the new concept offers a wider range of process-specific customizations without compromising the robustness and accuracy of performance. Further, the 24/7 operation is improved by separating data acquisition (based on ARM processors) from metrology control and analysis (based on MS Windows PC).

Gen3 also offers a significantly extended choice of process interfaces, e.g. SECS/GEM for communication with MES systems and Modbus for Riber's latest Crystal XE software for MBE. Also, the real-time and post-growth data analysis functionality has been further improved. Several completely new hardware components can now be combined with proven work-horse modules that have also been integrated into the new Gen3 platform.

A particular application is the epitaxial growth of ultraviolet (UV) LEDs, which presents significant challenges, including long runs, superlattices, high aluminium content versus a high doping level, very high growth temperature, and large wafer bow, says LayTec. The firm says that Gen3 families of EpiTT and EpiCurveTT tools offer technology advances to solve most of these problems, citing the following example applications.

Overcoming wafer-showerhead gap variation in UV LED epitaxy

For UV LED processes, EpiTT Gen3 can measure temperatures up to 1500°C. However, a further key new Gen3 feature is the possibility to choose between two types of metrology head: fiber-optical heads (FOHs) and new parallel-beam heads (PBHs). According to LayTec, EpiTT with parallel-beam heads is the tool of choice, e.g. for CCS (Close Coupled Showerhead) reactors, where the wafer-showerhead gap is adjusted to avoid pre-reactions and to achieve high growth rate in UV LED processes.

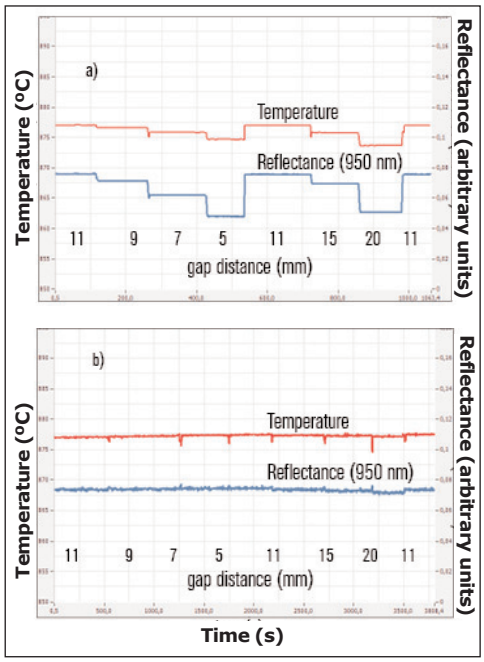


Figure 1: Reflectance (950nm) and temperature data while varying gap: (a) FOH shows 30% reflectance drop with temperature drop of several Kelvin, depending on sample structure; (b) PBH delivers stable reflectance and temperature signal. At standard gap (11mm), both heads measure same reflectance (AbsoluT thermal reference).

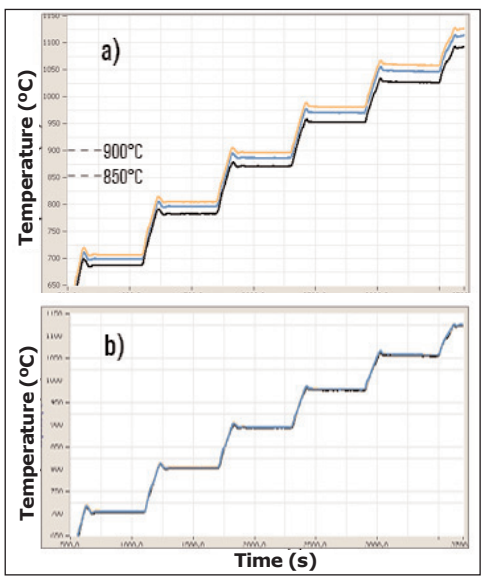


Figure 2: Temperature step run. True Temperature at 950nm: blue - pocket W5 (SSP); orange - pocket W6 (DSP); black - pocket W8 (PSS) measured by (a) conventional emissivity-corrected IR pyrometer and (b) EpiTT Gen3, which eliminates emissivity effects and straylight/defracting effects of wafer backside and/or PSS front-side.

Figure 1(a) shows that FOHs suffer from the off-focus situation resulting from such adjustment, which must be compensated by multiple-gap calibration, while Figure 1(b) shows that PBHs deliver a very stable reflection and temperature signal despite the gap variation and hence do not require complex and time-consuming multi-gap calibration.

So, for this specific reactor type, LayTec says that Gen3 with parallel beam head technology is the best way to achieve accurate temperature measurement using 950nm reflectance for emissivity correction.

Accurate temperature for PSS and DSP sapphire substrates

For UV LEDs, the emitted light usually exits the device structure through the sapphire substrate, so double-side polished (DSP) sapphire is frequently used. In addition, the front surface of the sapphire substrate can be modified by nano-patterned sapphire substrates (PSS) for enhanced light extraction. Both substrate types often cause unrecognized artifacts in temperature sensing.

As an example, Figure 2 shows a temperature step run with three types of sapphire substrates: DSP, PSS and SSP (single side polished).

Conventional IR pyrometry (Figure 2a) measures three different pocket temperatures for these wafer types. While the DSP sapphire substrate at 900°C gives the correct value, SSP is ~10K less than DSP and PSS is ~25K less than DSP. The level of the apparent (but not real) temperature reduction depends on temperature and on the details of back-side roughening, PSS patterning and the reactor configuration. However, EpiTT Gen3 comes with new software algorithms that take these specific effects into account and deliver the same accurate pocket temperature for SSP, DSP and PSS sapphire substrates (Figure 2b).

www.laytec.de/UVLED

ClassOne's 8-chamber Solstice electroplater selected by LED maker in Europe

ClassOne Technology of Kalispell, MT, USA, which manufactures wet-chemical processing equipment (especially for emerging markets and other cost-conscious users of ≤200mm substrates), has announced the purchase of its 8-chamber Solstice S8 electroplating system by what it describes as one of the world's leading LED makers.

"The unique flexibility and process control of the Solstice electroplating system were particularly important factors in addressing this customer's needs," says chief technology officer Kevin Witt. "The fully automated 8-chamber Solstice gives users the ability to process multiple wafer sizes at the same time on a single tool. ClassOne's distinctive design allows the chambers to be changed very quickly and easily. In addition,

ClassOne's Solstice S8 system.

Solstice can provide a high degree of whole-process control, enabling close monitoring of such parameters as film stress," he adds.

"ClassOne's level of support for the tool in Europe was another significant factor in making the sale," says president Byron Exarcos. "At this installation we will be providing not only product service but also ongoing process development assistance."

Solstice systems are designed to provide high-performance electroplating on ≤200mm wafers at a very reasonable cost. Because of their performance/price ratio — as well as their ability to handle smaller substrates — Solstice plating tools have become popular in emerging markets such as LED, MEMS, RF, power, and sensors, claims the firm. ClassOne's electroplaters allow users to deposit a broad range of metals and alloys on both opaque and transparent substrates. The Solstice systems are available in fully automated 75wph, 4- and 8-chamber configurations, as well as a smaller, semi-automated tool for process development.

www.classone.com/products

CORIAL makes available ICP etch process for 6-inch patterned sapphire substrates on single-module platform

Plasma etch and deposition equipment maker CORIAL of Bernin, France has announced the general availability of an inductively coupled plasma (ICP) process for sapphire patterning on 6" wafers, to be used in high-volume LED production with the fully automated Corial PS200 single-module platform.

The patterned sapphire substrate (PSS) is the standard in the LED industry for fabricating brighter LEDs, says the firm. CORIAL says that, going back to 2009, it has been among the first companies to supply a stand-alone ICP system with etching processes dedicated to PSS applications. Since then, the firm has innovated to offer cost-effective solutions for LED production.

Based on a production-proven plasma technology, the CORIAL PS200 is a fully automated single-module platform combining high productivity on sapphire substrates with etching performance for PSS application.

Key features of the Corial PS200 platform are listed as follows:

- a high-density plasma source providing uniformity and process repeatability;
- single-wafer processing with Brooks elevator for front-end cassette in vacuum load-lock and Brooks robot in vacuum transfer chamber for fully automated wafer handling;
- production flexibility with extendable platform configuration (up to three process modules);
- soft mechanical clamping with helium backside cooling, maximizing etching uniformity; and
- in-situ plasma cleaning process for the highest process repeatability.

CORIAL says that its patterning process on 6" wafers has been tested and qualified by a major LED maker in Asia.

Typical results for PSS on 6" wafers are cited as follows: average STD (standard deviation) within wafer of <0.5; PSS height of 1800nm ± 40nm and PSS width of 2800nm ± 40nm; ≤±1.5% etching uniformity (conical shape); and throughput of ≥ 2.5 wafers per hour.

In close cooperation with users, CORIAL's application engineers are developing recipes that best match the required specifications (PR types, PSS shapes etc), providing optimal edge-of-wafer results and maximizing process uniformity and repeatability.

www.corial.net

Nikkiso to begin shipping record-power 50mW UVC deep UV LEDs

Nikkiso America Inc of San Diego, CA, USA (the US arm of Tokyo-based Nikkiso Co Ltd, which is developing and commercializing deep ultraviolet LEDs) has announced general availability of 50mW deep UV LEDs. The VPS173 series UV LED product range delivers about 1.7 times the power output of the previous generation, with demonstrated operating lifetimes in excess of 10,000 hours at 350mA drive current.

Initial 50mW deep UV LED availability will include 285nm components in a surface-mount device (SMD) configuration, with pending releases of products emitting at wavelengths from 265nm to 300nm.

"UV LED technology is advancing rapidly, with extraordinary progress reported annually in optical output power, efficiency and cost," says Nikkiso America's president & CEO Dennis Martin. "Whether the application involves curing, medical, germicidal or analytical instrumentation, deep UV LED technology offers compelling advantages over lamp-based solutions and further enables new applications," he adds.

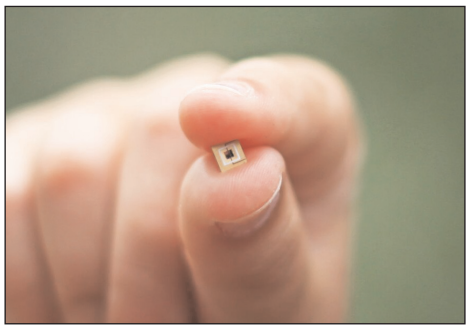
Nikkiso's proprietary aluminium gallium nitride (AlGaN) technology was developed by 2014 Nobel Prize winning professors Akasaki and Amano and enables what is claimed to be the world's highest performance and efficiency in the UV-B and UV-C portions of the spectrum. Production facilities are located in Japan's Ishikawa Prefecture and include epitaxy, wafer fab and packaging.

www.NikkisoUVLED.com

AquiSense participating in project for International Space Station biocontamination control system

UK-based AquiSense Technologies (Europe) Ltd, a subsidiary of UV-C LED system manufacturer AquiSense Technologies LLC of Florence, KT, USA, has been selected to participate in the project Biocontamination Integrated Control for Wet Systems for Space Exploration (BIOWYSE).

AquiSense is part of a seven-company consortium that includes Italian firm Thales Alenia Space, one of the main suppliers to the International Space Station (ISS). The BIOWYSE consortium will design, build and test innovative prevention, monitoring and mitigation modules to be integrated in a compact system.



AquiSense will design the key technology within the decontamination module, employing UV-C LED technology, similar to that used in the firm's PearlAqua water disinfection system. Richard Simons, a PhD graduate engineer from Imperial College London, has been appointed as program manager for AquiSense.

The proposed BIOWYSE project foresees the development and demonstration of an integrated biocontamination control system for water and humid areas, to be demonstrated on the International Space Station and future human exploration missions. BIOWYSE stems from the results of actual flight experiments and state-of-the-art prevention, monitoring and mitigation technologies. The project will further investigate the possibilities for spin-off developments in the terrestrial water management industries.

The project is funded by the European Commission under the €80bn Horizon 2020 program and is valued at €3m.

www.aquisense.com

Phoseon adds UK/Ireland/Scandinavia regional sales manager to European sales team

UV LED curing firm Phoseon Technology of Hillsboro, OR, USA has appointed David Richards as regional sales manager.

Richards has years of sales experience selling LED solutions for industrial processes in Europe. His primary responsibility will be to manage many of Phoseon's key accounts in the UK, Ireland and Scandinavia as Phoseon continues to grow the UV LED curing markets.

"We are extremely pleased to welcome David to the growing Phoseon Europe team, bringing valuable experience in the field of LEDs and OEM sales," says Rob Karsten, director of sales & marketing — EMEA. "David will bring significant capability and leadership to the organization which will be crucial as we continue to expand our European customer base," he believes.

www.phoseon.com

Excelitas launches OmniCure AC9 UV LED curing systems

Excelitas Technologies Corp of Waltham, MA, USA, which provides customized photonic solutions to OEMs, has introduced OmniCure AC9 UV LED curing systems for the curing of inks, adhesives and coatings. The systems' design features a high-performing, small form-factor, air-cooled solution to enable faster line speeds in industrial manufacturing and printing.

The OmniCure AC9150, AC9150P, AC9225, AC9225P, AC9300 and AC9300P UV LED curing systems have advanced front-end optics to provide high power, high peak irradiance and what is claimed to be exceptional uniformity. The systems deliver more than 14W/cm^2 peak irradiance for fast curing at varying working distances. A patented process for addressing individual UV LED module outputs provides uniformity for even curing over the entire area.

The three AC9-P versions of the AC9 series are equipped with a replaceable outer window for easier maintenance in printing applications at close working distances. The scalable design allows for multiple heads to be adjoined for customization and flexibility without compromising on output uniformity. By adapting the output to support specific process requirements, the new AC9 series can be used in a range of applications, including digital printing, industrial and electronics manufacturing, touch panel/display, solar panel, conformal coatings and automotive.

For a repeatable curing process, precise control of the UV irradiance level and time allows the correct dose of UV energy to be provided on every exposure. Intelligent system monitoring and control ensures that the systems' reliability meets the demands of any application.

OmniCure UV LED curing systems utilize air-cooled LED technology in a compact design, allowing for seamless integration into new or existing production lines. The design eliminates the need for costly re-tooling, external cooling or ozone extraction. The curing systems can also be mounted in any orientation for greater flexibility. External mechanical and optical accessories are also available upon request.

"Higher peak performance and custom lenses set OmniCure AC9 Series products apart from other UV LED curing systems on the market," claims Oliver Scheuss, VP of solid-state lighting & UV/microscopy at Excelitas.

The OmniCure AC9 Series of UV LED curing systems debuted at the IMI (Information Management Institute) Ink Jet Printing 2016 Conference in Anaheim, CA, USA (3–5 February).

www.excelitas.com/OmniCure
www.imiconf.com/InkJet16.html

Soraa launches flicker-free digital driver MR16 LED lamps

Soraa Inc of Fremont, CA, USA, which develops solid-state lighting technology built on 'GaN on GaN' (gallium nitride on gallium nitride) substrates, has incorporated advanced digital drivers into its MR16 LED lamps, making them flicker free. Featuring full-visible-spectrum light, the new Flicker Free MR16 LED lamp is said to eliminate the problem of stroboscopic effect ('invisible flicker') that plagues other MR16 LED lamps. In doing so, Soraa's digital driver addresses the adverse physiological effects associated with invisible flicker, and significantly expands the compatibility and capability of the MR16 lamp.

Soraa says it has created a high-capability digital driver that closely matches the very small form factor of a halogen MR16, leading to superior fixture compatibility compared to other low-flicker MR16s, it is claimed. In addition, the new digital driver MR16 LED lamps have expanded compatibility with transformers and dimmers and, like all of Soraa's lamps, they regulate temperature to maintain lifetime, color quality and efficiency across a range of application conditions.

The new digital driver MR16 LED lamps are claimed to be the first true ANSI size standard flicker free LED lamps. The lamps are available in 6W, 7.5W and 9W versions with light output equivalent to 35W, 50W and 75W halogen lamps, are fully dimmable, and the 6W and 7.5W lamps are suitable for enclosed, non-ventilated, indoor and outdoor fixtures (where other LED lamps struggle to perform, it is claimed). The Flicker Free MR16 LED lamps are also available with beam angles of 10°, 25° and 36°, color temperatures of 2700K, 3000K, 4000K and 5000K, and color rendering indexes (CRI) of 95 and 80. Plus, Soraa's 10° lamps work with the firm's magnetic accessory SNAP System (where, with a simple magnetic accessory attachment, beam shapes can be altered and color temperature can be modified, allowing flexibility in design and display).

Like all of Soraa's LED products, the Flicker Free MR16 lamps feature the firm's Violet-Emission 3-Phosphor (VP_3) LED technology, enabling the rendering of colors and whiteness. Utilizing every color in the rainbow, especially deep red emission, VP_3 Vivid Color renders warm tones accurately, and achieves a CRI of 95 and deep red (R9) rendering of 95. Also, unlike blue-based white LEDs without any violet emission, the VP_3 Natural White is achieved by engineering the violet emission to properly excite fluorescing brightening agents including natural objects like human eyes and teeth, as well as manufactured white materials such as clothing, paper and cosmetics.

www.soraa.com

EpiTop claims record 176.6mW output for single-die 280nm deep ultraviolet LED

High-power deep ultraviolet LED products to ship in mid-2016

EpiTop Optoelectronic Technology Co Ltd of Anhui province, China (which was established in 2010 and manufactures full-color LED epitaxial wafers and chips) has demonstrated what is claimed to be record optical output power of 176.6mW (at a DC operating current of 1A, at room temperature) for a deep ultraviolet (DUV) LED emitting at a wavelength at 280nm from a single die (a 4545 large-chip device).

In October 2015 parent company YuanRong Photoelectric Technology Co Ltd (Harmony Photoelectric Technology Co Ltd) extended its business from visible LEDs into DUV LEDs by acquiring Qingdao-based QD Jason Electric Co Ltd (founded in 2001, and reckoned to be China's only commercial DUV LED maker).

"The new world record high optical output power was realized by using our proprietary homemade MOCVD [metal-organic chemical vapor deposition] technology and improved fabrication and packaging approach," says EpiTop's president Bob Liang. "The device voltage is as low as 5.8V, even at 1A, with differential resistance of 1 Ohm only — such great electrical performance allows the large chip to be driven up to 1A under DC operation before saturation, a contribution to the high output power achievement," he adds.

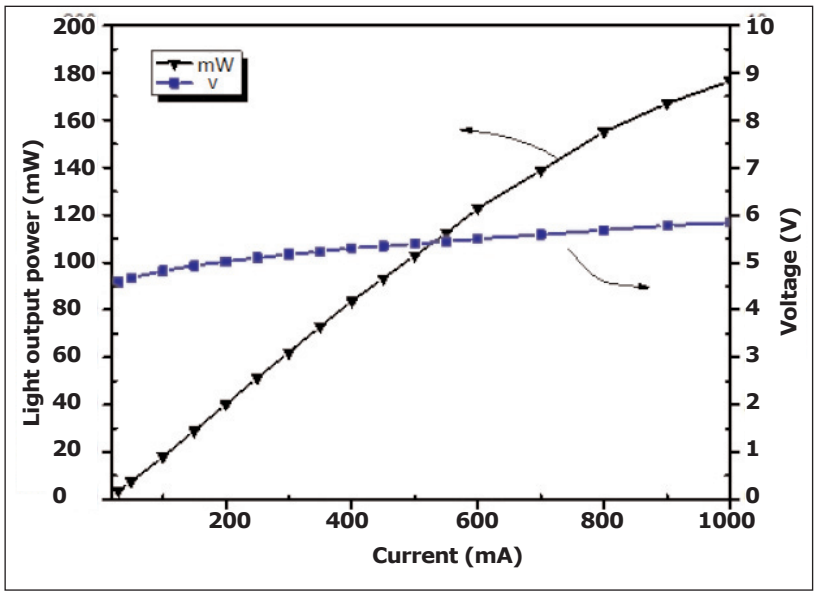


Figure 1: L–I and IV characteristics of EpiTop's 4545 large-chip UV LED at 280nm.

"We are working transferring our new technology into production," says Liang. "We expect in the middle of this year to start shipping high-power products, which will speed up the development of high-power DUV LED applications and, strengthen the company's world leading position in the DUV LEDs area," he adds.

Our DUV LEDs have already been used in many appliances like water purifier machines

"Our goal is to provide the world's most efficient and lowest-cost DUV LEDs devices," continues Liang. "Our DUV LEDs have already been used in many appliances like water purifier machines, humidifiers, air purifiers, sanitizing devices and so on. EpiTop Technology will continue to work closely with the customers to develop innovative products enabled by our DUV LEDs devices."

www.epitop.com.cn

Seoul Semiconductor licenses Lumitech's PI-LED technology patents

South Korean LED maker Seoul Semiconductor has agreed to license patents covering the PI-LED technology of Lumitech GmbH of Jennersdorf, Austria, which manufactures components for human-centric lighting. PI-LED technology facilitates tuning of white light through correlated color temperatures (CCTs) of 2500K to 7000K with high quality of colour rendering at consistently high efficiency, it is claimed. Based on the license agreement, Seoul Semiconductor has the right to offer tunable white components based on PI-LED technology worldwide.

"Seoul Semiconductor will apply PI-LED patent technology to the Bluetooth remote control of Smart lighting Acrich 3 and supply lighting manufacturers worldwide," says Seoul Semiconductor's chief technology officer Ki-bum Nam. "This will provide customers with a healthy and comfortable light."

Lumitech's PI-LED patents were originally filed in the mid-2000s. They refer to the manufacturing and the use of blue, red and special colour-converted mint LEDs in order to accurately provide LEDs with any chosen colour temperature and a high CRI, as well as individual colours. According to market studies, human-centric lighting will reach 10% of the general lighting market by 2020.

www.lumitech.at
www.SeoulSemicon.com

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Plessey to fabricate LEDs in cubic GaN on Anvil's 3C-SiC/Si substrates to overcome 'green gap' in efficiency

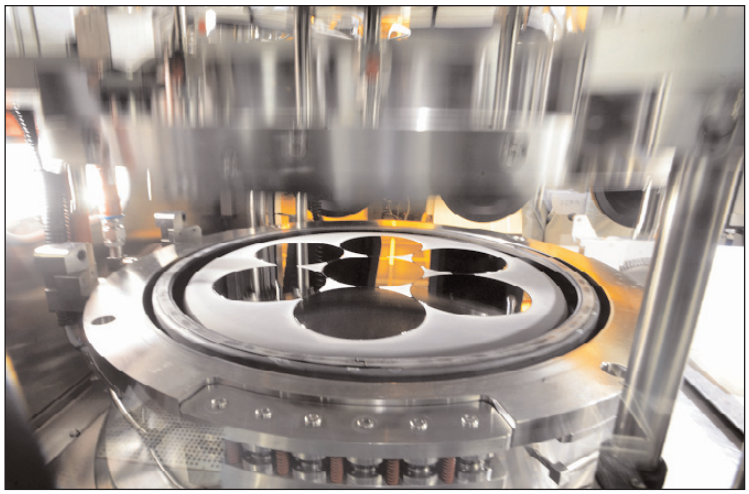
Innovate UK-funded collaboration targets large-diameter wafers to reduce cost of LED lighting

UK-based Plessey, Anvil Semiconductors Ltd of Coventry, UK and the University of Cambridge have announced that they are working together to fabricate high-efficiency LEDs in cubic GaN grown on Anvil's 3C-SiC/Si (silicon carbide on silicon) substrates.

Anvil was spun off in August 2010 from the University of Warwick's School of Engineering by its technology commercialization subsidiary Warwick Ventures Ltd in order to exploit patented developments in SiC power semiconductor technology. The firm's technology enables the growth of device-quality 3C-SiC epitaxy on 100mm silicon wafers to thicknesses that permit the fabrication of vertical power devices. The proprietary process is said to overcome mismatches in lattice parameter and thermal coefficient of expansion. The material has applications ranging from power devices and LEDs to medical devices and MEMS.

Cubic GaN has the potential to overcome the problems caused in conventional LEDs by the strong internal electric fields that impair carrier recombination and contribute to efficiency droop. This is particularly true for green LEDs, where the internal electric fields are stronger and are believed to cause a rapid reduction in efficiency at green wavelengths (the 'green gap'). The availability of cubic GaN from a readily commercializable process on large-diameter silicon wafers is as a key enabler for increasing the efficiency of green LEDs and reducing the cost of LED lighting, says Plessey.

The collaboration, which is partly funded by Innovate UK under the £14m Energy Catalyst Programme, follows on from work by Anvil and the Cambridge Centre for GaN (part of the University of Cambridge's Department of Materials Science and Metallurgy), where they grew cubic GaN on 3C-SiC on silicon wafers by metal-organic chemical vapor deposition (MOCVD). The underlying 3C-SiC layers were produced by Anvil using its patented stress-relief IP that enables the growth of device-quality silicon carbide on 100mm-diameter silicon wafers. The process can be readily migrated onto 150mm-diameter wafers and potentially beyond without modification and is therefore suitable for large, industrial-scale applications.



GaN growth chamber.

Using IP originally developed at the University of Cambridge, Plessey has started to commercialize LEDs produced in conventional (hexagonal) GaN grown on 150mm silicon wafers — i.e. its gallium nitride on silicon MaGIC (Manufactured on GaN-on-Si I/C) LEDs. Anvil's high-quality 3C-SiC on silicon technology, which is being developed for SiC power devices, is said to provide an effective substrate, to allow single-phase cubic GaN epitaxy growth and provides a process that is compatible with Plessey's GaN-on-Si device technology.

"The work that has previously been carried out at the University of Cambridge in collaboration with Anvil Semiconductors has demonstrated that high-quality cubic-GaN can be grown on large-area silicon substrates compatible with our manufacturing process," notes Plessey's chief technology officer Keith Strickland. "This has opened up the possibility to develop green LEDs with high efficiency that will allow us to demonstrate a new generation of efficient and controllable lighting products," he adds.

"The properties of cubic GaN have been explored before, but the challenges of growing this thermodynamically unstable crystal structure have limited its development," says professor Sir Colin Humphreys, director of the Cambridge Centre for GaN. "The high quality of Anvil's cubic SiC on Si substrates and our experience of developing conventional GaN LED structures on large-area wafers have enabled a breakthrough in material quality. This latest project will build on our ongoing collaboration with Plessey to deliver, for the first time, green LED devices with efficiency approaching that in blue and red LEDs," he adds.

"Our cubic SiC-on-Si has unlocked a route to large-area growth of cubic GaN," comments Anvil's CEO Jill Shaw. "We are delighted to be collaborating on this exciting project that offers the possibility of exploiting our technology in high-efficiency LEDs as well as in our core low-cost, high-efficiency power electronics markets."

www.anvil-semi.co.uk
www.plesseysemiconductors.com/led-plessey-semiconductors.php
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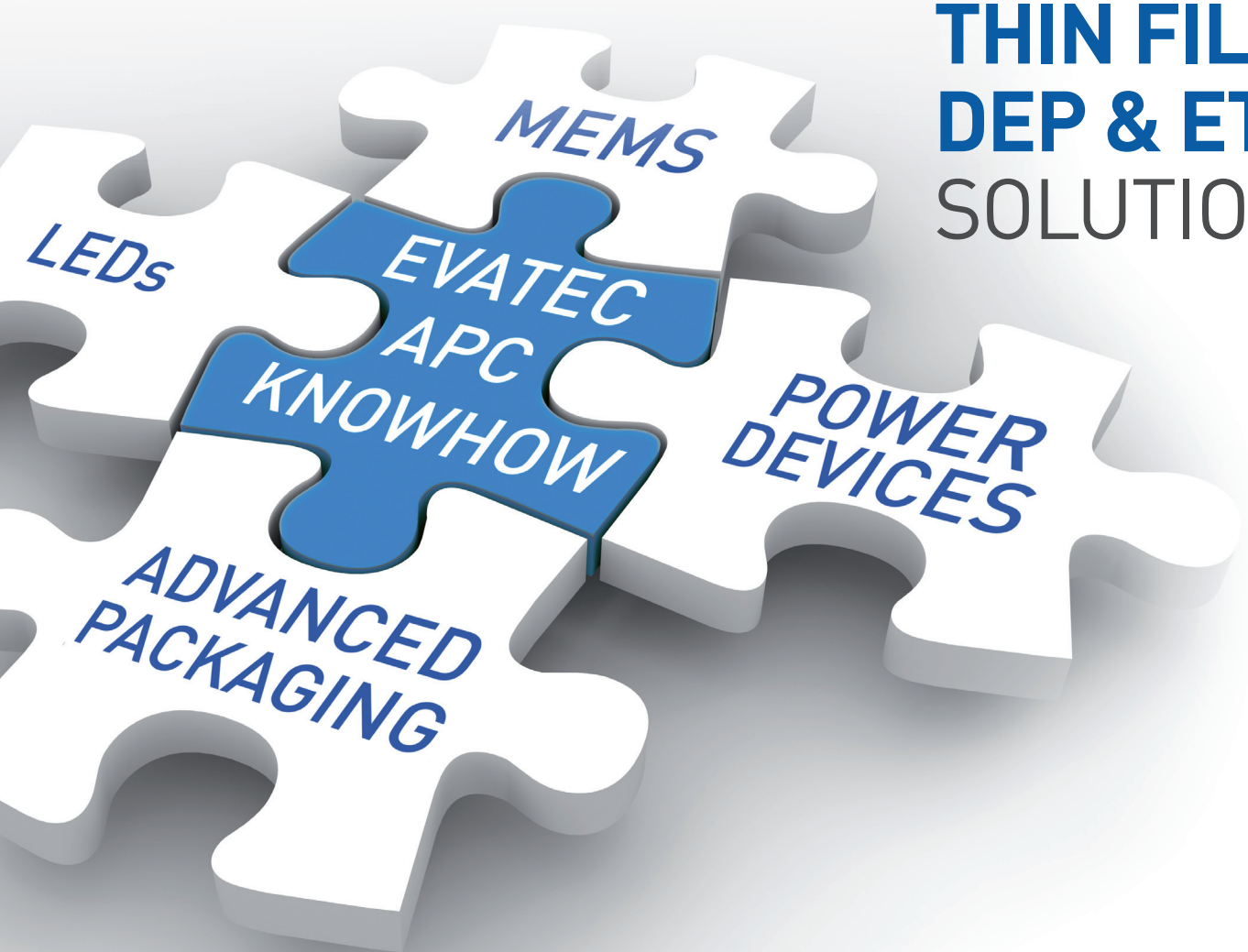

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Lumileds' sale to China-based GO Scale Capital-led consortium thwarted by US regulatory clearance

Philips to engage with other interested parties

Royal Philips NV of Amsterdam, The Netherlands (the world's largest lighting producer) and GO Scale Capital (an investment fund sponsored by China-based GSR Ventures and US-based Oak Investment Partners) have terminated the agreement for the consortium led by GO Scale Capital to acquire an 80.1% interest in its California-based LED-making division Lumileds (with Philips retaining the remaining 19.9%).

Despite efforts to mitigate the concerns of the Committee on Foreign Investment in the United States (CFIUS), regulatory clearance has not been granted for the transaction. GSR Ventures has existing investments in China-based Lattice Power (one of the few firms to manufacture gallium nitride based LEDs on silicon substrates rather than on sapphire or silicon carbide). The GO Scale Capital-led consortium partners also include Hong Kong-based Asia Pacific Resource Development Investment Ltd (APRD) and Nanchang Industrial Holding Group of Jiangxi Province in south-eastern China.

"This was a very good deal for both Lumileds and the GO Scale Capital-led consortium. This outcome does not, however, impact the fundamentals of the Lumileds business," comments Philips' CEO Frans van Houten. "Lumileds is a highly successful supplier of lighting components to the general illumination, automotive and consumer electronics markets with a strong customer base. We will now engage with other parties that have expressed an interest in exploring strategic options for Lumileds to pursue more growth and scale," he adds. "I would like to extend my appreciation to GO Scale Capital for having been a deeply committed partner to Philips during the transaction process."

With about 8800 staff in more than 30 countries, Lumileds supplies lighting components to the general illumination, automotive and consumer electronics markets, and generated revenue of about $2bn in 2015. The transaction valued the business at about $3.3bn.

The termination of the transaction with GO Scale Capital does not involve a break fee nor impact the separation process of the remaining Lighting business from Royal Philips, which is being pursued as an independent transaction. Philips will continue to report the Lumileds business as discontinued operations.

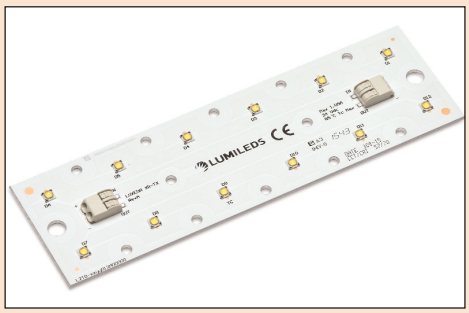
www.philipslumileds.com

Lumileds expands Matrix Platform with high-efficacy LUXEON XR-TX LED module for outdoor applications

LED maker Lumileds of San Jose, CA, USA has launched the LUXEON XR-TX module, incorporating 12 LUXEON TX high-efficacy LEDs to produce 3300 lumens and 140lm/W at nominal drive conditions (700mA current, 85°C board temperature, and 4000K/80CRI color; boards can be driven at up to 1.05A).

In a convenient rigid form factor, the modules are designed to be readily combined with third-party lens plates and drivers to rapidly design and bring to market LED streetlights, tunnel lights and high/low-bay fixtures. "Our Matrix Platform products eliminate the sourcing of LEDs, components and connectors, and drastically reduce the design efforts behind luminaire development," says Matrix Platform product manager Andrew Cohen.

An advantage to lighting manufacturers lies in the assembly process developed and used by Lumileds, the firm claims. "Using our proprietary pick-and-place system, customers can be assured of very tight control of flux, forward voltage and color specifications at the board level, compared to designing with individual LEDs, where accounting for variability is a greater challenge," notes Cohen.



The LUXEON XR-TX module.

The LUXEON XR-TX modules are available in a variety of correlated color temperatures (CCTs) suitable for streetlight and high/low-bay applications: 4000K, 5000K and 5700K with a minimum color rendering index (CRI) of 70. Each module features a metal-core PCB for what is said to be best-in-class thermal conduction, screw holes for ease of mounting to heat sinks, and convenient poke-in connectors for electrical inputs. Multiple LUXEON XR-TX modules (up to seven) may be daisy chained to achieve an assortment of system configurations and necessary flux levels.

The new module is part of the Lumileds Matrix Platform of infinitely configurable LED boards, linear flex and modules featuring LUXEON LEDs. The Matrix Platform comes in both off-the-shelf and built-to-spec options, offering a range of solutions for any application.

www.lumileds.com/LUXEONXRTX

Lumileds' Gen 3 LUXEON CoB Core Range boosts efficacy by 10% to 160lm/W

LED maker Lumileds of San Jose, CA, USA of San Jose, CA, USA has launched its LUXEON Core Range (Gen 3) third generation of chip-on-board (CoB) arrays, providing 10% higher efficacy at constant flux compared with previous generations.

"This performance upgrade is the result of significant improvements in both die development and our industry-leading phosphor solutions," says Eric Senders, product line director for the LUXEON CoB Family. The Gen 3 LUXEON CoB upgrade spans the firm's full range of products from the smallest light-emitting surface (LES) of 6.5mm (LUXEON CoB 1202s, which delivers cost-effective spotlights) to an LES of 23mm (LUXEON CoB 1216, for efficient replacement of 100–150W HIDs in indoor or outdoor applications).

Lumileds LUXEON CoB Core Range is offered over what is claimed to be the widest range of correlated color temperatures (CCTs of 2200K to 5700K) and color rendering indexes (CRIs of 70, 80 or 90).

Lumileds' new LUXEON Core Range (Gen 3) arrays.

Lumileds also attributes the performance to its low thermal resistance substrate, which is reckoned to be up to four times lower than other commercial products. The low thermal resistance enables smaller heat-sinks and optics, delivering lower system cost. All LUXEON CoB Core Range (Gen 3) arrays are hot tested at 85°C to ensure performance in real-world operating conditions and to minimize additional testing.

For ease of upgrade, the LUXEON CoB Core Range (Gen 3) products are fully compatible with the LUXEON CoB Gen 1 and Gen 2 arrays

For ease of upgrade, the LUXEON CoB Core Range (Gen 3) products are fully compatible with the LUXEON CoB Gen 1 and Gen 2 arrays. The firm adds that its ecosystem of compatible drivers, optics and holders helps to speed time-to-market for all directional lamps.

www.lumileds.com/LUXEONCoBCoreRange

Flip Chip Opto launches first high-power horticultural flip-chip COB LED

LED lighting technology firm Flip Chip Opto Inc of Fremont, CA, USA has launched what is claimed to be a first-in-class 2400W high-power horticultural flip-chip COB, as part of its new Duet series, geared towards the grow light industry. The Duet 2400 is based on the firm's patented 3-pad Pillar Metal Core Printed Circuit Board (P-MCPCB) technology, which allows a reduction in junction temperature to 0.003ºC/W on Duet 2400 at a maximum power of 2433W.

The Duet series represents Flip Chip Opto's horticultural solution to the flip-chip COB market. Duet 2400 features four independent illuminating sections with customizable light spectrums; the standard product line will run a peak of 450nm of royal blue, and 660nm of broadband red. The two different light spectrums complement the peak absorption rates of chlorophyll in most plant organisms. The Duet series also allows the substitution of other light spectrums for applications with plant organisms that do not absorb 450nm or 660nm spectrums.

The firm claims that, due to its thermal properties, the Duet 2400 allows designers to reduce the form factor of their cooling solutions while maximizing output, making it suitable for extreme applications such as greenhouses, commercial grow facilities, indoor farming, supplemental tree lighting, and other applications that require high-powered, energy-efficient LED grow lighting.

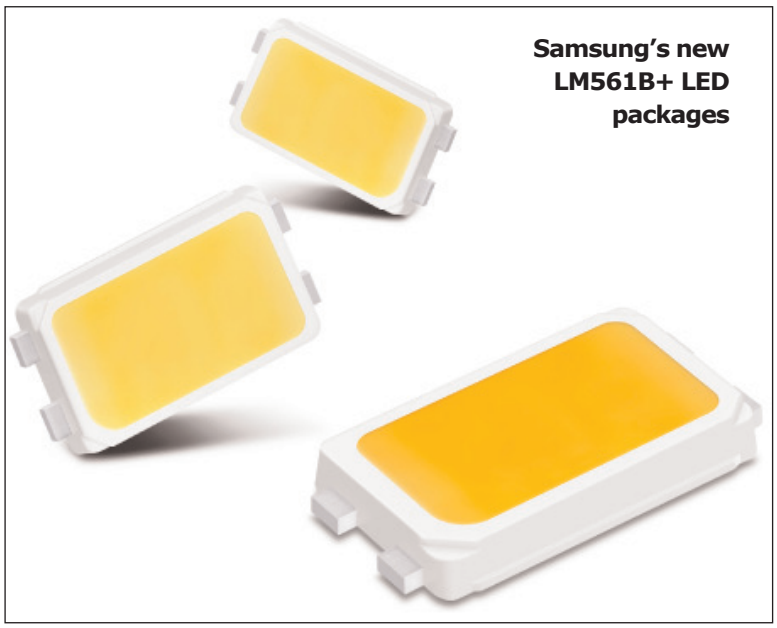
Flip Chip Opto showcased its entire product line at ELA Expo Lighting America in Mexico City (24–26 February) and is exhibiting in booth D70 at the Light + Building 2016 trade fair in Frankfurt, Germany (12–18 March).

www.fcopto.com

Samsung's new high-efficacy mid-power LED packages extend 3-step MacAdam ellipse bins and quarter bins across full range of correlated color temperatures

Samsung Electronics Co Ltd of Seoul, Korea says that LM561B+, its new high-efficacy mid-power LED package line-up, is now offered with 3-step MacAdam ellipse bins and quarter bins across the range of all correlated color temperatures (CCTs), from 2700K to 6500K, for use in premium luminaires. By leveraging the chromaticity control standard with the LM561B+, manufacturers can make lighting products that deliver greater uniformity and consistency in light color without any visible difference in the color output between packages, says the firm.

Since 2013, Samsung has been introducing high-performance mid-power LED packages such as the LM561 series for indoor lighting applications including LED lamps, L-tubes, ambient lighting and downlights. Its latest LM561 LED packages — the LM561B+ and LM561C — provide 190lm/W and 200lm/W of light efficacy respectively (claimed to be industry-leading performance). Later this year, Samsung will also extend its range of 3-step MacAdam ellipse bins and quarter bins for the LM561C across all CCT levels.



Samsung's new LM561B+ LED packages

In addition, for its high-color-rendering LM561B+ packages with a color-rendering index (CRI) of over 90, Samsung plans to apply advanced phosphor control technology, which should lead to about 15% higher flux performance.

In supporting its LED lighting component customers more efficiently, Samsung says that it is also strengthening its product certification program around the globe. Through cooperative relationships with recognized certification companies in the USA, Korean, European and Chinese markets, Samsung is working to help minimize any difficulties that customers may encounter due to varying certification requirements for lighting quality, safety and power efficiency. The partnerships aim to simplify complex procedures, reduce time to market, and ultimately have a positive impact on overall costs.

www.samsung.com

Nichia wins Texas patent infringement lawsuit against Everlight

Japan-based LED maker Nichia Corp says that the US District Court for the Eastern District of Texas has judged that Taiwanese LED packaging firm Everlight Electronics Co Ltd and its US subsidiary Everlight Americas Inc have infringed three Nichia patents. Nichia filed with the court for patent infringement in September 2013.

The court judged that Everlight has infringed Nichia's Patent No. 8,530,250, and rejected Everlight's assertion that the patent is invalid. The patent covers a process for manufacturing LEDs that Nichia developed in 2008, as well as LED products manufactured using the process. The Nichia products covered by the patent include Nichia's 757 and 157 series of products. The Everlight products found to infringe the patent include the XI3030, XI3535, 62-217D, 62-257D and 45-21S series of LED products.

The court also found that Everlight has infringed Nichia's US Patents No. 7,432,589 and No. 7,462,870. It also denied Everlight's contentions that these patents are invalid.

In response, Everlight notes that the court issued no damages against it and denied Nichia's request of injunctive relief (to prevent Everlight from selling LED products in the USA). Everlight aims to appeal.

Everlight also notes that in 2012 it filed a declaratory judgment action against Nichia's US Patent Nos. 5,998,925 and 7,531,960 (regarding YAG phosphor used in LEDs and the phosphor concentration) for invalidity and non-infringement. On 19 January, the District Court for the Eastern District of Michigan denied Nichia's motion for judgment and confirmed the jury verdict of invalidity on all Nichia's asserted claims.

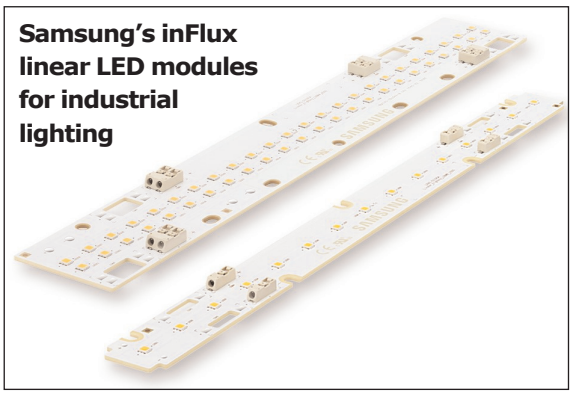
www.everlight.com
www.nichia.com

Samsung launches high-flux LED modules using flip-chip-based high-efficacy mid-power packages for industrial lighting

Samsung Electronics Co Ltd of Seoul, Korea has introduced inFlux, a new lineup of high-flux, linear LED modules optimized for industrial lighting applications such as plants, parking lots and warehouses. The modules serve as a replacement for conventional T8 and T5HO (high output) tubes and are suitable for high-flux LED luminaires covering up to 40,000lm in luminous flux.

"By providing a wide variety of installation layout options and brightness intensities, our new inFlux linear module will deliver greater design flexibility and convenience for lighting designers, as well as high performance and reliability for fixture manufacturers," says Jaewook Kwon, VP of the Lighting Marketing Group in Samsung's LED Business Team. "We will continue to reinforce our well-differentiated LED lighting engine lineups to be able to meet more diverse market needs."

The inFlux LED module incorporates the firm's mid-power LED package (LM301A), which features flip-chip technology that enables a shorter junction-to-base distance and less thermal barrier layers in each package, while avoiding the need for metal wire bonding. This leads to a reduction in thermal resistance of the packages, and allows each package to handle a wide range of current with improved light efficacy. Fully embracing the flip-chip LED approach, the new inFlux modules can provide better light performance, wider current alternatives and much lower heat resistance than modules using a conventional epi-up chip package, says Samsung.



Samsung's inFlux linear LED modules for industrial lighting

Compared with using high-power packages, high-efficacy mid-power packages can be placed more densely, which results in minimizing light deviation and increasing light uniformity of the inFlux module lineup, says the firm. By utilizing a mid-power package, the inFlux lineup also brings cost benefits to manufacturers, it adds.

The inFlux modules are available in six product types. Each comes in a different flux range between 1310lm and 9380lm with a length option, either 280mm or 560mm, and offers several correlated color temperature (CCT) variations, including 3000, 3500, 4000 and 5000K. The product options offer lighting fixture makers more design flexibility in addressing a wide variety of application requirements, says Samsung. Through a combination of different module types, LED fixture manufacturers can vary their lamp flux from 6000lm to 40,000lm.

The inFlux modules have been UL/cUL certified (USA), as well as CE and ENEC certified (Europe), and carry a 10-year warranty.

The firm says that it also makes it easier for fixture makers to take their lighting products through industry certification processes, due to cooperative relationships that Samsung LED has established with recognized certification companies in the USA, Korean, European and Chinese markets. These partnerships can simplify complex procedures, reduce time to market and ultimately have a positive impact on overall costs, the firm claims.

www.samsung.com

Osram Opto SSL products recognized in IESNA Annual Progress Report for innovative industry developments

Osram Opto Semiconductors GmbH of Regensburg, Germany says that three of its solid-state lighting products — the Oslon SSL (far-red) LED, Duris S 10 LED, and Duris S 2 LED — have been selected (out of hundreds of submittals) by the Progress Committee of the Illuminating Engineering Society of North America (IESNA) for inclusion in its annual IES Progress Report, which highlights significant developments in the art and science of lighting.

The committee (which consists of experts in fields such as sources, ballasts/power supplies, controls, luminaires and design) evaluates the entries and accepts only those that are considered unique or offer significant improvements over existing products available in the industry.

The Oslon SSL (far-red) LED and Duris S 10 LEDs were both chosen for inclusion based on their high efficiency with the smallest footprint. The Duris S 2 LED was selected due to its new form factor with 150° optics (providing optimal/increased performance).

www.ies.org/pdf/progressreport/2015_ProgressReport1_16.pdf

www.osram-os.com

Cree revenue growth led by commercial lighting, as OpEx cuts drive higher-than-expected earnings

Full-year CapEx target cut from $150m to $135m and free cash flow target raised from $85m to $100m

For fiscal second-quarter 2016 (to 27 December 2015), Cree Inc of Durham, NC, USA has reported revenue of $435.8m, up 2% on $425.5m last quarter and 5% on $413.2m a year ago, led by growth in commercial lighting and a solid quarter for the firm's LED Product sector, offsetting lower Power & RF Product revenue.

Specifically, Lighting Product revenue was $255m (59% of total revenue), up 3% on $248m (58% of total revenue) last quarter and up 11% on $230.2m (56% of total revenue) a year ago. Consumer lighting revenue was similar to fiscal Q1.

LED Product revenue was $153m (35% of total revenue), up 3% on $148.2m (35% of total revenue) last quarter and up 1% on $151.9m (37% of total revenue) a year ago, led by continued growth in commercial lighting (offsetting lower year-on-year consumer lighting sales). This allowed Cree to further reduce channel inventories to a level that should enable a higher-turns model in fiscal second-half 2016.

Wolfspeed Power & RF Product revenue was $28m (6% of total revenue), down 6% on $29.3m (7% of total revenue) last quarter and 12% on $31.1m (7% of total revenue) a year ago, due to the continued lower RF demand.

Although down on 33.9% a year ago, gross margin was level with last quarter, at 31.7%, led by gains in lighting, as the firm's strategy to better balance lighting revenue and profit growth has started to deliver results.

Specifically, although down from 39.1% a year ago and 35.5% last quarter, LED Product gross margin of 34.7% was slightly better than core business (excluding one-time license benefits from last quarter). Core LED margins also improved as Cree saw additional benefits from LED factory consolidation. During the quarter, Cree completed its LED business restructuring, recognizing $3m of expense for factory capacity and overhead costs reductions (bringing total LED restructuring charges to $102m). "The overall LED market remains very competitive, but our business has become more manageable in the near term as we continue to focus on high-power applications where SC5 technology drives system cost advantages," says Chuck Swoboda.

Lighting Product gross margin was 28.5%, up from 27.9% last quarter (due to better factory execution and a more balanced approach to revenue and profit growth) and 28.1% a year ago.

Wolfspeed Power & RF Product gross margin was 52.2%, down on 55.5% a year ago but up from 49% last quarter.

"Our lighting business continues to grow, the LED business has stabilized, and our Wolfspeed Power & RF division continues to make progress," says chairman & CEO Chuck Swoboda.

Operating expenses (OpEx) have been cut from $105m last quarter to $103m, below the targeted $106m due mainly to expense management and operational efficiencies.

Operating income was $35.5m (operating margin of 8.1% of revenue), at the upper end of the targeted range and up on $29.4m (margin of 6.9%) last quarter.

Cree completed its LED business restructuring, recognizing $3m of expense for factory capacity and overhead costs reductions (bringing total LED restructuring charges to $102m)

On a non-GAAP basis, net income was $30.5m ($0.30 per diluted share), down from $38m ($0.33 per diluted share) a year ago but up from $22.1m ($0.21 per diluted share) last quarter, and above the targeted range of $21–27m ($0.21–0.26 per diluted share), due mainly to the lower OpEx spending and the retroactive reinstatement of the US R&D tax credit that reduced the firm's effective tax rate. However, even excluding the impact of the R&D tax credit reinstatement and the Lextar share price increase, EPS would have been $0.27 per diluted share (still above the targeted range).

"We delivered on our goal of building financial momentum in Q2, with earnings that exceeded our targets driven by solid revenue growth, good margins and operating expense leverage," says Swoboda.

Cash generated from operations has rebounded from $46.8m last quarter to $77m (up five-fold on $14.8m a year ago). In addition to patent spending of $3.3m, spending on property, plant & equipment (PP&E) has been cut from $49.9m last quarter to $31.9m, reducing total capital expenditure (CapEx) from $54.2m to $35.2m.

Free cash flow has hence rebounded from –$40m a year ago and –$7.4m last quarter to an above-target +$41.7m. However, Cree also spent $62m to repurchase 2.5 million of its shares (following $70m to repurchase 2.7 million shares last quarter). Hence, during the quarter, cash and investments fell by $15m, from $632.1m to $617m (compared with $713m a year ago). Cree ended the quarter with $205m outstanding on its line of credit.

"Overall, we had a good first half of fiscal 2016 and are well positioned for a strong second half," comments Swoboda.

For fiscal third-quarter 2016 (ending 27 March), Cree expects revenue to fall to $400–430m, taking into account the typical seasonal decline of 5% in the Lighting and LED markets, offset partially by incrementally higher Wolfspeed Power & RF Product sales. Gross margin should be 31.7%, driven by improvement in commercial lighting due primarily to factory cost improvements, offset by the seasonally lower LED margins (with Wolfspeed Power & RF Product margin in a similar range). Operating expenses are targeted to be $100m, down $3m due primarily to lower variable LED and Lighting sales costs. Net income is expected to fall to $22–29m ($0.22–0.29 per diluted share).

After CapEx spending of $89m in fiscal first-half 2016 and with second-half capital expenditure targeted to be $46m, Cree is now expecting CapEx for full-year fiscal 2016 of $135m (lower than the previous target of $150m) in order to complete existing infrastructure projects and to provide incremental capacity for Lighting and Wolfspeed. Also, the firm has now raised its target for free cash flow from $85m to $100m.

www.cree.com

Cree adds XQ-A to XLamp XQ LED family to deliver lower system cost

Cree has expanded its portfolio of lighting-class LEDs by adding the XLamp XQ-A to the XQ LED family.

The compact, ceramic-based XQ-A enables lighting manufacturers to quickly and cost-effectively expand their product portfolios by leveraging an LED design that is similar to that of the proven and reliable XQ-E, says Cree. With a broad range of color options and optical symmetry, the XQ-A is said to be the smallest LED building block available for designs that use white and color LEDs.

"The XQ-A LED gives us more options to increase the capability of our machine-vision and industrial LED lights using the same compact XQ package," says Matt Pinter, lead design engineer of the firm Smart Vision Lights. "Unlike mid-power color LEDs, the compact, ceramic-based XQ-A LED will allow us to put two, three or even four LEDs under our new silicone lens technology where we could only use one LED before. This generates more light for industrial applications without compromising lifetime."

The ceramic XQ-A LED delivers lighting-class reliability, quality and long-life performance comparable to Cree's other ceramic high-power LEDs such as the high-performing XP and XT, says Cree. The new LEDs leverage the proven XQ platform to provide optical symmetry, consistency across all colors and tiny 1.6mm footprint to improve color mixing and simplify the production process for lighting manufacturers.

"The ceramic-based XQ-A LED family allows designers to offer high-quality solutions that do not compromise lifetime or affordability," says Dave Emerson, VP & general manager for Cree LEDs.

The XQ-A delivers up to 89lm and is characterized at 85°C. It is available in white colors ranging from 2700K to 6200K and CRIs of 70, 80 and 90. The LED is also available in red, red-orange, PC amber, green, blue and royal blue.

Cree boosts LED efficacy by 25%

Single high-power LED delivers nearly 1600lm at efficacy of 134lm/W

Cree has demonstrated a single high-power LED delivering luminous flux of nearly 1600lm at a luminous efficacy of 134lm/W with similar color quality to that of an incandescent light bulb.

Cree says that it has hence achieved a 25% increase in lumens per watt over production LEDs of similar color quality under operating conditions found in real-world LED lighting applications. This milestone — coupled with Cree's latest SC5 Technology platform — should lead to LED systems with increased performance, lower cost and better light, Cree reckons.

"Today, advancing LED technology goes beyond just increasing LPW," says John Edmond, Cree's co-founder & director of advanced optoelectronics. "Cree is also focused on improving spectral content and the efficacy of warmer color temperatures while pursuing tremendous opportunities to increase LPW at real-world operating conditions," he adds. "This R&D result continues Cree's high-power LED technology innovation and provides a path to better lighting experiences at the lowest overall system cost."

Many existing LEDs that provide excellent light quality do so by compromising LED efficacy, resulting in lower system performance or higher system cost, says Cree. The firm says that its latest innovation demonstrates a no-compromise solution that enables high-quality light at the lowest cost. As an example, an existing 60W LED replacement lamp with average light quality (3000K CCT & 80 CRI) could be upgraded to incandescent-like light quality (2700K CCT, 90+ CRI & 90+ R9) with the same light output and power consumption levels at no additional cost. The recently approved California Title 20 appliance standard for LED bulbs highlights the importance of this type of performance without cost and energy savings compromises.

Cree reports that the R&D LED performance was measured at 1587lm at a drive current of 350mA and a junction temperature of 85°C, delivering 134lm/W with a CRI Ra>90 and R9>90 at 2700K CCT.

EXALOS unveils 5000hr-lifetime tests results for 405nm GaN superluminescent LEDs

Bright, directional beam targets medical, industrial & consumer markets

EXALOS of Zurich, Switzerland, which designs and makes light sources based on superluminescent light-emitting diodes (SLEDs) and external-cavity tunable lasers for optical coherence tomography and fiber gyroscopes, has tested long-life gallium nitride (GaN) SLEDs that deliver, under specific test conditions, an estimated lifetime of more than 5000 hours. The results demonstrate that SLEDs can deliver much more reliable light sources for devices, claims the firm, suggesting that markets such as direct retina display, 3D printing or pico projectors might benefit from reliable, long-life semiconductors that generate extreme brightness.

EXALOS unveiled the findings in a paper at the SPIE Photonic West 2016 conference in San Francisco (16–18 February), where the firm demonstrated its SLED products.

EXALOS tested the reliability of GaN-based SLEDs emitting at a wavelength of 405nm, demonstrating that optimized doping levels provide decreased operating voltage on single-mode devices from more than 6V to less than 5V for an injection current of 100mA. The tests showed that magnesium (Mg) doping levels in the p-type (positive) layers have an impact on both the device's electro-optical characteristics and their reliability. SLED modules with standard and optimized p-type layers were tested in lifetime output.

Modules with standard and optimized p-type layers were finally tested in terms of lifetime, at a constant output power of 10mW, in continuous wave (cw) operation and at a case temperature of 25°C. The modules with non-optimized p-type doping showed a fast and remarkable increase in drive current during the first hundreds of hours together with an increase in the device series resistance. No degradation in the electrical characteristics was observed after 2000 hours on devices with optimized p-type layers. Under the specific test conditions, the estimated lifetime for those devices was higher than 5000 hours. Furthermore, maximum output powers as high as 350mW (for an injection current of 500mA) have been achieved in continuous-wave operation (cw) at room temperature.

"We have seen, in recent years, tremendous improvement in the performance and reliability of GaN-based laser diodes in the 405nm wavelength, which have been successfully commercialized in markets including medical and industrial applications, as well as laser projection and automotive head-lamp design," says CEO Dr Christian Velez. "Our tests now show that the GaN-based SLEDs can deliver high output power with ideal directional beams with higher power levels for applications such as direct retina projection and pico projection," he adds. "This is what we believe new markets are seeking for light sources."

EXALOS, which developed the industry's first blue SLED, has shipped more than 300,000 SLEDs in the 405–1600nm wavelength range since 2003. The firm claims to be the leading supplier to the SLED-based current sensor market and to the fiber-optic gyroscope market for both space- and land-based applications. Since the commercialization of SLED technology, EXALOS has also supplied SLEDs to the optical coherence tomography (OCT) market.

EXALOS expands into micro-LEDs for direct projection displays

New epi growth method yields vertical micro-emitters for augmented reality, virtual reality and pico projection

EXALOS has developed new methods of growing crystals for producing micro-light emitting diodes (LED), providing more efficient means of realizing light sources for direct projection displays, including for augmented reality (AR) and virtual reality (VR) applications.

The epitaxial growth technology was developed in collaboration with the Swiss Federal Institute of Technology in Lausanne, and leverages patent-pending methods of producing vertical emitters with what are claimed to be unprecedented robustness and performance.

Currently, EXALOS has produced devices with emission in the short-wavelength region for blue-violet micro-LEDs. The firm says that the design could be easily transferred to other emission wavelengths such that RGB light emission designs could be envisaged.

"For the next generation of display, micro-LEDs will be a critical component for efficiency and brightness, and EXALOS has now developed methods for creating micro-LEDs that have the performance and the features required for a wide range of applications, particularly in AR and VR," says CEO Dr Christian Velez. "We are ready to seek out partners for bringing new display products to market."

EXALOS detailed its micro-LED solutions at the SPIE Photonic West 2016 exhibition in San Francisco (16–18 February).

www.exalos.com

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FerroTec

TU Munich grows pulsed IR-emitting GaAs nanowire lasers on silicon chip

Team targets cw emission at other wavelengths, then electrical injection

The Technical University of Munich (TUM) has developed III-V semiconductor nanowire lasers grown directly on a silicon chip, making it possible to produce high-performance photonic components cost-effectively, it is reckoned, and paving the way in future for fast and efficient data processing with light.

The miniaturization of electronics is now reaching its physical limits, says TUM. "Today already, transistors are merely a few nanometers in size. Further reductions are horrendously expensive," notes professor Jonathan Finley, director of the Walter Schottky Institute at TUM. "Improving performance is achievable only by replacing electrons with photons," he adds.

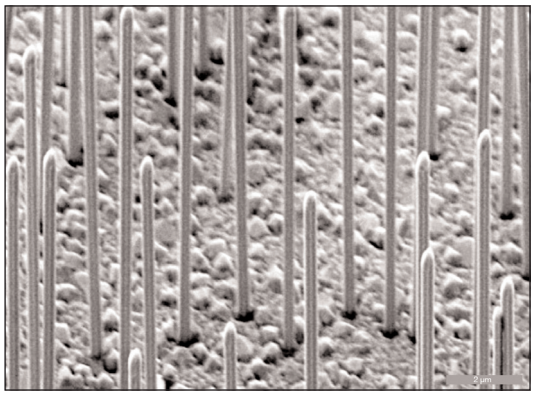
Photonics

Data transmission and processing with light has the potential of breaking the barriers of current electronics. Silicon-based photonics chips already exist, but the sources of light for transmitting data must be attached to the silicon in complicated and elaborate manufacturing processes.

Instead, Dr Gregor Koblmüller of TUM's Department of Semiconductor Quantum-Nanosystems has, in collaboration with Jonathan Finley, developed a process to deposit nanolasers directly onto silicon chips. A patent for the technology is pending.

"The two materials [III-V and silicon] have different lattice parameters and different coefficients of thermal expansion. This leads to strain," notes Koblmüller. "For example, conventional planar growth of gallium arsenide onto a silicon surface results therefore in a large number of defects."

Instead, by depositing nanowires that are free-standing on silicon, their footprints are merely a few square nanometers. The TUM team could hence preclude the emergence of defects in the GaAs material.



Nanowires on a silicon surface.

Atom-by-atom formation of nanowire

To generate coherent light, photons must be reflected at the top and bottom ends of the nanowire (forming a vertical-cavity laser), amplifying the light until it reaches the desired threshold for lasing.

To fulfil these conditions, the researchers needed to develop a simple yet sophisticated solution: "The interface between gallium arsenide and silicon does not reflect light sufficiently," says Benedikt Mayer, doctoral candidate in the team led by Koblmüller and Finley. "We thus built in an additional mirror — a 200nm-thick silicon oxide layer that we evaporated onto the silicon," he adds. "Tiny holes can then be etched into the mirror layer. Using epitaxy, the semiconductor nanowires can then be grown atom for atom out of these holes."

Only after the wires protrude beyond the mirror surface can they grow laterally — until the semiconductor is thick enough to allow photons to pass back and forth to allow stimulated emission and lasing. "This process is a very elegant because it allows us to position the nanowire lasers directly also onto waveguides in the silicon chip," says Koblmüller.

Basic research on the path to applications

Currently, the new GaAs nanowire lasers produce infrared light at a predefined wavelength and under pulsed excitation. "In the future we want to modify the emission wavelength and other laser parameters to better control temperature stability and light propagation under continuous excitation within the silicon chips," says Finley. The team has just published its first successes in this direction ('Monolithically Integrated High-beta Nanowire Lasers on Silicon', B. Mayer et al, Nano Lett. (2016) 16 (1), p152, http://pubs.acs.org/doi/full/10.1021/acs.nanolett.5b03404; 'Coaxial GaAs-AlGaAs core–multishell nanowire lasers with epitaxial Gain control', T. Stettner et al, Appl. Phys. Lett. (2016) 108, 011108, http://dx.doi.org/10.1063/1.4939549; and 'Continuous wave lasing from individual GaAs–AlGaAs core–shell nanowires', B. Mayer et al, Appl. Phys. Lett. (2016) 108, vol. 8, due to appear on 22 February).

The team now targets another goal. "We want to create an electric interface so that we can operate the nanowires under electrical injection instead of relying on external lasers," says Koblmüller.

"The work is an important prerequisite for the development of high-performance optical components in future computers," concludes Finley. "We were able to demonstrate that manufacturing silicon chips with integrated nanowire lasers is possible."

The research was funded by the German Research Foundation (DFG) through the TUM Institute for Advanced Study, the Excellence Cluster Nanosystems Initiative Munich (NIM) and the International Graduate School of Science and Engineering (IGSSE) of the TUM, as well as by IBM through an international postgraduate program.

www.wsi.tum.de
www.tum.de

ROFIN's German subsidiaries DILAS Diodenlaser and m2k-Laser merged

m2k becomes DILAS Semiconductor; Freiburg site remains but headquarters and sales combined in Mainz

US-based laser manufacturer ROFIN says that its wholly owned subsidiaries DILAS Diodenlaser GmbH of Mainz and m2k-Laser of Freiburg in Germany have merged (effective 1 January).

Founded in 1994 and acquired by Rofin-Sinar Technologies Europe S.L. (a subsidiary of Rofin-Sinar Technologies Inc of Plymouth, MI, USA) in 1997, DILAS Diodenlaser designs and manufactures high-power diode laser components, modules and systems.

Founded in 2001 by staff from the Fraunhofer Institute for Applied Solid State Physics (IAF) in Freiburg and acquired by Rofin-Sinar Laser GmbH of Hamburg, Germany in 2007, m2K manufactures single emitters, laser bars and laser modules including tapered amplifiers and lasers based on gallium arsenide (GaAs) emitting at wavelengths of 755–1064nm as well as mid-infrared high-power diode lasers in broad-area or ridge-waveguide designs based on gallium antimonide (GaSb) emitting at 1850–2500nm.

Since m2k-laser has mainly supplied its products to DILAS GmbH, the merger is expected to increase the efficiency of both entities. The combined unit will be headquartered in Mainz and will operate under the DILAS brand. The site in Freiburg will remain and is being transformed into a business unit of DILAS Diodenlaser GmbH, called DILAS Semiconductor.

With design and epitaxial services at the diode laser chip level from Freiburg plus diode laser packaging, beam shaping and systems technology from Mainz, the two sites provide complementary technologies, and the merger is a strategic and logical consequence of the long-term cooperation between both sites over years. The combined company aims to create a competitive footing by expanding its portfolio of products and technologies.

Sales activities for all DILAS products will be combined. The expanded product lines from DILAS were displayed at SPIE Photonics West 2016 in San Francisco (13–18 February).

http://spie.org/SPIE-PHOTONICS-WEST-conference
www.dilas.com

University of Sheffield spin-off Stratium raises £300,000 from IP Group and Finance Wales

Seed capital funds mid-IR quantum cascade laser product launch

Stratium Ltd of Cardiff, Wales, UK has announced more than £300,000 of seed capital investment from IP Group and Finance Wales.

The new funding allows the firm to enter the market for single-emitter quantum cascade lasers (QCLs) for 2.8–12μm wavelengths with the launch of its first product, Bruar, a 50mW (peak power) pulsed mid-infrared QCL chip-on-sub-mount — emitting at wavelengths of 2.8μm, 3.3μm or 10μm in room-temperature operation — for gas sensing and environmental monitoring applications. In addition, a new 100mW (peak) pulsed Bruar QCL chip-on-sub-mount was exhibited at the SPIE Photonics West 2016 event in San Francisco (16–18 February).

Stratium was formed in July 2015 on the basis of collaborative semiconductor laser research and innovation between the University of Sheffield's departments of Physics and Astronomy and Electronic and Electrical Engineering. Capabilities include both molecular beam epitaxy (MBE) and metal-organic chemical vapor deposition (MOCVD) as well as device fabrication, with the ability to produce bespoke 2" QCL epiwafers. It also has device fabrication technologies for producing custom optoelectronic devices. Stratium's particular expertise is in producing short-wavelength QCLs with record performance demonstrated in the 3.3–3.7μm wavelength range.

However, Stratium is strategically located in Cardiff, Wales, due to the strong business support network in the region and the increasing activity in the commercialization of compound semiconductor technology in and around Cardiff.

In January it was announced that the UK Government/Treasury would make a £50m investment to create the UK's first compound semiconductor R&D Catapult Centre, based in Cardiff, aiming to bring together entrepreneurs, engineers and scientists with state-of-the-art facilities to create new products and services. It is reckoned that, due to its existing relationships and location, Stratium is positioned to engage with the UK's top R&D centers to enhance its capabilities and create new highly skilled jobs.

Stratium's QCL products allow the detection and analysis of trace gases, in the parts-per-million (ppm) to parts-per-trillion (ppt) range. As most molecules have their fundamental rotational-vibrational absorption bands in the mid-IR region of the spectrum, a significant number of applications are available for laser sources emitting in this important wavelength range, says the firm.

"There are increasing opportunities for the adoption of quantum cascade laser technologies across several market sectors," notes Stratium's commercial director Phillip Cornish. As well as gas sensing and environmental monitoring, other applications include vehicle collision avoidance, breath diagnostics, vehicle emissions monitoring, petrochemical process monitoring and marine ship emissions monitoring. "With committed investors, Stratium is well placed to fulfil the need for QCLs with industrial-grade performance and reliability," he reckons.

There are increasing opportunities for the adoption of quantum cascade laser technologies across several market sectors. As well as gas sensing and environmental monitoring, other applications include vehicle collision avoidance, breath diagnostics, vehicle emmisions monitoring, petrochemical process monitoring and marine ship emissions monitoring

"This initial investment round will significantly help to optimize Stratium's QCL material growth, fabrication, test and characterization capabilities and will allow us to focus on our planned program of research and development to enhance our QCL product and intellectual property portfolio," says technical director Kenneth Kennedy.

"It is fantastic to see innovation and research, which started here at the university, leading to the launch of a product capable of having such a positive impact in a number of industries," comments Sarah Fulton, the University of Sheffield's director of research & innovation services.

"Finance Wales is pleased to co-invest with IP Group to back Stratium as its launches Bruar," states investment executive Ann Casey in Finance Wales' tech ventures team. "It's an important milestone for the company and also our first co-investment from the Wales Technology Seed Fund. Quantum cascade lasers are an emerging technology with significant potential, and Stratium's Bruar chip is an excellent example of how they're increasingly being used in a wide range of everyday technological applications," she adds. "Our investment will also enable Stratium undertake further research and development, scale up its technology and target new markets."

www.stratium.co.uk
www.sheffield.ac.uk
www.financewales.co.uk

Innovate UK investing £0.5m in North Wales photonics Launchpad

R&D projects centred on emerging cluster of photonics, electro-optics and opto-electronics businesses

UK Government agency Innovate UK (formerly the Technology Strategy Board) is to invest up to £500,000 in research and development projects centred on the emerging cluster of photonics, electro-optics, and opto-electronics businesses in North Wales.

The competition aims to stimulate this hotspot of businesses in North Wales by enabling companies to go further and/or faster towards commercial success. In collaboration with the Welsh Government and the Welsh Opto-Electronics Forum, the aim is to draw investment and people into the area, and to encourage networking and collaboration to strengthen the cluster.

Projects are hence being sought that may be too risky for firms to take forward without any support, or that may take them into new innovative areas, and where the majority of the project activities are carried out in North Wales.

Innovate UK is seeking to fund projects based on photonics, electro-optics and opto-electronics technologies that have the potential to create new products and services. End-market applications are broad, including optical communications, manufacturing and materials processing, health & life science, lighting, energy, security, and safety.

Innovate UK will fund industrial research projects, with estimated project sizes ranging from £50,000 to £90,000. Projects can last up to 12 months and must be led by a micro, small- or medium-sized company in the early stages of its development; businesses can work alone or in collaboration. Micro and small businesses will receive up to 70% of eligible costs; medium-sized businesses will receive 60%.

An integral part of Launchpad is the offer of support to help applicants to raise additional new external finance to fully fund the project and its subsequent commercialization. Successful applicants will also participate in a program of business support and growth activities that will run in parallel to projects.

The competition opens for applicants on 22 February. The deadline for video submissions is 6 April.

A briefing was held at The OpTIC Centre in St Asaph on 11 February.

https://interact.innovateuk.org/-/north-wales-photonics-launchpad

TeraXion's High-Speed Photonics Components Division acquired by Ciena

120 staff to remain in Québec, with key staff joining Ciena's Packet Optical Platforms organization

Ciena Corp of Linthicum, MD, USA has entered into a definitive agreement to acquire the High-Speed Photonics Components (HSPC) assets of TeraXion Inc of Quebec City, Canada (which designs and manufactures optoelectronic components and modules for high-speed fiber-optic transmission networks as well as fiber lasers and optical sensing applications) for $CAD46.6m (US$32m).

The asset purchase includes TeraXion's high-speed indium phosphide (InP) and silicon photonics technologies as well as critical underlying intellectual property. Ciena says that these technologies are key enablers of its WaveLogic coherent optical chipsets, which make the optical layer of next-generation networks more intelligent and responsive to today's web-scale demands.

"Being part of Ciena will provide the scale needed to accelerate the development of the HSPC technologies and will enable the continued development of highly differentiated solutions for Ciena's customers," says TeraXion's president & CEO Alain-Jacques Simard.

The TeraXion HSPC assets enhance Ciena's ability to develop differentiated solutions that enable service providers to scale their networks with greater programmability and agility, says Scott McFeely, senior VP, Networking Platforms at Ciena. "This acquisition also reinforces our commitment to serving as a growth and innovation engine in Canada, which is home to our largest employee base and more than 50% of our global research and development team," he adds.

With the acquisition, Ciena will maintain critical design and innovation resources in Québec City and bolster its R&D center of excellence in Ottawa. "This is a new chapter for our HSPC activities and clearly an exciting opportunity for our employees to advance our technology set as part of the vision of an industry leader like Ciena," says TeraXion's chief technology officer Martin Guy, who will join the Packet Optical Platforms organization at Ciena and serve as the firm's site leader in Québec City. "As part of Ciena, the HSPC team will be in a position to optimize its high-speed photonic solutions specifically for use in Ciena's WaveLogic coherent platform, providing significant benefits," adds Ian Woods, leader of TeraXion's current HSPC business unit, who will also be joining the Packet Optical Platforms organization.

Following the transaction, TeraXion will continue to operate its fiber-optic communication, fiber lasers and optical sensing applications business, with 120 staff remaining in Québec City. "We will keep supporting our existing customers with the same dedication to quality they have come to expect from TeraXion over the years while continuing to address future business opportunities in the markets we serve," says Simard.

www.teraxion.com

Source Photonics makes available first 25G SFP28-LR transceiver operating at industrial temperatures over 20km single-mode fiber

Optical communication product maker Source Photonics Inc of West Hills, CA, USA has announced the availability of what is claimed to be the first industrial temperature (i-temp) 25Gb/s SFP28-LR optical transceiver in the compact SFP+ form factor supporting wireless and Ethernet applications.

Source Photonics launched the first i-temp 6Gb/s SFP+ products in 2010 supporting 3G CPRI links and 10Gb/s SFP+ products in 2013 supporting LTE CPRI links. The addition of the 25G SFP28-LR transceiver to its product portfolio supports both Massive MIMO and the 24.33Gb/s CPRI standard for wide bandwidth frequency for air interfaces. The SFP28-LR will also be a key enabler for 1GB LTE networks.

Based on the SFP+ MSA form factor, the transceiver demonstrates a typical power consumption of 1.5W at 85oC high temperature, and supports up to 20km single-mode fiber transmission. The new SFP28 transceiver operates as a single channel at 25Gb/s and operates at an i-temp case temperature range of –40ºC to 85ºC. The industrial-temperature performance will ensure that the transceiver can operate in both temperature-controlled environments and in uncontrolled environments such as remote radio head (RRH) units placed atop cell towers.

Source Photonics is expected to start prototype sampling of the 25Gb/s SFP28-LR industrial-temperature transceivers in the middle of 2016.

www.sourcephotonics.com

POET's lab-to-fab initiative on track for product prototypes and initial market entry in 2016

Firm accelerating evaluation of expanded product roadmap to include display and sensing technology

POET Technologies Inc of San Jose, CA, USA — which has developed the proprietary planar optoelectronic technology (POET) platform for monolithic fabrication of integrated III-V-based electronic and optical devices on a single semiconductor wafer — says it is on-plan in every developmental, operational and commercial respect in its lab-to-fab initiative to deliver its first product prototypes this year.

POET says it is adhering closely to its commercialization timetable to introduce a monolithic optoelectronics process platform for the production of smart optical components. Built to deliver the power of light at near the competitive price points of copper, POET's platform is designed to allow significant improvements in energy efficiency, component cost and size.

The firm says that, since is previous corporate update in September, it has achieved the following milestones:

- POET has transferred its proprietary technology to multiple foundry partners, and received promising initial results of wafers processed at its newest foundry supplier Wavetek Microelectronics Corp, a member of the New Business Group of silicon wafer foundry United Microelectronics Corp (UMC). The manufacturing services agreement with Taiwan-based pure-play gallium arsenide foundry Wavetek (announced in January) addresses all of POET's current manufacturing requirements — including vertical-cavity surface-emitting lasers — in its commercialization initiative.
- A process has been initiated to produce integrated VCSEL prototypes, which POET expects to demonstrate in second-quarter 2016.
- Consolidation of Toronto–Connecticut–San Jose operations in Silicon Valley has been completed, nearly a full quarter ahead of plan.
- POET has also accelerated its evaluation of an expanded product roadmap to include display and sensing technology to take advantage of what it says are increasing market needs for integrated photonics.
- The firm has received specific interest in applications from prospective customers and is in advanced discussions to license for non-recurring engineering (NRE) fees and transfer its proprietary integrated planar optoelectronic technology. Included in the talks is the proposed establishment of a platform for the development of integrated sensing applications.
- POET is also in advanced discussions with a leading institution to enter into a joint development agreement to evaluate adaptation of the POET platform for applications in micro-displays for the burgeoning augmented reality market.

CEO Dr Suresh Venkatesan notes that POET is positioned at the confluence of next-wave mega-trends that both encompass and extend beyond data communications. "Photonics is experiencing a post-telecom second wave of growth — this one, fueled by consumers engaged in always-on social networking, cloud computing, Software as a Service (SaaS) and the ubiquitous devices that are central to our lives," says Venkatesan. "Social networking, cloud computing, the Internet of Things and the growth of mega-datacenters are galvanizing a renewed growth spurt in photonics," he adds.

www.poet-technologies.com

Taiwan's Wavetek providing high-volume manufacturing services

POET says it has achieved a milestone in its lab-to-fab transition with a manufacturing services agreement with Taiwan-based gallium arsenide foundry Wavetek Microelectronics Corp, a member of the New Business Group of silicon wafer foundry United Microelectronics Corp (UMC), and located at UMC Fab 6A in Hsinchu Science Park).

The POET platform transfer and manufacturing agreement with Wavetek (established in 2010 as Hsinchu Science Park's first 6" GaAs foundry) is an acceleration of POET's ultimate objective of working with a pure-play foundry offering a wide range of dedicated, flexible and competitive foundry services.

POET says it is encouraged by the promising initial results of its wafers sourced from its epitaxial wafer partners processed in the Wavetek facility using POET's proprietary technology, which has recently been transferred under a non-disclosure agreement (NDA) between POET and Wavetek. The agreement addresses all current manufacturing requirements — including vertical-cavity surface-emitting lasers (VCSELs) — in POET's ongoing commercialization initiative. A previously announced subsisting manufacturing services agreement was limited to prototype demonstration of VCSELs.

"Its manufacturing capabilities provide POET the foundry services we need to meet the high-volume and cost requirements that are critical to our success in delivering low-cost monolithically integrated optoelectronic transceivers," says POET's chief operations officer Dr Subhash Deshmukh about Wavetek.

www.wtkmicro.com

II-VI Inc completes acquisition of EpiWorks

Engineered materials and optoelectronic component maker II-VI Inc of Saxonburg, PA, USA has completed its acquisition of EpiWorks Inc of Champaign-Urbana, IL, USA (which manufactures epitaxial wafers for optical components, wireless devices and high-speed communication applications).

EpiWorks' revenues in 2015 were about $14m. Its 25,000ft^2, Class 1000 cleanroom epi foundry should provide significant expansion of II-VI's product portfolio. EpiWorks' expertise is reckoned to dovetail with II-VI's core competencies as an engineered materials company.

EpiWorks will operate as a business unit within II-VI and will be expanding its production capacity in Illinois. It will also continue to operate as an open metal-organic chemical vapor deposition (MOCVD) foundry.

"Long-term demand is strong for differentiated semiconductor technology that can be rapidly scaled to high volume, and EpiWorks now has access to substantial expansion capital, a global footprint and sales support around the world," says David Ahmari, who remains responsible for EpiWorks' sales, marketing & technology. "Teaming with II-VI allows us to go beyond the typical epiwafer foundry model by offering not just our leading wafer technology and II-VI's substantial scale, but a level of sophistication flexibility and capability needed in our rapidly evolving industry," he adds.

"The combination of II-VI and EpiWorks creates a world-class engineered semiconductor materials company that can uniquely innovate and scale next-generation technology and production methods," says Quesnell Hartmann, who will continue as the general manager of II-VI EpiWorks. "We have an aggressive multi-year plan for additional capacity, new capabilities, and novel products that cover a wide range of industries and markets," he adds.

We have an aggressive multi-year plan for additional capacity, new capabilities, and novel products that cover a wide range of industries and markets

"It has been a pleasure serving on the board with our co-founders, Dr Ahmari and Dr Hartmann," stated Ronald Chez, who served as EpiWorks' board chairman since its inception. "We would also like to thank Dr Raymond Milano and professor Ilesanmi Adesida, who have provided valuable insight and contributions to EpiWorks as independent members of our board," he adds.

"We would like to thank Mr Chez for serving as board chairman and for his ongoing support of our efforts to build a company of differentiated products and shareholder value," comments Hartmann.

The acquisition is valued at $43m in cash paid at closing plus a $6m earn out payable over three years (if various performance targets are achieved). II-VI financed the acquisition from available cash and borrowings under its credit facility.

II-VI will update its guidance for the fiscal third-quarter 2016 (ending 31 March) when it closes on its pending acquisition of Anadigics Inc of Warren, NJ, USA.

www.ii-vi-photonics.com
www.epiworks.com

II-VI Laser Enterprise debuts 1.5W 1060nm seed laser

The Zurich, Switzerland-based II-VI Laser Enterprise GmbH subsidiary of engineered materials and optoelectronic component maker II-VI Inc of Saxonburg, PA, USA has unveiled a new generation of high-power 1060nm single-mode laser diode seed modules.

The new laser diode module is designed to seed nanosecond pulsed fiber lasers addressing the fast-growing market for MOPA (master oscillator power amplifier) fiber lasers. The module delivers kink-free power up to 1.5W in nanosecond pulse operations, enabling highly efficient pulse amplification and improved frequency conversion for optimal beam quality and throughput in fiber-laser systems.

"With 40% more pulse power compared to our previous offering, our new diode seed module enables the next generation fiber-laser systems for a wide range of applications," says Karlheinz Gulden, general manager, II-VI Laser Enterprise. "Together with our distributed feedback laser [DFB] diode module designed for sub-nanosecond operations, we offer customers the most comprehensive seed laser diode portfolio in the market," he claims.

The new laser diode seed module features a higher-power 1060nm Fabry-Perot single-mode laser diode chip and a standard cooled telecom 10-pin mini butterfly-type package that includes a thermistor and back-facet monitor photodiode. The 75% smaller form factor of the mini butterfly package versus the legacy 14-pin version enables a reduction in overall footprint of the seed assembly. A broad- or narrow-band fiber Bragg grating [FBG] is optionally available to control the spectral properties for the suppression of stimulated Brillouin scattering (SBS) or for the improvement of frequency conversion performance, respectively.

II-VI Laser Enterprise showcased the new laser diode seed module at SPIE Photonics West 2016 in San Francisco, CA (16–18 February).

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

Anadigics chooses II-VI's final matching bid over Chinese firm's offer

$0.85 per share over 140% more than original $0.35 GaAs Labs offer

Broadband wireless and wireline communications component maker Anadigics Inc of Warren, NJ, USA says that on 26 February II-VI Inc of Saxonburg, PA, USA submitted a further revised set of proposed amendments to its original 15 January merger agreement to acquire Anadigics for $0.66 per share (which superseded a prior $0.62-per-share deal with GaAs Labs LLC — which had originally offered $0.35 per share on 11 November — leading to II-VI paying a termination fee owed by Anadigics to GaAs Labs). Among the proposed amended terms was an increase in the offer price to $0.85 per share and the extension of a loan to Anadigics.

Previously, an unnamed competing bidder designated 'Party B' initially (on 31 December) made an unsolicited offer of $0.68 per share, before raising its bid on 8 January to $0.70 per share, then $0.75 per share on 19 January, then $0.76 per share on 21 January, then $0.78 per share on 1 February. However, the proposal failed to include certain material terms and conditions requested by Anadigics. Because Party B is a Chinese company, in order to protect the firm and its stockholders, Anadigics required that, in the event that the closing of the proposed acquisition being delayed or thwarted by the review process to be conducted by the Committee on Foreign Investment in the United States (CFIUS), Party B would make a loan available to Anadigics and/or pay a reverse termination fee. Subsequently, after meeting these terms on 16 February, Party B's acquisition proposal was designated a 'superior offer' (as defined in the II-VI merger agreement). After II-VI on 18 February then raised its offer from $0.66 to $0.73 per share, on 20 February Party B raised its bid from $0.78 to $0.81 per share, which on 22 February was again declared by Anadigics to be a 'superior offer'. On 23 February, II-VI made its own $0.81-per-share bid (deemed a 'superior offer'). Party B then submitted a final bid of $0.85 per share before the deadline of 24 February specified by Anadigics. However, Anadigics gave II-VI two business days to deliver its final bid.

Now, after consultation with its financial and legal advisors, Anadigics' board has determined that II-VI's final matching $0.85-per-share bid renders Party B's 24 February bid no longer a superior offer. Factors considered included the following: (a) II-VI will provide a loan to address Anadigics' deteriorating liquidity; and (b) unlike Party B, the proposed merger with US firm II-VI will not be subjected to the delays and risks caused by the pre-closing review of the transaction by CFIUS. Hence, on 26 February, Anadigics executed II-VI's proposed amendment, as well as the loan agreement.

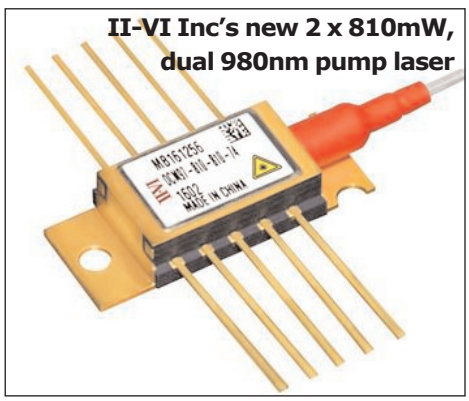
The $0.85 per-share price is $0.50 (or more than 140%) higher than the $0.35 per share offered by GaAs Labs on 11 November.

www.anadigics.com

II-VI launches dual 980nm pump laser with 810mW per port

Engineered materials and optoelectronic component maker II-VI Inc of Saxonburg, PA, USA (which produces pump laser modules for terrestrial and submarine optical networks) has announced general availability of its high-power 2 x 810mW, dual 980nm pump laser module.

As growing global demand for bandwidth is driving the need to scale the optical communications infrastructure with greater economy and efficiency, II-VI's dual-chip, dual-output pump laser modules enable designers to replace two laser modules with one. Housed within the compact 10-pin mini-butterfly package, they consume less electrical power, generate less heat, and enable significant reductions in the size of high-performance, multi-stage optical amplifier designs.



II-VI Inc's new 2 x 810mW, dual 980nm pump laser

"II-VI's 980nm pump laser technology, now entering its third decade of innovation, continues to meet the evolving needs of the market," says Dr Sanjai Parthasarathi, VP, product marketing & strategy, Optical Communications Group. "The established, proven building blocks of very high-power semiconductor lasers, compact module packaging and unique, independent dual-laser output designs come together in this new product to minimize the physical size and carbon footprint of optical networking equipment as they continue to be deployed in greater numbers," he adds.

The new product leverages II-VI's proven, high-reliability gallium arsenide (GaAs) laser technology platform and wafer fabrication facility in Zurich, Switzerland. Telcordia qualification testing has been completed and production is ramping up to serve several customers.

www.ii-vi-photonics.com

GigOptix reports record revenue & gross margin in Q4

Record annual revenue growth doubles from original forecast

For fourth-quarter 2015, GigOptix Inc of San Jose, CA, USA (a fabless supplier of analog semiconductor and optical communications components for fiber-optic and wireless networks) has reported a seventh consecutive quarter of revenue growth, to a record $11.1m (4% above the guidance of $10.7m given in October). This is up 6% on $10.4m last quarter and up 23% on $9m a year ago.

Full-year revenue was a record $40.4m, up 23% on 2014's $32.9m (above October's guidance of $40m, and almost doubling last February's original guidance for growth of 12% to $37.5m). This reflects double-digit growth in both the High-Speed Communications product line (Datacom & Telecom optical communications products plus wireless RF point-to-point products) and the Industrial ASIC (application-specific integrated circuit) product line.

In Q4/2015, High-Speed Communications (HSC) revenue was $7.7m (69% of total revenue), up slightly on $7.6m last quarter and up 28% on $6m a year ago. This was driven mainly by another strong quarter of growth in Datacom business related to the firm's dominant market position in 40Gb/s and 100Gb/s drivers and amplifiers for the transceivers and active optical cables (AOCs) that populate the ever-growing mega-datacenter installed base.

Industrial ASIC revenue was $3.4m (31% of total revenue), rebounding by 22% from last quarter's dip to $2.8m and up 13% on $3m a year ago. "This ASIC line has already started to be transformed from the legacy backend-design-focused products into the new generation of complete design of dedicated and customized advanced ASIC devices," notes chairman & CEO Dr Avi Katz.

"Fiscal 2015 was a transformational year for GigOptix. We delivered tremendous revenue growth and profitability while further enhancing all our financial metrics," says Katz.

On a non-GAAP basis, gross margin has risen further, from 62% a year ago and 66% last quarter to a record 67%, driven by a higher-margin product mix and operational efficiencies. Full-year gross margin has rebounded from 61% in 2014 to a record 65% in 2015 (above the initial guidance of about 60%).

Operating expenses were $5.1m, up from $4.5m last quarter, driven mainly by $0.4m of recurring operating expenses from subsidiary GigOptix-Terasquare-Korea (GTK) Ltd (established with the acquisition of Korea-based Terasquare Co Ltd, which is now GigOptix's center for ASIC product design and development).

Net income was $2.2m ($0.05 per diluted share), down slightly from $2.3m ($0.06 per diluted share) last quarter but up on $0.9m ($0.03 per diluted share) a year ago (and the seventh consecutive quarter of net income). Full-year net income has risen from $1.2m ($0.04 per diluted share) in 2014 to a record $7.3m in 2015 ($0.19 per diluted share, almost double the initial guidance of $0.07).

Adjusted EBITDA was $2.9m, down slightly from $3m last quarter but up on $1.6m a year ago (and the 18th consecutive quarter of positive adjusted EBITDA). Full-year adjusted EBITDA has risen from $4m in 2014 to a record $10.1m in 2015 (almost double the initial guidance of $5.1m).

Free cash flow was $0.8m (contributing to a record $1.6m for full-year 2015, compared to –$1.2m for 2014). Capital expenditure (CapEx) was $0.7m (up from just $0.2m last quarter). During the quarter, GigOptix used $5.2m for the all-cash purchase of Terasquare Ltd and the inception of GTK. Cash and cash equivalents hence fell from $35m to $30.2m.

We maintained our strong position in sales of coherent 100G telecom products, while introducing new, leading-edge products addressing all devices required for terrestrial 200 & 400G metro and long-haul limiting & linear applications

"These results further validate the success of the actions we have taken in the last few years to grow our company through intensive organic development coupled with strategic investments and acquisitions," says Katz. "Through swift commercialization of innovative new products, we continue to solidify our strong leadership position in our served markets, with the strongest performance coming from our domination in the fast-growing 40 and 100Gbps datacom portion of the High-Speed Communications market," he adds.

For first-quarter 2016, revenue is expected to be in-line with, to slightly up, on Q4/2015's $11.1m (contrary to the industry's normal seasonal decline) and up 23% on Q1/2015's $9.1m. Gross margin is expected to continue at the current level throughout 2016.

Operating expenses are expected to be seasonally higher (by about $400,000) due to higher payroll taxes, normal annual audit fees, and trade-show expenses, but these will taper off in the following quarters. CapEx should be maintained at a similar level to Q4/2015, primarily for production assets to support the expected revenue growth from new products in the High-Speed Communications unit.

"In fiscal 2016, we will enter new growth markets and extend our dominance in the High-Speed Communications area, to be an enabler of high-speed information streaming from end-to-end over the network, driving cloud connectivity at the enterprise and in the consumer links," says Katz. "Through the full integration of all past acquisitions, and the organic development of differentiating devices, we are now strongly positioned to further

increase our cloud-based links market-share by delivering a complete suite of 100Gbps devices for all datacom solutions used for Ethernet, Fiber Channel and Infini-Band Web2.0 mega-data-center connectivity," he believes. "In the first half of calendar 2016 we plan to release a complete 100Gbps chip set to provide a one-stop-shop solution for the short-reach (SR) and long-reach (LR) datacom links, including CDR [clock & data recovery] and DML [directly modulated laser] devices, alongside our industry-leading 100Gbps VCSEL TIA [trans-impedance amplifier] and drivers, which have been available in production volumes for quite some time. As the largest merchant supplier of 40Gbps solutions for the datacom market, and with significant market penetration already in place, we are confident of remaining a leader when the market moves to 100Gbps speeds, as early as calendar 2017," says Katz.

"We also maintained our strong position in sales of coherent 100Gbps telecom products, while introducing new, leading-edge products addressing all devices required for terrestrial 200Gbps and 400Gbps metro and long-haul limiting and linear applications," continues Katz. "The 100Gbps metro buildouts will commence in 2016 and last for several years. We see this as a solid revenue opportunity and fully expect to be a main supplier for this next-generation telecom infrastructure," he adds.

"In the RF market, the high-speed point-to-point backhaul E-band infrastructure is moving to the advanced qualification stage with the belief that the small- and micro-cell infrastructure initial installation will commence this year," notes Katz. "In addition, we are expanding our activities to address the next generation of technologies both for outdoor and indoor connectivity. We are currently engaged with several potential customers worldwide who are evaluating our products and hope to see some traction this year," he adds.

In the first half of calendar 2016 we plan to release a complete 100Gbps chip set to provide a one-stop-shop solution for the short-reach and long-reach datacom links, including CDR and DML devices, alongside our industry-leading 100Gbps VCSEL transimpedance amplifiers and drivers

"We also remain confident in the outlook for our highly profitable Industrial ASIC business, where we delivered several significant contract wins in 2015 and, more importantly, accelerated the transition from our legacy products to the fast-growing families of wireless and Wi-Fi CMOS low-power and ultra-wide-band-width devices, which are key components for a variety of emerging applications such as the Internet-of-Things (IOT)," Katz says.

"While we are still in the early stages of 2016, it is our current expectation that we will again generate double-digit revenue growth for the fourth consecutive year," says Katz. Revenue in full-year 2016 should be $46m, up 14% from 2015, while delivering another year of profitability. "We will strive to hold our quarterly non-GAAP gross margin to at least 66%, which will allow us to slightly increase our capital expenditure to proportionately support the revenue growth we expect next year," he adds.

www.gigoptix.com

GigOptix signs UKC Holding as Japan distributor and appoints director of Japan sales

GigOptix Inc of San Jose, CA, USA (a fabless supplier of analog semiconductor and optical communications components for fiber-optic and wireless networks) has signed Japan's largest electronic components distributor UKC Holding Corp as its distributor for all its product line sales in the country.

GigOptix says that the agreement strengthens its business presence in the Japanese enterprise and cloud connectivity markets, in particular in the telecom, datacom, RF and ASIC segments.

"We have been looking for a strong semiconductor fabless partner that specializes in the optical networks and RF connectivity space," says UKC's executive general manager Jun Takagi. "GigOptix has a well-recognized brand name, market-accepted technology, and excellent solutions, with a good match to the needs of the Japanese telecom, datacom, RF and ASIC customers. We look forward to utilizing our strong sales and engineering resources to further develop the customer base in the present markets and expanding their reach into the emerging and higher-volume consumer connectivity markets," he adds.

"UKC Holdings is an excellent ambassador for GigOptix in Japan. They have a strong presence that will enable us to expand our current market reach and provide the breadth of expertise that enables us to address new market segments," comments Dr Raluca Dinu, executive VP global customer operations at GigOptix.

In addition, Maasaki Shirashoji (formerly of Midoriya Electronics) joins GigOptix's global sales team as director of Japan sales. "We have strengthened the sales team in Japan to support our partnership with UKC Holdings and to realize GigOptix's growth aspirations for this territory," says Dinu.

www.ukcgroup.com

Oclaro's quarterly revenue grows 8%

Stronger-than-expected growth in 100G yields higher margin & income

For fiscal second-quarter 2016 (to 26 December), Oclaro Inc of San Jose, CA, USA (which provides components, modules and subsystems for optical communications) has reported revenue of $94.1m (above the $88–94m guidance), up 7.5% on $87.5m last quarter (the second consecutive quarter of revenue growth of 7% or higher) and up 8.4% on $86.8m a year ago.

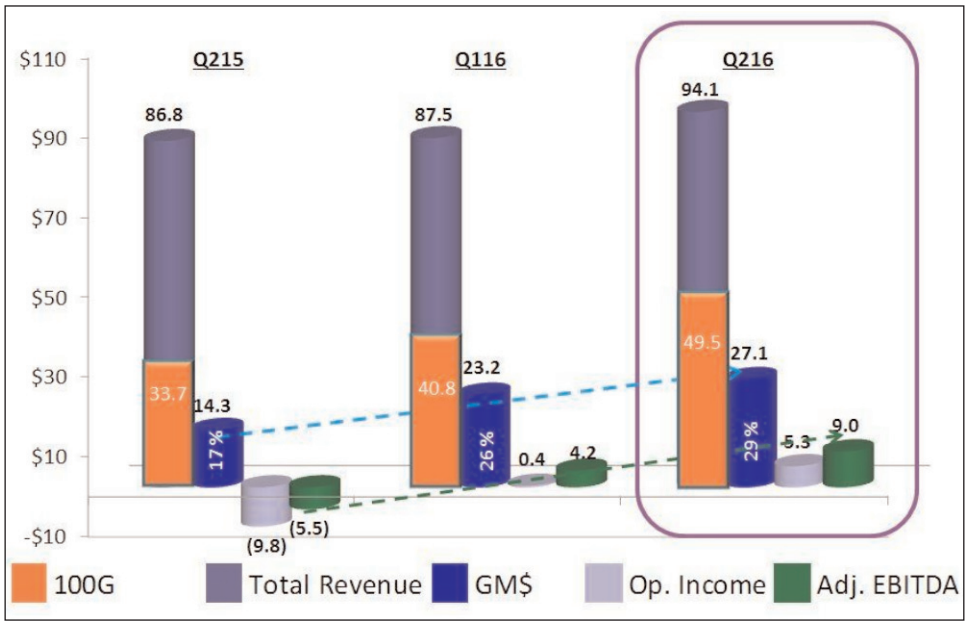
By region (compared with last quarter), the Americas rose from 30% to 35% of total revenue, while China fell back slightly from 38% to 37%, Europe fell from 19% to 16%, Southeast Asia fell from 11% to 10%, and Japan fell from 2% to 1%. There were three customers with greater than 10% of sales (21%, 16% and 10%, respectively).

By end-market (as a proportion of total revenue), Datacoms comprised 54% (versus 47% a year ago) and Telecoms 46% (versus 51% a year ago), with both client-side and line-side businesses growing. Specifically, line-side revenue was $43m, up almost 8% on last quarter. Client-side revenue was $50m, up about 7% on last quarter.

Growth was led by 100G product revenue of $49.9m (53% of total sales), up 21% (more than the expected 10–20%) on $40.8m (47% of sales) last quarter and up 44% on $33.7m (39% of sales) a year ago.

Wireless sales fell as Oclaro continued to de-emphasize lower-speed wireless business. "Given the strength of our 100G products, we further accelerated the discontinuation of some of our lower-margin 10G product lines," says CEO Greg Dougherty. Revenue for 10G-and-lower products was $33.3m (35% of total sales), down 7% on $35.9m (41% of total sales) last quarter.

Revenue for 40G products was $11.3m (12% of total sales), roughly flat on $10.8m (12% of total sales) last quarter but down from $19.3m (22% of total sales) a year ago.



"With a second consecutive quarter of 20% sales growth in our 100G portfolio, we again delivered stronger financial performance," says CEO Greg Dougherty. "Revenue growth drove higher gross margin and net income," he adds.

On a non-GAAP basis, gross margin was 28.8%, up from 26.4% last quarter (driven by 100G sales growth and manufacturing efficiencies, offset by a weaker mix of 10G) and up from 16.5% a year ago (as improvements in 100G sales mix, factory absorption, manufacturing overhead leverage and inventory management offset a reduction in 40G telecom business).

Due mainly to restructuring programs implemented last year, operating expenses have been cut further, from $24.2m (27.9% of revenue) a year ago and $23m (26.3% of revenue) last quarter to $21.8m (23.2% of sales).

Due to the improved revenue and gross margin, combined with lower operating expenses, operating income was $5.3m, up from $0.4m last quarter and compared with a loss of $9.8m a year ago.

"A combination of revenue growth, strong 100G mix and continued improvements in our execution, resulted in us delivering another strong financial quarter," says Dougherty. "This was our seventh consecutive quarter of improved financial performance," he adds. "We have achieved positive earnings per share in this quarter." Net income was $3.1m, compared with net losses of $1.8m last quarter and $9.9m a year ago.

Driven by improvements in working capital (both from receivables and payables) along with positive free cash flow, adjusted EBITDA more than doubled from $4.2m last quarter to $9m (above guidance), versus a loss of $5.5m a year ago. This exceeded capital expenditure (CapEx) of $8.3m (which more than doubled from $3.8m last quarter).

During the quarter, cash, cash equivalents, restricted cash and short-term investments hence rose from $107.7m to $115.7m.

"We continue to see robust demand for our 100G product portfolio combined with favorable market conditions," says Dougherty. "As we expand capacity in Asia, both for our current and new 100G products, we expect revenue growth in 2016 to continue."

For fiscal third-quarter 2016 (ending 26 March), Oclaro expects revenue to grow by $3–9m to $97–103m, despite the March

quarter typically being a down quarter due to the annual price negotiations toward the end of the preceding year. The increase is driven by a continuation of strong sequential growth in 100G. This will counteract declines of $3–4m in 10G and $1m in 40G (a 10% drop in combined 10G + 40G revenue, to be followed by a flat June quarter at $40m, before declines of 10% per quarter in the September and December quarters driven mainly by end-of-life 40G products). Gross margin should fall slightly to 26–28% in fiscal Q3. Operating income is expected to be $2–6m.

"We expect to see strong demand for our 100G products through this calendar year, driven by several projects in China, continued success for 100G client-side products, increased market share for our micro-ITLA lasers and modulators, and the production ramp of our CFP2-ACO products," says Dougherty. The China Mobile award involves over 21,000 line-side 100G parts. Most deliveries for this project are scheduled for calendar Q1–Q2/2016.

"We're also seeing very strong demand from North American and European router and optical companies for the 100G LR4 products," notes Dougherty. "Many customers appear to be moving away from 10G muxponder cards and going towards native 100G client interfaces," he adds. "The introduction of 100G single-mode inside the data center will begin to ramp in the middle of 2016," believes Dougherty. "Our focus has been on single-mode duplex fiber architectures. As a result of the outstanding performance of our high-speed lasers, we have received several early design wins for our QSFP28 products, both CWDM and LR4 [with production ramping through this summer]," he adds.

"Growth in [fiscal] Q3 will not be gated by demand," notes Dougherty. "We're running very tight on capacity for most of our 100G products, as well as our tunable 10G offerings," he adds. As a result of all these factors, Oclaro is gain increasing capacity for its CFP family of products (CFP, CFP2 and CFP4) — the firm's third capacity increase in the last 18 months.

The CFP2-ACO product has completed qualification at Oclaro's UK pilot operation and now achieved interim qualification for the China optical subassembly volume manufacturing line. Oclaro has also received customer signoff on the production lines at its factory in Shenzhen and for contract manufacturer Venture's factory in Penang. Oclaro remains on track for first shipments from Asia to customers in late March. "We will ramp both manufacturing lines for the ACO over this calendar year and we expect to go from shipping hundreds per quarter to thousands per quarter by the end of this year," believes Dougherty. "We continue to believe that the majority of the early demand will be focused on data-center interconnect, but expect to begin seeing the North American metro program start ramping later this summer," he adds.

"Our ability to grow will be governed by how quickly our capacity comes online, as well as the capability of some of our piece-part vendors to respond to our increased demand," says Dougherty. For full-year fiscal 2016, Oclaro still expects to invest $30–40m in CapEx to support additional capacity for both 100G client- and line-side growth.

www.oclaro.com

MACOM and AOI collaborate on production shipments of 100G QSFP28 transceivers for data-centers

M/A-COM Technology Solutions Inc of Lowell, MA, USA and Applied Optoelectronics Inc (AOI) of Sugar Land, near Houston, TX, USA (which makes fiber-optic access network products for the Internet data-center, CATV cable broadband and fiber-to-the-home markets) are collaborating to support initial orders and production ramp of 100G QSFP28 optical transceiver solutions for data-center applications.

The QSFP28 transceiver is now the predominant form factor for 100G switching and routing connectivity, and a key enabler as 100G begins to ramp in data-centers. As part of the collaboration, AOI will leverage MACOM's broad portfolio of CDRs, drivers and TIA chipsets in its QSFP28 solution. MACOM chipsets provide low power and a small form factor, which are critical enablers for the QSFP28 solutions.

"MACOM offers an extensive chipset product portfolio for data-center applications for both CWDM and PSM-4 applications, that is key for the transition of the mega-data-center customers from 40G to 100G," says Joshua Yeh, senior VP of AOI's Network Equipment Module business unit. "Through this collaboration, coupled with our internally sourced 25G laser diodes and 100G light engines, AOI is excited to offer customers volume production of 100G transceivers optimized for data-centers," he adds.

"This multimillion dollar order from AOI marks the beginning of a collaboration in support of AOI's market-leading position in the 100G optical data-center access market, builds upon on our success in the 100G long-haul and metro optical market, and underscores that MACOM is well positioned to benefit as 100G continues to ramp in data-centers," says Preet Virk, MACOM's senior VP & general manager, Networks. "We have the requisite technology, products and application support to enable data-center customers faster time to market while solving their most complex connectivity issues."

www.ao-inc.com
www.macom.com/opto

Emcore's quarterly revenue up 22% year-on-year to $22.5m

Outsourcing targets breakeven at $20m per quarter

For fiscal first-quarter 2016 (ended 31 December 2015), 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 $22.5m, down 2.3% on $23m last quarter but up 22% on $18.4m a year ago.

Results are for the Broadband Fiber Optics division, classifying the Telecom division and Photovoltaics segments as discontinued operations. Emcore completed the sales of its Space Photovoltaics business in mid-December 2014 to SolAero Technologies Corp and of its Telecommunications Fiber Optics business (the tunable laser and transceiver Digital Products lines) at the beginning of January to NeoPhotonics Corp of San Jose, CA, USA. The continuing Broadband Fiber-Optics business includes products for cable television (CATV) and fiber-to-the-premise (FTTP) networks as well as satellite communications, video transport and specialty photonics for defense & homeland security applications.

"Similar to last quarter, the results reflect continued strength in our CATV and components product lines despite seeing more pressure on our chips area," says chief financial officer Mark Weinswig.

"In the broadband cable TV segment, over the past six quarters, we have seen significant strength in the results and outlook," he adds. "In general, after tough times in 2012 and 2013, the cable TV optical network infrastructure business has seen improving market trends."

Revenue for chip-level device products has grown significantly over the last two years ago, but was relatively flat on last quarter at $4m (nearly 50% of the entire chip revenue for all of last year), with most being for Gigabit passive optical network (GPON) applications. "Previously we expected chip pricing pressure to materialize in the latter half of calendar year 2016," says president & CEO Jeff Rittichier. "We saw the impact beginning in our first fiscal quarter," he adds. "We are taking actions and implementing initiatives for cost reduction in the fab and expect to see improvements in our cost structure in the calendar year."

On a non-GAAP, gross margin was 32.9%, up on 28.1% a year ago but down from 41.1% last quarter and on the lower side of the targeted range of mid-30s, due primarily to: (1) low cable TV shipments leading to lower factory utilization and under-absorption of fixed manufacturing overhead costs (as a percentage of revenue); (2) an unfavorable product mix; and (3) a reduction in average selling prices (ASPs) due to re-pricing of GPON chips during the quarter. "As cable TV volumes increase, we will see improvement on the overhead and mix," believes Rittichier.

Operating expenses have been cut further, from $10.2m a year ago and $8.2m last quarter to $7.4m (due mainly to lower compensation costs), while still maintaining product development efforts (with R&D spending of $2.6m level on last quarter and up on $2.2m a year ago). Selling, general & administrative (SG&A) expenses have been cut further, from $8.6m a year ago and $5.6m last quarter to $4.8m. This is despite Emcore spending over $900,000 on arbitration activities related to Sumitomo (similar to last quarter).

Income from continuing operations was $1.3m ($0.05 per share), down from $2.7m ($0.10 per share) last quarter but still an improvement on a loss of $0.8m ($0.03 per share) a year ago.

Cash flow was a strong $5m. During the quarter, cash and cash equivalents rose by $3.6m from $111.9m to $115.5m, due to a significant reduction in accounts receivable in the inventory.

"With the continued strong results and large cash position, the board of directors is continuing to review options to enhance shareholder value," says Weinswig. Currently, the board expects to approve a cash dividend or distribution to shareholders, with the timing and amount to be determined a few months after completing the review.

For fiscal second-quarter 2016 (to 31 March), Emcore expects revenue to be steady at $21–24m. "The trends in cable TV continue to be strong, but we are mindful of any remaining inventory positions and upcoming product changes within our customer base," says Rittichier.

"While we are implementing a new strategy that should improve our operating model in future periods, those activities will lead to some additional costs in the next couple of quarters and take some time to realize," says Weinswig. Emcore hence expects gross margins to be in the low-to-mid 30s for fiscal Q2.

Also, beginning in the fiscal Q2, Emcore expects to see a rapid decline in legal defense costs. The firm filed its final closing statements in January relating to the arbitration and is now awaiting the arbitration panel's final ruling (within 60–90 days, during April). Normal SG&A levels should decrease in the March quarter then remain relatively flat throughout calendar year 2016.

"The cable television transmission product business outlook remains strong but consolidation at the MSO and OEM levels has caused a bit of turbulence along with inventory build-up, which we believe is

currently winding itself down," notes Rittichier. "We also see the MSOs rapidly shifting their spend to DOCSIS 3.1 product as they deploy architectures which will allow them to compete against deep and all-fiber networks and allow them to deploy over-the-top services efficient," he adds.

"For the chip-level device products, we do expect non-GPON chips to comprise a greater fraction of our chip business than they did over the past year, with our goal for non-GPON to be one-third of our chip revenues over the year," says Rittichier. "Non-GPON chip shipments in 2016 could be larger than our entire chip business was in 2015. Emcore's long history as one of the industry's premier optical semiconductor companies has given us a substantial portfolio of chips to sell, and the divestiture of our telecom module business eliminated any channel conflict concerns in the minds of our customers," he adds.

"The GPON business is really just our initial offering in the merchant chip market as Emcore fully intends to become a broad supplier of chip-level products to the entire telecom industry, as well as an important supplier of GPON chips," continues Rittichier. "We have a number of process and technology initiatives in the fab which will help us drive down costs, such as a migration to 3-inch wafers, outsourcing of commodity epitaxial growth and automated techniques for coding, simulation, test and sort," he adds. "These steps will enable us to compete more aggressively in the market over the long-term. Automation is especially important to this initiative, as we have operating leverage into the chip fab operations." New equipment is currently being installed to modernize the firm's fab and improve its productivity.

Emcore is working to implement new manufacturing strategies to improve performance and to turn fixed and semi-fixed expense into variable costs. "Our expectation is that these initiatives will also lower our working capital requirements further, tying up less cash and inventory, while reducing cycle times and improving yields," says Rittichier. "You should expect to see some buildup activities in our inventory position over the next few quarters, as we build bridge inventory to accommodate movements of certain manufacturing processes to EMS [electronics manufacturing services]," he adds. The transformation of the manufacturing processes has been underway since the beginning of the March quarter, aiming to improve operating leverage, cycle times, yields and product costs. Key components of the initiative are: (1) moving low-value-added processes to EMS; (2) installing more robust measurement and process control technologies at key points in assembly lines; (3) improving operating leverage through automation.

We expect to further strengthen Emcore China's automation and engineering teams

Emcore also aims to reduce the fixed and semi-fixed expense of its assembly operations. "We've nearly completed the outsourcing of our first true turnkey assembly products to EMS from Emcore China, freeing those engineers to focus on the areas that give us meaningful cost advantages or opportunities for competitive advantage," says Rittichier. "Upgraded processes are also in their final stage of development for a laser module in transmitter families that will smooth the automation of transmitter assembly by improving process shields," he adds. "We expect to further strengthen Emcore China's automation and engineering teams and look forward to seeing improvements as streamlined processes are developed and inserted into operations during our Six Sigma Black Belt projects."

Emcore's target operating model goal is to be at breakeven level (on a non-GAAP basis) at $20m per quarter of revenue.

www.emcore.com

Infinera creates Government Advisory Board

Infinera Corp of Sunnyvale, CA, USA, a vertically integrated manufacturer of digital optical transport networking systems incorporating its own indium phosphide-based photonic integrated circuits (PICs), has announced the appointment of Roger Baker, Diana Gowen and Henry Sienkiewicz to its newly created Government Advisory Board.

The advisory board has been set up to add expert executive perspective on the specific needs of the government sector to enable Infinera to accelerate and enhance its success with the US government. The three key government sector telecom leaders have joined the advisory board to support Infinera's future growth in this strategic sector.

"Delivering mission-critical networks to meet government needs is a priority," says Wray Varley, VP of government sales at Infinera. "We look forward to the guidance and leadership from our advisory board to help shape how the Infinera Intelligent Transport Network will contribute to the success of the US government telecom sector."

● Infinera says that James Dolce has resigned from its board of directors.

The resignation avoids potential conflicts of interest for Dolce, who is also a member of Juniper Networks' board of directors, following the announcement that Juniper has acquired network equipment maker BTI Systems Inc of Ottawa, Canada.

"Jim was a valuable contributor during his short time on Infinera's board," comments chairman Kambiz Hooshmand.

www.infinera.com

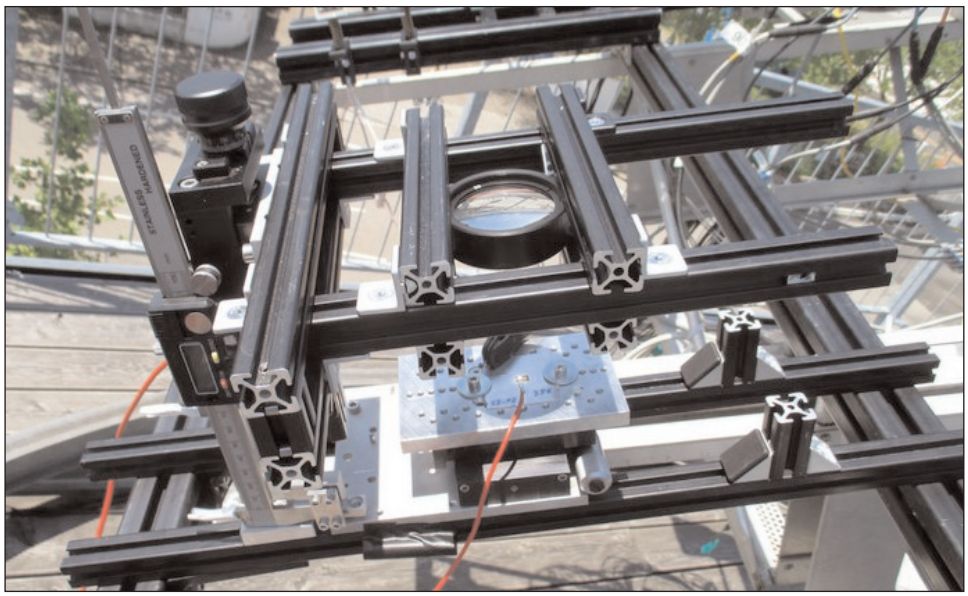
Fraunhofer ISE sets CPV module efficiency record of 43.4%

Four-junction cell plus high-efficiency optics yields record mini-module

Fraunhofer Institute for Solar Energy Systems ISE of Freiburg, Germany has set a new record of 43.4% for concentrator photovoltaic (CPV) energy conversion efficiency on the module level (exceeding its prior record of 38.9% announced in June 2015).

CPV technology is implemented in regions with a high share of direct irradiation in order to generate renewable electricity at cost-effective prices. The new milestone for CPV technology (which uses multi-junction solar cells) demonstrates the potential available for industrial implementation, says Dr Andreas Bett, deputy director of the Institute and Division Director of Materials, Solar Cells and Technology at Fraunhofer ISE.

Previously, in late 2014, Fraunhofer ISE researchers, together with partners Soitec of Bernin, France and French research center CEA-Leti in Grenoble, achieved record efficiency of 46% for CPV at the cell level, using a four-junction solar cell. The mini-module that has set the new CPV module record is based on this type of multi-junction solar cell in combination with high-efficiency optics.



Record 43.4%-efficient CPV mini-module, comprising four-junction solar cells.

Details of the technology will be presented at the CPV12 International Conference on Concentrator Photovoltaic Systems in Freiburg, Germany (25–27 April).

● Fraunhofer ISE and the US National Renewable Energy Laboratory (NREL) have recently (earlier in February) published a report 'Current Status of Concentrator Photovoltaic (CPV) Technology'.

www.cpv-12.org

www.ise.fraunhofer.de/en/publications/veroeffentlichungen-

First Solar EPC surpasses 6GW of global installed photovoltaic capacity

Cadmium telluride (CdTe) thin-film photovoltaic module maker First Solar Inc of Tempe, AZ, USA says that in early February it surpassed 6GWDC of capacity installed by its Engineering, Procurement and Construction (EPC) group. The firm is currently installing 30–40MW_{DC} per week on 2GW_{DC} of active projects around the world.

Partnerships with strategic customers have enabled First Solar to continually lower the cost of utility-scale solar generation, says Alan Stringer, VP of global project management & construction services, who adds that First Solar is setting the pace in driving down the cost of balance of systems (BoS). For example, First Solar's application of 1500V inverters is rapidly becoming an industry standard, notes Stringer. Also, the firm's manufacturing heritage, combined with the scale of installing 6GW, has enabled First Solar to develop a 'manufacturing in the field' concept that helps to drive down BoS cost.

"Power plant owners benefit from both the lower cost of utility-scale projects built by First Solar and the proven track record of innovation we bring to every project," says Stringer.

First Solar's inaugural EPC job was 2008's 10MW_{AC} El Dorado Solar Project in Nevada, consisting of 220,000 modules, and taking nearly two years from groundbreaking to commissioning. In early 2015, First Solar completed construction of the 550MW_{AC} Desert Sunlight Solar Project and the 550MW_{AC} Topaz Solar Farms, each utilizing more than 8 million modules and built in about the same amount of time it took to construct El Dorado.

www.firstsolar.com

First Solar raises CdTe PV research cell energy conversion efficiency record to 22.1%

Firm achieves raised target of 22% by end-2015

First Solar Inc of Tempe, AZ, USA has again raised its world record for cadmium telluride (CdTe) photovoltaic (PV) research cell conversion efficiency, from 21.5% (reported in February 2015) to 22.1%, as certified at the Technology and Applications Center (TAC) PV Lab of Newport Corp. The new record has also been documented in the US Department of Energy's National Renewable Energy Laboratory (NREL) 'Best Research Cell Efficiencies' reference chart.

The record research cell was fabricated at First Solar's manufacturing factory and Research & Development Center in Perrysburg, OH, USA using processes and materials suitable for commercial-scale manufacturing.

First Solar says the record confirms that it is on pace with its established research cell roadmap, and validates CdTe's growing competitive advantage over multi-crystalline silicon technology and other commercial thin film PV.

This is the ninth substantial update to CdTe record efficiency since 2011, establishing a sustained trend of rapid performance improvements that significantly outstrips all other commercial technologies, says First Solar.

"We are tracking very closely to a technology roadmap we first presented in 2013 and revised upward in March 2014," says chief technology officer Raffi Garabedian. "At that time, we said we'd hit a 22% research cell efficiency milestone by the end of 2015. We've delivered on that promise," he adds. "In recent years and based on our research cell progress, we've improved the efficiency and energy density of our mass-produced commercial PV modules at a rate at least three times faster than our multi-crystalline silicon competitors. We fully expect to further separate ourselves from the pack in coming years."

Garabedian notes that First Solar's lead manufacturing lines were producing PV modules with 16.4% conversion efficiency in fourth-quarter 2015, and that the research cell efficiency record serves as a driver for integrating performance improvement into the real-world manufacturing environment.

www.firstsolar.com
www.nrel.gov/ncpv/images/efficiency_chart.jpg

First Solar and Southern California Edison sign power purchase agreements for 500MW to come from projects in California, Nevada and Arizona

First Solar Inc of Tempe, AZ, USA, which makes thin-film photovoltaic modules based on cadmium telluride as well as providing engineering, procurement & construction (EPC) services, has signed power purchase agreements (PPAs) with utility firm Southern California Edison (SCE) for the off-take of electricity generated by four solar projects totaling 500MW_{AC} of capacity. The deals establish SCE as the largest single off-taker of energy from First Solar projects in the world.

The PPAs are for power generated by four projects in California, Nevada and Arizona (all currently in development by First Solar, with anticipated commissioning by the end of 2019):

- the 150MW_{AC} North Rosamond Solar Project in Rosamond, CA, which will occupy about 1175 acres of private land and produce about 488,000MWh/year;
- 100MW_{AC} from the Willow Springs Solar Project (near the North Rosamond Solar Project), which will occupy about 1450 acres of private land and produce about 330,000MHh/year;
- the 100MW_{AC} Sunshine Valley Solar Project in Amargosa, NV (less than four miles from the California border, on privately owned land), which will produce about 302,000MWh/year; and
- the 150MW_{AC} Sun Streams Solar Project on about 1500 acres of land in Tonopah, AZ, which will produce about 464,000 MWh/year.

With these agreements, SCE has 2.2GW of solar capacity under contract from projects developed and/or built by First Solar. SCE's first PPA with a project developed by First Solar was for the 21MW_{AC} Blythe Solar Project in 2009. The utility also has a long-term agreement for 250MW_{AC} of capacity of the 550MW_{AC} Desert Sunlight Solar Project in Desert Center, CA (commissioned in 2014). SCE has additional contracts in place for other projects currently in construction, including the Desert Stateline project in California and the Silver State South project in Nevada.

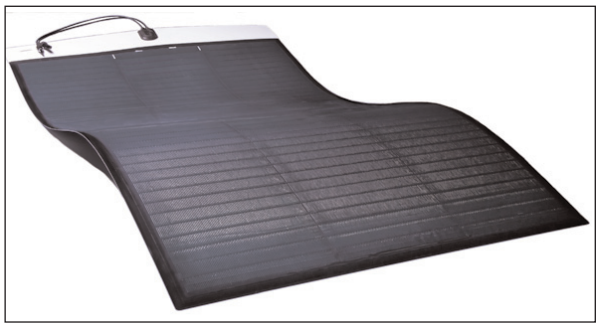
"As an early off-taker, SCE was visionary in their inclusion of utility-scale solar in their energy mix," comments Brian Kunz, First Solar's VP of project development — US West. "Their commitment to providing rate-payers with clean, affordable renewable energy continues with this set of agreements."

www.firstsolar.com

MiaSolé's FLEX-02 CIGS solar modules now UL, IEC and Class A certified

Copper indium gallium diselenide (CIGS) thin-film photovoltaic solar cell and panel maker MiaSolé of Santa Clara, CA, USA (which was founded in 2004 and acquired by Beijing-based renewable energy firm Hanergy in December 2012) says that its FLEX-02 solar modules are now IEC 61646, IEC 61730, UL 1703 certified and UL 790 Class A fire-rated.

The firm's FLEX module is claimed to be the highest-efficiency flexible, lightweight thin-film solar module on the market, with production efficiencies of 16%, providing high power density for applications from roofing to reservoir and landfill covers, to auto, truck and other transportation applications through off-grid and consumer applications.



MiaSolé's FLEX-02W module.

The modules are produced in high volume at MiaSolé's factory in Heyuan, China, which has passed UL, IEC and ISO9001 qualifications.

The low weight of the FLEX-02 module (<0.7lb/ft^2) allows installation on roofs and other structures that cannot support the weight of traditional glass solar panels.

Because they adhere directly to the surface of the structure or object, there are no penetrations, eliminating the worry of leakage and damage to valuable contents within a building. The FLEX-02 also blends into roofs (both metal and TPO), vehicles and other structures, preserving the original look without unsightly racking. The low-profile module is also claimed to provide superior wind resistance and a seismic advantage over traditional rack-and-panel systems (where the higher profile increases the likelihood of damage in a hurricane or earthquake).

www.MiaSole.com

Upland to sell MiaSolé's FLEX modules in New Mexico & El Paso, TX

MiaSolé has entered into a sales agreement for Upland Corp (a manufacturers' representative firm that provides building material solutions in roofing, insulation and waterproofing to the commercial construction industry) for the sales and marketing of its FLEX modules in the territories of New Mexico and El Paso, Texas.

Since 1984, Upland has provided building solutions to these construction partners including architects, building owners and contractors.

MiaSolé's FLEX modules bond directly to a roof surface with a simple peel-and-stick adhesive. In particular, the FLEX-02 Series module is available in two formats.

The FLEX-02W module is 39.3 inches x 102.3 inches and is rated at 360W, and designed for low-slope commercial single-ply roof systems. The FLEX-02N module is 14.6 inches x 102.3 inches and is rated at 120W, and designed specifically for standing-seam metal roofs.

http://uplandteam.com

Metal roofing maker Virte Solar to represent MiaSolé in Scandinavian market

Copper indium gallium diselenide (CIGS) thin-film photovoltaic solar cell and panel maker MiaSolé of Santa Clara, CA, USA (which was founded in 2004 and acquired by Beijing-based renewable energy firm Hanergy in December 2012) has entered into a representation agreement for Finland-based metal roofing manufacturer Virte Solar to represent it in the Scandinavia market.

Virte Solar will immediately begin shipping building-integrated solar roofing systems in the entire Scandinavia region including Norway, Sweden, Finland and Denmark. It will provide services for areas such as industrial, residential and agricultural construction, as well as renovation projects.

Virte Solar's building-integrated photovoltaic metal roofing uses MiaSolé's FLEX modules, which are claimed to be the most efficient thin-film lightweight flexible modules on the market (with a module efficiency rating of 16% in production).

The low weight of the module (<0.6lb/ft^2) allows installation on roofs that cannot support the weight of traditional glass solar panels. The FLEX-02 Series module is IEC 61646 & 61730 and UL 1703 certified.

The Virte Solar BIPV roofing product is a lightweight solution that is claimed to be virtually immune to wind and snow loads, and can be installed in locations where traditional silicon panel technology cannot be employed.

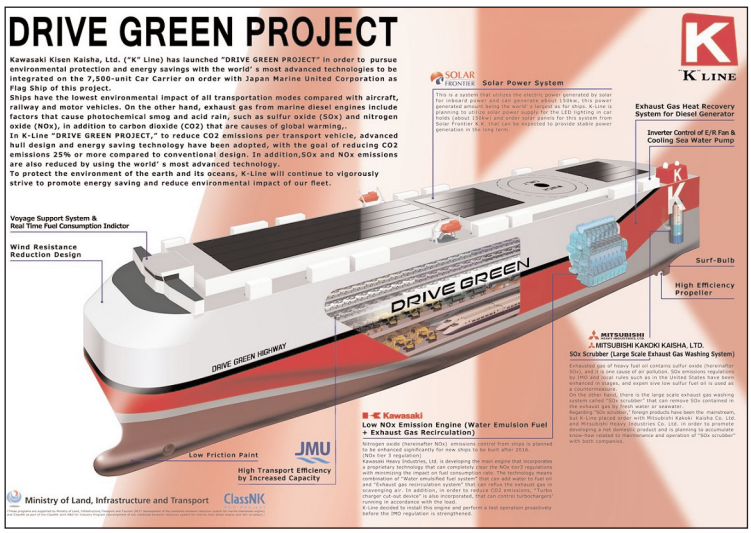
www.MiaSole.com

Solar Frontier's CIS PV panels installed on environmentally friendly transport ship

Tokyo-based Solar Frontier says that its CIS (copper indium selenium) thin-film photovoltaic (PV) solar panels have been installed by Kawasaki Kisen Kaisha Ltd (K Line, one of Japan's largest shipping companies) on its newest environmentally friendly transport ship.

The 'Drive Green Highway' car-carrier (which is 200m long by 37.5m wide, weighs over 76,000 tons and carries up to 7500 passenger vehicles) integrates energy-efficient technologies and design improvements to reduce its impact on the environment. It is the first of eight similar vessels to be built under K Line's Drive Green Project, and was launched at a ceremony in Nagasu Port in Kumamoto, a coastal city in southern Japan.

As well as energy-saving technologies including greenhouse-gas suppression systems in its engines, Drive Green Highway has more than 900 Solar Frontier CIS solar panels installed on its top deck, totaling 150 kilowatt-peak of electricity-generating capacity (one of the largest solar energy systems on any ship in the world). The electricity generated will be used to power all LED lighting on the vehicle decks.



Solar Frontier says that K Line selected its CIS PV modules for the new ship because they generate higher electricity yield (kilowatt-hours per kilowatt-peak) than crystalline silicon solar panels in real-world conditions, as well as being resistant to hot environments and salt-mist environments, such as at sea.

Combining the advantages of its design and technology improvements, Drive Green Highway should emit 25% less carbon dioxide (CO_2), 50% less nitrogen oxide (NO_x) and 90% less sulfur oxide (SO_x) for each vehicle that is transported by the ship.

"K Line is demonstrating how solar energy can improve the energy efficiency and reduce the ecological impact of the shipping industry," says Solar Frontier's CEO Atsuhiko Hirano. "This is one example of the greater role that solar energy has to play in our future, supporting an ever broader range of technologies in a wider range of industries," he adds.

www.solar-frontier.com

Solar Frontier, Development Bank of Japan and Taiyo Oil to co-develop 16.5MW project in Yamaguchi Prefecture

Solar Frontier is collaborating with government-owned Development Bank of Japan Inc (DBJ) and oil refining and distribution firm Taiyo Oil Co Ltd by establishing the joint company SDT Solar Power to develop and manage a 16.5MW solar power project in Yamaguchi Prefecture, Japan.

DBJ (which provides integrated investment and loan services) is directly investing in the project via its 'Special Investment Operations'. Established in 2015, this measure aims to contribute to regional economic revitalization and reinforce corporate competitiveness (DBJ is also inviting financial institutions to support the raising of funds through project financing).

Land owned by Taiyo Oil Company to build the solar power plant.

Taiyo Oil will lease 180,000m^2 of its land for the project and participate in managing the joint company. Founded in 1941, Taiyo Oil is developing new businesses under its Medium-Term Management Plan, which includes solar energy.

Construction should last from this July to August 2017. The plant should be operational in 2017, after which Solar Frontier's specialist team will also provide operation & maintenance services.

Consisting of about 100,000 of Solar Frontier's modules, annual output is expected to be about 20,000,000 kilowatt-hours (equivalent to the annual electricity consumption of 3880 average households in Japan), displacing about 10,500 tons per year of CO_2 emissions. Solar Frontier claims its CIS modules yield more energy (kilowatt-hours per kilowatt-peak) in real-world environments than crystalline silicon modules.

www.dbj.jp/en

Ultraviolet photodetectors on free-standing gallium nitride

Reduced defect density from free-standing GaN substrate reduces dark current and increases response in AlGaN UV avalanche photodiodes.

Researchers based in USA have been studying performance improvements in aluminium gallium nitride (AlGaN) ultraviolet (UV) avalanche photodiodes (APDs) gained from using free-standing gallium nitride substrates instead of gallium nitride on sapphire templates [Jeomoh Kim et al,Appl. Phys. Express, vol8, p122202, 2015].

The work involved Georgia Institute of Technology, University of Houston, Magnolia Optical Technologies Inc, US Army Night Vision Sensors and Electronic Division, and the US Defense Advanced Research Projects Agency (DARPA) Microsystems Technology Office (MTO).

AlGaN-based photodetectors have potential for high optical gain, high sensitivity, low dark current and detection of solar-blind radiation. Alternative technologies are photomultiplier tubes and silicon (Si)-based photodetecting devices. Photomultipliers are bulky and fragile, while silicon is a less efficient detector of UV, given that it has an indirect bandgap. Silicon's narrower bandgap also means that it is sensitive to solar radiation.

Producing high-quality AlGaN material is a challenge to fabricating high-performance photodetectors. The researchers explain: "A high density of crystalline defects, mainly threading dislocations, of AlGaN layers in an active region results in high leakage current and premature microplasma breakdown prior to reaching avalanche breakdown."

The epitaxial material (Figure 1) was grown by metal-organic chemical vapor deposition (MOCVD) on free-standing GaN or GaN-on-sapphire. Where the aluminium content of the structure (n-contact region) changed, the researchers used step-grading strain management of the transitions to avoid cracking.

The free-standing GaN substrate was n-type conductive, produced in a thick-film hydride vapor phase epitaxy (HVPE) process. The threading dislocation density was less than $5x10^6/cm^2$.

The GaN-on-sapphire template was produced by creating a low-temperature GaN buffer and then growing 3μm unintentionally doped GaN. The resulting dislocation density was $5.4x10^8/cm^2$, as determined by x-ray analysis.

The materials were fabricated into top-illuminated APDs with circular mesas. The annealed n- and p-contacts were titanium/aluminium/titanium/gold and nickel/silver/nickel/gold, respectively. The APDs were passivated with silicon dioxide. Interconnect and bond pads consisted of titanium/gold.

Contact	p^{++}-$Al_{0.05}Ga_{0.95}N$	0.02μm
Contact	p-$Al_{0.05}Ga_{0.95}N$	0.1μm
Drift	$Al_{0.05}Ga_{0.95}N$	0.3μm
Contact	n-$Al_{0.02}Ga_{0.98}N$	0.15μm
Contact	n-GaN	0.45μm

Figure 1. Epitaxial material structure for p-i-n APDs on free-standing GaN substrate or GaN/sapphire template.

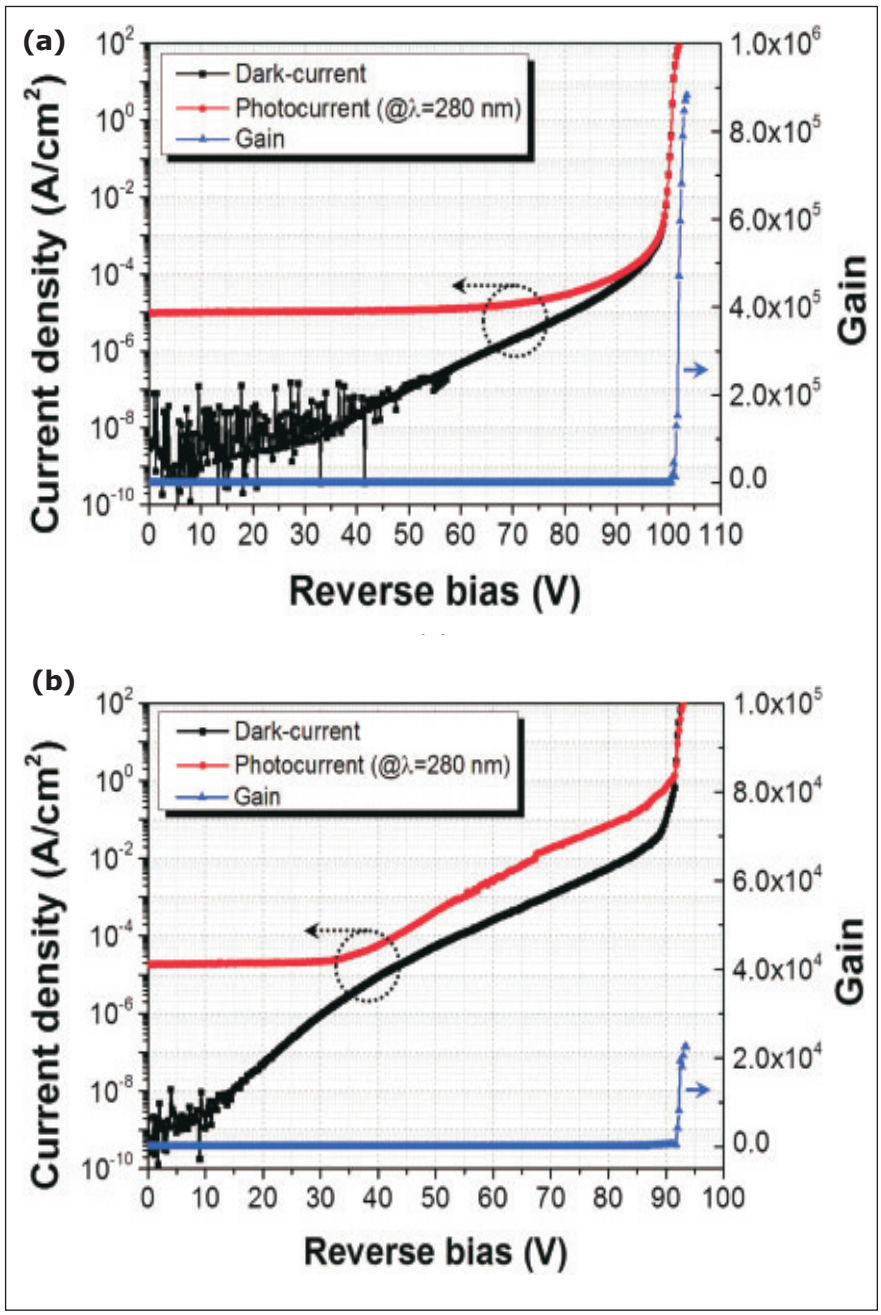
One effect of using free-standing GaN substrates was to increase the breakdown voltage under reverse bias to 95–100V, compared with 87–89V for the devices on GaN/sapphire templates. Also, the dark current was significantly reduced in APDs on free-standing GaN by factors ranging from 2x to 10x, depending on mesa diameter.

The researchers comment: "Considering the fact that dislocations in a device would increase the dark current density by trap-assisted tunneling current at a certain reverse bias and produce premature micro-plasmas prior to the onset point of avalanche breakdown, the use of a FS-GaN substrate with a low dislocation density is responsible for the low dark-current density and constant breakdown voltage of UV-APDs."

One effect of using free-standing GaN substrates was to increase the breakdown voltage under reverse bias to 95–100V, compared with 87–89V for the devices on GaN/sapphire templates. Also, the dark current was significantly reduced

The relatively small change in dark current with mesa size indicates

Figure 2. Reverse-bias current–voltage characteristics for 40μm-diameter (corresponding to 1256μm^2) APD grown on (a) free-standing GaN substrate or (b) GaN/sapphire template.



that surface leakage through the mesa walls was small, according to the researchers. The team adds: "The low etch damage of the mesa definition and high-quality dielectric passivation during the fabrication process possibly contributed to reducing the leakage current through the mesa sidewall surfaces."

The researchers estimated the peak field in a 40μm-diameter APD (1256μm^2 area) on free-standing GaN at ~3.2MV/cm in a one-dimensional simulation. This compares with the critical fields in GaN (2.4–3.3MV/cm) and $Al_{0.22}Ga_{0.78}N$ (3.5MV/cm).

The devices were subjected to mono-chromatic 280nm illumination (Figure 2). The avalanche gain was 82 with 100V breakdown and 5x10^5 beyond 102V. For devices on GaN/sapphire, the gain was ~160 with 88V breakdown and 2x10^4 with 93V breakdown.

The researchers comment: "Even though avalanche breakdown was observed, the avalanche gain of the UV-APD grown on the GaN/sapphire template is an order of magnitude lower than that of the UV-APD grown on the FS-GaN substrate."

The spectral response of a 70μm-diameter APD (3847μm^2) on free-standing GaN was measured under reverse bias up to 90V (Figure 3). The breakdown voltage was ~95V. The devices showed no premature micro-plasma breakdown effects in multiple current–voltage scans. By contrast, APDs on GaN/sapphire frequently showed such premature breakdown. The researchers attribute this to the higher defect density in AlGaN grown on GaN/sapphire templates.

The peak response under zero bias was 43.4mA/W at 354nm. The external quantum efficiency (EQE) was around 16%. With 80V reverse bias, the peak was 221.8mA/W at 362nm (~94% EQE). ■

http://dx.doi.org/10.7567/APEX.8.122202

Author: Mike Cooke

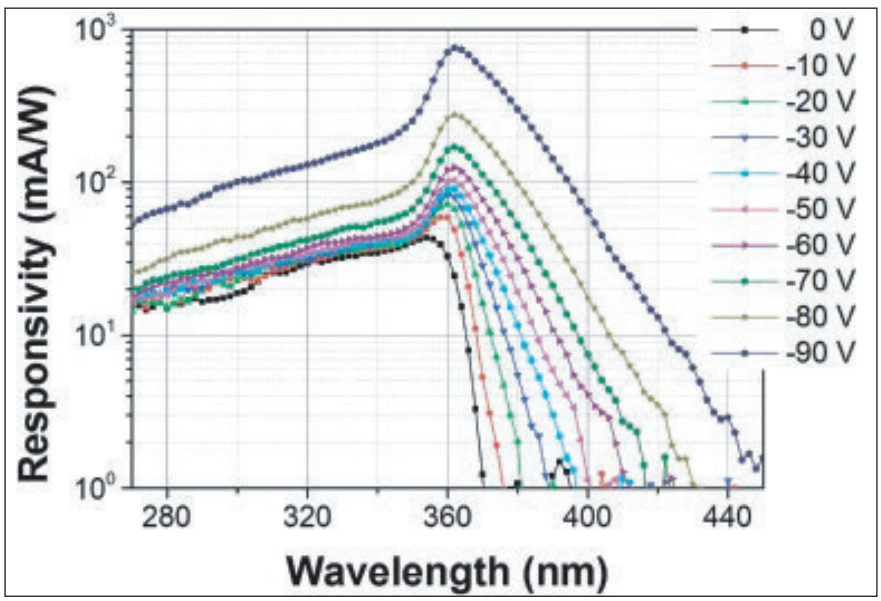


Figure 3. Reverse-bias voltage-dependent photocurrent response spectrum at room temperature for 70μm-diameter (3826μm^2) APD grown on free-standing GaN substrate.

Low-threading-dislocation AlGaN template for ultraviolet lasers

Device structures lase around 350nm wavelength under optical and electric pumping.

Sandia National Laboratories in the USA has reported aluminium gallium nitride (AlGaN) laser structures emitting ~350nm ultraviolet radiation from optical and electrical pumping [Mary H. Crawford et al, Appl. Phys. Express, vol8, p112702, 2015]. The researchers claim that their laser diode (LD) structure is one of only a few such reports in the sub-360nm range of wavelengths.

Pushing laser diode technology deeper into the ultraviolet would give access to applications such as fluorescence-based detection of biological agents and portable water purification.

Producing such devices is challenging since AlGaN is difficult to grow with sufficiently low threading dislocation densities (TDDs) and high enough p-type magnesium doping. Instead of using GaN templates, the Sandia team has developed low-TDD AlGaN templates on sapphire.

The researchers comment: "In contrast to GaN substrates, this approach to fabricating reduced-TDD templates can be applied to LDs across the entire AlGaN compositional range, providing a promising approach for further pushing LDs into the deep UV region."

Also, by avoiding GaN underneath the device layers, the structure is suitable for both laser diodes and bottom-emitting light-emitting diodes (LEDs). GaN absorbs radiation shorter than 365nm.

The laser material was grown by metal-organic vapor phase epitaxy (MOVPE) in a Veeco D-125 reactor. The AlGaN template was grown on c-plane sapphire (mis-cut 0.2° to m-plane), beginning with 1.9μm AlN. Next, 3μm n-$Al_{0.32}Ga_{0.68}N$ was grown with a threading dislocation density of 3–4x10^9/cm^2.

In contrast to GaN substrates, this approach to fabricating reduced-TDD templates can be applied to laser diodes across the entire AlGaN compositional range, providing a promising approach for further pushing laser diodes into the deep UV region

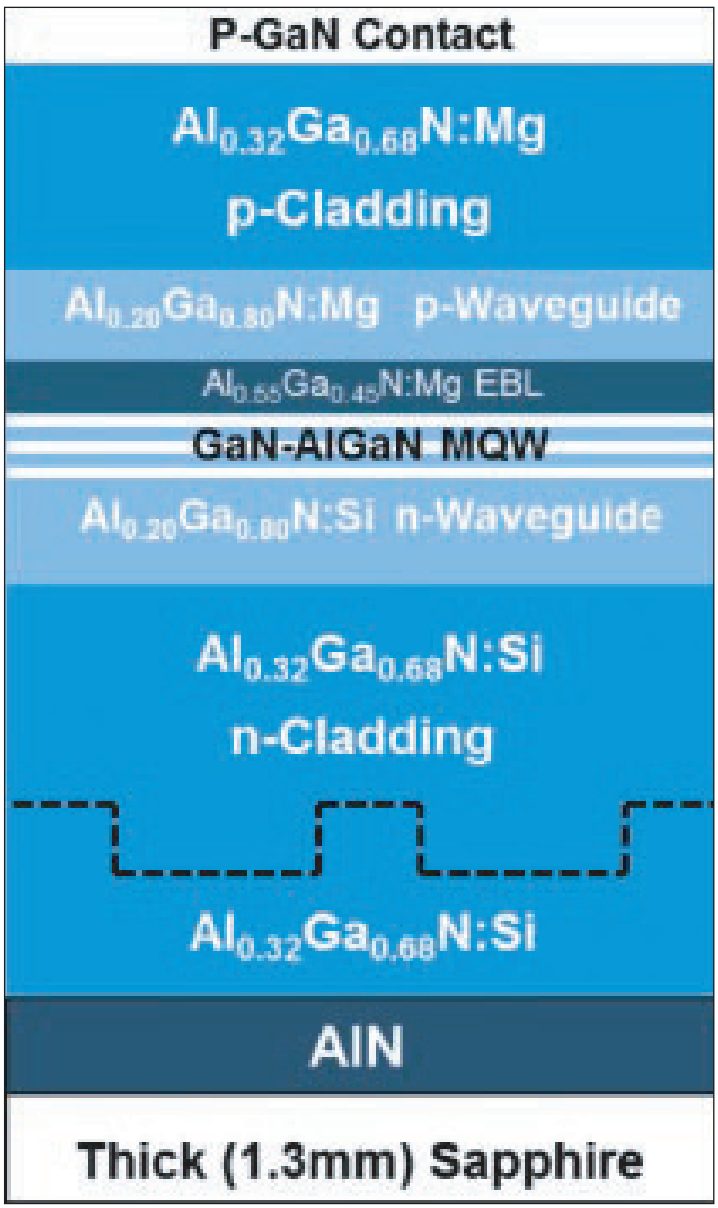


Figure 1. Schematic of laser diode heterostructure.

Low-TDD AlGaN was produced by first etching 0.45μm-deep trenches oriented perpendicular to the major flat of the sapphire substrate to give submicron-wide mesas. The period of the trenches was 2μm. Overgrowth of 7μm n-$Al_{0.32}Ga_{0.68}N$ gave a fully coalesced

planar surface with 0.2nm root-mean-square roughness on a 9μm^2 area. The TDD was 2–3x10^8/cm^2.

The researchers found that using standard 2-inch 0.4mm-thick sapphire substrate resulted in 70μm bowing, which in turn caused cracks to appear in the epilayers. Use of commercially available 2-inch 1.3mm-thick sapphire reduced the bowing to 15μm and eliminated cracking.

An optically pumped laser structure grown on the template consisted of 0.6μm cladding, 80nm waveguide, six 1.7nm GaN quantum wells separated by 7.5nm $Al_{0.20}Ga_{0.80}N$ barriers, 80nm waveguide, and 10nm $Al_{0.32}Ga_{0.68}N$ cap. All the layers were unintentionally doped. A 1mm-cavity laser based on this material had a threshold of 34kW/cm^2 for 266nm pumping from the fourth harmonic of a pulsed Nd:YAG laser. The emission wavelength was 346nm.

For laser diodes, the researchers added an electron-blocking layer (EBL) and p-side cladding (Figure 1). Starting with the low-TDD template, the n-side of the device consisted of 230nm n-cladding and 70nm n-waveguide. The active region contained three 2.3nm GaN wells (undoped) and 7.5nm $Al_{0.20}Ga_{0.80}N$ barriers (silicon-doped).

The p-side of the laser diode consisted of 12nm EBL, 60nm waveguide, 0.45μm cladding with aluminium composition graded down to a 0.32μm GaN contact.

Ridge waveguide laser diodes were fabricated with a titanium/aluminium/molybdenum/gold n-contact and palladium/gold p-contact. The facets were produced using an optimized dry/wet etch recipe. The facets were coated with high-reflectivity hafnium dioxide and silicon dioxide. The back mirror had a reflectivity of about 90% and the outcoupler reflectivity was around 80%.

Pulsed measurements were used to avoid self-heating. A device with 1mm cavity and 4μm-wide ridge emitted 352.7nm laser radiation with a threshold at 22.5kA/cm^2 (Figure 2). This threshold is high compared with reports of 8kA/cm^2 for 360nm wavelength, and 18kA/cm^2 for 336nm.

Simulations suggest that mode penetration into the p-GaN cap due to thin p-cladding resulted in an increased threshold.

Temperature-dependent measurements gave a characteristic temperature (T_0) for the current threshold of 140K, similar to previous reports on UV lasers. ■

http://dx.doi.org/10.7567/APEX.8.112702

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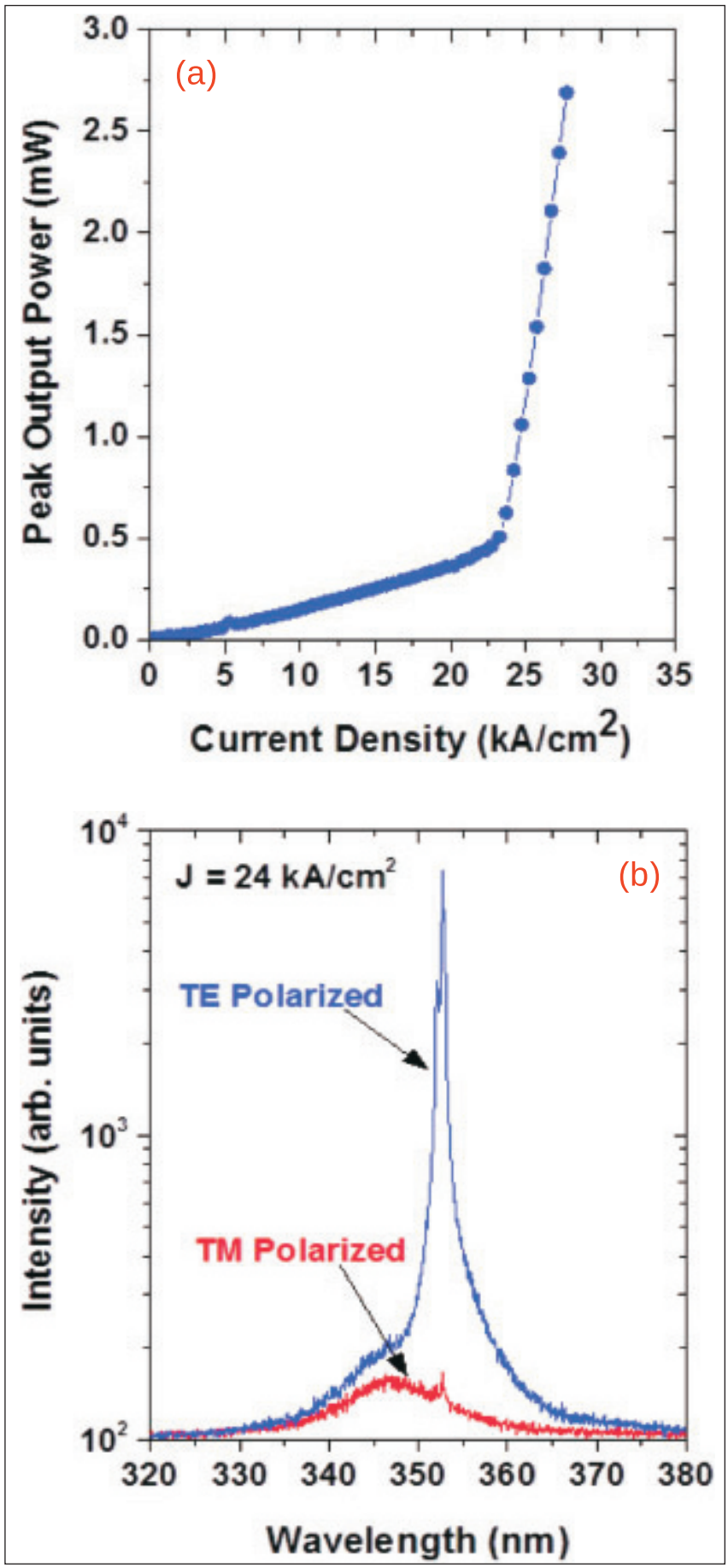

Figure 2. (a) Output power versus current density, and (b) polarization-dependent lasing spectra, for 4μm-wide ridge and 1mm-long cavity laser diode.

Low-threshold yellow laser diodes

Researchers build on work with green and yellow-green devices based on beryllium zinc cadmium selenide.

Yellow laser diodes with low thresholds have been produced by Jijun Feng (University of Shanghai for Science and Technology, China) and Ryoichi Akimoto (National Institute of Advanced Industrial Science and Technology (AIST), Japan) based on beryllium zinc cadmium selenide (BeZnCdSe) single quantum well (SQW) light-emitting active regions [Appl. Phys. Express, vol9, p012101, 2016].

The researchers see important potential biomedical applications for yellow (560–590nm) lasers such as flow cytometry and treatment of ocular disorders. Feng and Akimoto recently reported green and green-yellow laser diodes based on BeZnCdSe technology [www.semiconductor-today.com/news_items/2015/nov/aist_061115.shtml].

Previously groups have developed yellow lasers based on ZnCdSe, but room-temperature operation was only achieved with optical pumping. Although room-temperature operation has been achieved by adding sulfur (ZnCdSSe), the lifetime of devices was low.

Feng and Akimoto's laser hetero-structures (Figure 1) were prepared on n-type (001) gallium arsenide (GaAs) using molecular beam epitaxy (MBE). The n- and p-type doping came, respectively, from zinc and nitrogen impurities supplied by zinc chloride and nitrogen activated by radio frequency plasma. Separate chambers were used for II-VI and III-V growth layers. These chambers were connected by an ultra-high-vacuum transfer chamber. The III-V growth consisted of a 500nm n-GaAs buffer.

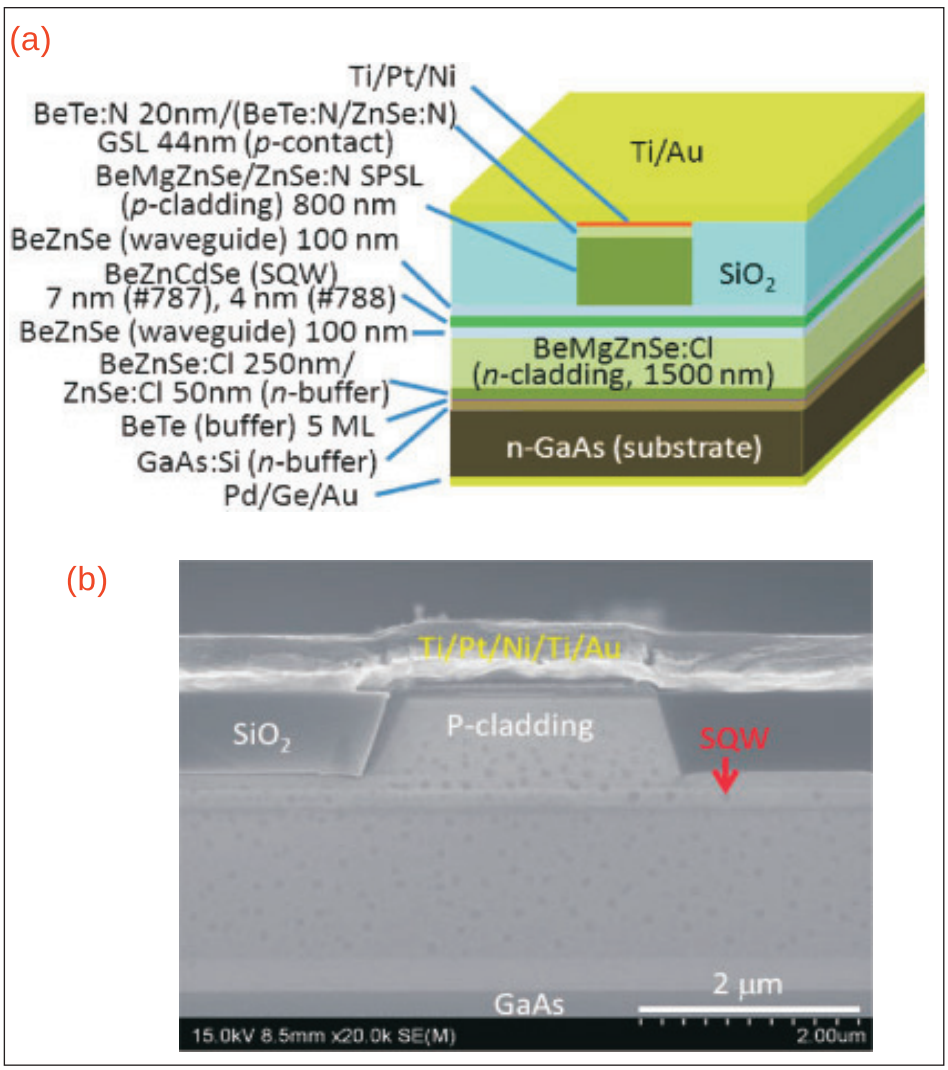

Figure 1. (a) Schematic diagram of yellow laser diode. (b) Cross-sectional scanning electron microscopy image of fabricated #787 LD (2µm wide).

The laser structure used a separate-confinement heterostructure around the BeZnCdSe SQW. Two samples were produced with SQWs containing varying Cd contents and of different thicknesses — a 7nm well with 47% Cd (#787) and a 4nm well with 52% Cd (#788). The thinner well for #788 avoided cracking of the epilayers. The Be content was around 1% in both cases. The p-side included a short-period superlattice (SPSL) cladding with six-monolayer pairs of BeMgZnSe/ZnSe:N (6ML/6ML). Previous work by a group that included Akimoto used 1000nm BeMgZnSe n-cladding. This was increased to 1500nm to suppress light absorption by the GaAs substrate.

Feng and Akimoto report: "The lattice mismatches for p- and n-cladding layers are about +0.03% to +0.05% and −0.10% to −0.11%, respectively. The use of the

SPSL can enhance the p-type doping level of the II–VI cladding layer with a wide bandgap."

Ridge-waveguide lasers were produced by patterned etching 900nm deep. The structure was then covered with 2μm silicon dioxide and polished back with chemical mechanical planarization (CMP). Further etching was performed to expose the metal mask used for the patterned etching. Electrodes were then formed on the p-region and the back-side of the substrate.

The cavities of the devices were formed through cleaving. The facets were coated with silicon dioxide and zirconium dioxide layers to give ~90% reflectivity at both ends of the cavity. The laser diode chips were mounted on copper heat-sinks with indium bonding.

Pulsed lasing above threshold from 500μm-long 5μm-wide laser diodes produced 567nm and 563nm yellow light for samples #787 and #788, respectively. The corresponding full-width at half-maximum (FWHM) values for the peaks were 2.4nm and 1.8nm.

Continuous wave (cw) operation of a 7μm-wide 300μm-long #787 laser diode achieved threshold at 10.8mA and 8.4V. The researchers compare this with a 10μm-wide, 800μm laser diode, previously reported by a group from NAIST and Hitachi in 2011, that achieved threshold at 94mA/9.6V. In terms of current density, Feng and Akimoto's device threshold was 0.51kA/cm^2, compared with 1.175kA/cm^2 for the 2011 report. The 2011 device used a gain-guided rather than refractive index-guided structure.

Feng and Akimoto attributed the low threshold current density for their laser diodes to suppression of lateral leakage current outside of the electrode by the silicon dioxide insulation around the ridge, confining most of the injected current to a vertical direction. The researchers used a similar approach with their recent green/yellow-green laser diodes.

A #788 laser diode with 3μm-wide and 300μm-long cavity achieved a cw threshold at 7.4mA/8.48V. The current density was 0.82kA/cm^2. ■

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Author: Mike Cooke

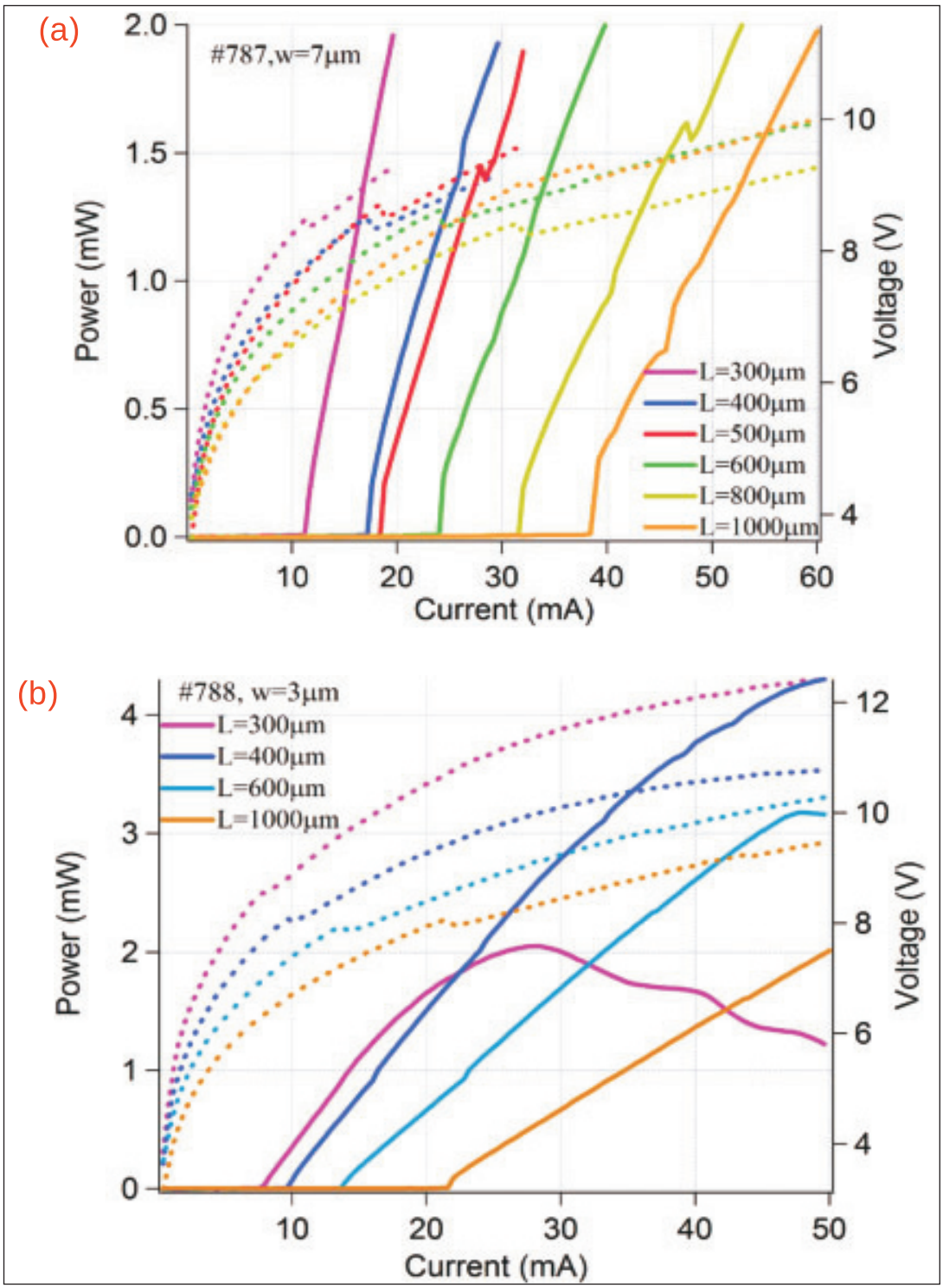

Figure 2. Light output power and voltage–current characteristics with varying mesa length for (a) 7μm-wide laser diodes of sample #787 and (b) 3μm-wide laser diodes of sample #788. Both are under cw operation at room temperature.

Exploring resonant energy transfer from InGaN wells to polymers

Researchers hope to guide future efforts towards rational design of hybrid devices that can optimize efficiency and limit competing losses.

University of Cyprus, Cyprus University of Technology, and University of Crete have been exploring the potential of Förster resonant energy transfer (FRET) from an indium gallium nitride (InGaN) single quantum well (SQW) to a light-emitting polymer layer [G. Itskos et al, J. Chem. Phys., vol143, p214701, 2015].

Rather than the usual transfer of energy and charge in electronic systems, FRET just transfers energy, potentially avoiding losses associated with charge transport and recombination. Such losses can be particularly severe at interfaces between materials.

FRET depends on dipole–dipole coupling between two light-sensitive materials ('chromophores') with non-radiative energy transfer from a donor to an acceptor. Since the dipole-dipole interaction is short range, the effect falls off rapidly with distance between the donor and acceptor. The effect is similar to near-field communication, except that it occurs at light rather than radio frequencies.

Proposals have been made and demonstrated for using the FRET effect in light-emitting and light-harvesting devices.

Grigorios Itskos, primary researcher and assistant professor at the University of Cyprus, comments: "The outcome of our investigation can guide future efforts towards a rational design of hybrid geometries that can optimize FRET and limit competing losses to render FRET-based devices feasible."

While InGaN is already used for commercial light-emitting diodes (LEDs), Itskos believes that the functionality of such devices could be further increased by combining them with soft semiconductors such as light-emitting polymers. "The spectral tunability and high light-absorption and emitting efficiency of the polymers can be exploited to demonstrate efficient down-conversion of the blue nitride emission, providing a scheme for efficient hybrid LEDs," Itskos says.

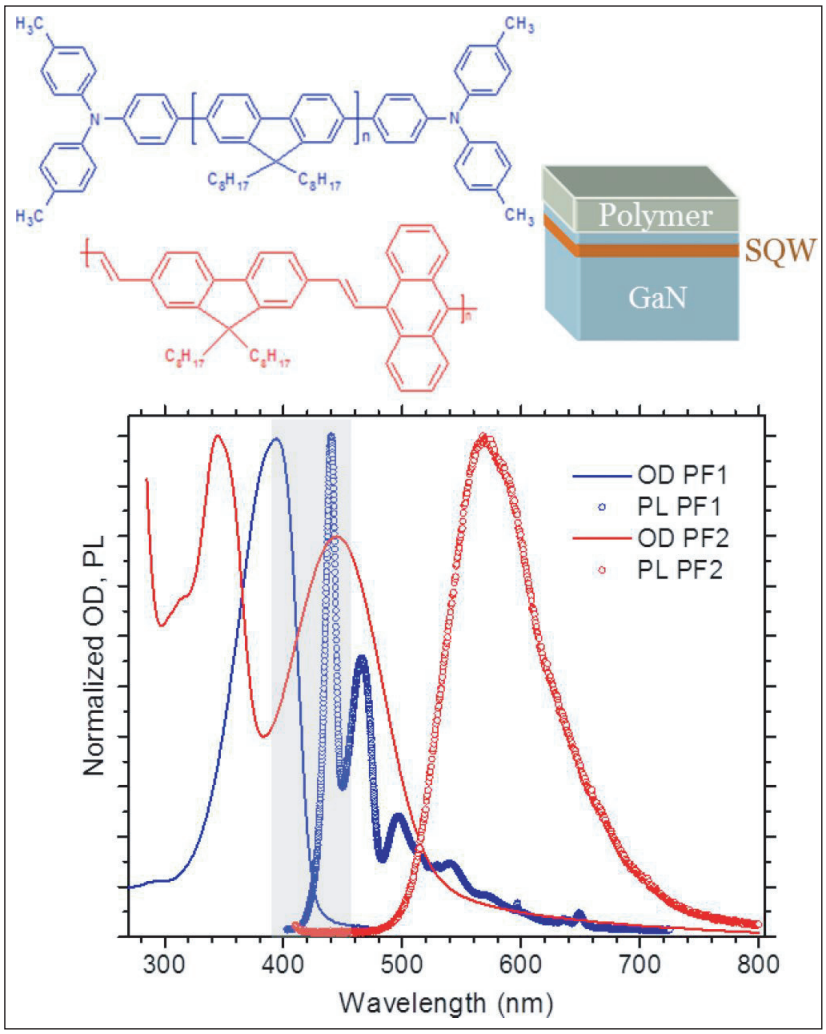

Figure 1. Normalized absorbance (solid) and PL (scatter) excited at 350nm of _10nm-thick films of polyfluorenes PF1 (blue) and PF2 (red), employed to complete the hybrid structures. Gray highlighted area indicates PL spectral range of inorganic (Ga,In)N SQWs hybrid component.

The InGaN quantum well structures were grown on c-plane sapphire with GaN template layer using radio frequency molecular beam epitaxy (RF-MBE). The InGaN well was sandwiched between a 0.5μm GaN

buffer and a cap layer. The cap consisted of gallium nitride or aluminium gallium nitride (AlGaN).

Polyfluorene homo- or co-polymers (Figure 1) were spin-coated in solution onto the heterostructures. The homopolymer (PF1) was poly(9,9-diocty-fluorenyl-2,7-diyl) end-capped with N,N-bis (4-methylphenyl)-aniline, typically known as PFO. The copolymer (PF2) was poly[(9,9-dioctyl-2,7-divinylenefluorenylene)-alt-co-(9,10-anthracene)].

The team used steady-state photoluminescence (PL), photoluminescence excitation (PLE), and time-resolved PL (TR-PL) to study the influence on FRET of SQW width (Figure 2), InN mole fraction, and growth temperature, along with top cap thickness, content, growth temperature, and n-doping. The researchers comment: "To our knowledge, no studies where the influence of doping on FRET has been explicitly examined have been reported to date."

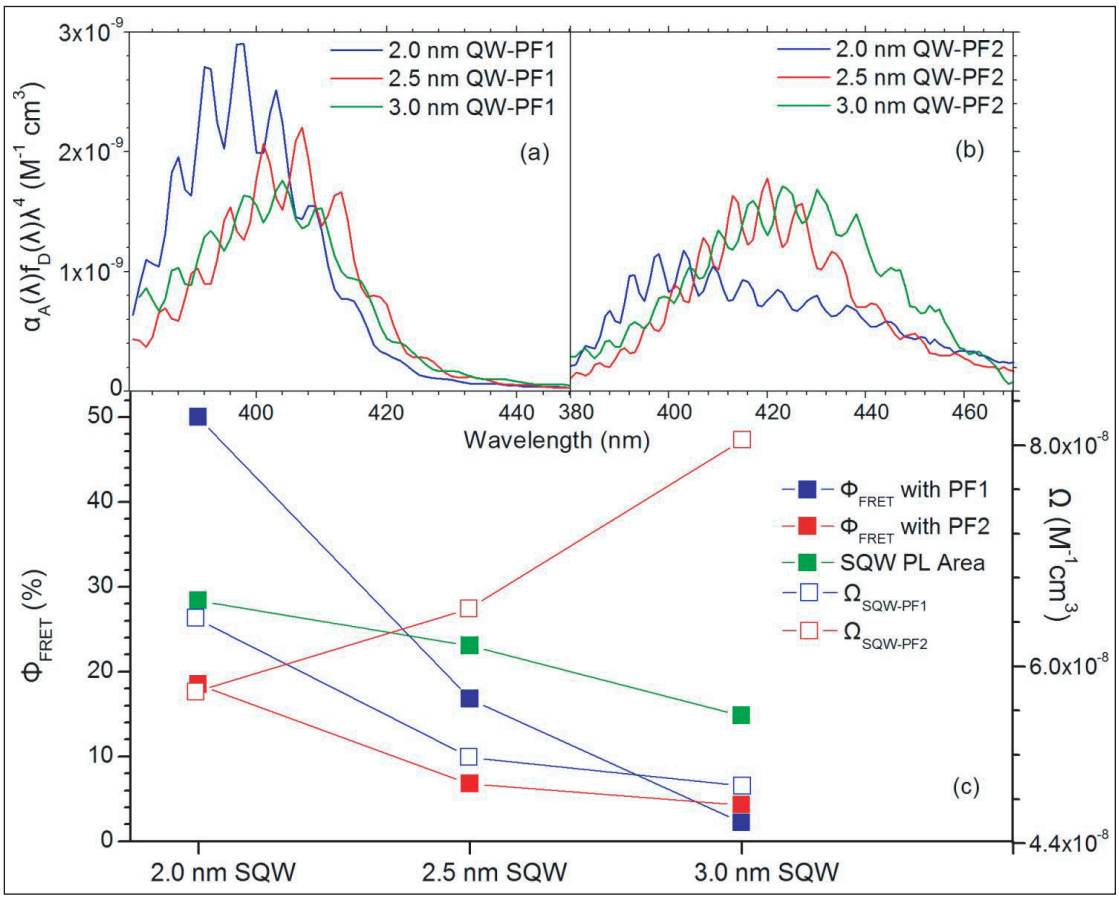

Figure 2. (a, b) Products of area-normalized emission of three SQWs with different well widths with molar absorptivity _A as a function of wavelength (_) of PF1, PF2, respectively. (c) FRET efficiency (blue, red solid symbols), spectral overlap (_) (blue, red hollow symbols) and QW PL integrated area (green solid symbols) for hybrid structures based on PF1, PF2, and three SQWs.

Simulations suggested that n-type doping of the cap would shift the electron wavefunction more to the center of the QW, improving overlap with the hole wavefunction that was little affected in position. Increased overlap should lead to increased light emission in photoluminescence or an increased efficiency of FRET coupling with the polymer layers. However, the experimental results showed a detrimental effect of doping on PL efficiency, in contradiction to the simulation model.

Itskos comments: "This constitutes a potential limitation for the implementation of such hybrid structures in real-world electronic devices, as electronic doping is required to produce efficient practical devices. Further studies are needed to establish the exact influence of doping on FRET."

The researchers write: "It is quite possible that doping in such a close proximity to the emission layer leads to dopant diffusion into the well and collisional exciton recombination affecting the QW PL quantum yield. A reduction of the SQW emission yield would then strongly influence the FRET process."

The team found three significant loss mechanisms that compete with FRET. The first loss came from recombination of SQW excitations at the interface with, or hole transfer to, the organic material. "This effect appears more intense in hybrids containing high Al content that appears to promote hole localization at the barrier," the researchers report.

The second loss was from back transfer of carriers and/or interfacial quenching subsequent to energy transfer to the organic acceptor. The final loss route was through quenching of SQW emission and FRET efficiency in the presence of an n-doped nitride interlayer, as discussed above.

According to Itskos, the studies indicate a strong link between the quantum well's luminescence and the hybrid structure's FRET efficiency. This correlation could allow optimizing the luminescent efficiency of the energy donor without the acceptor material layer, before creating an efficient hybrid FRET.

The team plans to perform a systematic study of hybrid structures based on doped nitride quantum wells to investigate the mechanisms via which electronic doping affects the FRET characteristics. ■

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Author: Mike Cooke

Thinning buffer layers for GaN-on-silicon light-emitting diodes

Plessey claims first general-lighting-class high-brightness devices with potential for epitaxy and reduced manufacturing costs.

Plessey Semiconductors Ltd in the UK has been improving its indium gallium nitride (InGaN)-on-silicon light-emitting diode (LED) technology [Liyang Zhang et al, Journal of the Electron Devices Society, vol3, p457, 2015]. A light output power (LOP) of 563mW at 350mA injection was achieved. The wall-plug efficiency was 52.7%.

The researchers comment: "To the best of our knowledge, these results represent the first general lighting class high-brightness GaN-on-Si LEDs using thin buffer layer technology. The technology enables faster epitaxy process throughput and reduced manufacturing costs, while the manufacturability results attest its feasibility as a potential replacement of incumbent sapphire technology."

Furthermore, the use of GaN-on-Si technology could also allow integration of bipolar transistors, Zener diodes and silicon photodiodes.

The team managed to reduce the epitaxial layer thickness to 3.75μm, where normally GaN-on-Si epilayers are between 6μm and 8μm.

Although production on silicon substrates promises reduced material and processing costs from the larger-diameter wafers (estimated 40–60% savings at die level), producing crack-free epilayers is challenging. The lattice constant mismatch is −17%. GaN and silicon also have different thermal expansion rates, with a +115% mismatch giving tensile stress on cool-down. By contrast, GaN buffers grown on sapphire have a

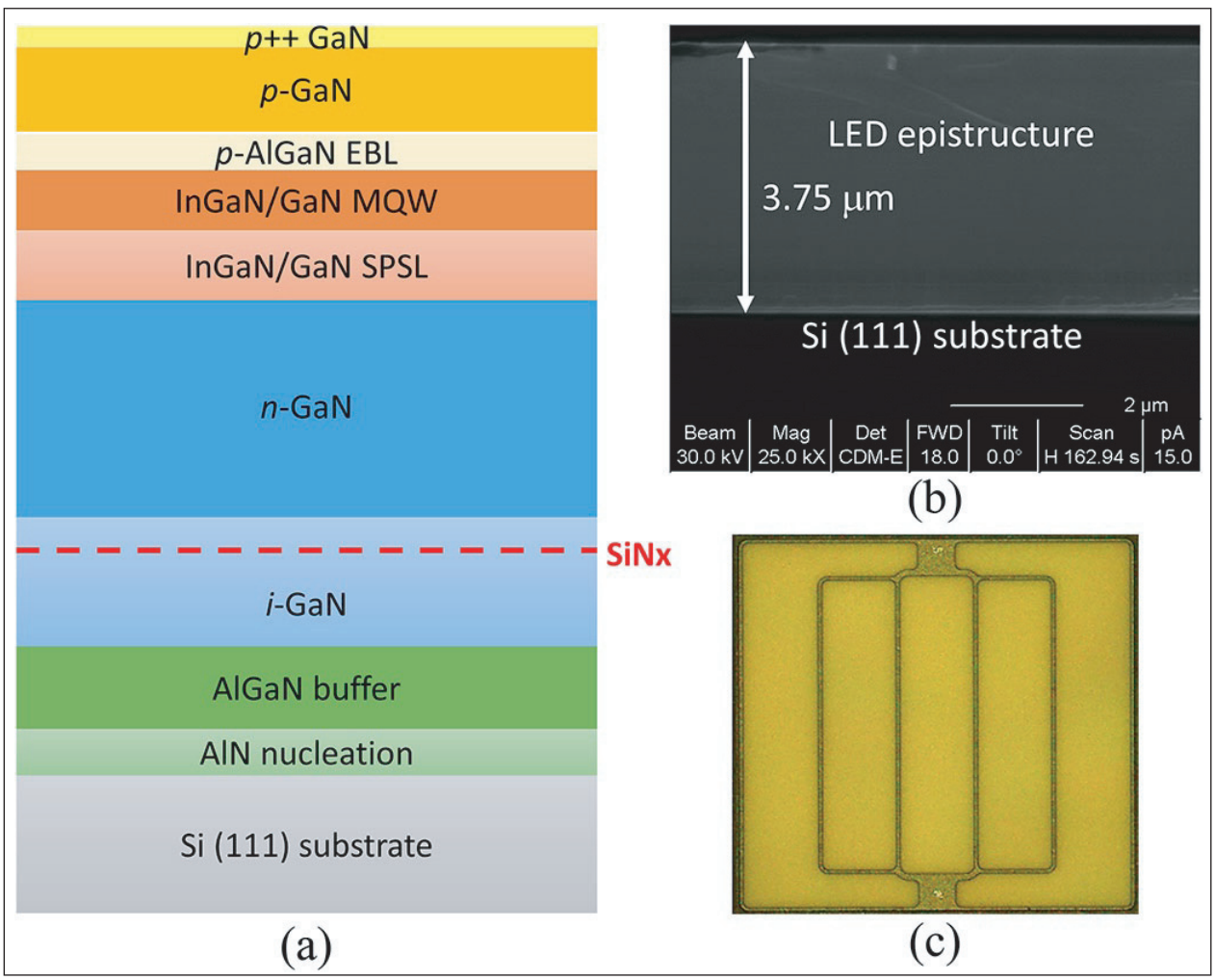

Figure 1. (a) Schematic diagram of LED epi-structure, (b) Scanning electron microscope (SEM) cross section and (c) device layout.

smaller –34% mismatch, giving compression of the epilayer on cooling, which also has the advantage of tending to inhibit cracking.

The researchers report: "Device processing is performed in a wafer fab which used to be a depreciated CMOS manufacturing line. This facility allows the use of systems such as cassette-to-cassette wafer handling and semi-automated stepper lithography, which greatly improves process throughput."

Full implementation of automated processing equipment such as lithography stepper tools requires wafer bow to be controlled.

The LED epitaxial material (Figure 1) was grown on 150mm silicon (111) wafers using ~1000°C metal-organic chemical vapor deposition (MOCVD). The substrate was 1mm thick.

The aluminium nitride (AlN) nucleation and graded aluminium gallium nitride (AlGaN) buffer layers were 200nm and 600nm, respectively. The unintentionally doped gallium nitride (i-GaN) buffer consisted of a slow-growth 800nm layer for recovery of crystallinity from the highly defective AlGaN, and silicon nitride interlayer for subsequent overgrowth of a thin layer of i-GaN. This was followed by 1.8µm of heavily silicon-doped n-GaN.

The LED active layer consisted of a 20-pair InGaN/GaN short-period superlattice (SPSL) and a 4-pair InGaN/GaN multiple quantum well (MQW). The p-type layers included an electron-blocking layer (EBL). Using a nitrogen atmosphere during the EBL growth improved incorporation of the magnesium dopant.

Atomic force microscope (AFM) analysis gave a dislocation density of $5x10^8/cm^2$ on optimized structures. V-pits of ~100nm diameter formed on the dislocations above the superlattice layer with a $3.3x10^8/cm^2$ density. Introducing a partial hydrogen ambient environment during growth of the GaN layers in the SPSL and MQW was found to reduce V-pit density and diameter. Wafer bow was reduced to less than 10µm.

The p-electrode consisted of a thin nickel contact and silver-based mirror. The titanium/aluminium n-contact was made to the Ga-face of the n-GaN layer. The researchers add: "To improve current spreading, an additional thicker Ti/Al electrode is formed directly above the n-electrode and is connected together through a series of small vias."

The wafer was then bonded to a silicon handle wafer to allow the growth substrate to be removed using chemical mechanical polishing (CMP) and wet etch. The AlN and AlGaN layers were removed with plasma etching. Potassium hydroxide was used to roughen the exposed n-GaN surface, improving light extraction.

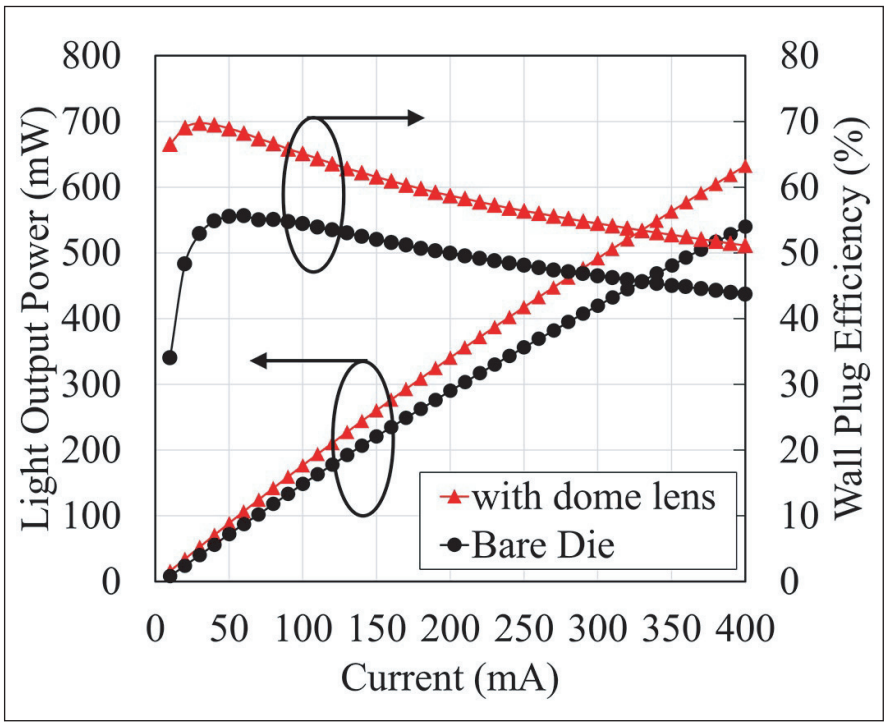

Figure 2. Light output power and wall-plug efficiency of bare die and dome lens packaged die as function of injection current.

The LED wafer was finally singulated into thin-film 1mmx1mm chips and mounted in 3.5mmx3.5mm plastic packages (3535).

The light output power (LOP) of bare dies was 480mW at 350mA injection and 3.05V forward potential (Figure 2). The dominant wavelength was 452nm. Encapsulated with a silicone domed lens allowed the LOP to be increased to 563mW, representing a wall-plug efficiency of 52.7% at $35A/cm^2$. Reducing the injection current density to $10A/cm^2$ would increase the efficiency to 64%.

The researchers quote, as state-of-the-art comparison, devices from Osram, produced on sapphire with similar configuration, that achieve 600–630mW LOP.

The hot-cold factor — the ratio of performance at 90°C/20°C — was 0.94. This is comparable with tier-1 devices on sapphire, according to the researchers.

Electroluminescence wavelength standard deviation over devices from 300 wafers was 2nm with a mean wavelength of 455nm. The researchers comment: "Statistically, this translates to 80% and 95% of the dies within a 5nm and 8nm bin range, respectively. This is a significant result, as LED die binning and sorting is a major cost and throughput overhead, and this technology paves the way for reduced binning and improved manufacturing yield."

Improved device reliability was indicated by 95% of devices having a 5V reverse-bias leakage less than 0.1µA. ■

http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=7174951

Author: Mike Cooke

Scandium nitride buffer for gallium nitride on silicon applications

Researchers grow a twin-free single-crystal ScN epitaxial layer as a buffer giving small mismatch for GaN-on-Si.

Researchers in Germany are proposing scandium nitride (ScN) as a suitable buffer for gallium nitride (GaN) on silicon (Si) growth [L. Lupina et al, Appl. Phys. Lett., vol107, p201907, 2015]. The attraction of ScN is a very small mismatch with GaN of less than 0.1%. This compares with the GaN/Si mismatch of ~17%.

However, when ScN is grown directly on silicon the resulting material suffers from serious crystal defects. The team — from IHP, Technische Universität Berlin, Siltronic AG, and BTU Cottbus — has developed a growth technique where yttrium (Y_2O_3) and scandium (Sc_2O_3) oxide are grown first. These layers allow single-crystal layers of ScN to be developed that avoid stacking faults away from the interface. The mismatch between ScN and Sc_2O_3 is estimated at 8.5%.

The researchers see potential application for GaN devices such as light-emitting diodes, laser diodes, photo-detectors, and high-power and high-frequency electronics.

The researchers comment that "based on the use of highly insulating oxides, the ScN/Sc_2O_3/Y_2O_3/Si buffer approach can, in principle, be further engineered for improved electrical breakdown field strength with respect to the Si interface, which is of importance for high-power/high-frequency applications of GaN-on-Si systems."

The researchers prepared templates with Sc_2O_3 and Y_2O_3 layers on 4-inch (111) silicon (Sc_2O_3/Y_2O_3/Si) by molecular beam epitaxy. The scandium nitride was grown on the template in a plasma-assisted molecular beam epitaxy (PAMBE) reactor chamber with electron-beam evaporation of elemental scandium and nitrogen radio-frequency plasma as sources.

X-ray and electron microscope analysis showed that the overgrown ScN layer was a single crystal with 'rock salt' structure (Figure 1) for growth temperatures less than 700°C. Additional x-ray diffraction peaks appear above 700°C that indicate that the material then consisted of differently oriented ScN crystal grains,

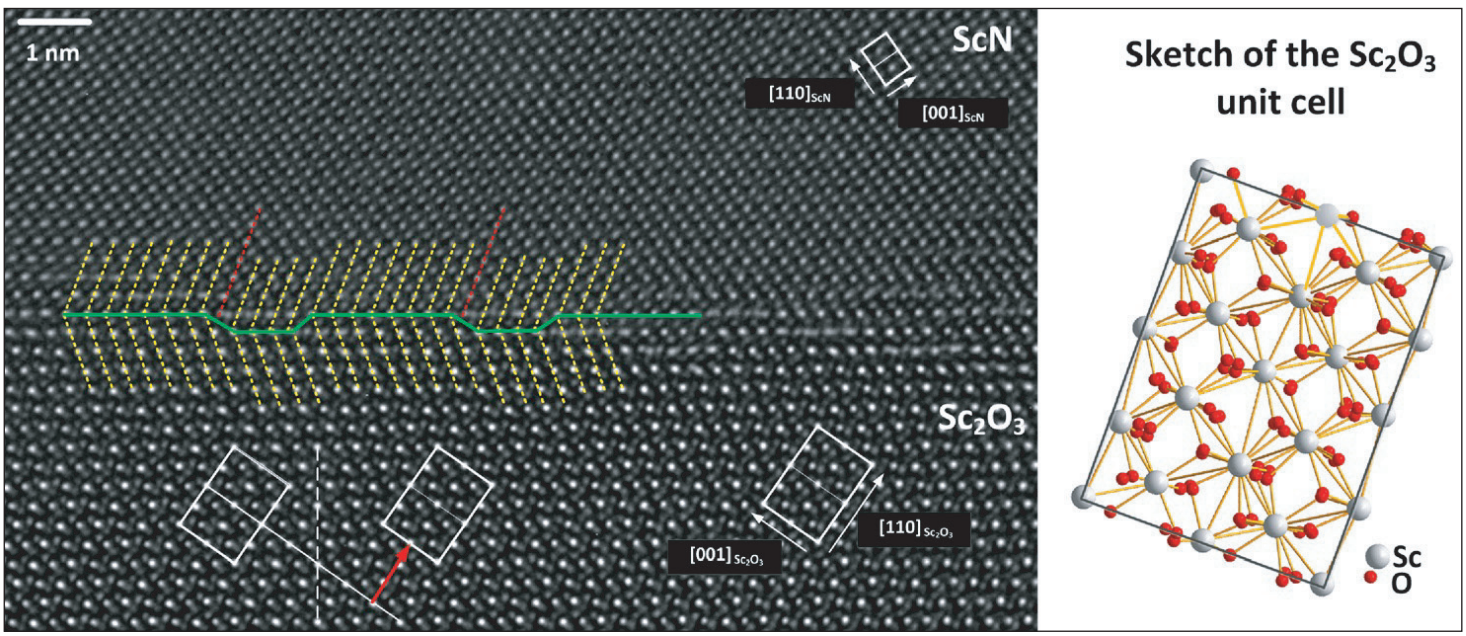

Figure 1. High-resolution transmission electron microscope (HRTEM) image obtained on Sc_2O_3 (lower part)/ ScN (upper part) interface and sketch of Sc_2O_3 unit cell. The red vector indicates stacking fault in anion sublattice of Sc_2O_3.

along with polycrystalline regions. These defects are thought to arise due to decomposition of the oxide buffer or the formation of Sc_2O_3/ScNO during the ScN growth.

The tensile strain was also assessed using x-ray analysis. It was found to increase with temperature. The researchers attribute this to strong oxygen incorporation in the ScN at higher temperature. They report: "This hypothesis was verified by a comprehensive investigation of the ScN/Sc_2O_3 interface using x-ray photo-electron spectroscopy, time-of-flight secondary-ion mass spectrometry, transmission electron microscope/energy-dispersive x-ray spectroscopy, and ab-initio calculations, which will be reported in a separate publication."

Raman analysis of phonon/lattice vibration effects on photo-luminescence suggested that material grown at 300°C and 400°C suffered from lower optical quality, probably due to point defects (Figure 2). The researchers concluded that 600°C was an optimal growth temperature.

The ScN energy bandgap was found to decrease with the thickness of the layer. The researchers suggest that this is due to decreasing oxygen concentration in thicker layers. The bandgap of Sc_2O_3 is 6.0eV and that of bulk ScN is 2.1eV.

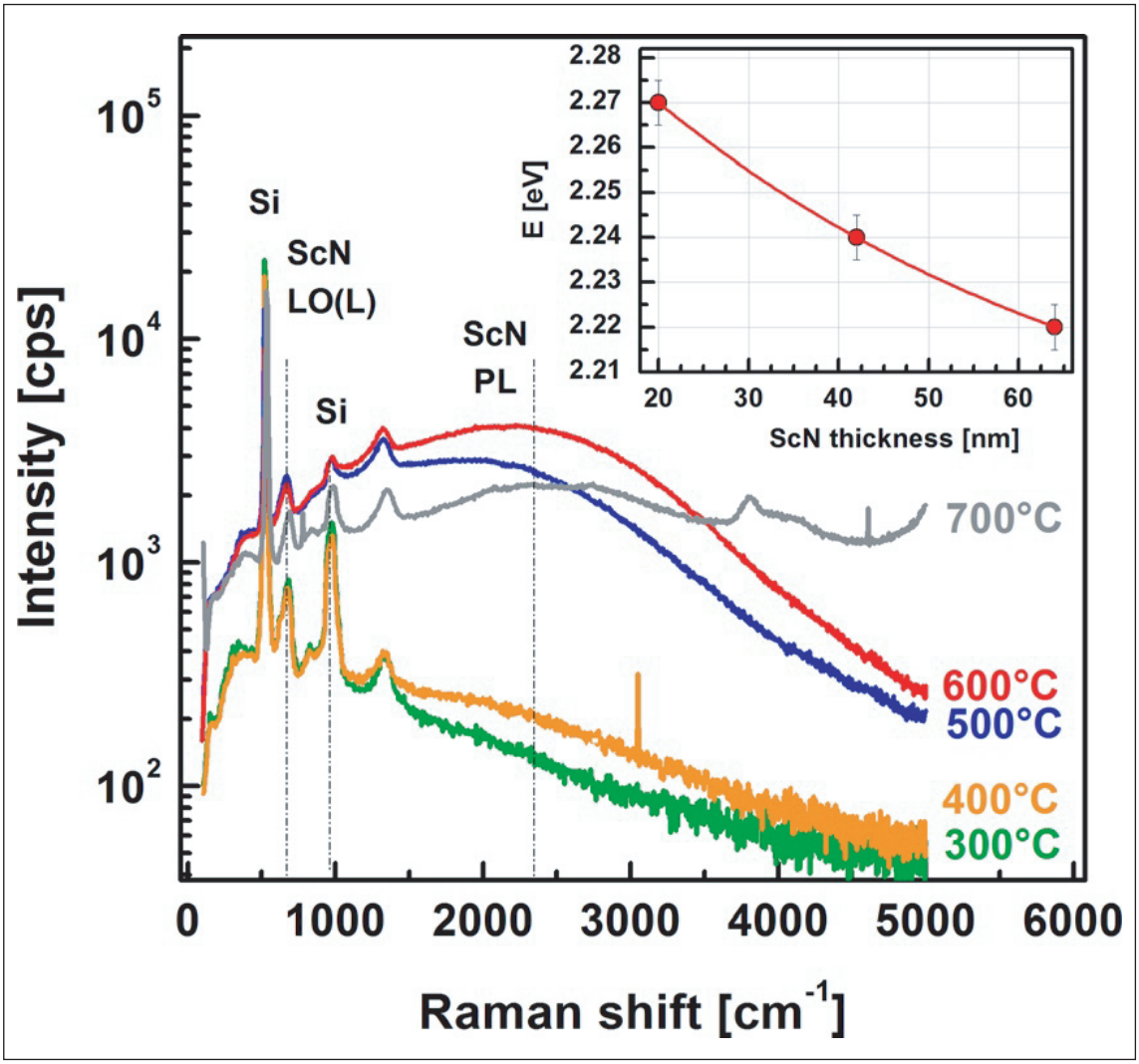

Figure 2. Room-temperature Raman spectra of about 20nm-thick ScN layers deposited at temperatures ranging from 300°C to 700°C. Excitation wavelength of 488nm was used as pump source. Inset: ScN bandgap obtained from ScN photoluminescence peak plotted as a function of ScN film thickness, grown at 600°C.

The researchers see potential application for GaN devices such as light-emitting diodes, laser diodes, photo-detectors, and high-power and high-frequency electronics.

The researchers comment: "Based on the use of highly insulating oxides, the ScN/Sc_2O_3/Y_2O_3/Si buffer approach can, in principle, be further engineered for improved electrical breakdown field strength with respect to the Si interface, which is of importance for high-power/high-frequency applications of GaN-on-Si systems."

Bandgaps for ScON compounds would be expected to be between these values.

The researchers report: "For an about 60nm-thick ScN layer, a bandgap value of about 2.22±0.005eV is extracted, indicating a relatively low oxygen level in the main part of the film."

The 600°C material also was found in further x-ray analysis to be free of stacking twin defects, where the layer sequence changes to another type and back again to the original. The researchers comment: "It is noted that this result is in contrast to the observations done for ScN films grown directly on Si(111) substrates."

■

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Author: Mike Cooke

Reducing current leakage in aluminium gallium nitride transistors on silicon

Researchers claim record level of current leakage for AlGaN HEMTs on silicon, comparable to devices on any other substrate.

Researchers in the USA have reduced current leakage for aluminium gallium nitride (AlGaN) high-electron-mobility transistors (HEMTs) on silicon to the level achieved for devices produced on much more expensive silicon carbide [Bo Song et al, IEEE Electron Device Letters, published online 3 November 2015].

The team from Cornell University, University of Notre Dame and IQE Massachusetts used re-grown source/drain contacts that avoided alloying processes to reduce contact resistance. The researchers comment: "HEMTs with non-alloyed contacts avoid unfavorable high-temperature processes, thus effectively suppressing the leakage commonly observed in AlGaN HEMTs."

Such HEMTs are being developed for high-speed high-power radio-frequency electronics, along with high-power conversion and switching.

The epitaxial material structures for the HEMTs (Figure 1) were grown on 6-inch (150mm) silicon using metal-organic chemical vapor deposition (MOCVD). The GaN buffer was 1.3µm thick.

The non-alloyed contacts were created with 660°C molecular beam epitaxy (MBE) of heavily doped n-type GaN. The re-growth regions for the n^+-GaN were made by reactive ion etch to a depth of 40nm through a silicon dioxide mask. The re-growth material was 80nm thick. The ohmic contact metals were titanium/gold.

Alloyed-contact comparison devices were produced with a titanium/aluminium/nickel/gold stack annealed in nitrogen at 870°C for 20 seconds.

The specific contact resistances of the re-grown and alloyed contacts were 0.1Ω-mm and 0.3Ω-mm, respectively. Hall measurements gave respective two-dimensional electron gas (2DEG) concentrations of $7.63 \times 10^{12}/cm^2$ and $4.57 \times 10^{12}/cm^2$. The corresponding mobilities were $1620 cm^2/V\text{-}s$ and $1420 cm^2/V\text{-}s$.

The HEMT devices had 2µm-long, 50µm-wide nickel/gold gates. The gate-drain/gate-source spacings were 4.75µm/2µm. No passivation was used.

The output drain current at 1V gate and 6V drain bias was 0.42A/mm for the non-alloyed re-grown contact and 0.29A/mm for the alloyed device. The respective peak transconductances were 142mS/mm and 126mS/mm. The corresponding threshold voltages

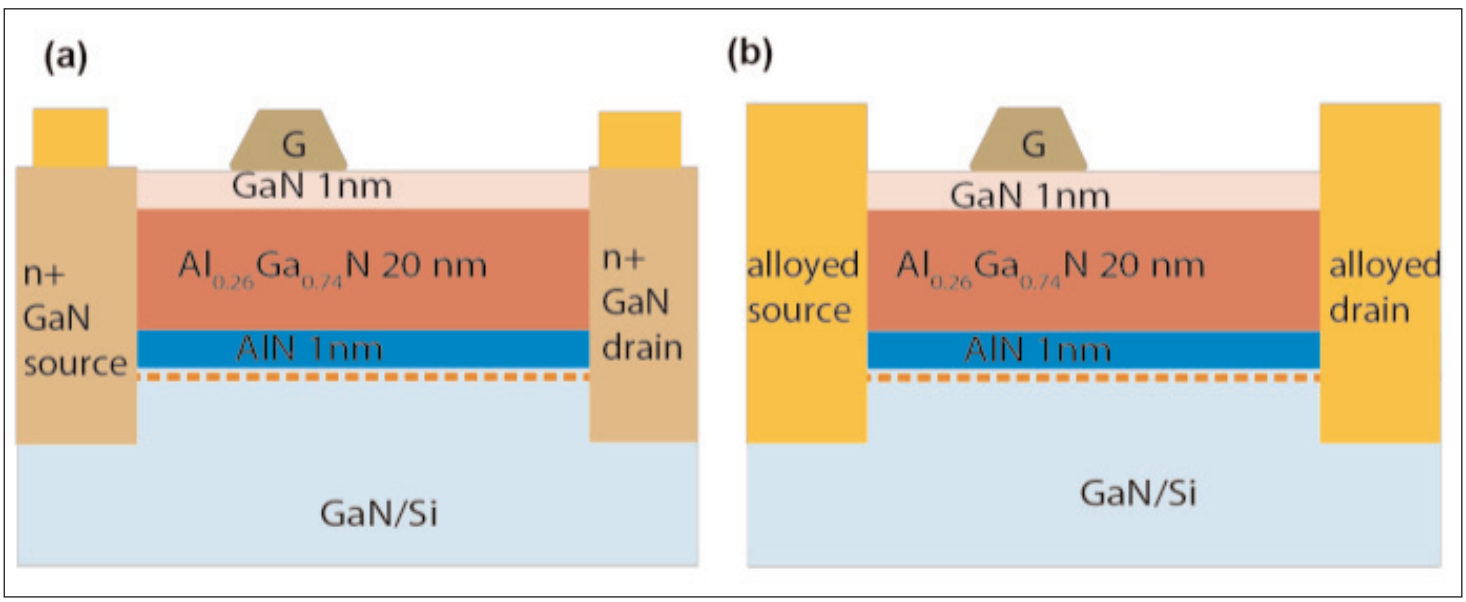

Figure 1. Schematic cross section of AlGaN/GaN HEMT on silicon with (a) non-alloyed contacts re-grown by MBE and (b) alloyed contacts.

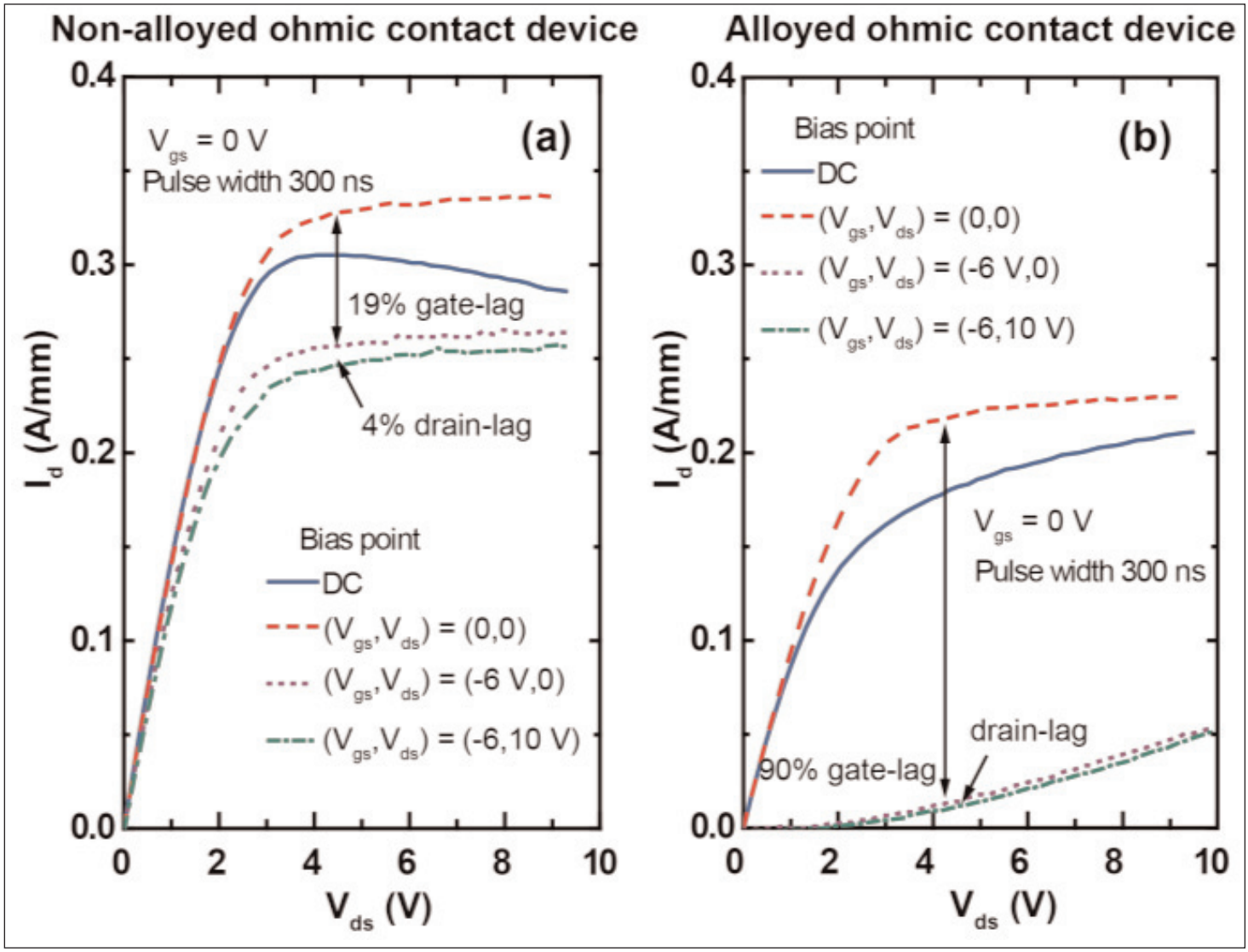

Figure 2. Pulsed current–voltage measurements in air at 0V gate potential for (a) non-alloyed and (b) alloyed devices.

were –2V and –1.4V, putting both devices firmly in the normally-on/depletion-mode camp.

The off-state gate leakage was ~10^{-12}A/mm for the non-alloyed/re-grown HEMT. The corresponding leakage for the alloyed device was ~10^{-6}A/mm. The researchers comment that the non-alloyed HEMT is close to the record low for GaN HEMTs produced on any substrate (e.g. expensive silicon carbide).

The subthreshold slope was also reduced in the non-alloyed HEMT — 73mV/decade, compared with 166mA/decade for the alloyed device. The theoretical limit at 300K is around 60mV/decade. The on/off current ratio is given as 2.5x10^{11} for the non-alloyed HEMT and 1.1x10^{5} for the alloyed device.

Soft breakdown for the alloyed HEMT occurred around 100V at 100μA/mm (10^{-4}A/mm), compared with the non-alloyed/re-grown contact device maintaining a low leakage at less than 10^{-10}A/mm up to 156V. The increase in current after 156V bias was attributed to field crowding near the gate edge. Neither of the devices employed field plates to reduce such crowding.

Current collapse, and gate and drain lag, were assessed using pulsed measurements (300ns width, 0.5ms period). The gate lag was 90% for the alloyed HEMTs while the non-alloyed devices reduced this to 19% (Figure 2). The gate lag in the non-alloyed HEMTs could be due to local air breakdown or residue traps. The 4% drain lag of the non-alloyed HEMTs could not be compared with a value for the alloyed devices since the gate lag in the latter case was so severe.

The researchers comment: "The small current collapse in the non-alloyed devices correlates well with its low gate leakage: the low leakage prevents electrons being trapped within hundreds of microseconds when the device is held at the off state. On the other hand, the high leakage in the alloyed device facilitates electron trapping and the electron emission rates from the traps are too low to recover the current, thus a severe current collapse." ■

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Author: Mike Cooke

Pushing on the vertical limits of gallium nitride power electronics

Researchers at the universities of Notre Dame and Cornell have been developing vertical rather than lateral structures for power applications. Mike Cooke reports.

Applications for III-nitrides such as gallium nitride (GaN) have recently extended beyond the quarter-century-old market for short-wavelength light-emitting devices into high-frequency and switching power electronics. The electronic uses of GaN depend on a high critical field for breakdown, associated with the wide bandgap of the material, while maintaining a relatively high mobility.

Up to now, work on the commercialization of GaN power switching and conversion devices has mostly used lateral current flow in high-electron-mobility transistors and other unipolar transistors on sapphire, silicon carbide (SiC) or silicon. However, vertical structures could avoid problems such as field and current crowding that lead to premature breakdown. Bulk and free-standing single-crystal GaN enables such vertical devices and much progress in this direction has been made in the past year.

The University of Notre Dame and Cornell University in the USA have been at the center of work using molecular beam epitaxy (MBE) and metal-organic chemical vapor deposition (MOCVD) on bulk gallium nitride (GaN) substrates to create vertical p–n diode structures. Cornell and Notre Dame, sometimes in collaboration with others, have published a number of papers and conference presentations in the past couple of months.

The researchers hope their work will lead to superior three-terminal GaN power switches using vertical p–n junctions, reaching towards the theoretical limits of GaN's critical field. Present lateral devices that operate in a unipolar manner (that is, not based on p–n junctions) tend to break down through gate leakage and allied effects, and not because of the intrinsic avalanche mechanism that gives the high critical field based on GaN's wide bandgap.

Pushing toward critical field

In [Meng Qi et al, Appl. Phys. Lett., vol107, p232101, 2015], Notre Dame and Cornell researchers report: "GaN vertical p–n junctions with off-state leakage current as low as 3nA/cm^2, breakdown field E_{br}~3.1MV/cm, and R_{on}~0.23mΩ-cm^2 are achieved in epitaxial diodes. These breakdown and leakage characteristics represent the highest performance metrics in GaN p–n junction diodes grown by MBE."

The researchers used bulk GaN substrates to reduce threading dislocation densities (TDDs). Such defects cause premature breakdown of electron devices. The estimated peak electric field in some of their devices of 3.1MV/cm was derived on the basis of simulations. They comment: "This electric field of 3.1MV/cm is close to the estimated critical field of 3.5–3.8MV/cm for GaN. It is among the highest experimental results reported."

MBE has a number of advantages over MOCVD such as a high degree of control of alloy compositions, high-quality aluminium nitride (AlN) layers and heterostructures, and efficient magnesium (Mg) acceptor doping for buried p-type layers that do not need activation annealing.

A disadvantage of MBE tends to be its slower growth rate compared with MOCVD or hydride vapor phase epitaxy (HVPE). Higher growth rates can be achieved with plasma rather than ammonia MBE, allowing thicker drift layers to be achieved. Thicker layers should lead to higher breakdown voltages (BVs) by reducing the peak electric field for a given potential difference across a structure.

The researchers also observed strong electroluminescence (EL) from their devices, indicating the high quality of the material. They add: "Since we can design for light to carry away a significant fraction of energy out of the diode, it can prove to be a very attractive way for device cooling in power electronics: a technique that has not been possible in indirect-bandgap power semiconductors such as Si and SiC diodes and transistors before."

Si and SiC are semiconductors with an indirect bandgap where recombination in p–n diodes produces heat rather than photons. Schottky-diode-based

metal–semiconductor junctions also tend to produce heat rather than light — carrier transport is through thermionic emission of electrons from the semiconductor into the metal. Heat generation in Schottky devices occurs in the metal where electrons dump their energy.

The p–n structures (Figure 1) were grown on GaN substrates with three different levels of threading dislocation density: 1–2x10^7/cm^3, 2-5x10^5/cm^3 and 5x10^4/cm^3. The MBE growth was carried out on the metal-polar (Ga) face of the substrate. An extensive surface preparation cleaning and outgasing procedure was carried out over several hours to remove con-

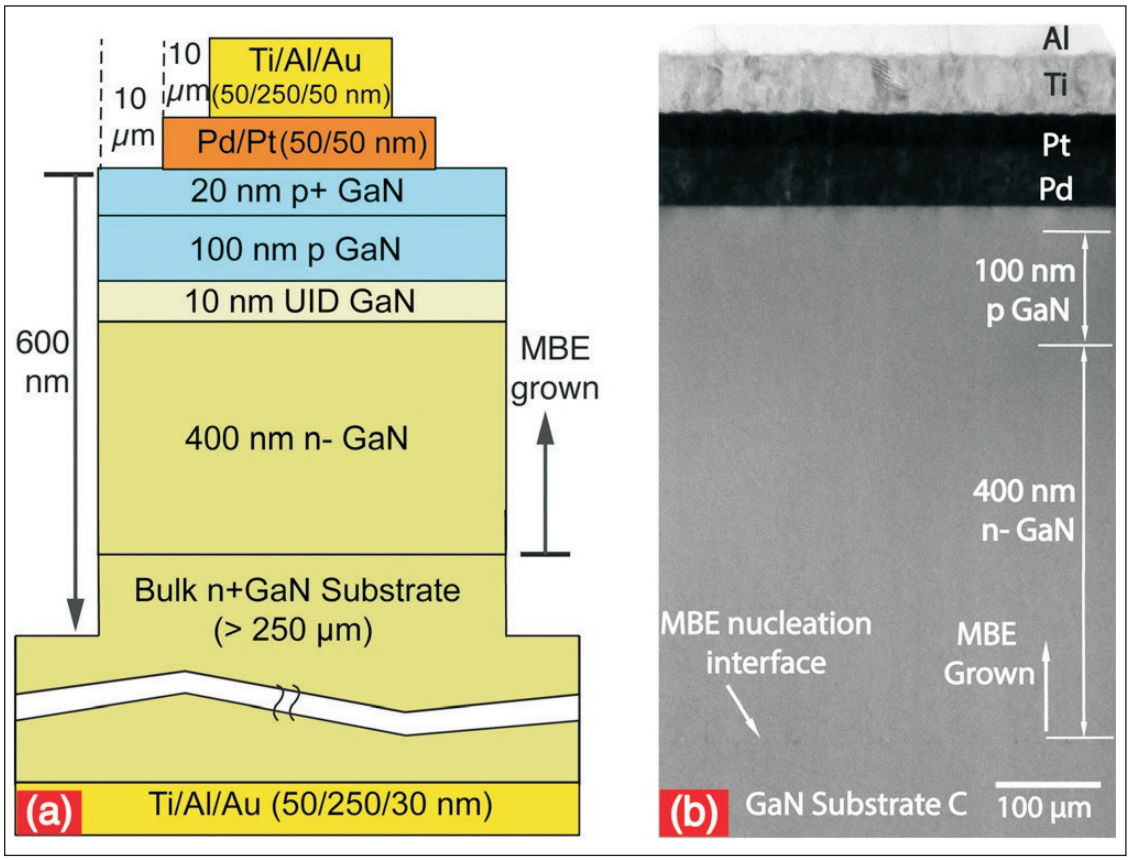

Figure 1. (a) Schematic structure and (b) cross-section TEM of fabricated vertical MBE-grown p-n diodes on low-dislocation density bulk GaN crystal substrate C (TDD~5x10^4/cm^3).

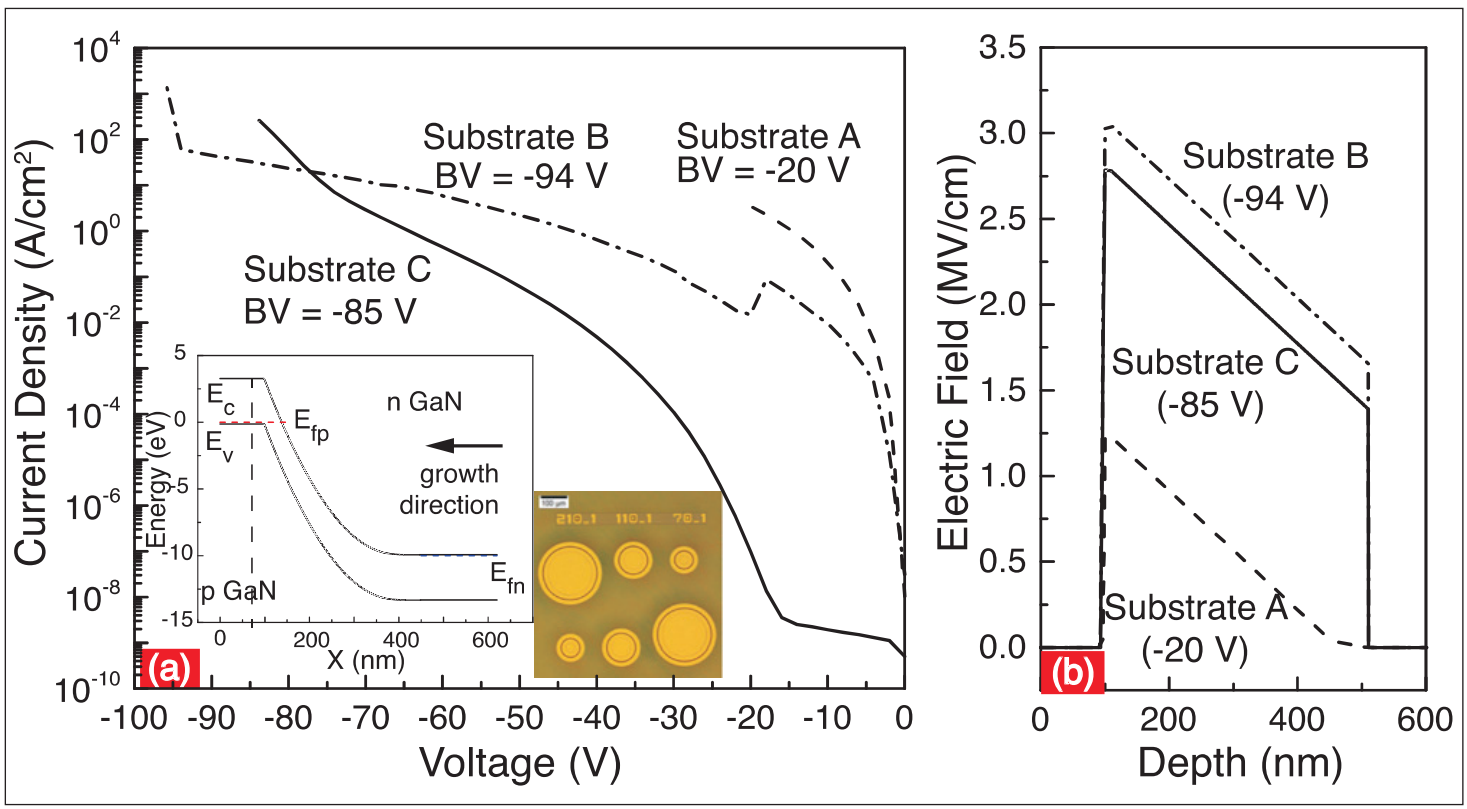

Figure 2. (a) Semilog plot of I–V characteristics with reverse bias voltages until breakdown for three vertical GaN p–n junctions on different GaN substrates. Inset figures show energy band diagram with 10V bias, as well as image of fabricated diodes under optical microscope. (b) Electric field profiles along vertical direction of three p-n junctions on different substrates at corresponding breakdown voltages.

taminants. The MBE began with a pure Ga flux soak to give a Ga-rich surface.

The 400nm GaN buffer layer was grown using plasma-assisted MBE at 720ºC. The nitrogen plasma was created using a 200W RF power source. The Mg and Al cells of the MBE equipment were kept heated at suitable standby temperatures to avoid oxygen out-gasing into the reaction chamber.

Oxygen acts as a donor dopant in GaN. Breakdown voltages in vertical GaN devices are very sensitive to doping density, and the researchers wanted careful control of the unintentional doping (UID) level. In particular, they wanted a high acceptor over donor ratio so that the bulk of the depletion/drift region was on the n-side. The team achieved an acceptor/donor density ratio of about 100.

The 10nm UID GaN layer was grown with the temperature ramping down from 720ºC to 600ºC. At the same time, the Mg cell temperature was increased from 200ºC to 400ºC to prepare for the growth of the p-GaN layers.

Excess Ga drops on the surface of the epitaxial material were removed using hydrochloric acid. Diode mesas were formed with reactive ion etching to a depth of 600nm. The n-electrode metals were applied to the back-side of the wafer. After deposition of the p-electrode metals, the devices were annealed at 400ºC for 10 minutes. The fabrication was completed with the deposition of titanium/aluminium/gold (Ti/Al/Au) metal pads on the p-electrodes.

Electroluminescence for substrate B (TDD 2–5x10^5/cm^3) was found with wavelength peaks around 3.2eV and 2.2eV with 330A/cm^2 injection, +5V bias. The 3.2eV radiation was associated with 3.4eV electron–hole recombination in the depletion region and photon absorption and re-emission from electrons dropping to the Mg acceptor levels ~0.2eV above the valence band in the p-GaN. The 2.2eV radiation was attributed to deep-level transitions.

Diodes on substrate C with the lowest TDD level of under 10^4/cm^3 showed extremely low current densities of less 1nA/cm^2 in the +2V to –5V region (Figure 2). The on/off current ratio for +5V/–5V bias was 10^{13}. Diodes on the higher TDD substrates A and B had reverse current leakage of around 10^{-4}A/cm^2 density and on/off ratio of around 10^8. The highest breakdown voltage of 94V was for substrate B diodes. The low TDD substrate C diode had a slightly reduced breakdown at 85V reverse bias. Details of the mechanism for reverse bias breakdown are still under investigation.

Powering over rivals

Cornell and Notre Dame also claimed a record 'figure-of-merit' (FOM) combination of breakdown voltage and on-resistance (R_{on}) [Zongyang Hu et al, Appl. Phys. Lett., vol107, p243501, 2015]. At the same time, the current–voltage profiles and temperature-dependent modeling suggested a long Shockley–Read–Hall (SRH) lifetime.

The researchers comment: "The long SRH lifetime and low R_{on} in GaN demonstrated in this work indicate possibilities to design GaN p–n diodes utilizing the

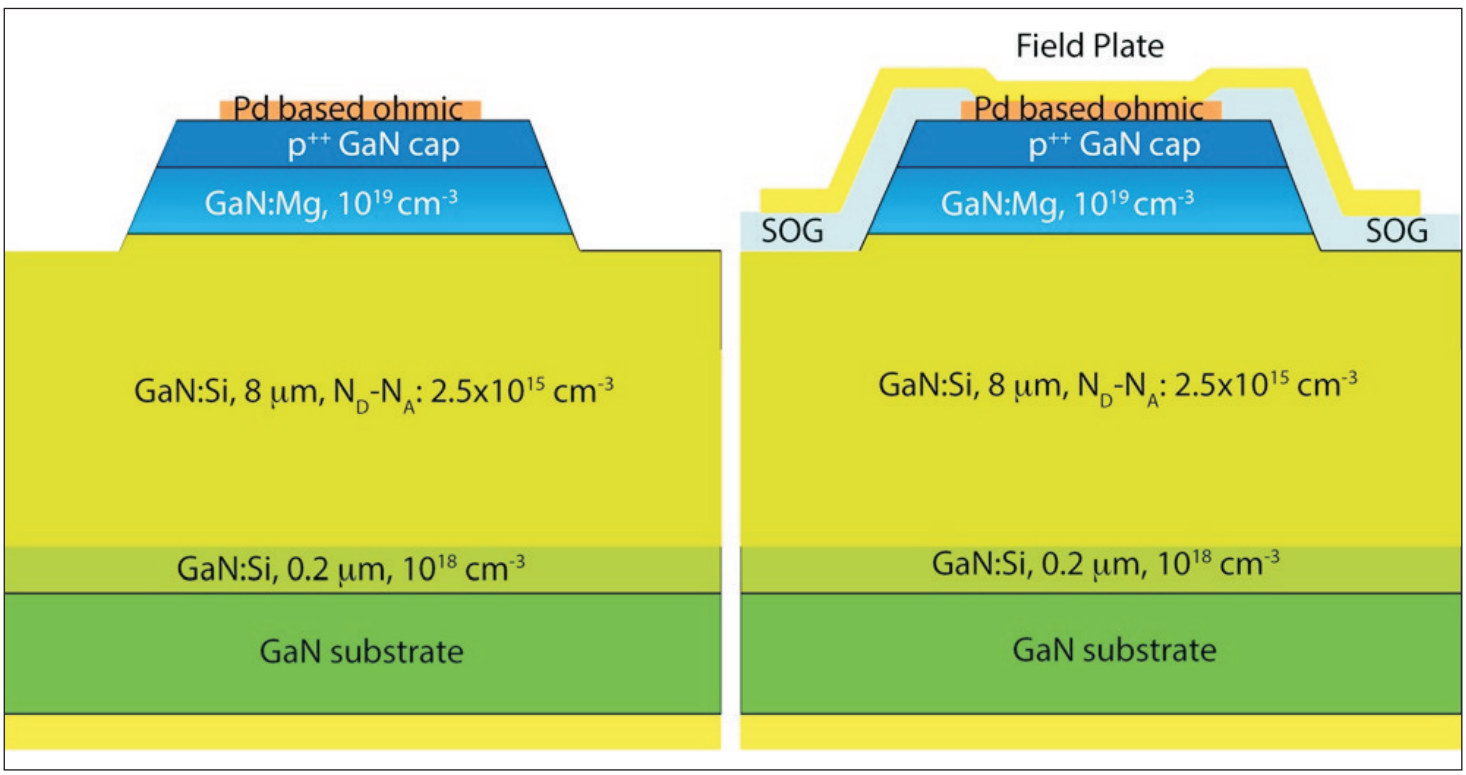

Figure 3. Schematic cross-sections of GaN p–n junction diodes: (left) without passivation/field plates and (right) with field plates.

bipolar benefits of the material. Performance far beyond the unipolar limit predicted by FOM might be achievable in GaN bipolar power devices."

The epitaxial structures were prepared using MOCVD on bulk GaN substrate with defect density ~10^6/cm^2. The upper p-type layers were 400nm of magnesium-doped GaN:Mg and a heavily-doped (p^{++}) cap. Hall-effect measurements determined the hole concentration in the p-type layers at 7x10^{16}/cm^3. The hole mobility was 24cm^2/V-s.

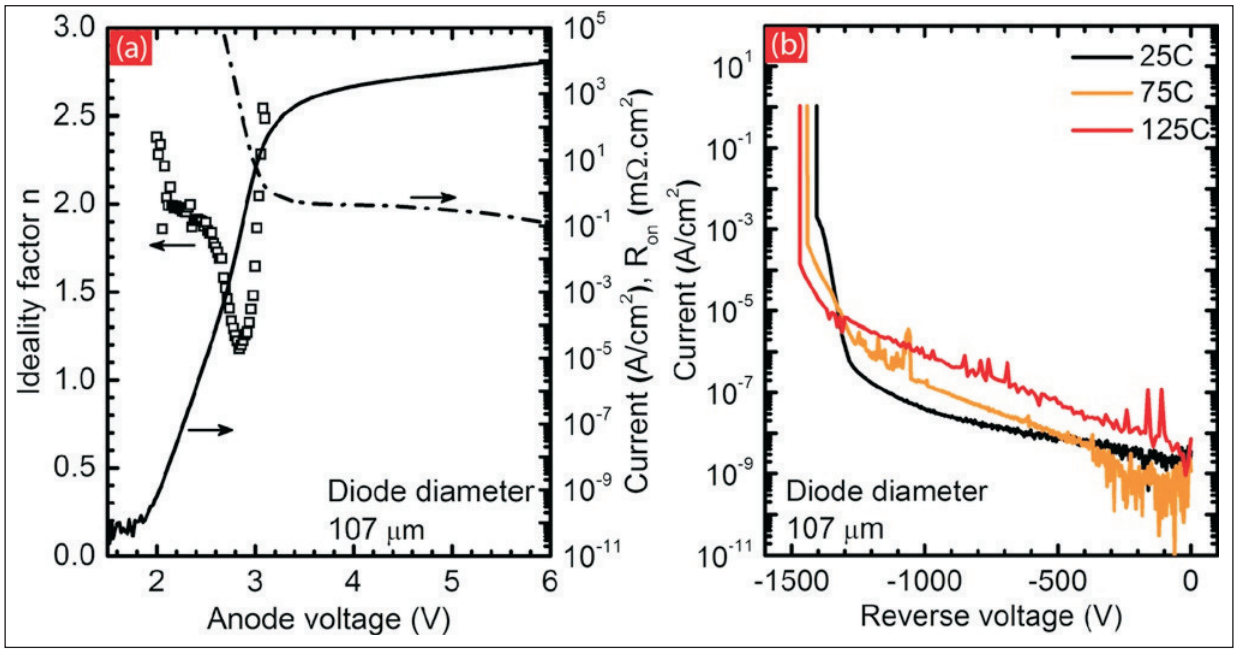

Figure 4. (a) Forward current-voltage characteristics at RT measured on GaN p–n diodes with mesa diameter of 107μm. (b) Temperature-dependent reverse current–voltage characteristics and breakdown voltages.

The diode fabrication (Figure 3) included a circular bevel mesa structure for edge termination to avoid surface leakage currents. Devices were also produced with spin-on-glass passivation and field plates to further improve edge-termination performance and increase reverse-bias breakdown voltages. Devices without passivation or field plates were used in capacitance–voltage analysis of the built-in junction potential and net carrier concentrations.

The forward current density for a 107μm-diameter bottom of the bevel mesa at 6V was "close" to 9.3kA/cm^2, based on a 117μm effective diameter to allow for current spreading (Figure 4). The differential on-resistance was around 0.12mΩ-cm^2.

"The on/off current ratio is about 14 orders of magnitude (limited by our measurement setup), thanks to minimized defects in GaN," the researchers comment. The ideality factor made a transition from around 2.0 at 2.0V to 1.1 at 2.8V. Ideality around 2 suggests domination of non-radiative SRH recombination through charge traps. Ideality factors around 1 are associated with diffusion currents and radiative electron–hole recombination. However, reported radiative recombination coefficients suggest that this effect would have been negligible in the voltage range studied. The SRH lifetime was estimated at around 12ns at room temperature. The recombination center concentration was calculated to be 3x10^{15}/cm^3.

"Near-unity ideality factors in GaN observed over a temperature window have never been reported previously," the researchers add. "The near-unity ideality factor is enabled by two primary facts: (1) a small SRH recombination current inside the depletion region due to a long SRH recombination lifetime, i.e. low concentrations of recombination centers; (2) low parasitic resistances allow diffusion current (η = 1) to dominate over a wide bias window."

The reverse-bias breakdown occurred at 1406V at room temperature (300K). This increased to 1442V at 350K and 1470V at 400K.

"The positive coefficient of BV versus temperature is a signature of avalanche breakdown, which is desired for reliable device operation for high power applications," the researchers explain. "The higher leakage current at higher temperatures suggests that trap-assisted conduction is most likely the dominating leakage mechanism."

The team claims a record Baliga figure of merit for all GaN power p–n diodes, or for any semiconductor system ever reported, of ~16.5GW/cm^2 (square of breakdown voltage divided by differential on-resistance).

Avalanche

The team from Notre Dame and Cornell has also worked with researchers based in Japan on vertical diodes on bulk GaN, this time using MOCVD [Kazuki Nomoto et al, IEEE Electron Device Letters, published online 8 December 2015].

The researchers from Cornell, Notre Dame, Quantum Spread Ltd and Hosei University comment: "The textbook-like behavior in our GaN p–n power diodes, with avalanche capability demonstrated in this work, signifies that the quality of epitaxial GaN is now

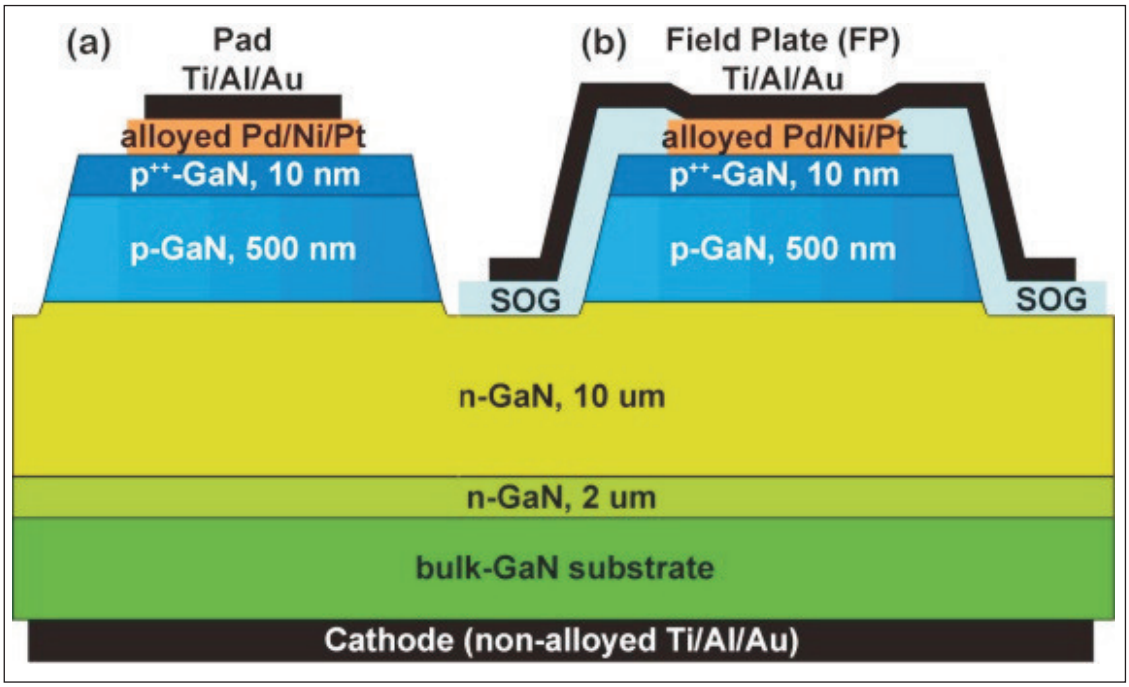

Figure 5. Schematic cross-sections of the GaN-on-GaN p–n junction diodes (a) without (w/o) field plate (FP) and (b) with field plate.

on par with that of SiC while the performance and yield of large-area power devices will most likely improve dramatically with further reduction of threading dislocations in bulk GaN substrates."

The work was in part supported by the US Advanced Research Projects Agency-Energy (ARPA-E) Strategies for Wide Bandgap, Inexpensive Transistors for Controlling High-Efficiency Systems (SWITCHES) Program.

The vertical diode material was grown on bulk 2-inch-diameter 400μm-thick GaN using metal-organic vapor phase epitaxy (MOVPE, a form of MOCVD). The n-GaN buffer and drift layers had $2x10^{18}/cm^3$ and $1–2x10^{16}/cm^3$ silicon doping, respectively. The researchers took particular care to restrict carbon and oxygen impurities in the drift layer to $1.2x10^{16}/cm^3$ and $1.7x10^{16}/cm^3$, respectively. The p-GaN and p^{++}-GaN layers had respective magnesium concentrations of $1x10^{18}/cm^3$ and $2x10^{20}/cm^3$. The doping and impurity levels were determined from secondary-ion mass spectrometry on calibration wafers.

Cathodoluminescence indicated threading dislocation densities of $\sim10^6/cm^2$ in the epitaxial layers, comparable to the level in the underlying bulk GaN. The researchers comment that this level is two orders of magnitude lower than for heteroepitaxial material on non-GaN substrates such as SiC.

After growth, the epitaxial material was annealed at 700ºC to activate the magnesium doping. The hole concentration in the p-GaN was $7.4x10^{16}/cm^3$ with $27cm^2$/V-s mobility, according to Hall measurements at 25ºC.

Diodes with and without a field plate (FP) were fabricated (Figure 5). The FP extended over the whole circular diode mesa. Spin-on-glass (SOG) insulation, 200nm thick, was used to reduce reverse leakage currents. The anode consisted of palladium/nickel/platinum (Pd/Ni/Pt), deposited before the SOG. The curing of the SOG at 425ºC for 30 minutes also affected the composition of the anode metals to give some alloying effect. The cathode on the substrate back side consisted of titanium/aluminium/gold (Ti/Al/Au). This metal composition was also used for the FPs.

The researchers say that they used the best of at least three devices to indicate the potential of GaN-on-GaN technology. Diode sizes were based on the bottom of the mesa diameter. The substrate was not thinned. Thinning would reduce series resistance effects.

The diode's ideality factor between 2V and 2.5V forward bias was ~2.0, indicative of SRH recombination. Above 2.5V, the ideality trends downwards to ~1.3 near 2.8V, indicating a decrease in recombination and an increase in diffusion current across the depletion region. The SRH lifetime was estimated to be 12ns. The turn-on voltage was around 3.0V, close to what would be expected from the 3.4eV GaN bandgap. The current below 2V forward bias was too low to be measured. The current swing was more than 14 orders of magnitude.

The differential specific on-resistance (R_{on}) of a 107μm-diameter diode was $\sim0.4m\Omega\text{-}cm^2$ at $\sim3kA/cm^2$, or $0.55m\Omega\text{-}cm^2$, including a factor for current spreading that effectively increases the diameter to 127μm. In fact, these values were lower than a theoretical estimate of $0.64m\Omega\text{-}cm^2$. "The difference may be attributed to the underestimated electron mobility or conduction modulation in p–n diodes, demanding further studies," the researchers comment.

The breakdown for 107μm-diameter diodes under reverse bias was around 830V without FPs and around 1706V with FPs. The diode without FP failed near the mesa edge. An increase in leakage current above 500V with FPs was attributed, most likely, to a leakage path introduced by the field-plate fabrication process. The Baliga figure of merit with FP was $5.3GW/cm^2$ ($(1706V)^2/0.55m\Omega\text{-}cm^2$).

The BV was nearly independent of diode diameter for devices without FP. However, with FPs the BV decreases with increasing diameter (~1.2kV with 707μm diameter). At the same time, the R_{on} value increased with diameter.

Based on the drift region thickness of 10μm, the researchers estimate a critical field of more than 3.5MV/cm. This is based on an ideal planar model and assuming 75% of the resultant maximum breakdown to allow for the non-ideal nature of the diode. The estimated critical field is among the best reported, according to the researchers.

The breakdown voltage increased with temperature to 1778V at 125ºC — a signature of avalanche breakdown, according to the researchers. The temperature of the 1706V BV was 25ºC.

A group led by Cornell and Notre Dame also presented record-breaking claim for a Baliga FOM of 12.8GW/cm^2 for MOVPE p–n diodes at the December 2015 International Electron Devices Meeting (IEDM) in Washington DC [session 9.7]. The respective values for breakdown voltage and differential on-resistance were 3.48kV and 0.95mΩ·cm^2. The other contributors to the work were US Naval Research Laboratory, Signatone Corp, Quantum Spread Ltd and Hosei University. Devices with drift layer thickness from 20μm to 32μm resulted in BV values in the range from 2.3kV to 3.5kV (Figure 6).

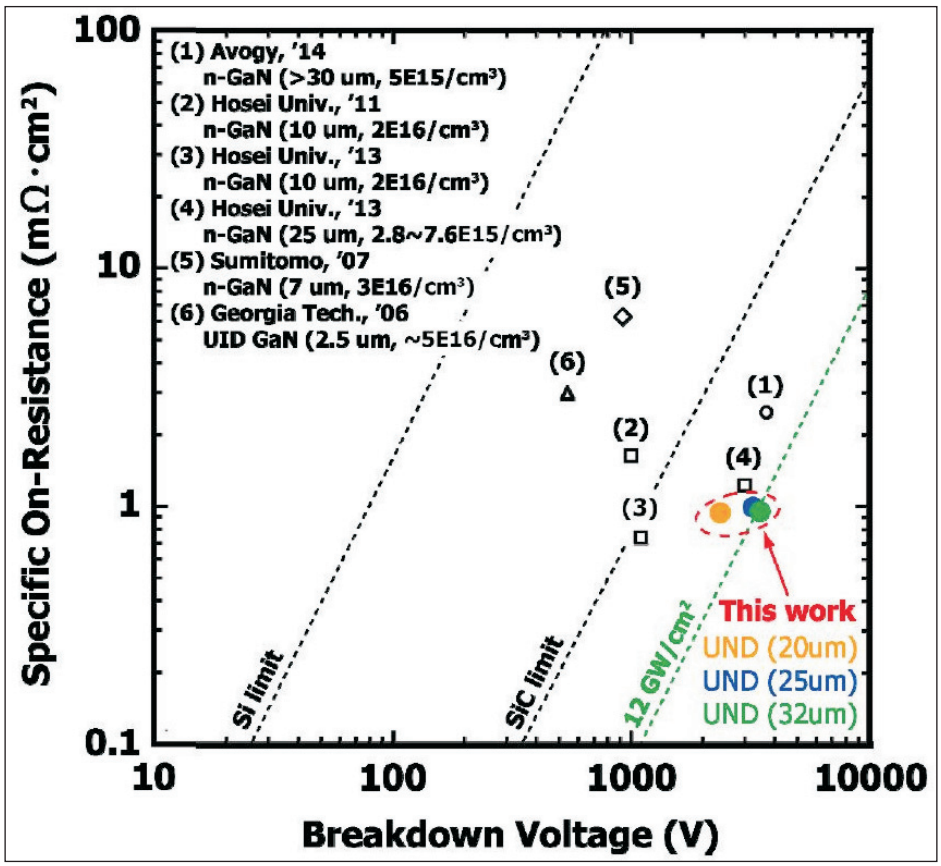

Figure 6. Baliga's figure-of-merit benchmark plot of reported vertical GaN-on-GaN p–n diodes.

The team also claimed a record low range of 1.1–1.3 for the ideality factors of the devices. ■

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

High-mobility AlGaN/GaN heterostructures grown on silicon substrates using simple stress control technique

Peking University researchers have recently increased mobility to 2240cm^2/Vs at sheet charge density of 7.7x10^{12}cm^{-2} for AlGaN/GaN heterostructures grown on silicon substrates using a low-aluminium-content AlGaN buffer layer.

Researchers in Peking University of China (PKU) have demonstrated high-quality AlGaN/GaN heterostructures grown on silicon substrates using a simple stress control technology with a low-aluminium-content AlGaN layer. [J. P. Cheng et al, Appl. Phys. Lett. 106, 142106 (2015)]. The use of this technology allows for high-mobility AlGaN/GaN heterostructures with electron mobility of 2040cm^2/Vs at sheet charge density of 8.4x10^{12}cm^{-2}. Very recently, by further balancing the stress and optimizing the growth conditions, the mobility has been improved to 2240cm^2/Vs at sheet charge density of 7.7x10^{12}cm^{-2}.

The researchers comment: "Thanks to the simple AlGaN buffer layer, this is a cost-effective method for realizing crack-free AlGaN/GaN heterostructures grown on Si substrates while maintaining high material quality."

For AlGaN/GaN HEMT on silicon substrate, the material quality and reliability, which are supposed to be related to dislocation density, remains a challenge to their widespread use. To date, there has not been much success in achieving high-quality AlGaN/GaN heterostructures grown on silicon substrates with two-dimensional electron gas (2DEG) mobility larger than 2000cm^2/Vs, even although such high values

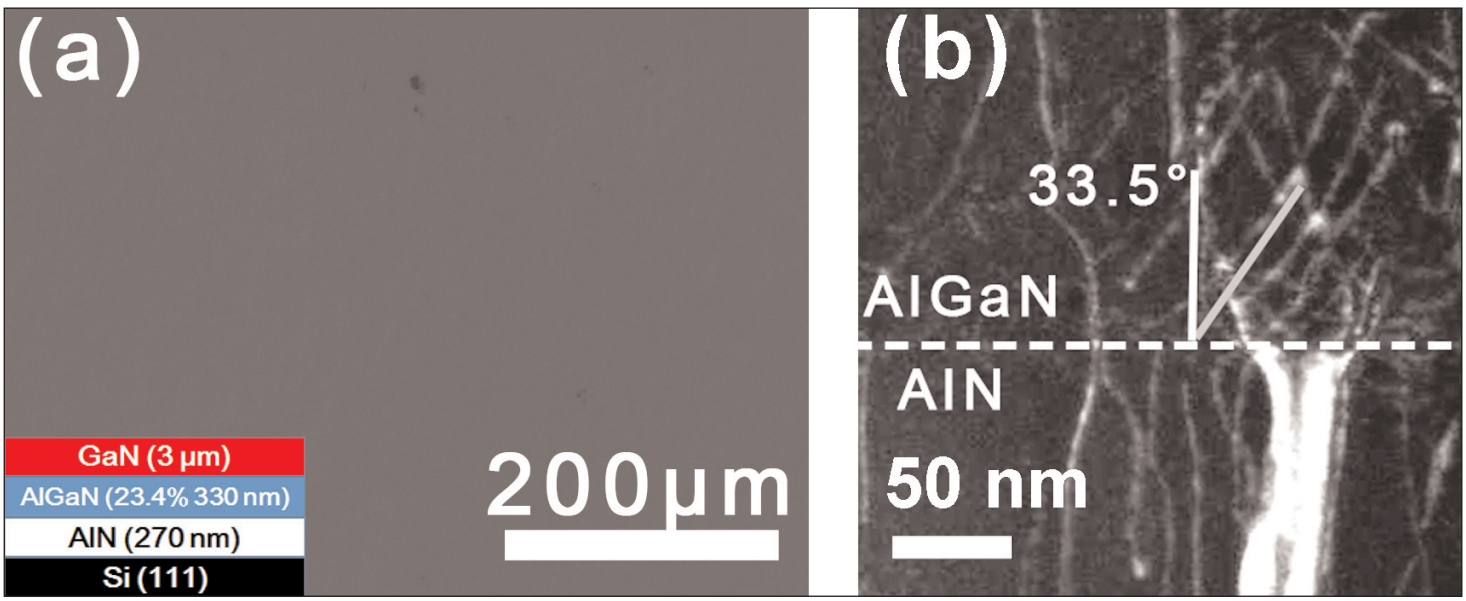

Figure 1. (a) Optical images of the sample. The insets show the corresponding cross-sectional diagrams for the sample. (b) Weak-beam g = (11$\bar{2}$0) TEM images of the samples. The average bend angle of dislocation inclination at the top of AlN buffer layer is about 33.5°.

have been reported for similar structures grown on silicon carbide (SiC) or sapphire substrates. The main reason is that the dislocation density in GaN layers is still higher than that grown on SiC or sapphire substrates. Also, regarding mass production. the complicated buffer layers that are generally used suffer from a time-consuming growth process. In order to solve these issues, it is necessary to develop a cost-effective GaN-on-Si technology to further reduce the dislocation density.

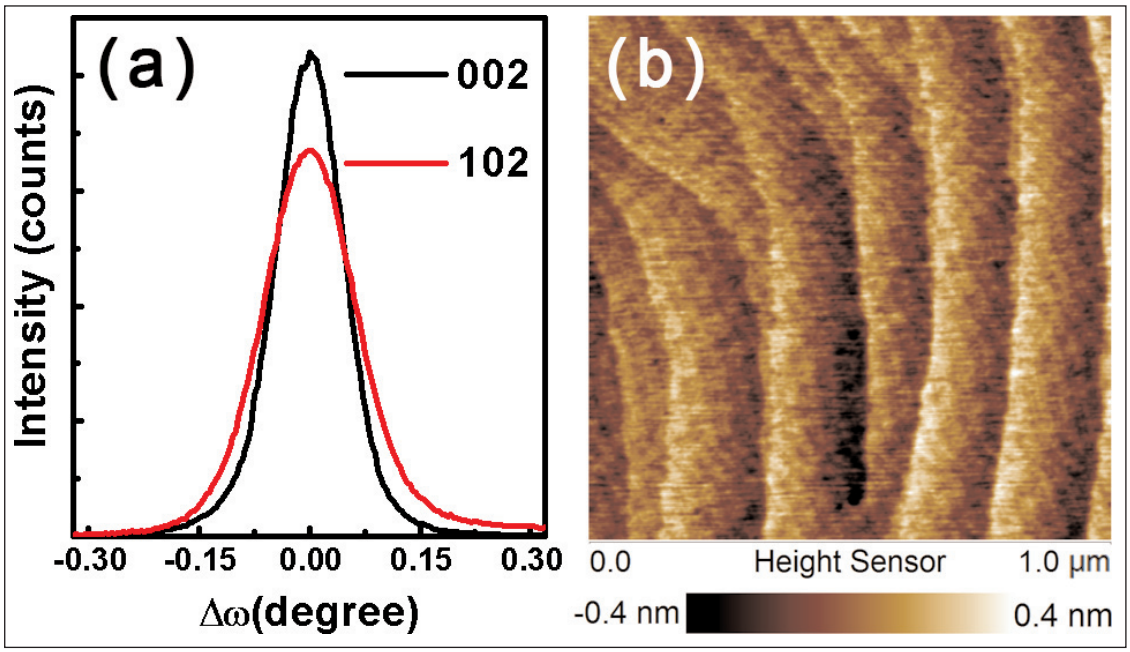

Figure 2. (a) Symmetric (002) and asymmetric (102) ω-scans of rocking curve in GaN layer of the sample. (b) AFM image.

The PKU team has hence developed a simple stress control technology to grow a high-quality GaN layer on silicon substrates. The GaN layers were grown on 4-inch p-type Si (111) substrates by metal-organic chemical vapor deposition (MOCVD). The sample structure (inset of Figure 1(a)) consisted of a 270nm AlN layer, a 330nm $Al_{0.23}Ga_{0.77}N$ buffer layer, and a 3μm GaN layer.

The material surface is crack free (Figure 1(a)). The average bend angle of dislocation inclination at the top of the AlN buffer layer is about 33.5°, as shown in the TEM image (Figure 1(b)). "The inclination of the dislocations is associated with the compressive stress induced by the lattice mismatch between the AlN and AlGaN layers," comment the researchers. "The large bend angles enhance the probability for dislocations to encounter and react with other ones," they add. "Upon entering the GaN layer, the dislocation density is reduced and then less compressive stress is consumed during dislocation evolution. As a result, more residual compressive stress is thus left to compensate the thermal tensile stress. This technology can filter dislocations and further reduce dislocation density, especially the edge dislocation density, which is essential to maintain the higher compressive stress."

The FWHM of the GaN (002) and (102) rocking curves for the sample are 389 arcsec and 527 arcsec, respectively (Figure 2 (a)). The corresponding AFM image (Figure 2(b)) presents atomic-step terraces. The root mean square (RMS) roughness is 0.11nm in a scanned area of 1μm x 1μm. These indicate that a high-quality

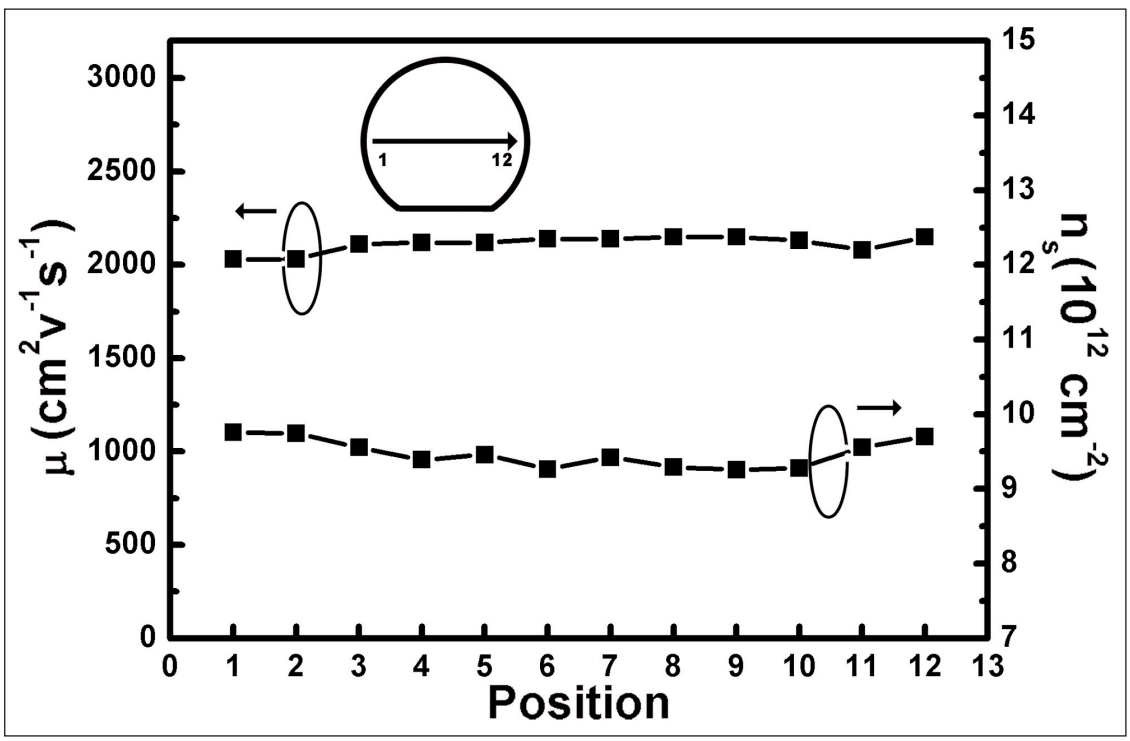

Fig. 3 The 2DEG density and mobility distribution across the AlGaN/GaN heterostructure sample. The inset shows the measured positions on the wafer.

and crack-free 3μm-thick GaN layer has been grown on a silicon substrate using this low-Al-content AlGaN intermediate layer.

Using this high-quality and crack-free GaN layer as the buffer layer, the researchers fabricated an $Al_{0.20}Ga_{0.80}N$ (~22nm)/AlN (~1nm)/GaN heterostructure. Room temperature Hall measurements using the Van der Pauw configuration on mesas with a 5cm x 5cm geometry showed that the 2DEG mobility and carrier density were 2040cm^2/Vs and 8.4x10^{12}cm^{-2}, respectively. The corresponding sheet resistance is about 367Ω/sq. Recently, the results have been improved by further balancing the stress and optimizing the growth conditions. The AlGaN/GaN heterostructures are very uniform, with a maximum electron mobility of 2150cm^2/Vs at an electron density of 9.3x10^{12}cm^{-2} (Figure 3). The sheet resistance across the wafer is as low as 313 ± 4Ω/sq, and hence the uniformity value is only 1.3%. For some wafers with a slightly lower-Al-content AlGaN barrier layer, the maximum electron mobility can be up to 2240cm^2/Vs at sheet charge density of 7.7x10^{12}cm^{-2}. The results are among the best reported in the literature for AlGaN/GaN heterostructures grown on silicon substrates, according to the researchers. They also fabricated AlGaN/GaN HEMTs with a gate-to-source distance, gate-to-drain distance and gate length of $L_{GS}/L_{GD}/L_G$ = 1.5μm/3μm/1.5μm. The initial results show excellent DC characteristics, with a maximum drain current density (I_{Dmax}) of 688mA/mm.

"This stress control technology is efficient for improving the crystal quality," comment the researchers. "Furthermore, the buffer structure with a single low-Al-content AlGaN intermediate layer is simpler than the commonly used complicated buffers and could reduce growth time and thus the cost," they add. "This technology can also be used during growth of InAlN/GaN heterostructures. On the other hand, it is easy to make the low-Al-content AlGaN layer conductive with silicon doping, which demonstrates the potential for fabrication of GaN-on-Si vertical devices. These results look promising for future low-cost and high-performance GaN-on-Si electronic devices." ■

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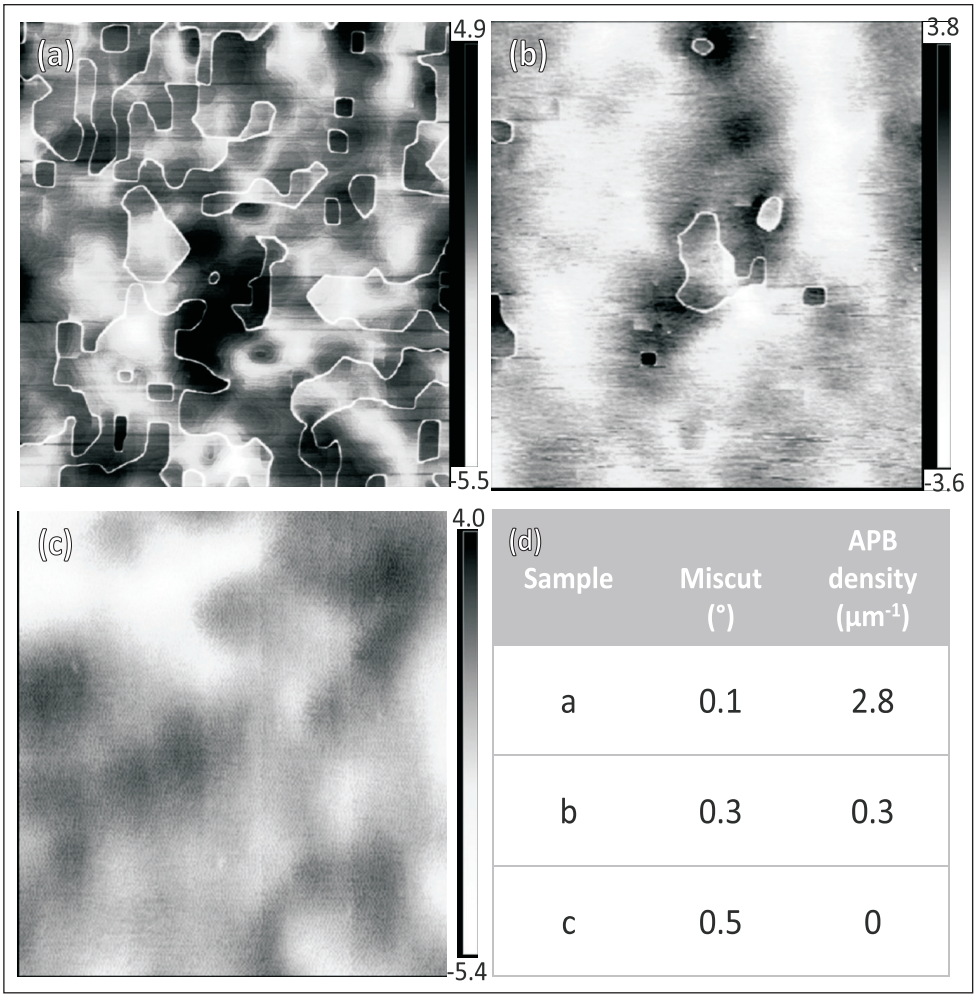
Single-crystal gallium arsenide on quasi-nominal silicon

Avoiding anti-phase boundaries by growing gallium arsenide on germanium-buffered silicon substrates with a small offcut angle.

Université Grenoble Alpes in France and Applied Materials in the USA have been developing techniques to grow gallium arsenide (GaAs) on silicon substrates with a small offcut angle [Y. Bogumilowicz et al, Appl. Phys. Lett., vol107, p212105, 2015]. The researchers label such substrates 'quasi-nominal', in comparison with the much larger offcut angles often used in attempts to grow GaAs on silicon.

The researchers comment: "We have found that small offcut variations greatly influence how GaAs grows on Ge-buffered silicon substrates and that the offcut angle that yields single domain layers in MOVPE can be as low as 0.5° instead of the 4–6° angle typically found in the literature."

The small 'quasi-nominal' offcut angle makes the process more compatible with existing silicon manufacturing technology and also eliminates the need for elaborate high-temperature silicon wafer preparation. The aim of such research is to make the high-mobility and direct-bandgap properties of III-V materials available for close integration into silicon electronics. High mobility enables higher-speed signal processing and a direct bandgap creates opportunities for the efficient generation and capture of light.



(d)

Sample	Miscut (°)	APB density (μm^{-1})
a	0.1	2.8
b	0.3	0.3
c	0.5	0

Figure 1. 5μmx5μm AFM images of surface of GaAs layers grown on Ge-buffered silicon (001) substrates with three different offcut angles: (a) 0.1°, (b) 0.3° and (c) 0.5°. Scales are labeled in nanometers. Table (d) presents APB density measured for each sample. AFM image sides are along <100> directions.

In order to bridge the 4% lattice mismatch between the materials, the researchers first applied a thick layer of germanium. There is also a thermal expansion mismatch, which can lead to cracking when the processed wafer cools.

An additional problem can arise with polar materials such as GaAs being grown on non-polar silicon where different 'anti-phase' domains are created with different gallium/arsenide layer sequences. Large offcut angles to give double atomic steps on the growth substrate surface is one way to deal with this. Another technique is to begin growth with an arsenic-only layer and then introduce the gallium source.

The researchers performed metal-organic vapor phase epitaxy (MOVPE) on 300mm (001) silicon wafers. The source precursors were trimethylgallium (TMGa) and tertiarybutylarsine (TBAs) in hydrogen carrier gas.

The substrate was 775μm thick with small offcut angle (less than or equal to 0.5°) in the <110> crystal direction. The researchers comment: "In our case, this small offcut was intentional, but in practice, nominal

(001) substrates are always slightly mis-oriented, whether intentional or not."

The substrate was prepared with a 1µm layer of germanium as a strain relaxed buffer. This layer was grown in a separate epitaxial tool specifically used for group IV elements. The source was germane (GeH_4). The deposition temperature was varied in two low/high-temperature steps (400°C/650°C). The process also included thermal cycling in hydrogen between 650°C and 850°C with the aim of minimizing the generation of threading dislocations to densities of the order of $10^7/cm^2$. The germanium layer exhibited root-mean-square roughness of less than 1nm on a 5µmx5µm field.

Applied's Siconi etch process was used to remove oxide residues after a wet etch designed to shift native oxide. The Siconi dry process was performed in-situ in the MOVPE reaction chamber before GaAs deposition, which consisted of a 700°C hydrogen bake and GaAs growth between 500°C and 700°C.

X-ray diffraction analysis showed the Ge and GaAs layers to be single crystal. The Ge and GaAs layers were tensile strained. The degree of strain relaxation was 104% and 106% for the Ge and GaAs layers, respectively. The analysis also suggested that the crystal quality improved for higher offcut angles (Figure 1).

The anti-phase boundary density was assessed using atomic force microscopy (AFM). The length of APB lines per unit area gave a per micron result. The 0.5° offcut sample had zero APBs. The threading dislocation density in the GaAs layer was between $5x10^7/cm^2$ and $1x10^8/cm^2$.

The researchers believe that avoiding APBs requires a distance between atomic steps to be less than a threshold value and control of the growth process to annihilate APBs that are inevitably generated initially. The atomic stepping is controlled by the offcut angle. ■

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Author: Mike Cooke

Toward quantum computing on silicon-on-insulator platform

Quantum dot field-effect transistors demonstrate highly anisotropic and gate-dependent magneto-transport of hole spin.

Researchers in France believe they have made preliminary steps towards establishing a silicon-on-insulator (SOI) complementary metal-oxide-semiconductor (CMOS) platform for quantum information processing. Quantum information processing promises a revolution in cryptography and database searching. In particular, the superposition of quantum amplitudes enables a radical form of parallel processing for which a large number of potential super-efficient algorithms have been developed (and implemented on a relatively small scale in various model/prototype systems).

CEA-Leti and CEA-Inac have adapted a quantum dot technology originally developed for very-large-scale integration (VLSI) CMOS circuits. The dots are located beneath the gate electrode of field-effect transistors [Romain Lavieville et al, Nano Letters, vol15, p2958, 2015]. The dots can be populated with a small number of charge carriers (electrons or holes, depending on nFET or pFET structure), when the operating temperature is 0.1K.

Control circuitry accesses the quantum dot FETs through SOI nanowire FETs developed at Leti. Together, Leti and Inac have demonstrated the co-integration and operation of quantum objects with conventional CMOS control circuitry in the form of standard ring oscillators. The devices were produced on 300mm SOI substrates.

Louis Hutin at Leti reports: "This technology has acquired a certain degree of robustness, and we aim at using it with very minor modifications to demonstrate qubits co-integrated with their control electronics. This co-integration success represents a critical asset for the eventual design of a quantum computer."

Since quantum bits (qubits) are generally encoded on spin states, the researchers have been exploring different manipulation and read-out schemes. Some of the research has used radio-frequency signals to access single-charge events, including spin states in some cases. Another approach (Figure 1) has explored electrical driving of the spin with high-frequency modulation of a p-FET gate [B. Voisin et al, Nano Letters, published online 24 November 2015].

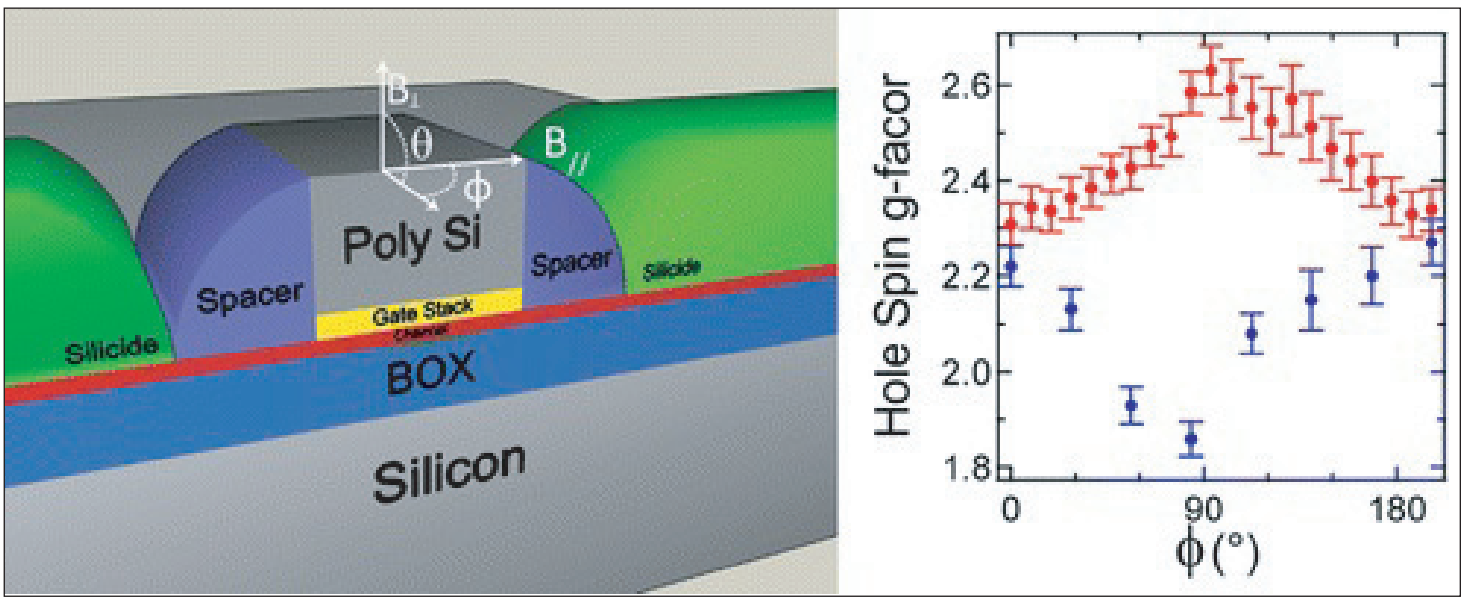

Figure 1. Schematic and plot of device with highly anisotropic and gate-dependent magneto-transport of holes as indicated by g-factor. The researchers believe that these characteristics could enable electrically driven g-tensor-modulation spin resonance with Rabi frequencies of several hundred megahertz.

Electrical control and read-out of spin states would allow faster and more localized action compared with more traditional magnetic field approaches. Also, the use of a semiconductor system rather than atomic trapping or superconducting devices should allow much easier upscaling of complexity.

This is true in particular for silicon-based devices as opposed to approaches based on III-V compound semiconductors. Silicon spintronic development has been enabled by the use of isotopically pure silicon-28, which avoids decoherence of quantum spin states through coupling with nuclear spins. The silicon-28 nucleus is the most common isotope and is spin-free/zero. The nuclear spins of III-V semiconductors limits the lifetime of quantum spin states in electron and hole carriers.

The team believes that actual qubit demonstrations in their CMOS SOI device structures could be close, and after that would come near- and long-range coupling of multiple qubits.

Leti and Inac are involved through CEA in the Silicon platform for Quantum Spintronics (SiSPIN) European Union (EU) Seventh Framework Programme, along with TU Delft, IBM Zurich, University of Copenhagen, University of Basel, and University of Linz. The SiSPIN collaboration is exploring technological implications ranging from improved switching performance of classical logic gates (e.g. towards lower energy consumption) up to implementation of quantum computing based on spin qubits. ■

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Index

To have your company listed in this directory, e-mail details (including categories) to mark@semiconductor-today.com
Note: advertisers receive a free listing. For all other companies, a charge is applicable.

1 Bulk crystal source materials

Mining & Chemical Products Ltd (part of 5N Plus, Inc)
1-4, Nielson Road,
Finedon Road Industrial Estate,
Wellingborough,
Northants NN8 4PE,
UK
Tel: +44 1933 220626
Fax: +44 1933 227814
www.MCP-group.com

Umicore Indium Products
50 Simms Avenue,
Providence, RI 02902,
USA
Tel: +1 401 456 0800
Fax: +1 401 421 2419
www.thinfilmproducts.umicore.com

United Mineral & Chemical Corp
1100 Valley Brook Avenue,
Lyndhurst, NJ 07071,
USA
Tel: +1 201 507 3300
Fax: +1 201 507 1506
www.umccorp.com

2 Bulk crystal growth equipment

MR Semicon Inc
PO Box 91687,
Albuquerque,
NM 87199-1687,
USA
Tel: +1 505 899 8183
Fax: +1 505 899 8172
www.mrsemicon.com

3 Substrates

AXT Inc
4281 Technology Drive,
Fremont,
CA 94538,
USA
Tel: +1 510 438 4700
Fax: +1 510 683 5901
www.axt.com
Supplies GaAs, InP, and Ge wafers using VGF technology with manufacturing facilities in Beijing and five joint ventures in China producing raw materials, including Ga, As, Ge, pBN, B_2O_3.

CrystAl-N GmbH
Dr.-Mack-Straße 77,
D-90762
Fürth,
Germany
Tel: +49 (0)911 650 78 650 90
Fax: +49 (0)911 650 78 650 93
E-mail: info@crystal-n.com
www.crystal-n.com

Crystal IS Inc
70 Cohoes Avenue
Green Island, NY 12183, USA
Tel: +1 518 271 7375
Fax: +1 518 271 7394
www.crystal-is.com

Freiberger Compound Materials
Am Junger Loewe Schacht 5,
Freiberg, 09599, Germany
Tel: +49 3731 280 0
Fax: +49 3731 280 106
www.fcm-germany.com

Kyma Technologies Inc
8829 Midway West Road,
Raleigh, NC, USA
Tel: +1 919 789 8880
Fax: +1 919 789 8881
www.kymatech.com

MARUWA CO LTD
3-83, Minamihonjigahara-cho,
Owariasahi, Aichi 488-0044,
Japan
Tel: +81 572 52 2317
www.maruwa-g.com/e/products/ceramic

MARUWA is a global supplier of ceramic substrates and wafers made of aluminium nitride (AlN), alumina (Al_2O_3), ZTA and silicon nitride (Si_3N_4). Products meet required properties such as high thermal conductivity and bending strength for power devices, especially wafers are suitable as a bonding wafer (GaN, SOI) for epi wafers.

sp3 Diamond Technologies
2220 Martin Avenue,
Santa Clara, CA 95050, USA
Tel: +1 877 773 9940
Fax: +1 408 492 0633
www.sp3inc.com

Sumitomo Electric Semiconductor Materials Inc
7230 NW Evergreen Parkway,
Hillsboro, OR 97124,
USA
Tel: +1 503 693 3100 x207
Fax: +1 503 693 8275
www.sesmi.com

III/V-Reclaim
Wald 10,
84568 Pleiskirchen, Germany
Tel: +49 8728 911 093
Fax: +49 8728 911 156
www.35reclaim.de
III/V-Reclaim offers reclaim (recycling) of GaAs and InP wafers, removing all kinds of layers and structures from customers' wafers. All formats and sizes can be handled. The firm offers single-side and double-side-polishing and ready-to-use surface treatment.

Umicore Electro-Optic Materials
Watertorenstraat 33,
B-2250 Olen, Belgium
Tel: +32-14 24 53 67
Fax: +32-14 24 58 00
www.substrates.umicore.com

Wafer World Inc
1100 Technology Place, Suite 104,
West Palm Beach, FL 33407,
USA
Tel: +1-561-842-4441
Fax: +1-561-842-2677
E-mail: sales@waferworld.com
www.waferworld.com

4 Epiwafer foundry

Spire Semiconductor LLC
25 Sagamore Park Drive,
Hudson, NH 03051,
USA
Tel: +1 603 595 8900
Fax: +1 603 595 0975
www.spirecorp.com

Albemarle Cambridge Chemical Ltd
Unit 5 Chesterton Mills,
French's Road, Cambridge CB4 3NP,
UK
Tel: +44 (0)1223 352244
Fax: +44 (0)1223 352444
www.camchem.co.uk

Intelligent Epitaxy Technology Inc
1250 E Collins Blvd,
Richardson,
TX 75081-2401,
USA
Tel: +1 972 234 0068
Fax: +1 972 234 0069
www.intelliepi.com

IQE
Cypress Drive,
St Mellons, Cardiff
CF3 0EG,
UK
Tel: +44 29 2083 9400
Fax: +44 29 2083 9401
www.iqep.com
IQE is a leading global supplier of advanced epiwafers, with products covering a diverse range of applications within the wireless, optoelectronic, photovoltaic and electronic markets.

OMMIC
2, Chemin du Moulin B.P. 11,
Limeil-Brevannes, 94453,
France
Tel: +33 1 45 10 67 31
Fax: +33 1 45 10 69 53
www.ommic.fr

Soitec
Place Marcel Rebuffat, Parc de Villejust, 91971 Courtabouef, France
Tel: +33 (0)1 69 31 61 30
Fax: +33 (0)1 69 31 61 79
www.picogiga.com

5 Deposition materials

Akzo Nobel High Purity Metalorganics
www.akzonobel.com/hpmo
Asia Pacific:
Akzo Nobel (Asia) Co Ltd,
Shanghai,
China
Tel. +86 21 2216 3600
Fax: +86 21 3360 7739
metalorganicsAP@akzonobel.com
Americas:
AkzoNobel Functional Chemicals,
Chicago,
USA
Tel. +31 800 828 7929 (US only)
Tel: +1 312 544 7000
Fax: +1 312 544 7188
metalorganicsNA@akzonobel.com
Europe, Middle East and Africa:
AkzoNobel Functional Chemicals,
Amersfoort, The Netherlands
Tel. +31 33 467 6656
Fax: +31 33 467 6101
metalorganicsEU@akzonobel.com

Cambridge Chemical Company Ltd
Unit 5 Chesterton Mills,
French's Road,
Cambridge CB4 3NP,
UK
Tel: +44 (0)1223 352244
Fax: +44 (0)1223 352444
www.camchem.co.uk

Dow Electronic Materials
60 Willow Street,
North Andover, MA 01845,
USA
Tel: +1 978 557 1700
Fax: +1 978 557 1701
www.metalorganics.com

Matheson Tri-Gas
6775 Central Avenue,
Newark, CA 94560,
USA

Tel: +1 510 793 2559
Fax: +1 510 790 6241
www.mathesontrigas.com

Mining & Chemical Products Ltd
(see section 1 for full contact details)

Praxair Electronics
542 Route 303, Orangeburg,
NY 10962,
USA
Tel: +1 845 398 8242
Fax: +1 845 398 8304
www.praxair.com/electronics

SAFC Hitech
Power Road, Bromborough,
Wirral, Merseyside CH62 3QF,
UK
Tel: +44 151 334 2774
Fax: +44 151 334 6422
www.safchitech.com

Materion Advanced Materials Group
2978 Main Street,
Buffalo, NY 14214,
USA
Tel: +1 716 837 1000
Fax: +1 716 833 2926
www.williams-adv.com

6 Deposition equipment

AIXTRON SE
Dornkaulstr. 2,
52134 Herzogenrath,
Germany
Tel: +49 2407 9030 0
Fax: +49 2407 9030 40
www.aixtron.com

AIXTRON is a leading provider of deposition equipment to the semiconductor industry. The company's technology solutions are used by a diverse range of customers worldwide to build advanced components for electronic and optoelectronic applications (photonic) based on compound, silicon, or organic semiconductor materials and, more recently, carbon nanotubes (CNT), graphene and other nanomaterials.

Evatec AG
Hauptstrasse 1a,
CH-9477 Trübbach, Switzerland
Tel: +41 81 403 8000
Fax: +41 81 403 8001
www.evatecnet.com

Ferrotec-Temescal
4569-C Las Positas Rd,
Livermore,
CA 94551,
USA
Tel: +1 925 245 5817
Fax: +1 925 449-4096
www.temescal.net

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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.

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Tel: +1 727 577 4999
Fax: +1 727 577 7035
www.plasmatherm.com

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95873 Bezons Cedex, France
Tel: +33 (0) 1 39 96 65 00
Fax: +33 (0) 1 39 47 45 62
www.riber.com

SVT Associates Inc
7620 Executive Drive,
Eden Prairie, MN 55344, USA
Tel: +1 952 934 2100
Fax: +1 952 934 2737
www.svta.com

Veeco Instruments Inc
100 Sunnyside Blvd.,
Woodbury, NY 11797,
USA
Tel: +1 516 677 0200
Fax: +1 516 714 1231
www.veeco.com

Veeco is a world-leading supplier of compound semiconductor equipment, and the only company offering both MOCVD and MBE solutions. With complementary AFM technology and the industry's most advanced Process Integration Center, Veeco tools help grow and measure nanoscale devices in worldwide LED/wireless, data storage, semiconductor and scientific research markets—offering important choices, delivering ideal solutions.

7 Wafer processing materials

Air Products and Chemicals Inc
7201 Hamilton Blvd.,
Allentown, PA 18195, USA
Tel: +1 610 481 4911
www.airproducts.com/compound

MicroChem Corp
1254 Chestnut St. Newton,
MA 02464, USA
Tel: +1 617 965 5511
Fax: +1 617 965 5818
www.microchem.com

Praxair Electronics
(see section 5 for full contact details)

8 Wafer processing equipment

EV Group
DI Erich Thallner Strasse 1,
St. Florian/Inn, 4782,
Austria
Tel: +43 7712 5311 0
Fax: +43 7712 5311 4600
www.EVGroup.com
Technology and market leader for wafer processing equipment.
Worldwide industry standards for aligned wafer bonding, resist processing for the MEMS, nano and semiconductor industry.

Logitech Ltd
Erskine Ferry Road,
Old Kilpatrick,
near Glasgow G60 5EU,
Scotland, UK
Tel: +44 (0) 1389 875 444
Fax: +44 (0) 1389 879 042
www.logitech.uk.com

Oxford Instruments Plasma Technology
(see section 6 for full contact details)

Plasma-Therm LLC
(see section 6 for full contact details)

SAMCO International Inc
532 Weddell Drive,
Sunnyvale,
CA,
USA
Tel: +1 408 734 0459
Fax: +1 408 734 0961
www.samcointl.com

SPTS Technology Ltd
Ringland Way,
Newport NP18 2TA,
UK
Tel: +44 (0)1633 414000
Fax: +44 (0)1633 414141
www.spts.com

SUSS MicroTec AG
Schleißheimer Strasse 90,
85748 Garching,
Germany
Tel: +49 89 32007 0
Fax: +49 89 32007 162
www.suss.com

Veeco Instruments Inc
(see section 6 for full contact details)

9 Materials & metals

Goodfellow Cambridge Ltd
Ermine Business Park,
Huntingdon,
Cambridgeshire
PE29 6WR,
UK
Tel: +44 (0) 1480 424800
Fax: +44 (0) 1480 424900
www.goodfellow.com
Goodfellow supplies small quantities of metals and materials for research, development, prototyping and specialised manufacturing operations.

10 Gas and liquid handling equipment

Air Products and Chemicals Inc
(see section 7 for full contact details)

Cambridge Fluid Systems
12 Trafalgar Way, Bar Hill,
Cambridge CB3 8SQ,
UK
Tel: +44 (0)1954 786800
Fax: +44 (0)1954 786818
www.cambridge-fluid.com

CS CLEAN SYSTEMS AG
Fraunhoferstrasse 4,
Ismaning, 85737,
Germany
Tel: +49 89 96 24 00 0
Fax: +49 89 96 24 00 122
www.cscleansystems.com

SAES Pure Gas Inc
4175 Santa Fe Road,
San Luis Obispo,
CA 93401,
USA
Tel: +1 805 541 9299
Fax: +1 805 541 9399
www.saesgetters.com

11 Process monitoring and control

k-Space Associates Inc
2182 Bishop Circle
East, Dexter,
MI 48130,
USA
Tel: +1 734 426 7977
Fax: +1 734 426 7955
www.k-space.com
k-Space Associates Inc specializes in in-situ, real-time thin-film process monitoring tools for MBE, MOCVD, PVD, and thermal evaporation. Applications and materials include the research and production line monitoring of compound semiconductor-based electronic, optoelectronic, and photovoltaic devices.

KLA-Tencor
One Technology Dr,
1-2221I, Milpitas, CA 95035, USA
Tel: +1 408 875 3000
Fax: +1 408 875 4144
www.kla-tencor.com

LayTec AG
Seesener Str. 10–13,
10709 Berlin,
Germany
Tel: +49 30 89 00 55 0
Fax: +49 30 89 00 180
www.laytec.de
LayTec develops and manufactures optical in-situ and in-line metrology systems for thin-film processes with particular focus on compound semiconductor and photovoltaic applications. Its know-how is based on optical techniques: reflectometry, emissivity corrected pyrometry, curvature measurements and reflectance anisotropy spectroscopy.

WEP (Ingenieurbüro Wolff für Elektronik- und Programmentwicklungen)
Bregstrasse 90, D-78120
Furtwangen im Schwarzwald,
Germany
Tel: +49 7723 9197 0
Fax: +49 7723 9197 22
www.wepcontrol.com

12 Inspection equipment

Bruker AXS GmbH
Oestliche Rheinbrueckenstrasse 49,
Karlsruhe, 76187,
Germany
Tel: +49 (0)721 595 2888
Fax: +49 (0)721 595 4587
www.bruker-axs.de

13 Characterization equipment

J.A. Woollam Co. Inc.
645 M Street Suite 102,
Lincoln, NE 68508, USA
Tel: +1 402 477 7501
Fax: +1 402 477 8214
www.jawoollam.com

Lake Shore Cryotronics Inc
575 McCorkle Boulevard,
Westerville, OH 43082,
USA
Tel: +1 614 891 2244
Fax: +1 614 818 1600
www.lakeshore.com

14 Chip test equipment

Keithley Instruments Inc
28775 Aurora Road,
Cleveland, OH 44139,
USA
Tel: +1 440.248.0400
Fax: +1 440.248.6168
www.keithley.com

15 Assembly/packaging materials

ePAK International Inc
4926 Spicewood Springs Road,
Austin, TX 78759,
USA
Tel: +1 512 231 8083
Fax: +1 512 231 8183
www.epak.com

Gel-Pak
31398 Huntwood Avenue,
Hayward, CA 94544, USA
Tel: +1 510 576 2220
Fax: +1 510 576 2282
www.gelpak.com

Wafer World Inc
(see section 3 for full contact details)

Materion Advanced Materials Group
2978 Main Street,
Buffalo, NY 14214,
USA
Tel: +1 716 837 1000
Fax: +1 716 833 2926
www.williams-adv.com

16 Assembly/packaging equipment

Ismeca Europe Semiconductor SA
Helvetie 283, La Chaux-de-Fonds,
2301, Switzerland
Tel: +41 329257111
Fax: +41 329257115
www.ismeca.com

Kulicke & Soffa Industries
1005 Virginia Drive,
Fort Washington,
PA 19034,
USA
Tel: +1 215 784 6000
Fax: +1 215 784 6001
www.kns.com

Palomar Technologies Inc
2728 Loker Avenue West,
Carlsbad, CA 92010,
USA
Tel: +1 760 931 3600
Fax: +1 760 931 5191
www.PalomarTechnologies.com

TECDIA Inc
2700 Augustine Drive, Suite 110,
Santa Clara, CA 95054,
USA
Tel: +1 408 748 0100
Fax: +1 408 748 0111
www.tecdia.com

17 Assembly/packaging foundry

Quik-Pak
10987 Via Frontera,
San Diego, CA 92127, USA
Tel: +1 858 674 4676
Fax: +1 8586 74 4681
www.quikicpak.com

18 Chip foundry

Compound Semiconductor Technologies Ltd
Block 7, Kelvin Campus,
West of Scotland, Glasgow,
Scotland G20 0TH,
UK
Tel: +44 141 579 3000
Fax: +44 141 579 3040
www.compoundsemi.co.uk

United Monolithic Semiconductors
Route departementale 128,
BP46, Orsay, 91401,
France
Tel: +33 1 69 33 04 72
Fax: +33 169 33 02 92
www.ums-gaas.com

19 Facility equipment

MEI, LLC
3474 18th Avenue SE,
Albany, OR 97322-7014,
USA
Tel: +1 541 917 3626
Fax: +1 541 917 3623
www.marlerenterprises.net

20 Facility consumables

W.L. Gore & Associates
401 Airport Rd, Elkton,
MD 21921-4236,
USA
Tel: +1 410 392 4440
Fax: +1 410 506 8749
www.gore.com

21 Computer hardware & software

Ansoft Corp
4 Station Square, Suite 200,
Pittsburgh, PA 15219, USA
Tel: +1 412 261 3200
Fax: +1 412 471 9427
www.ansoft.com

Crosslight Software Inc
121-3989 Henning Dr.,
Burnaby, BC, V5C 6P8, Canada
Tel: +1 604 320 1704
Fax: +1 604 320 1734
www.crosslight.com

Semiconductor Technology Research Inc
10404 Patterson Ave., Suite 108,
Richmond, VA 23238,
USA
Tel: +1 804 740 8314
Fax: +1 804 740 3814
www.semitech.us

22 Used equipment

Class One Equipment Inc
5302 Snapfinger Woods Drive,
Decatur, GA 30035, USA
Tel: +1 770 808 8708
Fax: +1 770 808 8308
www.ClassOneEquipment.com

23 Services

Henry Butcher International
Brownlow House, 50–51
High Holborn, London WC1V 6EG,
UK
Tel: +44 (0)20 7405 8411
Fax: +44 (0)20 7405 9772
www.henrybutcher.com

M+W Zander Holding AG
Lotterbergstrasse 30,
Stuttgart,
Germany
Tel: +49 711 8804 1141
Fax: +49 711 8804 1950
www.mw-zander.com

24 Consulting

Fishbone Consulting SARL
8 Rue de la Grange aux Moines,
78460 Choisel,
France
Tel: + 33 (0)1 30 47 29 03
E-mail: jean-luc.ledys@neuf.fr

25 Resources

Al Shultz Advertising Marketing for Advanced Technology Companies
1346 The Alameda,
7140 San Jose, CA 95126, USA
Tel: +1 408 289 9555
www.alshuktz.com

SEMI Global Headquarters
3081 Zanker Road,
San Jose, CA 95134, USA
Tel: +1 408 943 6900
Fax: +1 408 428 9600
www.semi.org

Yole Développement
45 rue Sainte Geneviève,
69006 Lyon, France
Tel: +33 472 83 01 86
www.yole.fr

event calendar

If you would like your event listed in *Semiconductor Today*'s Event Calendar, then please e-mail all details to the Editor at mark@semiconductor-today.com

1–3 March 2016
SIL 2016: Strategies in Light, co-located with The LED Show
Santa Clara Convention Center, CA, USA
E-mail: registration@pennwell.com
www.strategiesinlight.com

15–17 March 2016
SEMICON China 2016
Shanghai New International Expo Centre, China
E-mail: semichina@semi.org
www.semiconchina.org

19–24 March 2016
APEC: 2016 IEEE Applied Power Electronics Conference and Exposition
Long Beach Convention Center, CA, USA
E-mail: apec@apec-conf.org
www.apec-conf.org

20-24 March 2016
Optical Fiber Communication Conference and Exposition (OFC 2016)
Anaheim Convention Center, CA, USA
E-mail: OFC@compusystems.com
www.ofcconference.org

4–7 April 2016
SPIE Photonics Europe 2016
SQUARE Brussels Meeting Centre, Brussels, Belgium
E-mail: info@spieeurope.org
http://spie.org/SPIE-PHOTONICS-EUROPE-conference

7 April 2016
2D Materials Processing Technology Workshop
Alan Turing Building — National Graphene Centre, University of Manchester, UK
www.oxford-instruments.com/2dworkshop

13–16 April 2016
LED Taiwan 2016 and Taiwan International Lighting Show
Taiwan World Trade Center, Taipei, Taiwan
E-mail: sluo@semi.org
www.ledtaiwan.org

17–21 April 2016
SPIE Defense + Commercial Sensing 2016 (DCS), incorporating:
SPIE Defense + Security (Conference on Sensors, Imaging, and Optics)
SPIE Commercial + Scientific Sensing and Imaging (Conference on Advanced Technologies and Applications)
Baltimore Convention Center, Baltimore, MD, USA
E-mail: customerservice@spie.org
http://spie.org/SPIE-DCS-conference

25–27 April 2016
12th International Conference on Concentrator Photovoltaics (CPV-12)
Freiburg, Germany
E-mail: info@cpv-12.org
www.cpv-12.org

advertisers' index

26–28 April 2016
SEMICON Southeast Asia (SEMICON SEA)
Penang, Malaysia
E-mail: skoh@semi.org
www.semiconsea.org

6 May 2016
31st annual Reliability Of Compound Semiconductors (ROCS) Workshop 2016
Hyatt Regency Miami, FL, USA
E-mail: rocs@jedec.org
www.jedec.org/home/gaas

16–19 May 2016
2016 CS MANTECH (International Conference on Compound Semiconductor Manufacturing Technology)
Hyatt Regency Miami, FL, USA
E-mail: conferencechairman@gaasmantech.org
www.csmantech.org

5–10 June 2016
CLEO 2016:
Conference on Lasers and Electro-Optics
San Jose Convention Center, CA, USA
E-mail: info@cleoconference.org
www.cleoconference.org

7–9 June 2016
SEMICON Russia 2016
Moscow, Russia
E-mail: esuvorov@semi.org
www.semiconrussia.org

13–17 June 2016
2016 Symposia on VLSI Technology & Circuits
Hilton Hawaiian Village, Honolulu, HI, USA
E-mail: vlsi@vlsisymposium.org
www.vlsisymposium.org

22–24 June 2016
Intersolar Europe
Messe München, Germany
E-mail: info@intersolar.de
www.intersolar.de

26–30 June 2016
Compound Semiconductor Week 2016 (CSW2016), including:
43rd International Symposium on Compound Semiconductors (ISCS2016);
28th International Conference on Indium Phosphide and Related Materials (IPRM2016)
Toyama International Conference Center, Japan
E-mail: secretary2016@csw-jpn.org
www.csw-jpn.org

11–14 July 2016
Intersolar North America (co-located with ees North America and SEMICON West)
San Francisco, CA, USA
E-mail: info@intersolar.us
www.intersolar.us

12–14 July 2016
SEMICON West 2016
Moscone Center, San Francisco, CA, USA
E-mail: semiconwest@xpressreg.net
www.semiconwest.org

28 August – 1 September 2016
SPIE Optics + Photonics 2016
San Diego Convention Center, CA, USA
E-mail: customerservice@spie.org
http://spie.org/optics-photonics1

6–7 September 2016
2nd International Forum on Sapphire Market & Technologies
Shenzhen, China
E-mail: veyrier@yole.fr
www.i-micronews.com/events/yole-events/eventdetail/142/-/2nd-int-forum-on-sapphire-market-technologies.html
alongside:

6–9 September 2016
18th China International Optoelectronic Exposition (CIOE 2016)
Shenzhen Convention & Exhibition Center (SZCEC), China
E-mail: cioe@cioe.cn
www.cioe.cn/en

7–9 September 2016
SEMICON Taiwan 2016
Taipei Nangang Exhibition Center, Taiwan
E-mail: semicontaiwan@semi.org
www.semicontaiwan.org

12–15 September 2016
25th International Semiconductor Laser Conference (ISLC 2016)
Kobe Meriken Park Oriental Hotel, Kobe, Japan
E-mail: islc2016@ics-inc.co.jp
www.islc2016.org

19–22 September 2016
LED China 2016
Shanghai New International Expo Centre (SNIEC), China
E-mail: led-trust@ubm.com
www.LEDChina-sh.com

2–6 October 2016
29th IEEE Photonics Conference (IPC 2016)
Waikoloa, Hawaii, USA
E-mail: c.c.scott@ieee.org
www.ipc-ieee.org

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