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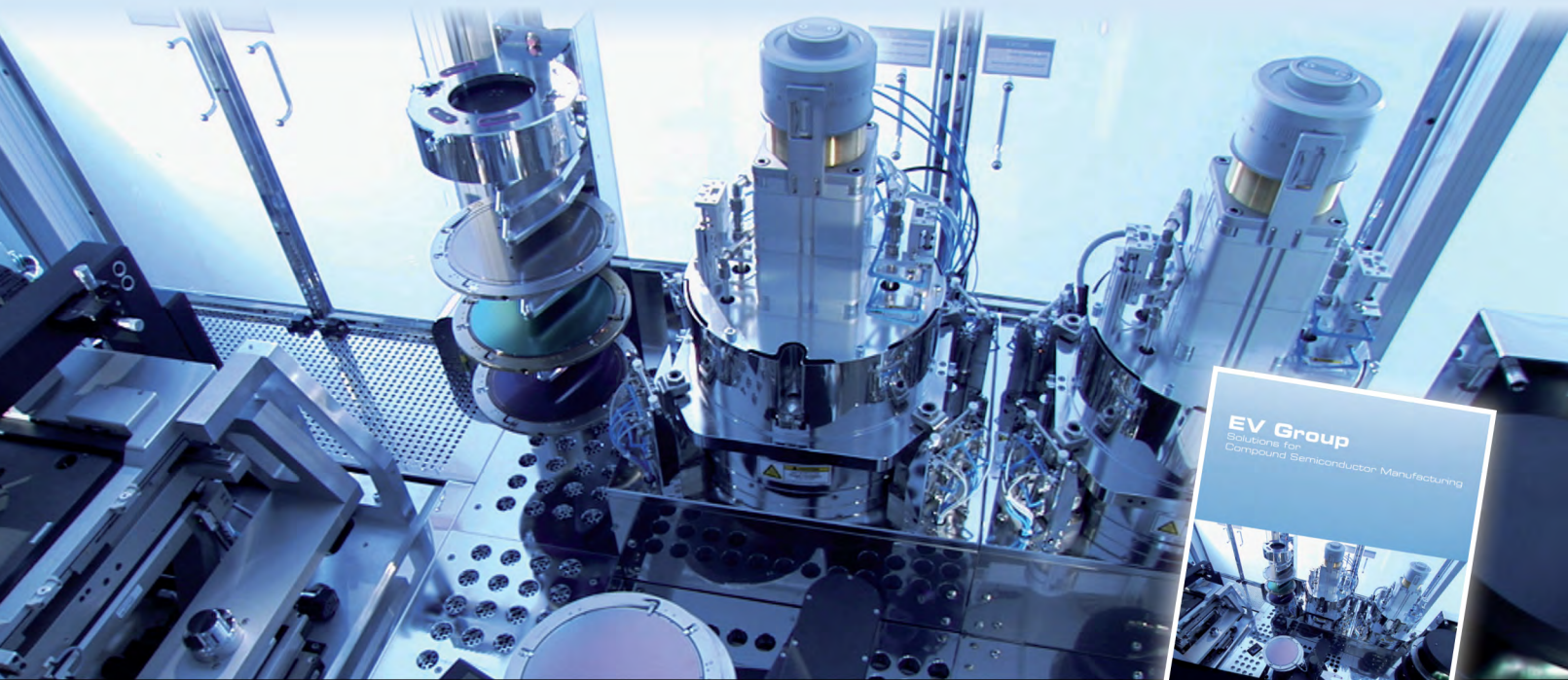

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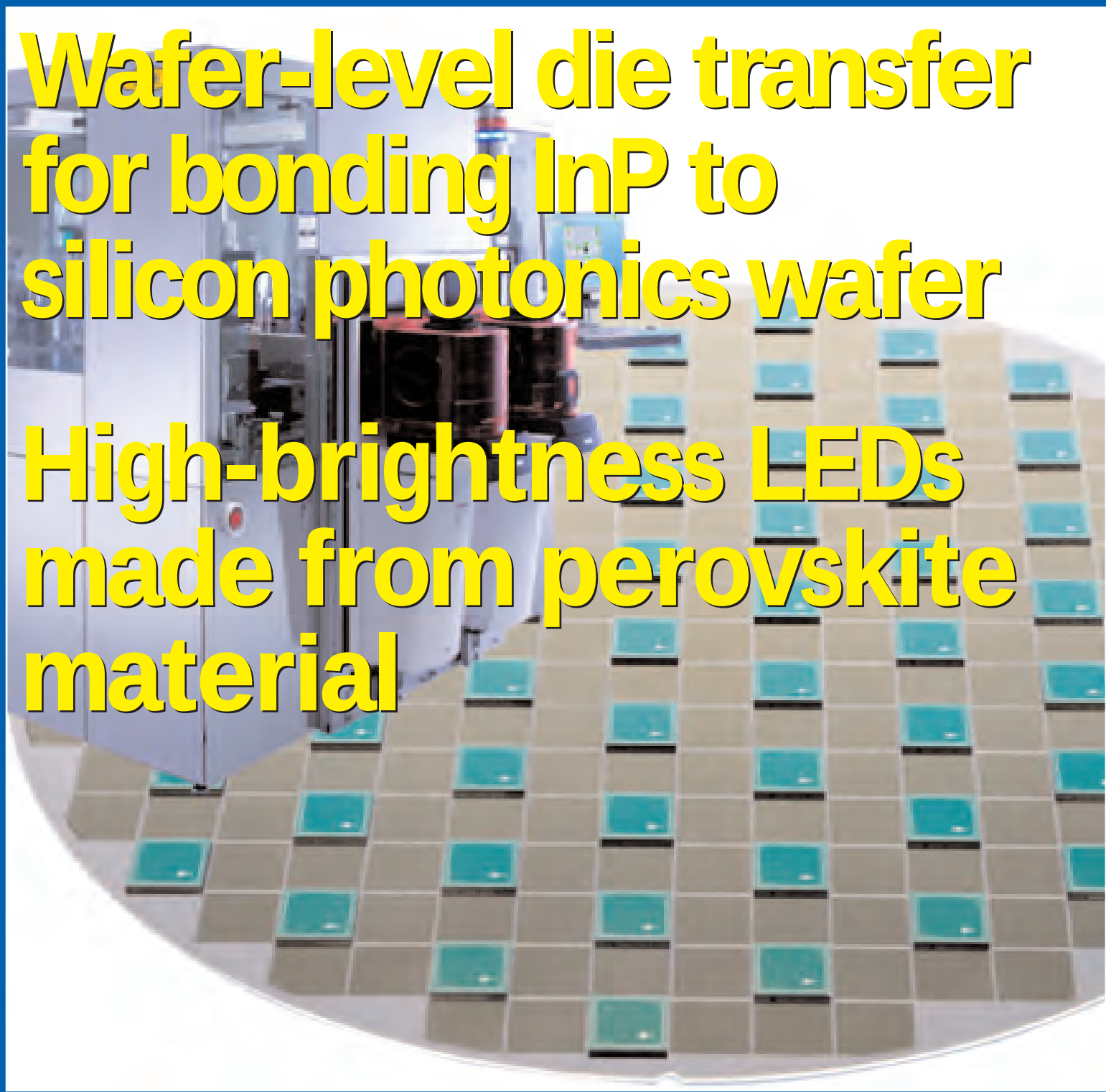


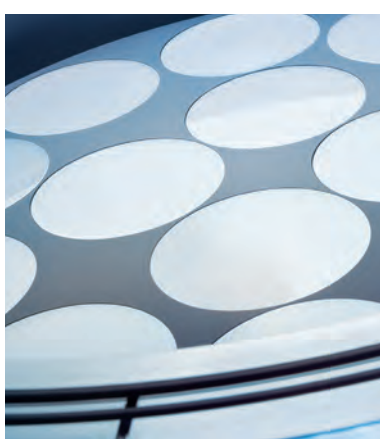
Wafer-level die transfer for bonding InP to silicon photonics wafer

High-brightness LEDs made from perovskite material

Infineon to buy IR • First Solar's record 21% thin-film cell
Ushio acquiring Oclaro's industrial & consumer unit

Light Up a Brighter World

MaxBright MHP MOCVD System



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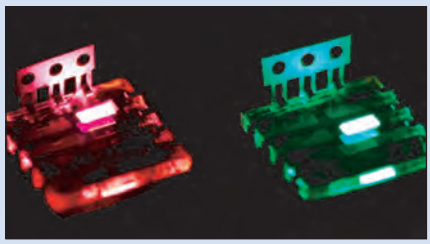

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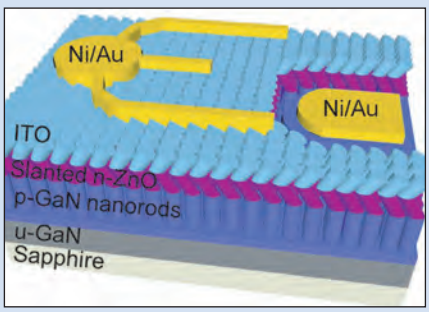

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Cover: Enabling silicon photonics through advances in III-V integration on silicon — EV Group's Dr Martin Eibelhuber discusses a wafer-level die transfer process for bonding InP laser dies to a silicon photonics wafer, allowing volume production. **p64**

editorial

Mergers & acquisitions abound

Recent weeks have seen a continuation in the ongoing spate of industry mergers and acquisitions, as some firms restructure to retrench to their core business and others acquire firms to expand into emerging technologies.

On pages 50–52 we report the second-quarter 2014 results of Oclaro, including its progress in cutting losses through the restructuring that has halved its number of sites (from 20 to 10) and more than halved its workforce (from 3000 to about 1400) over the year to 1 July. Most recently, in early August, it announced the sale of its Japan-based Industrial & Consumer LED and laser business to Tokyo-based light source manufacturer Ushio. Apart from cutting its workforce further (to 1200), the divestment allows Oclaro to focus on its core optical communications business.

Likewise, although not a merger or a divestment, Cree is investing $83m to acquire a 13% stake in Taiwan-based vertically integrated LED firm Lextar in order to secure a supply of sapphire-based mid-power LED chips in exchange for a royalty-bearing license on certain Cree LED chip and component intellectual property, while Cree focuses on the high-power LED chip sector (see page 45).

Meanwhile, in the photovoltaic sector, Chinese renewable-energy power generating firm Hanergy has completed its acquisition of Silicon Valley based development-stage company Alta Devices, which fabricates micron-thick gallium arsenide solar cells, that can then be lifted off the GaAs substrate (which can then be reused repeatedly, cutting costs) while the resultant thin-film solar cells can be transferred to a flexible substrate (see page 57). Alta joins three copper indium gallium diselenide (CIGS) PV firms — Germany's Solibro (from Q.Cells SE) and US firms MiaSolé and Global Solar Energy (GSE) — that have been acquired by Hanergy just in the last few years, as the firm builds its Hanergy Solar subsidiary.

In the microelectronics sector, communications component maker GigOptix has proposed to acquire fellow Silicon Valley firm GSI Technology (which provides memory products for networking and telecoms equipment) — see page 14. This complements several microelectronics acquisitions made by GigOptix for wireless and optical communications in recent years.

In addition, San Diego-based Peregrine Semiconductor, a fabless provider of RF integrated circuits and front-ends based on silicon-on-insulator (SOI) is being acquired by the North American subsidiary of Japan's Murata, which is expanding from its core business of passive components, power supply modules, and RF communications filters and modules, targeting the increasing silicon-based integration of wireless functions in smartphones (see page 18). This follows a collaborative sourcing and licensing agreement in May last year regarding Peregrine's UltraCMOS-based RF switches. It also follows Peregrine's settlement of a patent lawsuit over RF SOI technology with RF Micro Devices, whose own merger with TriQuint is being voted on by shareholders of both firms in the first week of September (see page 12).

But the biggest acquisition announced in August is the $3bn takeover by Germany's Infineon of California-based International Rectifier (page 24). Both mainly silicon-focused, Infineon will complement its power devices (including silicon carbide technology) with IR's power management expertise, including gallium nitride on silicon (GaN-on-Si) technology, which many say will become the 'technology of choice' for power electronics.

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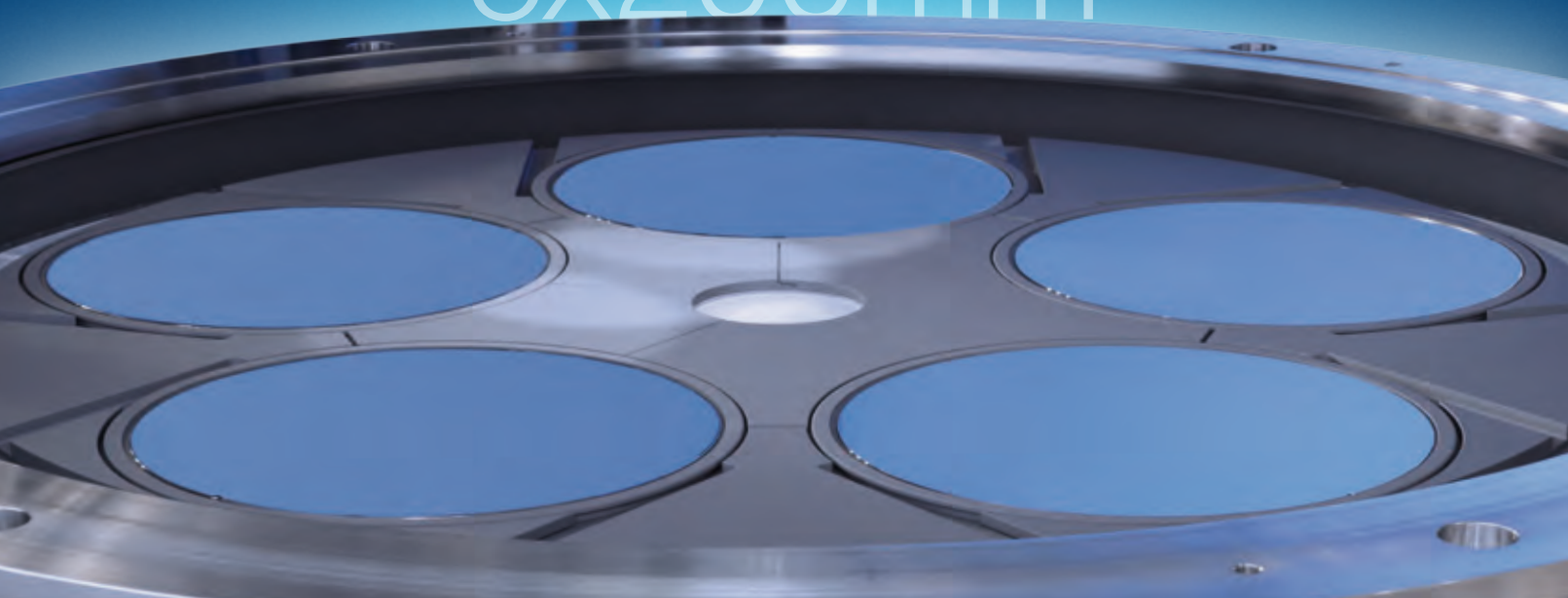

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Mid-power LEDs to account for 48% of market in 2014

Lighting to exceed backlighting in packaged LED revenue

The growing lighting end-market in 2014 is now projected to account for 35% of all packaged light-emitting diode (LED) dollars, according to a Research Note from Jamie Fox, principal analyst at market research firm IHS Inc. For the first time, this is more than all backlighting combined. In 2013, lighting and backlighting accounted for 31% of market revenue each.

Mid-power devices are projected to represent 48% of packaged LED revenue in lighting applications in 2014 and 81% in terms of units. This represents a major change since 2010 when high-power LEDs, such as 1 Watt devices, dominated. In Western regions the mid-power percentage is lower, while in Asia it is higher. Many Chinese suppliers selling LEDs to their large domestic market predominantly produce mid-power LEDs, notes Fox.

From 2011 to 2013, the market for mid-power LEDs grew rapidly, driven by the attractive dollar-per-lumen ratio and the availability of capacity previously used for backlighting. The trend was initially led by South Korean companies such as Seoul Semiconductor and Samsung. However, mid-power LEDs have become an essential part of most global companies' portfolios, with other suppliers such as Lumileds and Cree following the trend. Nichia also has a competitive offering in mid-power, says Fox.

IHS still ranks Cree as the largest provider of packaged LEDs in lighting applications, closely followed by Nichia and Lumileds. Despite this, during the last few years the competition from Asian companies has increased in lighting applications.

In 2015 and beyond, IHS forecasts that the share of mid-power LEDs will continue to increase. The share of chip-on-board (COB) is also growing and playing an increasingly important role as completed lighting products are being designed for a wider variety of target end-markets. High-power LEDs are still popular in some areas such as street lighting, says IHS, and should retain a strong presence in the market.

Excluding lighting, the rest of the LED market is almost completely flat from year–to-year, and is forecast to stay that way to 2019, according to IHS's LED Intelligence Service. The lighting market, led by mid-power LEDs, will drive the growth, it is concluded.

https://technology.ihs.com/Services/467369/led-intelligence-service

LED materials market to grow from $5bn in 2013 to $11.7bn in 2018

The global LED materials market will grow from $5.01bn in 2013 to $11.71bn in 2018, according to a new study from Frost & Sullivan. As LEDs are rapidly taking the place of older, less durable and energy-efficient lighting technologies around the world— and since chemicals and materials are needed at all stages of the LED fixture's manufacturing process — chemical companies will play a critical role in the future of the LED industry, notes Frost & Sullivan. The breadth of material requirements means that few market participants have visibility across the entire market, creating the need for a holistic vision of market potential, it adds.

The study 'Analysis of the global LED materials market' (which includes applications for chemicals through the four stages of the LED manufacturing value chain: chip fabrication, packaging, module construction, and fixture assembly) finds that revenue growth in chemicals demand is expected to be ahead of growth in the LED industry itself.

Historically, demand for LEDs in electronics applications such as display backlighting has driven growth in chemicals demand for LED applications. However, this market is now relatively mature, and demand from the general lighting sector will dominate future growth, says Frost & Sullivan. Of the four value chain tiers involved in manufacturing LEDs, the greatest need for chemicals will emerge from the final stage, assembling the fixture.

"While prices of LEDs are falling at all stages of the value chain, price pressure is particularly strong in the packaging stage," notes Frost & Sullivan's Chemicals, Materials & Foods Analyst. "As a result, chemical companies that offer innovative products enabling cost savings for LED manufacturers will be well positioned to succeed."

Further, market participants must leverage design opportunities offered by the LED space, the firm adds. Unlike traditional luminaries, LED light sources need not be designed around a replaceable bulb. The possibilities for innovative designs and material options will give rise to opportunities that did not exist with previous lighting technologies.

"Chemical companies therefore need to partner with fixture manufacturers to help them understand how chemicals and materials can be used to design the LED fixtures of the future," says the analyst.

www.chemicals.frost.com

Chip-on-board LED market to reach $9180m by 2020

The global chip-on-board LED market is expected to reach $9179.7m by 2020, according to the report 'Chip on Board (COB) Light Emitting Diode (LED) Market Analysis By Application (Automotive, Backlighting, Illumination) And Segment Forecasts To 2020' by Grand View Research Inc. Increasing urbanization and infrastructure spending are expected to be the key drivers of growth over the forecast period.

COB LEDs are energy efficient, have greater reliability and require less space, notes the report. Furthermore, they offer high intensity and homogenous luminosity, making them suitable for high-power applications. In recent times, the use of solid-state lighting technology rather than traditional lighting has led to significantly increased adoption of COB LED, it adds.

High demand for COB LED due to increased adoption by several lighting application segments (to gain benefits over technologies such as CFL and incandescent lighting) is also expected to positively impact the global market over the next six years. Furthermore, advances in design and cost saving through economies of scale are expected to provide significant growth opportunity over the forecast period. However, the complex manufacturing process and high price, coupled with fluctuating global economic conditions, may be a challenge for industry participants, the report cautions.

Further key findings from the study suggest that:

- The illumination segment dominates the market and is expected to be the largest and fastest-growing application over the next six years. This segment accounted for over 45% of the market in 2013, mainly because of COB LEDs' wide area light-emitting property. The backlighting application segment is expected to grow substantially due to the rise in the number of applications in handheld devices, monitors and LED televisions.
- Asia Pacific accounted for over 50% of global market revenue in 2013, and is expected to dominate demand over the forecast period. Further, it is expected to exhibit the fastest growth from 2014 to 2020, due to government initiatives favoring COB LED adoption and a large number of market participants.
- Key firms operating in the market include Philips LumiLEDs Lighting Company, Cree Inc, Samsung Electronics Co Ltd, Citizen Electronics Co Ltd, Osram Opto Semiconductors GmbH, Everlight Electronics Co Ltd., Seoul Semiconductor Co Ltd, Nichia Corp, Lumens Co Ltd, and LG Innotek Co Ltd. The market is consolidated in nature, and the development of efficient and cost-effective products is expected to serve as a key growth strategy over the forecast period.

www.grandviewresearch.com/industry-analysis/chip-on-board-light

LED lighting module revenue to grow 500% by 2019, overtaking backlighting applications

Revenues for LED modules in lighting applications are expected to increase at a compound annual growth rate (CAGR) of 32.8% to $7.8bn by 2019, according to Strategies Unlimited's first report on the global LED module market.

'The Worldwide Market for LED Modules' analyzes the market for LED modules used in backlighting and lighting, providing forecasts for modules used in nine lighting applications including troffers, downlights, street lights, and retrofit lamps.

Backlighting will comprise a larger portion of the module market through 2018, when point saturation plus increased usage by luminaire manufacturers of third-party LED modules will allow the lighting portion to surpass it.

Lighting end-applications seeing the largest growth in LED modules will be troffers, area lights, and street lights. "The large installed base of troffers and high/low-bay luminaires means that. although the penetration of modules within LED troffers and LED area lights is lower than for downlights, the sheer size of the installed base means more potential for LEDs and strong growth for LED modules," says research analyst Stephanie Pruitt.

Prices for LED modules in lighting will fall as the overall price of the luminaire also falls. However, it is anticipated that, as LED modules continue to evolve (allowing simplified design and production as well as interchangeability), they will make up a larger portion of the overall luminaire cost. "What we are seeing now is a split in the market between basic packaged LEDs on a PCB to really high-end modules which also have optics and thermal management on board," notes Pruitt. "Currently, there is not much standardization in the market, and so the majority of manufacturers are producing modules on a custom basis," she adds." As the LED lighting market continues to grow, more integration will help with the adoption and streamlining of LED modules, which will allow for healthy growth."

North America and Europe will see strong LED module growth in professional applications that require high light quality, the report says. The large installed base and continued new construction in China will drive unit growth there, but its lower average selling prices (ASPs) mean that it will only be the third largest market in revenue terms by 2019.

www.strategies-u.com

SiC to displace silicon in electric vehicles by 2020

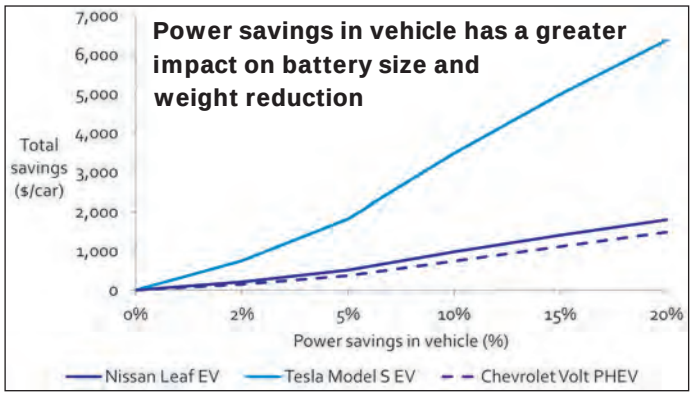
Wide-bandgap materials to improve efficiency and cut battery costs

Wide-bandgap (WBG) semiconductor materials such as silicon carbide (SiC) and gallium nitride (GaN) are best positioned to address emerging power electronics performance needs in electric vehicles (EVs), with SiC displacing silicon as early as 2020, according to Lux Research.

As silicon struggles to meet higher performance standards, WBG materials are benefiting critically from evolving battery economics, says the market analyst firm. On the Tesla Model S, for example, a 20% power saving can result in gains of over $6000 in battery cost, or 8% of the vehicle's cost.

"Efficient power electronics is key to a smaller battery size, which in turn has a positive cascading impact on wiring, thermal management, packaging, and weight of electric vehicles," notes Lux Research analyst Pallavi Madakasira, lead author of the report 'Silicon vs. WBG: Demystifying Prospects of GaN and SiC in the Electrified Vehicle Market' (part of the Lux Research Energy Electronics Intelligence service).

"In addition to power electronic modules, opportunities from a growing number of consumer applications — such as infotainment and screens — will double the number of power electronic components built into a vehicle," she adds.



Lux Research analysts evaluated system-level benefits that WBG materials are bringing to the automotive industry, and predicted a timeline for commercial roll-outs of WBG-based power electronics. Their findings include the following:

● *Lower power saving threshold*. At 2% power savings, if battery costs fall below $250/kWh, then SiC diodes will be the only economic solution in EVs requiring a large battery, such as the Tesla Model S. However, for plug-in electric vehicles (PHEVs), the threshold power saving needs to be a higher 5%.

● *SiC ahead in road to commercialization*. SiC diodes lead GaN in technology readiness and will attain commercialization sooner, based on the current Technology Readiness Level (TRL). Based on the TRL roadmap, SiC diodes will be adopted in vehicles by 2020.

● *Government funding driving WBG adoption*. The USA, Japan and UK, among others, are funding R&D in power electronics. The US Department of Energy's Advanced Power Electronics and Electric Motors is spending $69m this year and defining performance and cost targets; Japan funds a joint industry and university R&D program that includes Toyota, Honda and Nissan.

https://portal.luxresearchinc.com/research/report_excerpt/17422

GaAs integrated circuit market to grow to $8bn in 2017

Power amplifier prices to rise from $2.90 to over $3.50

The gallium arsenide integrated circuit market will grow to $8bn in 2017, according to a report 'The GaAs IC Market' by The Information Network.

The biggest enabler of the mobile data increase and the most important driver of the GaAs RF IC market is the handset segment. Much of the content of a handset is silicon-based, but power amplifiers (PAs) and switches in the front-end of the phone use GaAs devices.

Since every cell phone contains power amplifiers (PA) to enable the handset to transmit voice and data back to the base station tower (to route a call to another phone or Internet address), power amplifiers are the most critical radio frequency component in the phone, and are currently dominated by circuits made with GaAs.

3G handsets often contain up to five PAs, and GaAs makes up 100% of the market, which is close to $5bn. In addition, the number of PAs per handset is growing because of: complex 3G systems, global roaming support, and data roaming support. Pricing for PAs has risen from $0.80 per handset to $2.90 currently and is projected to exceed $3.50 after long-term evolution (LTE) and advanced wireless services (AWS) spectrum emerge in advanced handsets in the marketplace.

While industrialized countries are using 3G networks, there is currently a mixture of 2/2.5G and 3G networks globally, and the majority of subscribers are actually on 2G-based networks — and are predicted to remain so for a number of years.

2G handsets contain one PA, so it represents a sizable market. But because they are not as technologically advanced as 3G cell phones (particularly smartphones), silicon is making inroads into the GaAs domain. In 2013, only 90% of PAs were made in GaAs, 5% in silicon CMOS, and 5% in silicon LDMOS, reckons the report. Nevertheless, Between 70% to 80% of Skyworks' and RF Micro Device's GaAs businesses is in PA.

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Anadigics' Q2 sales down 33% year-on-year, but infrastructure compensating for decline in legacy mobile

Restructuring targets EBITDA breakeven at quarterly revenue of $25m

For second-quarter 2014, broadband wireless and wireline communications component maker Anadigics Inc of Warren, NJ, USA has reported revenue of $23.3m, down 33% on $34.6m a year ago and level with Q1/2014 but slightly above the guidance of $23m (which had been lowered on 26 June from initial guidance of 8–12% growth).

There were three greater-than-10% customers (Huawei, Samsung and distributor Richardson Electronics) plus three customers at 5–10% (including infrastructure custom).

As part of its strategic restructuring announced in June, Anadigics segments revenue into two categories: Infrastructure (products for CATV, small-cell, WiFi, M2M, optical and other general RF applications) and Mobile (WiFi and Cellular products mainly addressing the smartphone, handset and tablet markets). Mobile revenue has fallen 6.7% from $17.9m last quarter to $13.1m. However, Infrastructure revenue has risen by 10% to $10.2m (to 44% of total revenue).

"In the mobile markets, our dependence on Samsung has decreased substantially," notes chairman & CEO Ron Michels. In May, Anadigics announced multiple design wins at several Chinese smartphone OEMs. "While the decline in our business from Samsung has not been fully offset with the new designs we are winning in China, the quality of these new design wins is significantly higher," he adds. "We expect these trends to continue and will support these mobile markets for the foreseeable future."

"We saw a rise in infrastructure revenue offset a decline in mobile revenue, resulting in an increase in gross profit despite lower utilization [of just 35%, down from 45–50% last quarter]," says VP & chief financial officer Terry Gallagher.

On a non-GAAP basis, gross margin has risen from 10.9% last quarter to 12.8%, driven by a richer mix of infrastructure, more than offsetting the lower capacity utilization.

Operating expenses have been cut by 12% from $12.1m last quarter to $10.7m, mainly due to R&D expenses being cut by 16% from $8m to $6.7m, while selling & administrative expenses fell by 4.9% from $4.1m to $3.9m.

Net loss has been cut from $12m ($0.14 per share) a year ago and $9.6m ($0.11 per share) last quarter to $7.8m ($0.09 per share, better than the revised guidance of $0.10, which itself had been cut from initial guidance of $0.11). Likewise, despite flat sales, earnings before interest, taxes, depreciation and amortization (EBITDA) loss has improved by 25% from $4.7m last quarter to $6.25m.

After being cut from $1.3m in Q4/2013 to $400,000 last quarter, capital expenditure has been cut further, to $350,000. During the quarter, cash, cash equivalents and restricted cash rose from $14.1m to $16.7m. However, excluding $7m drawn under the firm's credit facility, net cash was $9.7m, down $4.4m.

"With the restructuring [announced on 26 June], Anadigics is better positioned to compete in infrastructure markets where our products are differentiated and we can be more selective in targeting mobile applications that are better aligned to our profitability objectives," says Michels. "Combined with a significantly lower operating cost structure, we expect these changes in product focus to drive greater returns for shareholders," he adds. "Design-win traction with existing and new customers for both mobile and infrastructure applications has been strong."

In line with its restructuring, for Q3/2014 Anadigics expects revenue to fall sequentially by 18–20%, driven by reductions in legacy mobile that are not fully offset by anticipated growth in sales to infrastructure and targeted mobile customers. "We believe it represents the trough," says Michels.

Despite the lower revenue and factory utilization, gross margin should rise by about 200 basis points due to a richer product mix and lower manufacturing costs. "With our strategic restructuring actions and other improvements, we expect operating expenses to decline by more than 15%," says Gallagher. These factors should enable a further sequential EBITDA improvement of about 25%. "Expected sell-through of certain inventory and anticipated asset sale proceeds in excess of our restructuring payouts should provide cash to fund a portion of the projected EBITDA loss, thereby limiting Q3's cash consumption," he adds.

"With our restructuring revenue rolling faster than we expected, we were able to accelerate our business model transition through the strategic restructuring we announced in June," says Michels. "This restructuring enables a number of important short- and long-term objectives. With more resources focused on our strategic infrastructure markets, we anticipate greater penetration and a continued sequential growth in our infrastructure revenue," he adds. "With that and the completion of our restructuring activities, we expect to achieve sequential improvements in our broader financial performance, including higher gross profit margins, lower operating expenses, and improved EBITDA. We anticipate achieving EBITDA breakeven at a quarterly revenue below $25m. From there, we expect infrastructure to expand well beyond 60% of our revenue... This will generate high marginal profitability and produce greater financial returns as we continue to grow. With our anticipated EBITDA improvements, lower cash consumption, and growth trajectory, we believe the business is adequately capitalized with our existing cash."

www.anadigics.com

Analog Devices completes acquisition of Hittite

New RF & Microwave Group led by Hittite's former president & CEO

Analog Devices Inc (ADI) of Norwood, MA, USA (which provides semiconductors for signal processing) has completed its acquisition of Hittite Microwave Corp of Chelmsford, MA, (which designs and makes analog, digital and mixed-signal RF, microwave and millimeter-wave ICs, modules and subsystems as well as instrumentation) in an all-cash transaction at $78 per share (reflecting a total enterprise value of about $2bn).

"ADI's portfolio now spans the entire frequency spectrum of RF, microwave and millimeter wave," says president & CEO Vincent Roche. "Complemented by our world-class signal processing franchise, we believe our customers will benefit from more complete solutions across a breadth of applications, including industrial instrumentation, aerospace & defense electronics, communications infrastructure, and automotive safety," he adds.

ADI also announced that its new RF and Microwave Group (RFMG) will be led by Hittite's former president & CEO Rick D. Hess. RFMG combines product and technology development teams from ADI's RF and microwave group and Hittite.

As a result of the acquisition, Hittite's shares of common stock have been delisted from the NASDAQ Global Select Market.

www.analog.com
www.hittite.com

RFaxis ramps production of broadband sub-GHz CMOS RFeIC to support IEEE 802.11ah and ZigBee Alliance 920IP initiatives

Fabless semiconductor firm RFaxis Inc of Irvine, CA, USA, which designs RF semiconductors and embedded antenna solutions for wireless connectivity and cellular mobility, is ramping up production of the RFX1010, a highly integrated broadband CMOS RF front-end integrated circuit (RFeIC) to serve the ZigBee and Internet of Things (IoT) market segments that use the 600/700/800/900MHz 'sub-GHz' frequency bands. The firm says the addition of RFX1010 means that it is now a one-stop-shop for the IoT/M2M (machine-to-machine) wireless community with an entire family of ZigBee/ISM (industrial, scientific & medical) RF front-end solutions ranging from 600MHz to 6GHz.

920IP is the most recent ZigBee IP release from the ZigBee Alliance to support IPv6-based full wireless mesh networking solution to control low-power, low-cost devices, such as those for HEMS (Home Energy Management Systems) and ECHONET Lite in the 920MHz frequency band designated by Japan's Ministry of Internal Affairs and Communications (MIC). Integrating a half-watt power amplifier (PA), low-noise amplifier (LNA), antenna switch and all impedance matching networks into a single-chip/single-die CMOS device and assembled in a 3mm x 3mm QFN (quad-flat non-lead) package, the RFX1010 is an RF front-end solution for both 920IP and emerging IEEE 802.11ah standard-based applications.

"By adding RFX1010, RFaxis now offers the industry's most comprehensive and high-performance RF front-end portfolio, at a price point utterly disruptive in the IoT/ZigBee market," claims chairman & CEO Mike Neshat. "RFX1010 is a market-proven product that has passed the most rigorous, industrial-rating qualification by our strategic partners. We have already secured several design-wins with Tier-1 customers in North America and Asia," he adds. "We applaud the most recent 920IP initiatives by the ZigBee Alliance, which we believe will accelerate the adoption of sub-GHz radio for the nascent HEMS and Smart Home/Smart Energy markets in Japan and the rest of the world."

The RFaxis IoT/M2M RFeIC portfolio now consists of RFX2401C and RFX2411 for 2.4GHz, RFX1010 for sub-GHz (600–900MHz), and RFX5000/RFX5000B for 5–6GHz frequency bands. These devices can work with all popular wireless standards including ZigBee, Bluetooth, Bluetooth Low Energy, ANT, 6LoWPAN and other generic ISM or proprietary radios, says the firm. They provide key RF functions, including the power amplifier (PA) and low-noise amplifier (LNA) as well as the antenna switches that are needed to guarantee robust operating range and high receive sensitivity of any wireless system, even in the harshest RF environment, adds RFaxis.

Built upon the firm's patented single-chip/single-die RFeIC architecture and fabricated in industry-standard bulk CMOS technology, the RFeICs not only simplify RF designs but also provide a significant cost reduction compared with traditional gallium arsenide (GaAs) or silicon germanium (SiGe)-based RF front-end solutions, claims RFaxis. All the RFeICs are available in bare die form, making it possible for wireless module manufacturers to design miniature SiP (system-in-package) or compact, pre-certified ZigBee/ISM modules. The bare dies are offered at a lower price than their packaged counterparts, targeting hardware developers in the IoT/M2M ecosystem.

www.rfaxis.com

RFMD and TriQuint schedule shareholder meetings concerning merger for 5 September

RF Micro Devices Inc of Greensboro, NC, USA and RF front-end component maker TriQuint Semiconductor Inc of Hillsboro, OR, USA have each scheduled special shareholder meetings for 5 September, mainly to seek shareholder approval for their proposed merger (announced in February) under a new holding company, currently named Rocky Holding Inc.

RFMD's meeting will be held at 9am local time, at the office of Womble Carlyle Sandridge & Rice LLP (One West Fourth Street, Winston-Salem, NC 27101). TriQuint's meeting will be held at 1pm local time, at TriQuint's headquarters (2300 NE Brookwood Parkway, Hillsboro, OR 97124). Each firm's shareholders of record as of the close of business on 16 July will be entitled to vote at their respective meetings.

The companies also announced that the registration statement on Form S-4 filed with the US Securities and Exchange Commission (SEC) by Rocky Holding Inc on 14 April, and as subsequently amended (which includes a joint proxy statement/prospectus of RFMD and TriQuint), was declared effective by the SEC on 30 July. On 30 July, Rocky Holding Inc filed a revised joint proxy statement/prospectus pursuant to Rule 424(b) of the Securities Act of 1933, as amended, in order to make available the document that will be mailed to RFMD and TriQuint shareholders in connection with the respective special meetings. The joint proxy statement/prospectus is available on the SEC's EDGAR system under the name 'Rocky Holding, Inc' and can be accessed at: www.sec.gov/cgi-bin/browse-edgar?company=Rocky+Holding&owner=exclude&action=getcompany.

RFMD and TriQuint will soon begin mailing the joint proxy statement/prospectus to their respective shareholders to provide additional information and instructions for voting.

Closing of the merger remains subject to customary conditions set forth in the parties' Agreement and Plan of Merger and Reorganization of 22 February, including approval by shareholders of both RFMD and TriQuint and other regulatory approvals.

www.triquint.com
www.rfmd.com

Skyworks' analog and RF solutions enabling wireless automotive platforms

Analog semiconductor maker Skyworks Solutions Inc of Woburn, MA, USA says that a tier-one automotive supplier is leveraging several of its solutions in its vehicle-based wireless platforms ramping across several leading car makers, including General Motors, Chrysler, Fiat and Toyota.

The control system enables drivers to remotely activate garage door openers, entry door locks, home lighting, security systems and entry gates. Currently offered in all automotive brands, the platform is compatible with more than 99% of garage door opening systems as well as a wide variety of home safety and convenience products. The three-button interface is located as an easy-to-install module in automobile rear-view mirrors for a battery-free, programmable solution that eliminates the need for traditional clip-on transponders.

"Skyworks' advanced analog and RF solutions are being leveraged across multiple in-vehicle applications that are enhancing safety and the overall driving experience," says John O'Neill, VP of broad markets marketing at Skyworks. "As wireless technology in automobiles continues to rise, we are capitalizing on the increasing number of addressable semiconductor opportunities that add value, minimize OEM costs and complexity, and improve time to market," he adds.

According to the report 'Connected Car Market: Global Industry Analysis, Size, Share, Growth, Trends and Forecast' from Transparency Market Research, the global connected car market is expected to increase at a compound annual growth rate (CAGR) of 34.7% to $131.9bn by 2019, driven by safety and security services along with gaming, entertainment, traffic information, weather and location services.

Skyworks offers a range of analog, mixed-signal and RF semiconductors that are key components to the design of wireless automotive systems and transportation infrastructure, enabling new safety and convenience features.

Skyworks' new automotive solutions are available now for both sampling and production.

www.skyworksinc.com

Skyworks powers NETGEAR's 802.11ac router

Analog semiconductor maker Skyworks Solutions Inc of Woburn, MA, USA says that that several of its solutions are powering the Nighthawk X6 platform from networking product maker NETGEAR of San Jose, CA, USA. The device is reckoned to be the industry's first tri-band WiFi 802.11ac router delivering speeds up to 3.2Gb/s and supporting the increasing number of wirelessly enabled devices in the home. Skyworks is powering the two 5GHz front-end modules (FEMs) and the 2.4GHz module in addition to the radio-frequency content across these bands.

"Today's connected customers are using an increasing number of WiFi devices in the home," says Sandeep Harpalani, NETGEAR's director of product marketing for retail networking products. "By leveraging Skyworks' leading-edge connectivity solutions within our Nighthawk X6 platform, we are able to provide customers with high-definition coverage throughout the home."

"This analog-rich application is the industry's first tri-band WiFi router solution capable of providing up to two times the total data rate of routers available in the market today, allowing consumers to stream simultaneous HD content wirelessly on several devices at once," notes Bradley C. Byk, Skyworks' senior VP of worldwide sales.

High-performance 802.11ac WiFi currently enables media applications for several hundred million residential gateways, service providers and over-the-top set top boxes, smart televisions and whole home audio systems. According to ABI Research, by the end of 2014, 802.11ac is expected to be included in more than 50% of total WiFi integrated circuits shipped. ABI also predicts that, as the technology continues to expand with new protocols, nearly 18 billion more chipsets will ship cumulatively from 2015–2019.

The Nighthawk X6 AC3200 Tri-Band WiFi Router (R8000) intelligently segments slower and faster devices into the most appropriate WiFi band. This network load balancing and segmentation enables the X6 to mitigate interference and more effectively support all WiFi devices. It also supports NETGEAR Beamforming+, a smart signal-focusing technology that improves WiFi connections by locking onto a wireless device on the network and pinpointing WiFi signals directly at the device. As consumers move, Beamforming+ adjusts for distance, delivering fast downloads, clearer voice over Internet calls, uninterrupted HD video and lag-free gaming. The boost in speed, reliability and range of WiFi connections is delivered on all three WiFi bands.

Skyworks' WiFi connectivity solutions include integrated front-end modules as well as discrete power amplifiers (PA), low-noise amplifiers (LNA), SPDT, SP3T and DPDT switches, and power management devices. These enable Internet of Things applications including mobile devices, computing, networking and home entertainment. Skyworks' 2.4GHz, 5GHz, and dual-band products cover WLAN 802.11a,b,g,n and the emerging high-throughput 802.11ac standards. The firm's portfolio supports a wide range of end products from access point and routers to mobile/portable subscriber equipment.

www.netgear.com/home/products/networking/wifi-routers/R8000.aspx

Skyworks receives Mexico's Technology and Innovation Award

Skyworks has received the National Technology and Innovation (PNTi) award from Mexico in two categories: Technology Management and Process Innovation.

The PNTi is one of four awards given by Mexico's federal government to businesses that have demonstrated a commitment to innovation and technology that make them more productive and competitive globally. Skyworks was recognized for its management systems, continuous improvement, best practices, and intellectual property development.

"Our recognition in two categories is a testament to the best practices that our employees embrace on a daily basis," says Bruce J. Freyman, Skyworks' executive VP of worldwide operations.

Chairman & CEO David J. Aldrich congratulates Mexicali employees.

Skyworks has been manufacturing integrated circuit modules in Mexicali since 1969. The firm is currently one of the largest employers in Mexicali (with 3100 staff) and participates in governmental programs that promote R&D in Mexico. Skyworks says that, over the last several years, it has worked with governmental agencies, universities and R&D centers to increase competencies, create new capabilities, grow business opportunities and nurture supplier development in Mexicali. In 2013, the firm was awarded the National Quality Award, and in 2012 it received Baja California's State Quality Award.

www.skyworksinc.com

GigOptix proposes to acquire GSI Technology for $161m

Merger to create high-speed communication semiconductor firm

GigOptix Inc of San Jose, CA, USA (a fabless supplier of analog semiconductor and optical communications components for fiber-optic and wireless networks) is proposing to acquire GSI Technology Inc of Sunnyvale, CA for $6.50 per share. This consists of (i) $2.00 per share in cash, (ii) GigOptix common stock worth $1.33 (based on the volume-weighted average price of GigOptix's common stock for the three trading days ending one day prior to the closing of the merger) and (iii) a special dividend of $3.17 per share in cash payable by GSI. The offer represents a 32% premium above the closing price of $4.94 per share for GSI's common stock on 18 August and a 12% premium above the closing price of $5.80 on 8 July.

The latter date was the day before GSI commenced a modified Dutch auction self-tender offer, after which GSI accepted for purchase about 3.85 million shares (14% of the outstanding common stock) at $6.50 per share, on par with GigOptix's offer price). About 10.5 million shares were tendered, representing in excess of 38% of the shares outstanding prior to the commencement of the Dutch auction.

On a preliminary basis and subject to confirmatory due-diligence, GigOptix believes that the combined firm (which would have generated about $86m in sales based on reported revenues over the most recent trailing 12 months for each firm) would be immediately accretive on an adjusted EBITDA basis.

GigOptix says that, by offering both GSI's high-performance memory products for networking and telecoms equipment and GigOptix's high-speed communications components, the firms would enhance their collective product and service offerings, providing a wider range of companion and complementary products and more effectively challenging their respective competitors.

GigOptix is a fabless supplier of high-speed semiconductor components that enable end-to-end information streaming over optical and wireless networks. Products address long-haul and metro telecom applications as well as emerging high-growth opportunities for Cloud and data-center connectivity, storage-farms connectivity, interactive applications for consumer electronics, high-speed optical and wireless networks, and the industrial, defense and avionics industries. The firm claims that its business is unique as it consists of both RF and ASIC technologies products serving the high-speed telecom, datacom, storage and consumers optical and wireless communication markets, as well as the military/aerospace, testing and medical industrial markets.

Through our high-speed communication products we offer a broad portfolio of high-performance optical and wireless components to telecom and datacom customers, including (i) mixed-signal radio-frequency integrated circuits (RFIC), including 10–400Gbps laser and optical drivers and trans-impedance amplifiers (TIA) for telecom, datacom, and consumer electronic fiber-optic applications; (ii) power amplifiers and transceivers for microwave and millimeter-wave monolithic microwave integrated circuit (MMIC) wireless applications including 50–60GHz, 71–76GHz and 81–83GHz power amplifiers and transceiver chips; and (iii) integrated systems in a package (SIP) solutions for both fiber-optic and wireless applications. This product line also partners with key customers on development projects that generate engineering project revenue and help to position the firm for future product revenues with these key customers.

GigOptix believes that there would be significant synergies in a combined company, providing a diverse product portfolio integrated approach to the firms' respective major customers

Through GigOptix's industrial products, it offers digital and mixed-signal application-specific integrated circuit (ASIC) solutions for industrial, military, avionics, medical and communications markets. The Industrial product line partners with ASIC customers on development projects that generate engineering project revenue and that lead to future product revenues with these ASIC customers.

GigOptix designs, develops and sells analog ICs, multi-chip modules (MCMs), and digital and mixed-signal ASICs, as well as wireless communications MMICs and modules, focusing on the fast-growing market for electronic solutions that enable high-bandwidth optical connections found in telecom, datacom and storage systems, as well as in consumer electronics and computing systems.

Since the firm's inception in 2007, it has expanded its base through the acquisition and integration of six businesses with complementary products and customers. Specifically, it has expanded its product line from a few 10Gbps ultra-long-haul optical drivers to include: drivers, receivers and TIAs for 10–400Gbps optical applications; power amplifiers for RF applications including wireless and GNSS; and custom ASICs spanning 40nm to 0.6μm technology nodes. The direct sales force is based in three countries and is supported by channel representatives and distributors throughout North America, Europe, Japan and Asia. Also, in February the firm formed the silicon photonics-focused joint venture BrPhotonics Produtos Optoeletrônicos LTDA (BrP) in Campinas, Brazil, taking 49%:51%

ownership with Fundação CPqD – Centro De Pesquisa e Desenvolvimento em Telecomunicações (the largest optical Brazilian Federal R&D institute focused on innovation in information and communication technologies). GigOptix has hence enhanced its businesses in Brazil, and obtained direct access to a attractive and rich set of technologies, intellectual property and skills in CPqD addressing COMS devices such as DSP and silicon photonics advanced technologies and devices.

GigOptix believes that there would be significant synergies in a combined company, providing a diverse product portfolio integrated approach to the firms' respective major customers, including Alcatel-Lucent, Cisco Systems and Huawei Technologies and other telecom and datacom customers that would be able to deliver better value to our customers while driving more revenue to the combined operations.

"Together, we can create a world-class high-speed communication semiconductor business," says GigOptix's co-founder, chairman & CEO Dr Avi Katz. "Our combination will deliver superior value to our respective shareholders, as it will strengthen the value proposition that we provide to our mutual customers, becoming a major lead supplier of semiconductor devices for the new era of high-speed core, metro and cloud connectivity infrastructure markets," he believes. "GSI Technology's shareholders, as new shareholders in GigOptix, would not only achieve a significant realization event, but would also be able to share in the growth of the combined company."

GigOptix believes that the proposed combination would receive all necessary regulatory approvals and expects that the proposed transaction would be completed in fourth-quarter 2014. Upon consummation of the proposed transaction, GSI shareholders and vested option holders would own about 45% of the combined company.

GigOptix has received a commitment letter from Opus Bank to fully debt finance the cash portion of the offer. A copy of the letter has been provided to GSI's management and board of directors.

GigOptix's proposal is subject to the negotiation of a definitive merger agreement, and receipt of necessary board, stockholder and regulatory approvals, as well as completion of a due diligence review of GSI. GigOptix would also require the approval of its stockholders to increase its available common stock and approve the issuance of shares in connection with the transaction.

www.gigoptix.com
www.gsitechnology.com

IN BRIEF

MACOM names ex-Hittite veteran as SVP of global sales

M/A-COM Technology Solutions Inc of Lowell, MA, USA (which makes analog semiconductors, components and subassemblies for analog, RF, microwave and millimeter-wave applications) says that Thomas Hwang is joining it as senior VP of global sales.

Hwang spent the last 10-plus years at Hittite Microwave Corp of Chelmsford, MA (which designs and makes analog, digital and mixed-signal RF, microwave and millimeter-wave ICs, modules and subsystems as well as instrumentation) in positions including VP of sales. There, he helped to grow annual revenue from $30m to $274m prior to the firm's acquisition in July by Analog Devices Inc of Norwood, MA.

MACOM is adding a "high-performance RF and microwave industry veteran with Thomas' experience and track record," says president & CEO John Croteau. "We add another impact player with a proven ability to realize our growth aspirations."

www.macomtech.com

GigOptix adds senior director of CMOS Engineering as its SiGe technology enters high-volume applications

GigOptix Inc of San Jose, CA, USA (a fabless supplier of analog semiconductor and optical communications components for fiber-optic and wireless networks) has appointed industry veteran Emad Afifi to the newly created role of senior director of CMOS Engineering for the Datacom and Consumer Product Lines.

"Now that we see our SiGe [silicon germanium] technology moving into the high-volume applications in the datacom and consumer markets, augmenting and diversifying the design activities in our Zurich and Auburn design centers, we hired Mr Emad Afifi to lead the next generation of CMOS products," says chief technical officer Andrea Betti-Berutto. "Emad adds more than 20 years of CMOS and SiGe high-speed links product development experience to GigOptix," he continues. "Emad will lead our CMOS consumer and advanced product initiatives and will help us accelerate GigOptix's presence into these markets."

Prior to joining GigOptix, Afifi co-founded Ensphere Solutions, where he was VP of engineering, in charge of SiGe and CMOS transceiver and SerDes development. His experience includes participating in more than 20 integrated circuit (IC) and system-on-chip (SoC) designs covering different communication standards from ADSL to optical communications. Prior to Ensphere, Afifi worked in various engineering roles for more than 15 years at Centillium Communications and Philips Semiconductors.

RFaxis unveiling family of RF front-ends for IEEE 802.11ac in nanometer-scale CMOS

Fabless semiconductor firm RFaxis Inc of Irvine, CA, USA, which designs RF semiconductors and embedded antenna solutions for wireless connectivity and cellular mobility, is unveiling a family of Nano RF products code named Nucleus.

The initial device, Nucleus45, is a fully integrated 5GHz 802.11ac RF front-end IC (RFeIC) in 40nm CMOS, scheduled for sampling to strategic customers in fourth-quarter 2014. A dual-band/dual-mode RFeIC in the same 40nm node, Nucleus4, will be available in Q1/2015. The firm will also introduce its next-generation Nucleus2 series products, providing a seamless migration from the 40nm to 28nm process node.

Driven by key applications such as smartphones, PCs/tablets, high-definition video streaming, and the Internet of Things (IoTs), Wi-Fi continues to enjoy huge market success, maintaining its explosive growth momentum, says RFaxis. According to market research firm Strategy Analytics, over 2 billion Wi-Fi chips were shipped in 2013, with annual shipment projected to exceed 3 billion units by 2017.

To further improve wireless speed and real-life data throughput, the Wi-Fi industry is rapidly adopting the latest IEEE standard, 802.11ac, which supports advanced modulation schemes such as 256QAM, up to 8x8 MIMO (multiple-in multiple-out) and MU-MIMO (multi-user MIMO), to deliver unprecedented high data speeds approaching 10Gbps. To further reduce size, enhance processor capability, and increase integration, Wi-Fi system-on-chip (SoC) vendors have been constantly moving toward smaller CMOS process nodes for their next-generation products, says RFaxis.

As CMOS technology continues its migration path toward deeper-submicron nodes (such as 40nm, 32nm and 28nm), the reduction in supply voltage, along with passive losses associated with substrate leakage, poses great design challenges for radio-frequency power amplifiers (RF PAs) and front-ends with high-power capability, good linearity and competitive efficiency, says RFaxis. On the other hand, these nanometer-scale CMOS processes also provide new features and advantages, such as unprecedented signal processing power that can provide huge benefits to RF/analog designs if utilized properly.

For instance, DPD (digital pre-distortion) has been routinely used on existing mainstream Wi-Fi SoCs to help to deliver reasonable on-chip output power with good linearity for OFDM (orthogonal frequency-division multiplexing) modulation, while ET (envelope tracking) is rapidly emerging as a promising enabling technology for CMOS PAs to replace incumbent GaAs-based PAs for 3G/4G-LTE handset applications.

While these digital techniques can be applied to control and enhance any type of RF front-end solution, the best synergy occurs when both the SoC (baseband/transceiver) and RF components are designed and fabricated in the same CMOS process, reckons RFaxis. That is the goal of the Nucleus product family. Due to its patented architecture, proprietary technology and in-house design expertise, RFaxis says that it has overcome technical hurdles and achieved high and linear RF power with low-voltage CMOS devices.

A prime example is RFaxis' RFX240, a 2.4GHz 11b/g/n/ac PA based on standard 0.18μm CMOS process, that delivers 26dBm (400mW) linear power with 3% error vector magnitude (EVM) for 64QAM OFMD at 5V supply voltage, with power-added efficiency (PAE) that surpasses that of competitor designs using GaAs or SiGe processes, it is claimed. RFaxis' portfolio of 2.4/5GHz RFeICs — complete with PA, LNA and antenna switches — have been in high-volume production as a result of low-cost CMOS process technology.

RFaxis says that, with the Nucleus product family, it will integrate high-performance RF in nanometer process nodes. Nucleus45 is designed to deliver 18dBm output power to meet the most stringent linearity requirement for 256QAM modulation for 11ac – without the use of any DPD techniques. The integrated LNA provides a low noise figure of 2.5dB at system level, with all losses associated with impedance matching and antenna switch included. The RF performance matches that with state-of-the-art designs from more expensive semiconductor processes such as GaAs, silicon germanium (SiGe) or silicon-on-insulator (SOI), it is claimed.

RFaxis says that the Nucleus solution provides the wireless industry with a path to synchronize robust RF, digital and mixed-signal designs in deeper-micron process nodes, enabling users to achieve their RF performance targets with accelerated design cycle, greatly reduced development risk and shortened time-to-market while avoiding massive new R&D investment.

"RF front-ends play a very critical role in maximizing the number of bars and guaranteeing the highest data rates for wireless communication devices such as smartphones and tablets," says chairman & CEO Mike Neshat. "Due to unique challenges in RF design, the wireless industry has been relying on expensive GaAs or SiGe technologies for their RF front-end requirements. RFaxis is the first and only company in the world that is shipping complete RF front-end solutions in pure CMOS process," he adds. "With the introduction of Nucleus, RFaxis is on solid track to fulfill its mission by offering the wireless industry an RF front-end solution that is native to CMOS and matches seamlessly with mainstream SoCs for Wi-Fi, ZigBee, Bluetooth, or Internet of Things."

www.rfaxis.com

TowerJazz qualifies second fab to support FEM demand

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 qualified Migdal Haemek (Fab 2) capacity for RF SOI radio-frequency silicon-on-insulator switch and bulk CMOS controller process platforms to augment its Newport Beach fab and support the growing demand for RF front-end modules (FEM). The move has more than doubled the firm's total wafer capacity for these technologies while providing flexible dual-sourcing capability for clients.

So far, over 30 products have been taped out to Migdal Haemek and initial wafer production has begun. The product pipeline remains strong and is now feeding both factories. R&D has also been expanded, with a team established at each site to exploit local talent, accelerating the roadmap and ensuring that TowerJazz continues to provide a technology advantage in addition to increased supply flexibility.

TowerJazz says that its CS18 SOI technology offers the insertion loss, isolation and harmonics necessary to support current and future generations of RF products. CS18, together with its CA18 CMOS controller technology, also offers enabling features such as dense digital libraries, MIM capacitors, inductors, multiple resistors, eFuse, and process design kits (PDKs) to ensure first-time success.

Market research firm Mobile Experts expects the RF front-end component market to reach $8.9bn in 2014 then rise rapidly to over $13bn in 2018. Proliferation of smartphones, along with increasing RF data paths per phone, is driving this exceptional market growth. TowerJazz reckons that its RF CMOS (both bulk and SOI) and silicon germanium (SiGe) BiCMOS technologies are suited to benefitting from this global trend.

"Seemingly insatiable demand for RF silicon content in smartphones and Internet of Things (IoT)-enabled devices is fueling the demand for our RF technologies, and we are excited to meet this growing demand by opening an additional factory to this product line," says Dr Marco Racanelli, senior VP & general manager of TowerJazz's RF/High Performance Analog Business Group. "We continue to invest heavily in R&D efforts. Having established a second RF R&D team in Migdal Haemek allows us to provide leap-frog technology platforms in accelerated time lines," he adds. "The qualification of an additional site for wafer production has not only doubled our manufacturing capacity, but also added regional diversity for customer assurance and business continuity planning. Two-site development and manufacturing also enables quick and seamless production ramp of the locally developed platforms."

www.towerjazz.com

Murata to acquire Peregrine for $465m

RF front-end and SOI technology to supplement Murata's RF modules

Murata Electronics North America Inc, a subsidiary of Murata Manufacturing Co Ltd of Kyoto, Japan, has agreed to acquire all outstanding shares of Peregrine Semiconductor Corp of San Diego, CA, USA that are not already owned by Murata, for $12.50 per share in cash (a total transaction value of $471m, or $465m excluding Murata's existing holding).

Peregrine is a fabless provider of radio-frequency integrated circuits (RFICs) and RF front-end (RFFE) solutions based on silicon on insulator (SOI) technology for mobile and analog applications. Upon closing the transaction, Peregrine will continue with its current business model but become a wholly owned subsidiary of Murata, as part of Murata's strategy to expand its core business. Murata designs and manufactures ceramic-based passive electronic components and solutions, communication modules and power supply modules, including developing electronic materials and multi-functional, high-density modules. Murata's annual revenue is ¥846bn (about $8.4bn).

"This acquisition will combine Murata's world-leading mobile RF module capabilities with Peregrine's best-in-class RF front-end products," says executive VP Norio Nakajima, director of Murata's Communication business unit. "Peregrine invented RF SOI, has led its development for 20 years, and accomplished a large number of industry firsts. We have worked closely with them for many years," he adds. "Their innovation, including the Global 1 all-silicon integrated RF front-end, is a key strategic area for the mobile industry. This transaction will deepen our existing partnership and position us to meet the expanding opportunities in this field," reckons Nakajima.

"Murata is the world's leading RF module and filter provider, and we have benefited from our many years of partnership with them," says Peregrine's chairman & CEO Jim Cable PhD. "As part of the Murata team, we will be able to expand our existing partnership and speed the industry's transition to an integrated all-CMOS RF front-end," he reckons. "We remain committed to providing leading solutions to customers in all our current markets."

The acquisition will deliver to Murata RF front-end capabilities and SOI process technology, which the firm describes as key areas for the growing integration of mobile technologies. As the radio requirements of smartphones and other wireless devices continue to become more complex, this complexity can only be solved with silicon technology, it is claimed. Peregrine supplies many wireless markets, including: smartphones, test & measurement, automotive, public safety radio and wireless Infrastructure. Peregrine will also provide Murata with a portfolio of intellectual property rights (IPR) covering the entire RF SOI front-end.

The transaction, which has been approved by the boards of directors of both firms, is expected to close by the end of 2014 or early 2015, subject to approval by Peregrine's stockholders, regulatory approvals, and customary closing conditions.

www.psemi.com
www.murata.com

Peregrine ships first monolithic power limiters

At June's IEEE MTT-S International Microwave Symposium (IMS 2014) Peregrine launched the UltraCMOS PE45140 and PE45450, claimed to be the first turnkey, monolithic alternatives to discrete PIN-diode RF power limiters based on GaAs (with a form factor up to eight times smaller). "Because we were able to architect the entire solution onto a single chip, Peregrine's programmable power limiters offer unique flexibility and unprecedented, robust RF protection," says senior marketing manager Kinana Hussain.

The programmable power limiters feature two operating modes (power limiting and power reflecting) selectable through a low-current, analog voltage on the control pin (V_{CTRL}). In power-limiting mode, the device is invisible to the load, and features very low insertion loss and high linearity. When the incoming RF-signal power exceeds the limiting threshold set through the V_{CTRL} pin, the device limits the input RF power. In power-reflecting mode, the device reflects most incident power back to the source. This mode also uses an external power detector to sample the input RF power and toggle the V_{CTRL} pin from power-limiting to power-reflecting mode for maximum protection. The power limiters also protect RF ports in unpowered or unbiased conditions.

Now shipping, the devices offer repeatable and reliable protection designed for test & measurement, land mobile radio (LMR), wireless infrastructure, military and radar systems. Peregrine designed the PE45140 to accommodate the frequency ranges needed in military, LMR and radar applications. Specifically, the power limiter can protect RF front-ends and low-noise amplifiers (LNAs) in LMRs; tactical radio receivers from intentional jammers in military warfare; and transceiver (TRX) modules in radiolocation, shipborne and air-traffic-control (ATC) radar systems. Designed for higher frequency ranges, the PE45450 can protect RF ports in test & measurement equipment and RF receivers in wireless-infrastructure equipment.

Peregrine upgrades high-isolation, multi-throw switches for emerging requirements in wireless infrastructure

Peregrine has introduced the UltraCMOS PE42442 and PE42452 high-isolation, multi-throw switches.

Successors to the PE42451, the SP4T (single-pole, four-throw) and SP5T (single-pole, five-throw) switches include additional features that support the latest wireless infrastructure demands, including an extended temperature range to 105°C and control logic support of 1.8V and 3V. With the rapid expansion of LTE and soon LTE-A, these high-isolation switches provide a reliable solution for wireless infrastructure applications and enable LTE infrastructure designs to maximize spectral efficiency and data throughput, claims Peregrine.

"As the demands of the wireless infrastructure market shift, Peregrine has strategically added key features that help our customers adapt to emerging trends," says senior marketing manager Kinana Hussain.

"Peregrine is in a unique position to address many of these demands, largely due to the capabilities of our UltraCMOS technology," he reckons. "RF engineers can now leverage an increased temperature range, lower power consumption and more design flexibility, coupled with key UltraCMOS advantages in reliability, linearity, ESD and consistent RF performance."

Building on the foundation of the PE42451, the PE42442 and PE42452 include several new features. Temperature support was increased to 105°C for use in rugged conditions, a 1.8V logic control was included to enable lower power consumption, and a wider power supply range of 2.3–5.5V was employed for maximum design flexibility. Also, the insertion loss, isolation and ESD protection on the switch were enhanced.

Covering a frequency range of 450MHz to 4GHz, the PE42442 and PE42452 deliver linearity invariance over supply, flexible control and ESD protection. The PE42442 SP4T RF switch is a four-throw version of the PE42452 and offers a 52dB port-to-port isolation at 2.7GHz and 61dB at 900MHz. The PE42452 SP5T RF switch is a pin-compatible upgraded version of the PE42451 and delivers 52dB isolation at 2.7GHz and 61dB at 900MHz. The 50Ω absorptive switches have high linearity up to 4GHz with a more than 55dBm IIP3. The high-isolation switches deliver ESD protection of 4kV HBM on all RF pins, enabling high manufacturing reliability.

Offered in a 24-lead 4mm x 4mm QFN package, samples and volume production parts are available now. For 10,000-quantity orders, the PE42442 is priced at $1.60 each and the PE42452 at $1.92 each. Evaluation kits are also available.

www.psemi.com

UC Riverside-led team granted $1.7m to study van der Waals ultra-thin-film materials

Two-Dimensional Atomic-layer Research and Engineering program targets improved personal electronics, optoelectronic devices and energy conversion systems

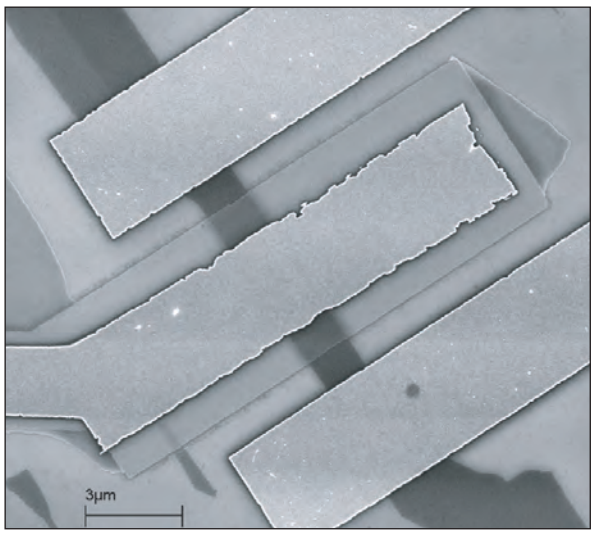
Three University of California, Riverside researchers are part of team recently awarded a grant of almost $1.7m from the US National Science Foundation (NSF) to characterize, analyze and synthesize a new class of ultra-thin-film materials that could improve the performance of personal electronics, optoelectronic devices and energy conversion systems.

The team is led by Alexander Balandin, the University of California Presidential Chair in Electrical and Computer Engineering and founding chair of the materials science and engineering program at UC Riverside's Bourns College of Engineering. Other members of the team are UC Riverside professor Roger Lake, UC Riverside research professor Alexander Khitun, and University of Georgia assistant professor Tina Salguero.

The project targets a new class of 'van der Waals' materials as well as heterostructures implemented with such materials. The ultra-thin materials may consist of just one atomic plane (making them two-dimensional). The project aims to investigate novel electrical, optical and thermal phenomena in such materials and heterostructures.

The research is expected to produce new material synthesis techniques and enable practical applications of ultra-thin-film materials in electronic switches, optical detectors, low-power information processing and direct energy conversion. The novel devices implemented with the ultra-thin films of van der Waals materials have potential for high speed and low energy dissipation, say the researchers.

Interest in two-dimensional materials was stimulated by the success of the ultimate two-dimensional material, graphene — a single atomic plane of carbon atoms. Graphene research activities resulted in the observation of new physical phenomena and led to many proposals of practical applications, including improving the performance of everything from smart phone to batteries to tennis rackets.



Prototype device with a 2D channel that will be used by the researchers.

Electrical and thermal conduction in graphene differs substantially from that in conventional bulk three-dimensional materials. Graphene's unusually high thermal conductivity was discovered at UC Riverside by a group led by Balandin. The exceptional heat conduction property of this two-dimensional material is presently finding its way into practical applications in thermal management.

Each member of the NSF-funded team will cover different aspects of the research and application of the van der Walls materials. Balandin will conduct materials characterization, fabrication and experimental testing of nanodevices, Lake will perform first-principles theoretical analysis and computer simulation of the properties of new materials and devices. Khitun will design circuits and systems based on two-dimensional materials and atomic heterostructures. Salguero will synthesize new materials using chemical approaches.

The NSF funding to the UC Riverside team was awarded via the Emerging Frontiers in Research and Innovation (EFRI-2014) program Two-Dimensional Atomic-layer Research and Engineering (2-DARE).

http://ndl.ee.ucr.edu
www.nsf.gov/funding/pgm_summ.jsp?pims_id=13708

From left, Alexander Balandin, Roger Lake and Alexander Khitun.

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IN BRIEF

MACOM adds 15W GaN-on-SiC 3.5GHz pulsed power transistor

M/A-COM Technology Solutions Inc of Lowell, MA, USA (which makes analog semiconductors, components and subassemblies for analog, RF, microwave and millimeter-wave applications) has launched a gallium nitride on silicon carbide (GaN-on-SiC) HEMT pulsed power transistor operating in the DC–3.5GHz frequency range for civilian and military radar pulsed applications.

Offered in both an enhanced flanged (Cu/W) and flangeless (Cu) ceramic package (providing excellent thermal performance, it is claimed), the MAGX-000035-015000 and MAGX-000035-01500S are gold-metalized unmatched GaN-on-SiC RF power transistors optimized for RF power amplifier applications. The transistors provide a typical 17W of peak output power with 15.5dB of power gain and 63% drain efficiency, as well as ruggedness over multiple octave bandwidths for demanding application. The devices have high voltage breakdowns and a mean time to failure (MTTF) of 600 years.

"The new 15W peak GaN power transistor offers a versatile and high-performance solution for pulsed driver and power applications over a broad frequency range," says product manager Paul Beasly. "The device is an ideal driver stage for MACOM's higher-power GaN transistors for L-band and S-band pulsed radar applications."

Samples of the MAGX-000035-015000 and MAGX-000035-01500S are available from stock.

http://cdn.macom.com/datasheets/MAGX-000035-015000_V1pdf

Raytheon to provide power systems for More Electric Aircraft

Raytheon UK's HiTSiC technology involved in Aerospace Growth Partnership projects

Raytheon of Waltham, MA, USA has been selected to provide power systems expertise as part of several major aerospace industry consortia that are currently developing the More Electric Aircraft (MEA) of the future. This marks the firm's formal entry into the MEA market following its significant investment in commercial aviation power solutions.

Driven by the demand to optimize aircraft performance, decrease operating and maintenance costs, increase dispatch reliability, and reduce gas emissions, the concept of the more electric aircraft (MEA) provides for the utilization of electric power for all non-propulsive systems (traditionally driven by a combination of different secondary power sources such as hydraulic, pneumatic, mechanical and electrical). Recent technical advances in power electronics, fault-tolerant architecture, electro-hydrostatic actuators, flight control systems, high-density electric motors, power generation and conversion systems have ushered in the era of the MEA. This trend is accelerating, as aircraft OEMs collaborate with their suppliers to design new systems and implement new electrical-intensive architectures. Adoption of the MEA concept is seen as a critical enabler for the aircraft industry to unlock significant improvements in terms of aircraft weight, fuel consumption, total life cycle costs, maintainability and aircraft reliability.

Raytheon's strategy is leveraging its unique HiTSiC (high-temperature silicon carbide) produced at its UK foundry, tailored to optimal power delivery

Under the Aerospace Growth Partnership (AGP, a UK-based collaboration between government and industry), Raytheon's involvement spans the full range of power architecture and product collaborative initiatives, including: Power Off-take and Power Conversion for the More Electric Engine (SILOET II, Rolls-Royce), Electric Engine Start power delivery (POMOVAL, Labinal Power Systems), Motor Drive power delivery sub-systems (LAMPS, UTC), Dedicated HiTSiC Power Modules (R-PSM, Raytheon), and the Harsh Environment Health Monitoring Devices (HEEDS, AEC).

Central to Raytheon's strategy is leveraging its unique HiTSiC (high-temperature silicon carbide) produced at its UK foundry, which is tailored to optimal power delivery in high-density, high-temperature power supplies. Existing modules have a maximum operating temperature of around 150°C due to the limitations of silicon devices. As a result, large, heavy liquid cooling systems are required. Raytheon's silicon carbide can operate at temperatures above 300°C, allowing more compact modules and greater efficiency, which is suitable for commercial aircraft (breaking away from the traditional tradeoffs while providing great value for money, claims Raytheon).

"Raytheon has a 25 year track record in electronic systems for harsh operating conditions where high current, power density, temperature and value are the key factors," says Steven Doran, managing director of Power and Control at subsidiary Raytheon UK. "The SWAP-V (size, weight, power – value) goal is being achieved through greater collaboration with industry and academic experts in emerging technologies for harsh environments," he adds.

www.raytheon.com
www.theagp.aero
www.moreelectricaircraft.com

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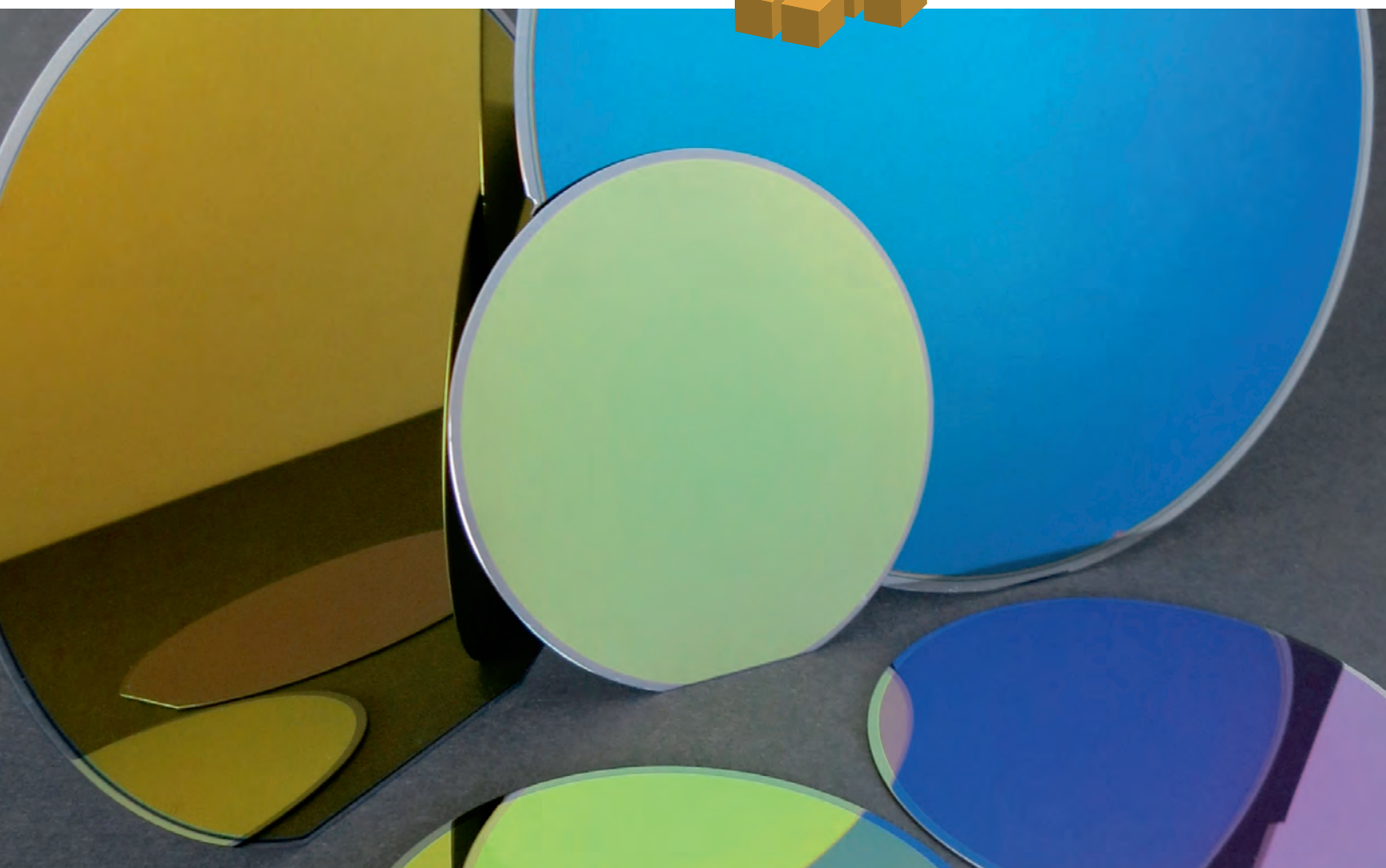

III-N MOCVD HEMT
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Silicon

GaN-on-Si Epiwafers

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Germanium
Silicon

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Infineon to acquire International Rectifier for $3bn

Power semiconductor maker adds system expertise in power conversion while expanding in GaN-on-Si and boosting economies of scale

Infineon Technologies AG of Munich, Germany has signed a definitive agreement to acquire International Rectifier Corp (IR) of El Segundo, CA, USA for $40 per share in cash (totalling about $3bn), representing a premium of 48% over IR's average share price during the last three months and a premium of 51% over the closing share price on 19 August.

Infineon will fund the transaction using cash-on-hand and fully underwritten credit facilities of €1.5bn in total (fully underwritten by Bank of America Merrill Lynch International Ltd and Citigroup Global Markets Ltd, who are also acting as financial advisors). Upon closing of the transaction, Infineon's capital structure should stay well within the previously communicated targets of 30–40% gross cash-to-revenue, no more than 2x gross debt-to-EBITDA and a positive net cash position.

The acquisition combines two semiconductor firms with what are claimed to be leadership positions in power management technology. By integrating International Rectifier, Infineon complements its offerings and will be able to provide a broader range of products and services.

Infineon's and International Rectifier's product portfolios are reckoned to be highly complementary. IR's expertise in low-power, energy-efficient IGBTs and intelligent power modules, power MOSFETs and digital power management ICs will integrate with Infineon's range of power devices and modules.

With IR, Infineon acquires a manufacturer of gallium nitride on silicon (GaN-on-Si)-based power semiconductors. It is reckoned that the combination will accelerate Infineon's position in GaN discretes and GaN system solutions, improving its ability to pursue a strategically important technology platform with significant future growth potential.

The transaction will result in a broad range of products creating what is described as a comprehensive provider of silicon-, silicon carbide (SiC) and gallium nitride (GaN)-based power devices and integrated circuits. Infineon believes that the increase in exposure to the distribution channel will allow it to meet the needs of a broader range of customers.

The integration of IR should generate economies of scale through optimization of the combined entity's operating expense structure and through acceleration of the ramp-up of Infineon's 300mm thin wafer manufacturing capability.

Infineon says that it will also have a much broader and stronger regional scope. IR has a strong presence in the USA and will also help to improve Infineon's position in Asia.

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"With their great knowledge of specific customer needs and their application understanding, International Rectifier employees will contribute to Infineon's strategic development, from product thinking to system understanding and system solutions," says Infineon's CEO Dr Reinhard Ploss. "The combination of Infineon's and International Rectifier's products, technological and innovative excellence, as well as distributional strength will unleash great potential," he reckons.

"This transaction provides significant value to our stockholders and opens new strategic opportunities for both our customers and employees," says International Rectifier's president & CEO Oleg Khaykin. "By combining two complementary providers in power management solutions, International Rectifier will benefit from Infineon's products and technologies, manufacturing and operational excellence and greater R&D scale."

International Rectifier's board of directors and Infineon's supervisory board have approved the transaction. Subject to regulatory approvals in various jurisdictions and customary closing conditions (as well as the approval of International Rectifier's stockholders), the transaction is expected to close late in 2014 or early in 2015.

The acquisition is expected to be accretive to pro-forma earnings per share (EPS) within the first fiscal year of closing. Synergies are expected to drive significant accretion going forward, building on International Rectifier's existing successful operational restructuring. In the second full fiscal year of operation after closing, International Rectifier's margin contribution is expected to be at least in line with Infineon's target of 15% segment result margin over the cycle. As such, Infineon maintains its target of 15% average-cycle segment result margin.

www.infineon.com
www.irf.com

TriQuint first manufacturer to reach Manufacturing Readiness Level 9 for gallium nitride

RF front-end component maker TriQuint Semiconductor Inc of Hillsboro, OR, USA says that it is the first gallium nitride (GaN) RF chip maker to achieve Manufacturing Readiness Level (MRL) 9, meaning that its GaN manufacturing processes have met full performance, cost and capacity goals, and that the firm has the capability in place to support full-rate production.

To benchmark MRL 9, TriQuint applied the manufacturing readiness assessment tool and criteria of the US Air Force Research Laboratory (AFRL) to its high-frequency, high-power GaN production line. TriQuint says that its ongoing development of GaN-based devices is leading to smaller, more efficient power amplifiers, typically used for military radar and electronic warfare programs as well as commercial wireless communications and infrastructure.

"TriQuint recently completed its Defense Production Act Title III GaN on silicon carbide (SiC) program and now we've proven that we provide the GaN maturity needed to support full-rate production programs," says James Klein, VP & general manager, Infrastructure and Defense Products. "This has been a great team effort utilizing our partnerships across the industry, including US DoD, domestic and international customers, and a great supply base."

Key to the firm's assessment, TriQuint has shipped more than 170,000 0.25μm GaN power amplifier devices in support of an ongoing international radar production program. During phased-array radar field testing, about 15,000 devices have accumulated more than 3.67 million device hours, with no reported device failures. TriQuint continues to demonstrate reliability, with a mean time to failure (MTTF) of greater than 70 million hours at 200°C, much greater than the industry standard of 1 million hours MTTF.

As an established GaN provider for domestic and international defense programs, TriQuint explored the potential of GaN beginning in 1999, and released its first GaN-on-SiC production process in 2008. Since then, the firm has continued to make investments towards maturing the technology. GaN wafers are now manufactured with yields that match the firm's conventional gallium arsenide (GaAs) technologies.

In GaN research and product development for both defense and commercial applications, TriQuint says that it continues to provide record-setting GaN circuit reliability and compact, high-efficiency products, paving the way for more robust performance, lower maintenance, and longer operational lifetimes.

TriQuint is also accredited by the US Department of Defense (DoD) as a Microelectronics Trusted Source (Category 1A) for its foundry; post-processing; packaging & assembly; and RF test services.

The DoD's Manufacturing Readiness Assessment (MRA) ensures that manufacturing, production and quality assurance can meet operational mission needs. This MRA tool assesses science and technology companies on criteria that provide guidance about the maturity and risk of a given technology — reviewing the industrial base readiness; technology development; and quality and manufacturing management. The process ensures that the product or system transitions successfully from the factory to the field.

www.triquint.com/applications/defense

IN BRIEF

MACOM launches 650W GaN-on-SiC L-band radar transistor

M/A-COM Technology Solutions Inc of Lowell, MA, USA (which makes analog semiconductors, components and subassemblies for analog, RF, microwave and millimeter-wave applications) has launched a gallium nitride on silicon carbide (GaN-on-SiC) HEMT power transistor for L-band pulsed radar applications.

The MAGX-001214-650L00 is a gold-metalized pre-matched GaN-on-SiC transistor that offers what is claimed to be the highest peak power in the industry for a single-ended power transistor optimized for pulsed L-band radar applications. The device guarantees 650W of peak power with a typical gain of 19.5dB and efficiency of 60%. It also has very high breakdown voltages, allowing users reliable and stable operation at 50V under more extreme load mismatch conditions.

The device is assembled in a high-performance ceramic flange package and has undergone MACOM's rigorous qualification and reliability testing. Operating at 1200–1400MHz, the MAGX-001214-650L00 is highly robust, with a mean time to failure (MTTF) of 5.3×10^6 hours.

"The device is an ideal candidate for customers looking to combine two power transistors and realize over 1000W of peak power in a single pallet for next-generation L-band radar systems that require increased performance in smaller footprints," says product manager Paul Beasly.

Samples of the MAGX-001214-650L00 are available now from stock.

www.macom.com/products/product-detail/MAGX-001214-650L00

IN BRIEF

EPC presents latest-generation eGaN FET performance at power industry conferences in China

EPC is giving application-focused presentations on its latest-generation eGaN technology at two industry tradeshows in China:

● 3rd Wireless Power World 2014 (Shanghai, 26–27 August)

In 'eGaN FET Based Wireless Energy Transfer – New Zero Voltage Switching (ZVS) Class-D Topology', Dr Johan Strydom, VP, Application Engineering will show how the superior characteristics of eGaN FETs, such as low output capacitance, low input capacitance, low parasitic inductances and small size, make them suitable for increasing efficiency in highly resonant, Rezence (A4WP)-compliant, wireless power transfer systems. A comparison between amplifiers designed using MOSFETs and eGaN FETS will examine comparative peak power, load variation, and load regulation performance.

● IIC China 2014 Fall Exhibition — Power Management & Power Semiconductor conference (Shenzhen, 4–5 September)

In 'Generation 4 eGaN Technology', Peter Cheng, Asia Pacific field applications director, will discuss the latest developments in DC–DC converters with eGaN FETs. The firm's new Gen 4 family of eGaN FETs features significant gains in key switching figures of merit that widen the performance gap with the aging power MOSFET, the firm says. Application examples include a 12V to 1.2V, 50A point-of-load converter achieving 93.5% efficiency, and a 48V to 12V, 30A non-isolated DC–DC intermediate bus converter achieving efficiency above 98%.

www.english.iic-china.com
www.wirelesspower-world.com

EPC introduces A4WP-compliant wireless power transfer demo kit delivering 35W at 6.78MHz

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 announced the availability of a complete demonstration wireless power transfer kit. The 40V (EPC9111) or 100V (EPC9112) wireless kits have three components: source (or amplifier) board; Class 3 A4WP-compliant source (or transmit) coil; and Category 3 A4WP-compliant device (or receiving) board including coil.

The system is capable of delivering up to 35W into a DC load while operating at 6.78MHz (the lowest ISM band). The demonstration kit is intended to simplify the evaluation process of using eGaN FETs for highly efficient wireless power transfer. The EPC9111 and EPC9112 utilize the high-frequency switching capability of EPC's GaN transistors to facilitate wireless power systems with greater than 75% efficiency.

Value of eGaN FETs in wireless power transfer systems

The requirements of wireless energy transfer systems include high efficiency, low profile, robustness to changing operating conditions and, in some cases, light weight. These requirements translate into designs that need to be efficient and able to operate at high switching speeds without a bulky heat-sink, says EPC. The design must also be able to operate over a wide range of coupling and load variations. The fast switching capability of eGaN FETs is suitable for highly resonant power transfer applications, says the firm.

The popularity of highly resonant wireless power transfer is growing rapidly, particularly for applications targeting portable device charging. The end applications are varied and evolving quickly, from mobile device charging to life-extending medical implementations and safety-critical hazardous environments, says EPC.

Source (amplifier) board

The source board is a highly efficient, A4WP-compliant, zero voltage switching (ZVS) Class-D amplifier featuring either the 40V EPC2014 (EPC9111) or 100V EPC2007 (EPC9112) eGaN FET.

The source board is configured in an optional half-bridge topology (for single-ended configuration) or default full-bridge topology (for differential configuration), and includes the gate driver(s) and oscillator that ensure operation of the system at 6.78MHz.

The amplifier boards are available separately as EPC9506 and EPC9507 for evaluation in existing customer systems.

Source (transmit) coil

The source coil, as well as the device coil, are Rezence (A4WP)-compliant and have been pre-tuned to operate at 6.78MHz. The source coil is class 3 and the device coil is category 3 compliant.

Device (receiving) board including coil

The device board includes a high-frequency Schottky diode based full-bridge rectifier and output filter to deliver a filtered unregulated DC voltage. The device board comes equipped with two LEDs, one to indicate that the power is being received and a second LED that indicates that the output voltage has reached the maximum and is above 37V. The device board can also be configured as a half-bridge rectifier that allows for double output voltage operation.

The EPC9111 and EPC9112 wireless power transfer demonstration systems are priced at $895 each and are available from Digi-Key.

www.digikey.com/short/dfvbb

Cree and APC Novacom extend partnership for GaN HEMT distribution in Europe

Cree Inc of Durham, NC, USA is enhancing its support of the European market by extending its partnership with UK-based distributor APC Novacom.

APC Novacom now stocks all Cree RF devices that do not require a European Union (EU) license, including gallium nitride (GaN) high-electron-mobility transistor (HEMT) die, and supports Cree's European market through both volume distribution and small-volume stock for network representatives.

Suited to a wide range of RF communications applications — satellite communications (SatCom), military satellite communications (MilSatCom), broadband amplifiers, radar, point-to-point radio, telecoms, data links, and tactical data links — Cree GaN HEMT devices are said to exhibit superior performance properties compared to silicon (Si) or gallium arsenide (GaAs) die, including: higher breakdown voltage, higher saturated electron drift velocity, higher thermal conductivity, and higher efficiency.

The GaN HEMTs also offer greater power density and wider bandwidths than competing Si and GaAs technologies.

Cree RF products now available through APC Novacom include: general-purpose broadband die, general-purpose 28V and 40V broadband GaN HEMTs, 28V and 50V telecom GaN HEMTs, 0.25µm die, and GaN HEMTs for satellite communications and L-, S-, X-, and C-band applications.

www.cree.com/RF
www.apc-novacom.co.uk

GaN Systems showcases 100V and 650V power semiconductors at EPE '14 ECCE Europe

GaN Systems Inc of Ottawa, Ontario, Canada, a fabless developer of gallium nitride (GaN)-based power switching semiconductors for power conversion and control applications, showcased its latest devices at the 16th European Conference on Power Electronics and Applications (EPE '14 – ECCE Europe) in Lappeenranta, Finland (26–28 August).

The exhibition provides the first opportunity in Scandinavia for GaN Systems to present its two newest product lines – a series of five normally-off 100V GaN transistors and a family of low-inductance, thermally efficient 650V transistors.

Based on proprietary Island Technology, the firm says that its devices bring advantages and higher performance to applications ranging from onboard battery charging, high-voltage DC–DC and AC–DC conversion, UPS (uninterruptible power supplies), air-conditioning, appliances, heavy-duty battery-operated power tools and E-bikes.

The five normally-off 100V GaN transistors span 20–80A with very low on-resistance. The family consists of the devices GS61002P, GS61004P, GS61006P and GS61008P (which are respectively 20A/21mΩ, 40A/11mΩ, 60A/8mΩ and 80A/5mΩ parts) and the GS71008P (an 80A/5mΩ half-bridge device).

The second of GaN Systems' latest product lines comprise five normally-off 650V GaN transistors with reverse current capability, zero reverse recovery charge, and source-sense for optimal high-speed design. The GS66502P, GS66504P, GS66506P and GS66508P are respectively 8.5A/165mΩ, 17A/82mΩ, 25A/55mΩ and 34A/41mΩ parts, while the GS43106L is a 30A/60mΩ cascode device.

Both the 100V and 650V devices are delivered in GaN Systems' compact, near-chip-scale, embedded GaNPX packages, which minimize inductance and optimize thermal performance.

The firm is also showing its 100A and 200A high-current parts, which were launched earlier this year. "GaN Systems is the first company in the market to have such a wide range of gallium nitride power switching semiconductors available for sampling now," claims president Girvan Paterson.

www.gansystems.com
www.epe2014.com

GaN Systems' gallium nitride power semiconductor products.

AXT returns to quarterly profitability ahead of plan

GaAs and InP revenues both up by a third on Q1/2014

For second-quarter 2014, AXT Inc of Fremont, CA, USA has reported revenue of $21.4m, down 11% on $23.8m a year ago but up 11% on $19.3m last quarter.

"While the business environment remains challenging, during the second quarter we experienced stronger demand in both our semi-insulating and semi-conducting gallium arsenide substrates as well as continued strength in indium phosphide," says CEO Morris Young.

By product sector, GaAs substrate revenue was $11.3m, up 33% on $8.5m last quarter and 8% on $10.6m a year ago. InP substrate revenue was $3m, up 36% on $2.2m last quarter and 50% on $2m a year ago. Germanium (Ge) substrate revenue was $1.7m, almost halving from last quarter's $3.2m and less than a third of the $5.3m a year ago. Raw materials sales were $5.4m, level with $5.4m last quarter but down from $5.8m a year ago.

Gross margin has rebounded from just 12.9% a year ago followed by a further dip to 14.1% last quarter, reaching 19.4%. Operating expenses have been cut from $5.1m last quarter to $4.7m, due mainly to cost-saving initiatives implemented during Q1.

Net income was $319,000 ($0.01 per diluted share), compared with net loss of $2m ($0.06 per diluted share) both last quarter and a year ago. During the quarter, cash and cash equivalents rebounded, from $22.8m to $26.3m.

"Through a combination of higher revenues, positive sales mix, other income and the first full quarter of benefit from our cost-savings measures, we achieved profitability ahead of our plan," notes Young. "With continued focus on cash management, we drove improvement in our balance sheet, growing our cash position and reducing inventory," he adds.

"Looking forward, we remain cautiously optimistic about our opportunities to drive further growth in our business," Young says.

www.axt.com

5N Plus' Q2 revenue up 21% year-on-year

For second-quarter 2014, specialty metal and chemical products firm 5N Plus Inc of Montreal, Québec, Canada has reported revenue of $136.6m, down 4% on $142.4m last quarter but up 21% on $112.6m a year ago.

5N Plus provides specialty purified metals such as bismuth, gallium, germanium, indium, antimony, cadmium, selenium and tellurium, and also produces related semiconducting compounds such as cadmium telluride (CdTe), cadmium sulphide (CdS) and indium antimonide (InSb) as precursors for the growth of crystals for solar, LED and eco-friendly materials applications. The firm also has fully integrated closed-loop recycling facilities.

Net earnings were $4.4m ($0.05 per share), roughly level with $4.5m ($0.05 per share) last quarter. Net earnings a year ago were $34.3m ($0.41 per share), but that was only after the positively impact of the MCP litigation settlement of $45.2m ($0.54 per share). Adjusted EBITDA has risen from $6.5m a year ago and $10.5m last quarter to $10.8m (its highest in the last eight quarters). During the quarter, net debt rose from $60.6m to $70.4m, but this is still down on $84.7m a year ago.

"We continued to improve profitability, reporting another strong quarter in terms of EBITDA supported by increasing demand, especially for our bismuth-based products, and a more favorable sales mix and underlying commodity pricing trend," says president & CEO Jacques L'Ecuyer. "We continue our efforts aimed at improving efficiency, reducing costs and working capital throughout the group," he adds.

"We made progress in the quarter towards executing on our growth plan by completing the acquisition [in early April] of the remaining 33.33% ownership interest in our subsidiary Sylarus Technologies LLC [of St. George, UT], a germanium substrate supplier, changing its name to 5N Plus Semiconductors LLC, and [in early May] we acquired all the issued and outstanding shares in the capital of AM&M Advanced Machine and Materials Inc and its metal powder atomization technology for electronic packaging, solar modules and additive manufacturing applications," L'Ecuyer continues.

Also, on 27 May, 5N Plus entered into new supply agreements with cadmium telluride (CdTe) photovoltaic (PV) module maker First Solar Inc of Tempe, AZ, USA, the world's leading thin-film solar module manufacturer, covering its compound semiconductor needs until end-March 2019.

After a spike to $159.6m in Q1/2014, order bookings in Q2/2014 were $99.6m, level with a year ago. Likewise, after rising to $187.3m last quarter, order backlog was $150,4m, down only slightly on $153.3m a year ago.

"In order to support our operations and growth plan, we successfully completed the issuance [in late June] of a convertible subordinated debenture for a total amount of CA$66m ($60.8m) before fees," L'Ecuyer concludes. "Combined with the new credit facility [of US$125m, announced on 7 August], this will further improve our financial flexibility and enable us to execute on several growth initiatives which we are currently working on."

www.5nplus.com

AXT appoints chief financial officer

AXT has appointed Gary L. Fischer as VP & chief financial officer, responsible for the firm's global finance and accounting organization and reporting to CEO Morris Young.

"Gary brings to the table a wealth of public-company experience in finance, strategic planning, global operations and investor relations," comments Young. "He has years of executive-level leadership, building technology businesses from early-stage to sustainable long-term profitability and revenue growth," he adds. "This will be tremendously beneficial to AXT as we seek to increase our footprint in the global marketplace, leveraging our diversified portfolio of products as well as our key competitive differentiators."

Fischer is a Silicon Valley veteran, with experience working in Asia and Europe. In 1993, he joined advanced memory solutions firm ISSI as CFO. He took the company public in 1995 and later became its president & chief operating officer. In 2005, Fischer joined eRide, a fabless semiconductor firm that develops both GPS devices and software for location-based services (acquired in 2009). Fischer continued with eRide as a consultant into 2014 and expanded his consulting practice to assist growth companies on a variety of finance and M&A projects.

5N Plus announces new US$125m credit facility

5N Plus has signed a new US$125m senior secured multi-currency revolving syndicated credit facility that will replace its existing US$100m senior secured revolving facility.

The new facility is more correlated with the firm's balance sheet and will be used to refinance existing indebtedness and for other corporate purposes, including capital expenditures and growth opportunities.

The new credit facility is on a revolving basis, has a four-year term, and carries interest at either prime rate, US base rate, HK base rate or Libor plus a margin based on 5N Plus' senior consolidated debt-to-EBITDA ratio. At any time, 5N Plus has the option to request that the new facility is expanded to US$150m through the exercise of an additional US$25m accordion feature, subject to review and approval by the lenders.

"This credit facility provides the company with an expanded and flexible credit line, at lower rates than the current credit facility," says chief financial officer Richard Perron.

www.5nplus.com

Veeco's first-half 2014 MOCVD orders up 80% year-on-year

10% cut in Data Storage-focused OpEx targets EBITDA breakeven below $100m in quarterly revenue by 2015

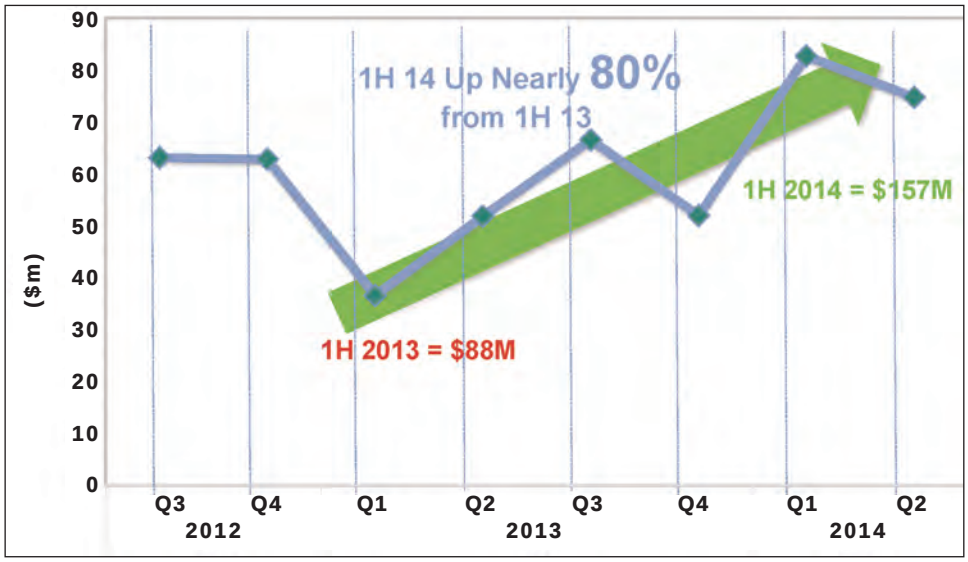
For the second-quarter 2014, epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA has reported revenue of $95.1m, up 5% on $90.8m last quarter but down 2.5% on $97.4m a year ago.

Data Storage revenue has fallen by 16% on $21.5m a year ago and 10% on $20m last quarter to $18m (just 19% of sales). However, growth was driven by LED & Solar revenue up 1.6% on $76m a year ago and 8.8% on $70.8m last quarter to $77.2m (81% of sales). In particular, molecular beam epitaxy (MBE) revenue was $10m, up on $6.8m last quarter. Metal-organic chemical vapor deposition (MOCVD) revenue rose by 4.7% from $64m last quarter to $67m. First-half 2014 MOCVD revenue was up 30% year-on-year.

Q2 gross margin of 32% was on the high-end of the 30-32% guidance but, reflecting the tough pricing environment in the MOCVD business, it was weaker than last quarter's 37% (which was unusually high due to the inclusion of certain high-margin tools in the mix).

"Q2 performance was also impacted by higher operating expenses [$46.6m, up from $41m both last quarter and a year ago], as we rolled in some temporary, duplicative spending, tied to our site consolidation activities," says chief financial officer Shubham Maheshwari. "R&D in Q2 was high [up from $19.8m in Q1 to $21m], due to the spending on next-generation products."

Net loss was $6.1m ($0.16 per share), up from $2.4m ($0.06 per share) last quarter and $1.3m ($0.03 per share) a year ago but at the low end of the guidance range of $9.2-5.6m ($0.23-0.14 per share). Adjusted earnings before interest, taxes, depreciation and amortization (EBITDA) loss was $7m, up from $2.2m a year ago.



Veeco's MOCVD order trend.

During the quarter, cash balance rose by $2m from $483mto $485m.

For the third consecutive quarter, Veeco's book-to-bill ratio was over 1. Orders have risen from $84.8m a year ago and $102.6m last quarter to $104m. In particular, Data Storage orders were $23.4m (22% of total orders), up on the trough of just $15.4m last quarter but still down 12% on $26.7m a year ago. LED & Solar orders were $80.7m (78% of total orders), down on $87.1m last quarter but still up 39% on $58m a year ago. Of this, MBE orders were $6m (level with a year ago but up from $5m last quarter) and MOCVD orders were $75m (down 10% on last quarter but up 44% on $52m a year ago).

"We do not see the slight MOCVD decline [sequentially] as a reversal of positive trends," says Maheshwari. "It is more reflective of the fluctuations in this business and the few large deals that are being worked every quarter," he adds. "Large orders from a small number of customers are causing orders to bounce around on a quarter-to-quarter basis," notes chairman & CEO John R. Peeler. "But the order trend, over the last 6 quarters, is very strong, including the following factors: the trend line from Q1 of 2013 onward shows a 50% compound annual growth rate; first-half MOCVD orders are up nearly 80% from the first half of last year [$157m versus $88m]; we expect Q3 orders to be higher than Q2 orders; and finally, we're forecasting second-half orders above first-half orders... the MOCVD business recovery is well underway," he adds.

"We continue to see positive trends in the LED market, including strong LED chip demand, very high LED fab utilization rates and solid customer quoting activity," says Peeler. "We had several significant wins during the quarter from LED customers in China and Korea who selected Veeco MOCVD equipment for their capacity expansions." Customer wins this quarter included large multi-unit deals from Changelight in China, and a top LED manufacturer in Korea (where Veeco is seeing utilization rates of 85% or better, improved customer financials, and meaningful pickup in activity, driven by demand for LEDs for ultra-high-definition TVs, which use twice as many LEDs as traditional LED TVs and require more stringent chip performance). "In the case of Changelight, we beat our competi-

tor, the incumbent supplier, by having more productive systems with a lower total cost of ownership," says Peeler.

For third-quarter 2014, Veeco expects revenue of $92–100m. Although bookings have been over $100m for the last two quarters, the midpoint of this revenue guidance is just $96m. "One of our customers, just last week, pushed out shipments from September into Q4, due to temporary funding delays on their part," says Maheshwari. "This causes Q3 revenue guidance lighter than the normal expectations, and we expect to see corresponding pickup in Q4 revenues."

Q3 gross margin should be 31.5–33.5%, flat on Q2 because of a few low-margin tools that were booked previously now flowing through. "We are experiencing slightly better pricing environment on the orders we are booking currently," notes Maheshwari.

Operating expenses should fall back to $41–42m. Cost-reduction activities will have a modest impact, but pick up speed exiting 2014, says Maheshwari.

Excluding the impact of a planned $2.6m restructuring charge related to the firm's business and facility streamlining activities, non-GAAP net loss is expected to be $2.9–6.1m ($0.07–0.15 per share). Adjusted EBITDA loss should be $0.2–3.7m.

"Business conditions in MOCVD have improved. However, we have seen limited improvement in our other businesses," says Maheshwari. "We have been working to streamline our operations in order to simplify the company, reduce expenses, and enable a continued high level of R&D investments in growth opportunities, including LED and organic LED," he adds. "We are in the process of consolidating our Data Storage business from three sites to our main site here in Plainview... We are streamlining sales & service facilities and reducing corporate overhead." These activities are phasing in through the year. "As a result we expect that, as we exit 2014, our overall OpEx would decline by about 10% [to $38–39m], and we can achieve an EBITDA breakeven level below $100m in [quarterly] revenue," says Maheshwari.

Veeco expects gross margin to stay in the low- to mid-30s for the remainder of 2014. However, Maheshwari believes that gross margin can bet get back to over 40% as Veeco sees new products, a pickup in business volume, and manufacturing cost reductions benefiting the firm in 2015.

"We remain focused on delivering improved results by:
(1) developing and launching game-changing new products that enable cost-effective LED lighting, flexible OLED display encapsulation and other emerging technologies;
(2) improving customer cost of ownership as well as our gross margins;
(3) driving process improvement initiatives to make us more efficient;
(4) lowering expenses," says Peeler. "It is our goal to get the company back to double-digit adjusted EBITDA profitability by 2015 through a combination of improved business conditions, execution on our growth initiatives, a more streamlined Veeco, and lower operating expenses," Peeler concludes.

www.veeco.com

China's Changelight chooses Veeco MOCVD systems for expansion from red, orange, yellow LEDs into GaN LEDs

Changelight Co Ltd of Xiamen, China has selected epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA as its primary equipment provider as it enters the market to produce gallium nitride (GaN)-based blue/green high-brightness LEDs for display and general lighting applications.

During second-quarter 2014, Changelight ordered multiple TurboDisc MaxBright M GaN metal-organic chemical vapor deposition (MOCVD) systems. In addition, it purchased a TurboDisc K475 MOCVD system to expand its production of red, orange and yellow (ROY) LEDs. Changelight was established in February 2006, specializing in quaternary alloy aluminium gallium indium phosphide (AlGaInP) red, orange and yellow LED wafers and chips as well as gallium arsenide (GaAs) solar cells.

"In the past we have used competitive MOCVD equipment for the majority of our production of ROY LEDs," says Changelight's general manager professor Wang Xiangwu. "As we make this important move into the GaN-based lighting market, we decided to switch to Veeco's MaxBright M MOCVD system, which we believe will offer the best throughput and cost of ownership to help enable our success and growth in the general illumination market," he adds.

The MaxBright M offers a modular, compact design for improved serviceability and up to 15% improved footprint efficiency compared to the standard MaxBright MOCVD system. It features more layout configuration options to fit various fab spacing requirements, including sub-floor storage, enabling more wafer starts per square foot, which translates into a lower cost of ownership, says Veeco.

"We have seen Changelight dominate the ROY market in China for some time and believe that, with our technology and its knowledge of the industry, Changelight is well positioned to successfully expand into the backlighting and general illumination market," says Jim Jenson, senior VP & general manager of Veeco MOCVD.

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

Aixtron's orders rise for fifth consecutive quarter

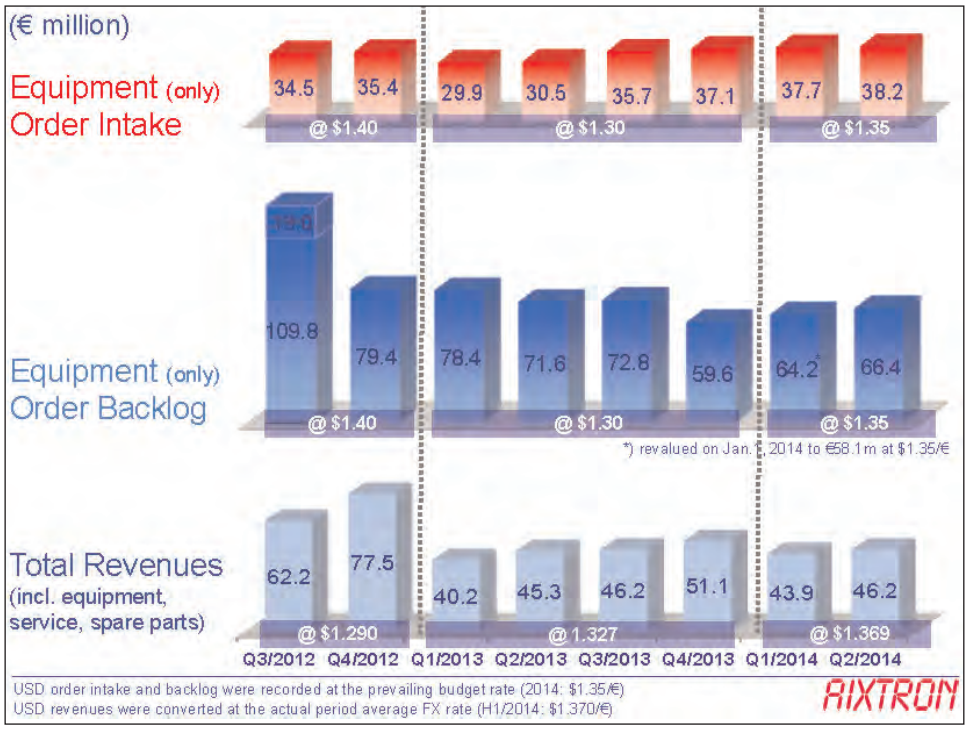
Phase Two of 5-Point-Program underway; launch of next-gen MOCVD

For second-quarter 2014, deposition equipment maker Aixtron SE of Aachen, Germany has reported revenue of €46.2m, rebounding by 5% from €43.9m last quarter (which had been down 14% on the previous quarter) and up 2% on €45.3m a year ago.

Global demand for LEDs continues to increase, driven by the growing adoption of LEDs in the general lighting market. Utilization rates of most leading LED chip makers also remain high, says the firm. However, the increasingly positive market sentiment has not yet translated into substantially increased order levels for Aixtron's LED manufacturing capacity. Nevertheless, Aixtron generated increased revenues sequentially and year-on-year.

Operating expenses have risen slightly from €22m a year ago and €21.7m last quarter to €23.2m. This is due mainly to R&D costs rising by 22% from €12.7m a year ago and by 13% from €13.7m last quarter to €15.5m, largely as a result of Aixtron's next-generation metal-organic chemical vapor deposition (MOCVD) system being in the qualification phase at key customers. At 34% of revenue, R&D spending remained at a relatively high level, underlining the important strategic significance of internal R&D capabilities, says Aixtron. In contrast, selling, general & administrative (SG&A) expenses have been reduced further, by 13% from €9.1m last quarter to €7.9m.

Consequently, although still worse than –€9.8m a year ago, EBIT (operating loss) has been cut slightly, from –€10.9m in Q1 to –€10.6m. Due mainly to the operating loss and a scheduled increase in inventories for new MOCVD tools and spares, free cash flow is down further, from –€3.7m a year ago and –€13.8m last quarter to –€17.5m. Cash and cash equivalents (including bank deposits with a maturity of more than three months) have fallen further, from €306.3m at end-2013 and €292m at end-March 2014 to €275.6m at end-June.



Order intake has improved by 25% from €30.5m a year ago to €38.2m, representing a fifth consecutive quarter of sequential growth, including €37.7m last quarter (reflecting an improving market sentiment in first-half 2014). Total equipment order backlog was €66.4m at the end of June, up on €64.2m at the end of March and up 14% on €58.1m at the start of 2014.

"Demand for LEDs is growing partially due to a wide range of new LED lighting products being sold into the warehouses and stores, especially into regions such as China," comments president & CEO Martin Goetzeler. "A successful sell-out to consumers would represent the next stage of the transition away from traditional to LED lighting," he adds.

"Evidenced by positive feedback from our customers, we have made good progress in the qualification process and are preparing for the market launch of our new MOCVD tool generation later this year," notes Goetzeler. "Furthermore, we continue to push the development of our other technology areas. These include MOCVD for power electronic and logic applications, ALD for memory, OVPD for OLED applications and PECVD for carbon nanomaterials including graphene. Here we continue to see substantial market potential," he adds.

In parallel, Aixtron has now entered Phase Two of its 5-Point-Program for returning to sustainable profitability. The focus is on lowering material costs, discretionary spending and the optimization of processes, preparing the ground for a return to sustainable profitability.

Aixtron reiterates its original full-year 2014 guidance (made at the end of February) for revenue to be in line with last year's (which was €182.9m). The firm is not expected to be profitable on an EBIT basis over the course of this year. Nevertheless, management continues to expect a year-on-year improvement in earnings due to progress made in cost savings and restructuring.

www.aixtron.com

Vishay orders Aixtron MOCVD system to expand IR LED production

Deposition equipment maker Aixtron SE of Aachen, Germany says Vishay Semiconductor GmbH of Heilbronn, Germany has acquired a metal-organic chemical vapor deposition (MOCVD) system (delivered at the end of March) to expand its infrared LED production capacity. The firm aims to substantially extend its product portfolio in this area.

"We opted for Aixtron's planetary reactor, as it deposits high-quality layers and offers very high production stability, long operating times, and high throughput rates," comments Dr Heinz Nather, senior vice president OPTO Division at Vishay Semiconductor. "Aixtron will support us with process expertise, thus enabling us to rapidly and efficiently expand our gallium arsenide-based infrared LED production," he adds.

"We have great expectations of our ongoing cooperation with Vishay," remarks Dr Frank Schulte, VP of Aixtron Europe, who describes Vishay Semiconductor as one of the world's leading producers of semiconductors and power electronics.

Vishay Semiconductor is part of international electronics group Vishay Intertechnology Inc of Malvern, PA, USA which, with more than 22,000 staff and sales of almost $2.5bn, is one of the world's largest manufacturers of discrete semiconductor elements (diodes, rectifiers, transistors, optoelectronic components, integrated circuits) and passive electronics components (resistors, capacitors, inductors, sensors, transformers).

www.vishay.com/ir-emitting-diodes
www.aixtron.com

IN BRIEF

Order from KAUST

Saudi Arabia's King Abdullah University of Science and Technology (KAUST) has ordered an Aixtron AIX BM plasma-enhanced chemical vapor deposition system (for delivery in Q3/2014), capable of handling 4" substrates, for growing graphene and carbon nanotubes.

"We plan to expand our research in this rapidly growing field with the aim of finding a wide range of new applications," says professor Pedro Da Costa, team leader in KAUST's Laboratory for Carbon Nanostructures.

"Our BM Pro system is based upon the showerhead, vertical flow concept, which delivers both uniformity and scalability, rapid heating and plasma-based processing to successfully grow mono and multi-layer graphene and various types of nanotubes," says Frank Schulte, VP Aixtron Europe.

USTC orders additional plasma etching system for quantum information processing

UK-based etch and deposition equipment maker Oxford Instruments says that an additional PlasmaPro 100 plasma etch system has recently been ordered by the Center for Micro and Nanoscale Research and Fabrication at the University of Science and Technology of China (USTC) Hefei city, Anhui Province, adding to their existing installed base of Oxford Instruments etch and deposition systems.

The systems are installed in USTC's newly opened cleanroom and will be used for fundamental research into the increasingly important field of quantum information processing. Multiple Oxford Instruments plasma systems, including a PlasmaPro 100 ICP380 and PlasmaPro NGP 80 RIE and PlasmaPro 100 PECVD deposition tools, were already installed in USTC's new facility during the past year.

"We chose Oxford Instruments systems as we have found that they offer extensive process capabilities, and great flexibility, backed by excellent support and service packages," comments USTC's professor Zhu. "These tools will allow our researchers to push the limits in micro- and nanoscale fundamental research," he adds. "USTC has a very strong background in both nanoscale science and engineering, and this new state-of-the-art nanofabrication facility aims to drive collaborative, interdisciplinary, and fundamental research in the micro- and nano-scale."

Quantum information processing is one of the leading topics at Oxford Instruments' Nanotechnology Tools two-day workshop in Beijing, 24–25 September.

www.oxford-instruments.com/BTNT-Beijing

Keysight begins operation as subsidiary of Agilent

The electronic measurement business of Agilent Technologies Inc of Santa Clara, CA, USA has begun operating under the name Keysight Technologies Inc of Santa Rosa, CA. It will remain a wholly owned subsidiary of Agilent until early November, when the separation (which was announced on 19 September 2013) is expected to be completed and Keysight begins trading on the NYSE under the symbol KEYS.

Keysight provides electronic measurement instruments and systems and related software, software design tools and services used in the design, development, manufacture, installation, deployment and operation of electronic equipment. The firm is said to hold the number one position in its industry segments of communications; aerospace and defense; and industrial, computers, and semiconductors.

"We are mindful of our rich heritage as part of Agilent and prior to that, Hewlett-Packard," says president & CEO Ron Nersesian. "We are also mindful of our responsibility and commitment to our stakeholders, including customers, our shareholders and our employees. We look forward to the many opportunities ahead that will allow us to focus solely on electronic measurement."

www.keysight.com

Morgan Advanced Materials provides extended electrostatic chuck life via replaceable wear-resistant films

Morgan Advanced Materials has announced new solutions in sacrificial wear layers to extend the life of alumina or beryllia electrostatic chucks (ESCs) for semiconductor, solar and LED applications. Applied as a final protective layer, the Diamonex technical hard-coats offer extended life benefits to new or refurbished ESCs.

Made of diamond-like-carbon (DLC) and other nanocomposite materials, the thin wear-resistant films are adjusted to meet specific resistivity requirements of the ESC while protecting electronic layers and extending the overall life of the part. They have a broad range of chemical resistance, meet chamber process compatibility requirements, and can withstand high-temperature heated chuck applications.

Morgan Advanced Materials' chucks.

The hard-coats can be applied to new or refurbished ESCs, even for ESCs originally designed without a sacrificial wear layer. The technical films are available for chemical vapor deposition (CVD), physical vapor deposition (PVD), etch and ion implant processes. The films feature mesa patterning for low defectivity and can be used in most high-temperature processes, says the firm.

www.morganadvancedmaterials.com
www.diamonex.com/wearlayers

Mitsubishi launches bonding services using proprietary room-temperature wafer bonding systems

In response to external demand, Tokyo-based machinery manufacturer Mitsubishi Heavy Industries Ltd (MHI) has launched wafer bonding services using its wafer bonding systems, which have been developed in-house and are capable of bonding different kinds of materials at room temperature.

Up to now the firm has offered trial services to businesses and other potential users considering adopting the system. Now, those services have been expanded to include businesses and research institutes with no immediate plans to acquire the system. In launching the new services, MHI aims to boost recognition of the effectiveness of room-temperature wafer bonding (a technology originating in Japan) in order to expand machine sales. The firm also aims to develop bonding services into a new areas of business.

Room-temperature bonding is a process where, by irradiating ion beams and atom beams in a vacuum, wafer surfaces become activated and bond. Because no heating is necessary (unlike conventional bonding), room-temperature bonding can be applied to bond materials with different coefficients of thermal expansion. Moreover, the technology

MHI's wafer bonding systems

is suited to the production of micro-electro-mechanical systems (MEMS) devices, which demand superior finishing precision, and biodevices that cannot be heated. Bondable materials include silicon, oxide dielectrics, glass, compound semiconductors, metals, and ceramics.

MHI completed development and began marketing its first room-temperature wafer bonding machines in 2005. The lineup currently includes a fully automated system accommodating wafers up to 12" (300mm) that is capable of manufacturing three-dimensional (3D) integrated LSI (large-scale IC). This newest system is rapidly entering use in fields such as MEMS sensors, LEDs, high-frequency devices, biodevices, power devices, etc.

MHI says that, up to now, businesses and institutions planning to acquire its room-temperature wafer bonding machine have confirmed the system's bonding performance and quality via bonding tests performed at MHI using actual material samples. In recent years, as the room-temperature bonding process itself has become a focus of interest worldwide, MHI has seen a significant increase in such material bonding requests, especially from university and business research laboratories and factories engaging in small-lot production. MHI hence decided to accept requests for bonding services regardless of whether the user plans to acquire a machine or not.

The new bonding services are performed using four demonstration systems at the Technology & Innovation Headquarters' Advanced Technology Research Center in Yokohama and the Machine Tool Division in Ritto City (Shiga Prefecture). Fees vary, depending on factors such as wafer size, number of units to be bonded, etc. Trial bonding of smaller-size chips is also performed under designated conditions.

www.mhi-global.com/products/

ClassOne launches spin rinse dryer systems with increased performance and lower cost

ClassOne Technology has launched the Trident line of spin rinse dryer (SRD) tools, which aim to bring more advanced SRD performance to smaller and emerging-technology users while also reducing costs.

The Trident SRDs utilize Deluge technology to deliver a continuous and consistent cascade of rinse water — and eliminate the expense of spray-nozzle replacement. All systems provide full PLC control with color touch-screen displays as well as ultra-pure non-contact N2 heaters, full wrap-around bowl heaters, direct-drive brushless motors, negative-pressure motor seals and FM4910 compliance.

"Many of our customers are price conscious," says president Byron Exarcos. "They've been asking for a simple, robust SRD with state-of-the-art capabilities, but one that would fit their budgets," he adds. "Our new Trident SRDs are significantly lower in price than others on the market — and at the same time, they also raise the bar in SRD performance," he claims.

Trident SRD systems are available in four different configurations: bench-top, roll-around, single-stack and double-stack models. The tools can process batches of up to 50 wafers, of 75–300mm in diameter.

Both the Trident SRD and Solstice plating systems were exhibited at July's SEMICON West in San Francisco.

www.classone.com

Rubicon grows for fifth quarter, with 4–6-inch wafers compensating for decline in 2" cores

Qualifications of 4–6" PSS at LED makers target high volumes next year

For second-quarter 2014, Rubicon Technology Inc of Bensenville, IL, USA (which makes monocrystalline sapphire substrates and products for the LED, semiconductor and optical industries) has reported revenue of $14.5m, up slightly on $14.3m last quarter and up 37% on $10.6m a year ago (rising for a fifth consecutive quarter).

Revenue from 2" and 4" cores fell by $1.8m, down 16% from $11.4m last quarter to $9.6m, of which two-thirds was 2" ($6.5m, down from $8.5m in Q1). The decline was due to more crystal production being directed into wafer products and because the firm had exhausted its excess boule inventory in Q1/2014.

The average selling price (ASP) for 4" cores rose about 10% sequentially due to strong demand from the LED market and the result of LED chip makers moving from 2" to 4" substrates in order to boost throughput from their existing facilities. However, consequently, there were declines in both 2" volumes and pricing (by 2%). "Now that MOCVD utilization rates are high, many LED chip manufacturers are looking for ways to increase throughput from existing operations, and moving to a larger substrate is one of the most effective ways to do that," notes president & CEO Raja Parvez. "We view the recent move to 4" substrates as validation of our belief that we will soon see greater adoption of 6" and even 8" substrates. This is important for Rubicon because of our strength and expertise in larger diameters."

Sales of polished and patterned wafers rose from $1.1m last quarter to $2.9m. Of the $1.8m increase, $1.1m was from 4" polished wafers, $500,000 from 6" polished wafers, and $200,000 from patterned wafers. The rise for 6" was mainly from the LED market, although shipments also resumed to the silicon-on-sapphire (SoS) market (worth $100,000).

Both 4" polished and 4" and 6" patterned sapphire substrates (PSS) are new products. "A significant development in the introduction of our PSS product came this quarter with the initial qualification of our 4" and 6" PSS wafers at three customers, two of which are major, international LED chip makers," Parvez says. "These customers plan to expand their use of patterned wafers in their production and they have chosen Rubicon because of our vertical integration and our strong capability in both polishing and patterning large-diameter wafers," he adds. "Orders will likely be limited in the second half of this year, as we continue to work on spec alignment and additional testing." However: "We believe these customers have the potential to contribute significant revenue next year," he continues.

"We had our first volume order of 4" polished wafers in the quarter and began producing 4" PSS wafers for our first qualified PSS customer," says chief financial officer William Weissman. "We expect a steady flow of orders from this customer. This will not likely be a high-volume user. However, we received initial qualification of our PSS product at several new accounts which do have a potential to be significant volumes through polishing and PSS operations next year," he adds. "We also continue to make good progress on qualification of PSS with other major LED chip makers," Weissman continues. "While we are behind where we had hoped to be from a revenue perspective, we are pleased with the level of interest in the product and the qualification process."

Crystal growth operations continued to run at full capacity throughout the quarter. Utilization for polishing and patterning operations remained low, but that began to improve during the quarter (from 20% to 30–35%) due to the increased wafer volumes. Idle plant cost fell from $2.4m last quarter to $1.9m.

Operating expenses were $2.9m, down from $3.4m last quarter, due mainly to lower legal fees and reduced headcount. Wafer costs continued to be higher than normal due to the large number of PSS samples produced and the cost of establishing a 4" polishing line.

Net loss was $10m ($0.39 per share), cut from $10.9m ($0.43 per share) last quarter but up from $5.9m ($0.26 per share) a year ago. During the quarter, Rubicon used about $5m in cash: $2m in operations ($4m last quarter) and $2.7m in capital expenditure (up from $2m last quarter). Cash and cash equivalents fell from $27.7m to $24.7m.

"While idle plant and development costs at our wafering facility continued to be a drag on earnings in the second quarter, we are making progress in continuing to improve our overall cost position," says Weissman. "Utilization of our wafer operations is improving and we expect wafer costs to decline as we move from development to production in our new product lines," he adds.

"We expect continued progress in growing the wafer business in the third quarter, with additional volumes in both polished and PSS wafers," says Parvez. "However, we are seeing very limited demand for 2" core in the third quarter as our polishing customers currently have excess inventory. In addition, we believe that recent capacity additions in the sapphire market, which are primarily targeted at the developing mobile device market, are temporarily impacting the 2" market," he adds.

For third-quarter 2014, Rubicon expects revenue to fall to $8–12m, with a loss per share of $0.39–0.44. The relatively wide range of expected revenue is due to the near-term uncertainty in the 2" market. "We expect 2" inventories at our polishing customers to be reduced over the course of the third quarter and for

demand for that product to improve in Q4," says Parvez.

"We continue to execute on our vertical integration strategy and are making good progress with the wafer business," says Parvez. "The recent initial qualification of our PSS product at three new customers this quarter was an important step in the introduction of that new product line and qualification efforts continue with a number of other major LED manufacturers," he adds. "With increasing volume and experience, and as customer specifications become better defined, we will reduce our idle plant costs and our wafer product cost. Furthermore, while pricing for certain product groups may take a step back from time to time for various reasons, we believe the general pricing trend for sapphire will continue to improve for some time."

www.rubicon-es2.com

Ammono launches p-type GaN

Ammono S.A. in Warsaw, Poland, which produces bulk gallium nitride (GaN) using ammonothermal technology, has added a new product in its portfolio — the p-type truly bulk AMMONO-GaN substrate — presented by Dr Marcin Zajac at the International Workshop on Nitride Semiconductors (IWN2014) in Wroclaw, Poland (24–29 August).

Typically, dedicated donor doping can increase GaN conductivity, providing electrons as majority charge carriers (n-type). Successful and efficient p-type doping of GaN has always been a difficult technological task, because of the high activation energy of typical acceptors. Until now, only thin layers of p-type GaN could be obtained by epitaxial methods or ion implantation.

In contrast, in the ammonothermal process the incorporation of acceptors during growth results in a larger hole concentration and p-type conductivity, without the generation of structural defects. The dislocation density in p-type AMMONO-GaN remains the same as the dislocation density of n-type AMMONO-GaN substrates, being below $5x10^4 cm^{-2}$. Carrier (free hole) concentration in this material is at the level of $10^{16} cm^{-3}$, while electrical resistivity is 10–100Ω.cm.

Ammono says that the new p-type GaN substrates should enable the fabrication of novel devices. In this area, where many solutions are already patented, the introduction of such a new substrate offers new potential for device architectures, reckons the firm. It is expected that laser diodes, LEDs, high-power transistors and high-frequency transistors may gain many benefits by using this new material.

www.ammono.com

Fukuda Crystal Lab grows 2-inch scandium aluminum magnesium oxide crystal rivalling sapphire

Commercial launch as GaN blue LED substrate targeted for spring 2015

Fukuda Crystal Laboratory Co Ltd has grown $ScAlMgO_4$ scandium aluminum magnesium oxide (SCAM) crystal with a 50mm (2 ") diameter that could be used as a substrate for gallium nitride (GaN)-based light-emitting devices such as blue LEDs and blue-violet laser diodes.

The lab says that, compared with sapphire (often used as a blue LED substrate), SCAM is suited to reducing crystal defects in GaN-based semiconductors. SCAM is hence expected to improve the brightness of light-emitting devices.

A research group led by professor Takashi Matsuoka of Tohoku University's Institute for Materials Research formed a GaN-based LED structure using the prototype crystal, and confirmed that the effect was to improve the brightness.

The lattice mismatch between SCAM and GaN is as small as 1.8%, and SCAM causes few dislocation

crystal defects. Although it is difficult to make the SCAM crystal, Fukuda Crystal Laboratory has grown the 2" SCAM crystal by the Czochralski (CZ) method, improving the crystal quality by tailoring the furnace structure and changing the crystal growth conditions.

When the prototyped SCAM crystal was cleaved and its C surface examined by x-ray diffraction, its full width at half maximum (FWHM) was 12.9 seconds, which is equivalent to the quality of a perfect silicon (Si) crystal, it is claimed.

Also, Fukuda Crystal Laboratory fabricated the wafer just by cleaving an ingot of SCAM crystal without cutting or polishing it, making it possible to lower the cost of wafers. When a thin film of GaN was grown on the cleaved surface of the SCAM crystal by metal-organic chemical vapor deposition (MOCVD) at a temperature of 1040°C, a low-dislocation crystal with a mirror surface was formed.

Fukuda Crystal Laboratory plans to increase the diameter of the SCAM crystal and commercialize it. Specifically, it intends to launch a 2" SCAM substrate by spring 2015.

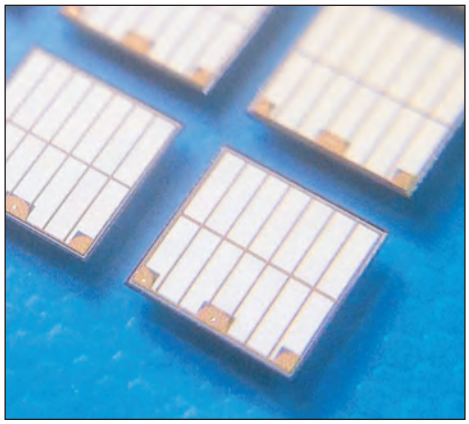
www.fxtal.co.jp/index_e.html

SemiLEDs releases family of 80mil EV LED chips

LED chip and component maker SemiLEDs Corp of Hsinchu, Taiwan has announced sampling and volume availability of a complete line of 80 mil x 80mil rugged metal LED chips, including white, blue, and ultraviolet (UV) variants.

The EV-80mil family provides packagers and integrators with a wider variety of high-efficiency/high-output choices to address the growing number of applications in both the commercial lighting and industrial spaces. With the new family, a single 80mil x 80mil device will typically replace four 40mil x 40mil LED chips, simplifying packaging and optical designs while minimizing color fringing and shadow effects common to multi-chip implementations. SemiLEDs EV family, which combines vertical LED architectures with rugged copper-alloy substrates, has proven to be suited to handling the increased thermal and electrical demands of large-chip implementations, says the firm.

"Applications in commercial and residential lighting, along with UV industrial applications, share the common challenge of achieving high output in compact form-factors, in the most cost-effective manner," comments Mark Tuttle, general manager for SemiLEDs Optoelectronics Co Ltd. "SemiLEDs' unique vertical-metal architectures allow these devices to be driven hard, without compromising either their stability or reliability, allowing packagers and integrators to deliver maximum optical power from extremely small package or chip-on-board footprints," he adds. "The EV-80mil line is also able to deliver substantial versatility, including die-level white options that incorporate SemiLEDs' proprietary ReadyWhite phosphor coating technology, which minimizes blue-leakage and delivers impressive levels of color uniformity with tight binning options for low-profile and multi-color white packaged LEDs."



SemiLEDs 80mil x 80mil LED chips.

The EV-80mil ReadyWhite chips incorporate SemiLEDs' proprietary phosphor technology and, when packaged in a typical 5mm x 5mm ceramic package, can be expected to deliver up to 1200 lumens at 3A. They are available in correlated color temperatures (CCTs) of 2600–10,000K with color rendering indices (CRIs) from a minimum 65 to a minimum of 90, after packaging.

SemiLEDs says that, combined with their vertical LED chip architecture, its ReadyWhite solutions deliver a package-ready white chip for COB, single-die or multi-die packaging applications, eliminating requirements for sophisticated and costly phosphor manufacturing technology.

Reduced chip count from the larger devices also simplifies system architectures for high-bay and other multi-die kilolumen applications

When driven with currents below 1.0A, with the 80mil ReadyWhite chips deliver up to 145 cool-white lumens per watt in typical package configurations, and are suited to applications such as outdoor street or area lighting, or heavy-duty flashlights/torches.

The 80mil blue chips are available in standard wavelengths from 445nm to 460nm (with options up to 470nm additionally available upon request) and deliver up to 4000mW of optical power at 450nm in typical ceramic packaging.

As single-chip implementations, the ReadyWhite and blue chips are suited to narrow-beam-pattern kilolumen applications that benefit from simplified optics and compact emitter sizes, including projectors, MR/GU/PAR spotlights, and automotive front lighting. The reduced chip count from the larger devices also simplifies system architectures for high-bay and other multi-die kilolumen applications.

"While much of the news in the LED industry is focused on general lighting, there is an incredible amount of innovation going on in the industrial and medical arenas," says Tuttle. "The 80mil UV solution from SemiLEDs allows tremendous power per square millimeter for high-output-density industrial requirements," he adds. "Applications ranging from spot curing to 3D printing and fiber-optic-coupled systems, as well as completely new applications, are all benefitting from the increased optical control that is enabled by solid-state solutions such as SemiLEDs single-die 80mil series."

The UV 80mil is offered in wavelengths of 360–420nm with optical outputs up to 4000mW when driven at 3A in typical ceramic packages. For industrial applications, including spot curing of polymers, inks and adhesives, to 3D printing and fiber-optic-coupled systems, the 80mil design enables an 8–10W single-chip point source, eliminating the need for sophisticated optic designs to collimate light, as well as avoiding dark gaps inherent to designs that use multiple smaller chips. The single-chip approach increases flexibility for varying the beam patterns through secondary optics, increases UV exposure consistency, and maximizes delivered UV optical power across the target areas, says SemiLEDs.

The EV-80mil series of LED chips is RoHS-compliant, with production quantities available now.

www.semileds.com

SemiLEDs launches Enhanced FlipChip LED series to maximize lumen density and simplify integration

LED chip and component maker SemiLEDs Corp of Hsinchu, Taiwan has announced sampling and volume availability of the first in its new Enhanced FlipChip (EF) LED series.

The series launches with the EF-B40, a blue 40-mil flip chip that simplifies the packaging and integration process by eliminating wire bonding while increasing both lumen density and decreasing the lumen-per-dollar value proposition, the firm claims, while enabling packagers to use standard surface-mount assembly techniques.

"SemiLEDs' unique flip chip approach combines a sapphire front surface and proprietary back side architecture that provides the electrical contacts exclusively on the bottom of the chip, making it fully compatible with chip-on-board (COB) surface-mount processes," says Mark Tuttle, general manager for SemiLEDs Optoelectronics Co Ltd. "Eliminating wire bonds also lowers the profile of the chips, and allows them to be placed more closely together, which results in higher lumen density and reduces the complexity of the optics," he adds. "The EF series is an ideal platform for COB assemblies, or really for any approach that calls for either secondary optic design or high-density mounting."

Flip-chip construction presents what was originally the bottom sapphire layer in a horizontal LED structure as the top surface of the chip. By flipping the chip in this way, the electrical pads become part of the bottom of the device rather than running bonding wires from the top surface of the chip down to the package or board. Not only are delicate areas of the chip protected by the clear sapphire layer but, by eliminating wire bonds (arguably the most failure-prone part of any LED assembly), both reliability and overall design flexibility of the packaged device are increased. In addition, individual chips may be more closely mounted, opening the door to more densely packed arrays of LED chips. The nearly continuous light-emitting surface — unbroken by gaps, bonding wires, or top electrodes — can greatly simplify the mounting and mixing requirements of the optics, producing smooth lighting effects. In addition, in a flip-chip structure, the heat-generating junction is positioned adjacent to the substrate, increasing thermal conductivity and allowing improved device performance at high currents.

The EF-B40 is available in wavelengths of 445-460nm, with outputs of up to 300 lumens at 1A as a packaged emitter. The SAC-compatible chips are offered with standard Au bonding pads, or are available with an AuSn option to further reduce thermal resistance and add to system reliability.

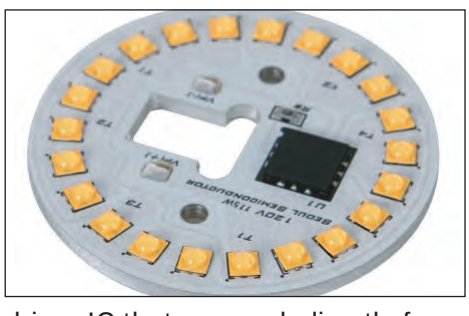
A 140º viewing angle makes the EF suitable for general and commercial lighting, while the lowered profile addresses the needs of LED backlight, smartphone flash or LED projector applications. The EF series of LED chips are RoHS compliant, with production quantities available now.

www.semileds.com

Seoul Semiconductor launches Acrich-based module for omnidirectional lamps

South Korean LED maker Seoul Semiconductor has launched a new Acrich module optimized for omnidirectional lamps to meet ENERGY STAR requirements. The module consists of the Acrich MJT 2525 series LED along with Seoul Semiconductor's latest generation of Acrich 3 driver IC and a reflector optic.

With dimensions of 2.5mm x 2.5mm and wide a beam angle, the Acrich MJT 2525 series LED has what is claimed to be industry-leading lumen density of 15lm/mm^2. It incorporates Seoul Semiconductor's proprietary Acrich Multi-Junction chip Technology to create the high-voltage LED package. The Acrich 3 IC is the firm's latest-generation



driver IC that can work directly from the AC mains. It enables lower-cost driver solutions and is designed to work with existing TRIAC or phase-controlled dimmers without sacrificing power quality or efficiency.

All LEDs and the driver IC are incorporated on a single 38mm-diameter board, making the light engine easy to use in an A19 form factor, the firm says. Along with the light engine comes a reflector that has been optimized to create the omnidirectionality of the light pattern. An optional heat bridge can also be used to improve thermal dissipation of the light engine.

"The new Acrich A19 module is optimized for the performance and cost requirements of the retrofit lamp market," says Jay Kim, executive VP of Lighting sales. "This new module combines the light source, driver, optics and primary thermal management in a single compact system, simplifying designs and lowering costs for lighting manufacturers," he claims.

www.seoulsemicon.com/en

Plessey partners with Solid State Supplies for UK and Ireland distribution

UK-based Plessey has entered into a distribution agreement with electronics distributor Solid State Supplies Ltd of Redditch, UK to expand its European network with coverage in the UK and Ireland markets for its GaN-on-Si LED products.

"Plessey's gallium nitride on silicon technology looks set to cause major disruption in the LED lighting market," comments Solid State Supplies' managing director John Macmichael. "Our in-house lighting division is already geared up to support lighting and luminaire designers with these new LEDs," he adds.

"Plessey is very pleased to join forces with a distributor that has a focused lighting division already up and running, helping the significant number of lighting and luminaire makers in the UK," says Plessey's regional sales director David Owen. "Solid State Supplies has a strong portfolio of products to support the lighting eco system, which is now enhanced by the addition of the Plessey GaN-on-Si LED product range. This will accelerate the time to market for Plessey LEDs in this region."

Plessey's regional sales director David Owen (left) and Solid State Supplies' managing director John Macmichael (right).

Plessey's MaGIC (Manufactured on GaN-on-Si I/C) high-brightness LED (HB-LED) technology has won awards for its ability to cut the cost of LED lighting by using standard silicon manufacturing techniques.

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

SETi's UV LEDs used in decontamination system on International Space Station

Conducting science experiments in space, aboard the International Space Station, presents many challenges from working in a microgravity but, due to the Microgravity Science Glovebox (MSG), those aboard the space station have been able to safely conduct their experiments since 2004. Over the past 10 years, the MSG has been put to good use on a wide range of research programs but now, thanks to the activation of a new decontamination system inside the MSG, crew members can now safely perform biological research.

Developed and built by Teledyne Brown Engineering Inc (TBE), the decontamination system uses high-power UVCLEAN ultraviolet light-emitting diodes (UV LEDs) from Sensor Electronic Technology Inc (SETi) of Columbia, SC, USA, developed in part through the US Defense Advanced Research Projects Agency (DARPA) Compact Mid-Ultraviolet Technology (CMUVT) program. The UV LEDs have the power to sanitize the surfaces, liquids and air inside the MSG within minutes and, for the safety of the crew, are used before and after experiments are conducted.

NASA astronaut Rick Mastracchio prepares to use Teledyne Brown's system to decontaminate hardware used for life science experiments inside the Microgravity Science Glovebox on the ISS. Photo Credit: NASA.

The upgraded MSG with TBE's decontamination system and SETi's UV LEDs will allow for a much wider range of microgravity experiments and will be available to all biological payloads that operate in the MSG with a concern about contamination.

"Our products passed space flight qualification in the past", comments SETi's president & CEO Dr Remis Gaska. "However, this is the first space launch, installation and successful testing of our devices in the orbit," he adds. "This demonstrates the level of maturity of deep UV LED technology".

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High-brightness LEDs made from perovskite material

Solution-processed organometal halide perovskites target efficient, colour-tunable light emitters for low-cost displays, lightings and optical communications

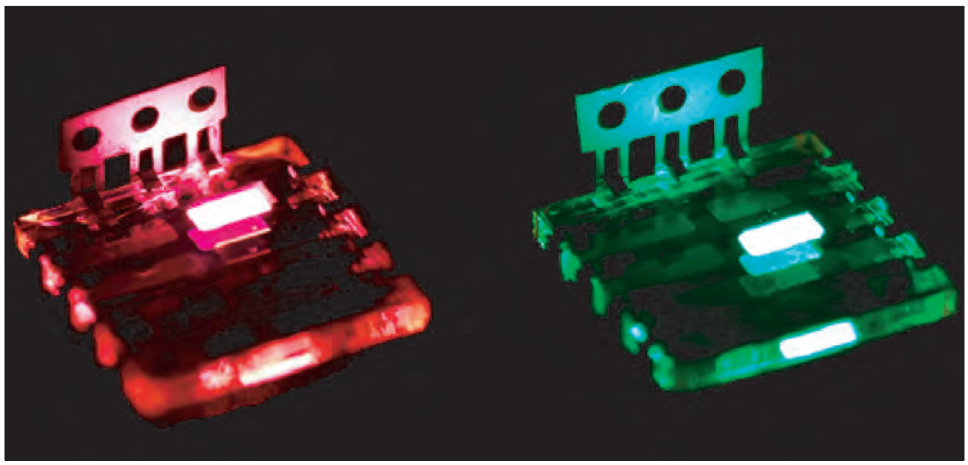
A hybrid form of perovskite — the same type of material that has recently been found to make highly efficient solar cells that could replace silicon — has been used to make low-cost, easily manufactured LEDs, potentially opening up a wide range of commercial applications in future, such as flexible colour displays.

This particular class of semiconducting perovskites have generated interest in the solar cell field over the past several years, after professor Henry Snaith's group at the UK's University of Oxford found them to be remarkably efficient at converting light to electricity. In just two years, perovskite-based solar cells have reached efficiencies of nearly 20%, a level that took conventional silicon-based solar cells 20 years to reach.

Now, researchers at the University of Cambridge, University of Oxford and the Ludwig-Maximilians-Universität in Munich, Germany have demonstrated a new application for perovskite materials, using them to make high-brightness LEDs (Zhi-Kuang Tan et al, published online in Nature Nanotechnology; doi:10.1038/nnano.2014.149).

Perovskite is a general term used to describe a group of materials that have a distinctive crystal structure of cuboid and diamond shapes. They have long been of interest for their superconducting and ferroelectric properties. But in the past several years their efficiency at converting light into electrical energy has opened up a wide range of potential applications.

The perovskites that were used to make the LEDs are known as organometal halide perovskites, and contain a mixture of lead, carbon-based ions and halogen ions (halides). These materials dissolve well in common solvents, and assemble to form perovskite crystals when dried, so they are cheap and simple to make.



LEDs made from perovskite material. Credit: Zhi-Kuang Tan.

"We have designed the diode structure to confine electrical charges into a very thin layer of the perovskite, which sets up conditions for the electron-hole capture process to produce light emission," says the paper's lead author Zhi-Kuang Tan, a PhD student at the University of Cambridge's Cavendish Laboratory.

Perovskite LEDs are made using a simple and scalable process in which a perovskite solution is prepared and spin-coated onto the substrate. This process does not require high-temperature heating steps or a high vacuum, and is therefore cheap to manufacture in large scale

The perovskite LEDs are made using a simple and scalable process in which a perovskite solution is prepared and spin-coated onto the substrate. This process does not require high-temperature heating steps or a high vacuum, and is therefore cheap to manufacture in large scale. In contrast, conventional methods for manufacturing LEDs make the cost prohibitive for many large-area display applications, the researchers say.

"The big surprise to the semiconductor community is to find that such simple process methods still produce very clean semiconductor properties, without the need for the complex purification procedures required for traditional semiconductors such as silicon," comments professor Sir Richard Friend of the Cavendish Laboratory, who led the program at Cambridge.

"It's remarkable that this material can be easily tuned to emit light in a variety of colours, which makes it extremely useful for colour displays, lighting and optical communication applications," says Tan. "This technology could provide a lot of value to the ever-growing flat-panel display industry," he reckons.

The team is now looking to increase the efficiency of the LEDs and to apply the material to diode lasers, which are used in a range of scientific, medical and industrial applications, such as materials processing and medical equipment. The first commercially available LED based on perovskite could be available within five years, it is reckoned.

www.nature.com/nnano/journal/vaop/ncurrent/full/nnano.2014.149.html
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Cree's quarterly revenue up 8% to record $436m, driven by 18% growth in lighting products

CapEx increased to support growth in lighting and LEDs

For fiscal 2014 (ended 29 June), Cree Inc of Durham, NC, USA has reported record revenue of $1.65bn, up 19% on fiscal 2013's $1.39bn.

Specifically, for fiscal fourth-quarter 2014, revenue was a record $436.3m, towards the low end of the targeted range of $430–460m but up 8% on $405.3m last quarter and up 16% on $375m a year ago. All three product segments grew.

Lighting Product revenue (mainly LED lighting systems and bulbs) was $208.2m, up 18% on $176.7m last quarter and 56% on $133.6m a year ago (rising from 36% of total revenue through 44% to 48% of total revenue). Full-year revenue has grown by 43% from fiscal 2013's $495m to $706m in fiscal 2014.

LED Product revenue (LED components, LED chips, and silicon carbide materials) was $199.5m, down slightly from $201m last quarter and down by 8% from $217.4m a year ago (falling from 58% of total revenue through 49% to 46% of total revenue). Full-year revenue has grown by just 4% from fiscal 2013's $801.5m to $834m in fiscal 2014.

Power & RF Product revenue was $28.6m, up 4% on $27.4m last quarter and up 19% on $24m a year ago (remaining 6–7% of total revenue). Full-year revenue has grown by 20% from fiscal 2013's $89.4m to $107.5m in fiscal 2014.

On a non-GAAP basis, overall gross margin rebounded slightly from 37.8% last quarter to 37.9%, still down on 38.2% a year ago but above the expected 37.5%. This was driven by Lighting Product gross margin rising from 25.1% a year ago and 27.4% last quarter to a slightly better-than-expected 29.1% (due mainly to cost reductions and productivity improvements for LED fixtures). In contrast, LED Product gross margin has fallen from 45.7% a year ago and 45.6% last quarter to 45.1%, while Power & RF Product gross margin has fallen further, from 57.1% last quarter to 56.9% (yet still up on 53.7% a year ago). Nevertheless, overall full-year gross margin is down slightly from 38.4% in fiscal 2013 to 38.2% in fiscal 2014.

Cree is starting to see incremental operating leverage from investments made over the last two years

Operating expenses rose from $100m last quarter to $108m, at the upper end of the targeted range due to higher R&D spending to support increased development activities in both LEDs and lighting. For example, highlights during the quarter include introducing the XLamp XP-L LED, the first commercially available single-die LED to achieve luminous efficacy of up to 200 lumens per watt at 350mA.

Net income has risen from $45.6m ($0.38 per diluted share) a year ago and $47.7m ($0.39 per diluted share) last quarter to $51.3m ($0.42 per diluted share). Full-year net income has risen from $155m ($1.32 per diluted share) in fiscal 2013 to $203m ($1.65 per diluted share) in fiscal 2014.

During the quarter, operating cash flow was $91.1m (up from $60.2m last quarter). Capital expenditure has risen from $36.2m to $64m. Hence, free cash flow was $26.8m up from $19.3m). During fiscal 2014, operating cash flow was $319.3m (up from $285.2m in fiscal 2013). Capital expenditure has risen from $98.3m in fiscal 2013 to $198.7m. Hence, free cash flow was $120.6m (down from $187m in fiscal 2013).

During the quarter, cash and investments fell by $61m to $1.162bn. However, over the year, cash and investments rose by $139m from $1.024bn, due to increased profitability and solid execution that more than offset investment of almost $300m ($198.7m in capital expenditure and $100m in stock repurchases).

"The strength of our operating model gives us the flexibility to make investments to support our goal to grow the business and increase operating margin," says chairman & CEO Chuck Swoboda. "Our new product pipeline, brand momentum and strong balance sheet put us in a great position to enable our long-term customer goal of 100% upgrade to LED lighting."

For fiscal first-quarter 2015 (ending 28 September 2014), Cree expects revenue to grow to $440–465m, consisting of solid growth for Lighting Products (driven by strong growth in LED fixtures and LED bulbs in a similar range to fiscal Q4/2014), flat to single-digit growth for LED Products, and single-digit growth for Power & RF Products. Gross margin should fall slightly to 37.5% (even with an increased lighting mix). Operating expenses are targeted to be similar sequentially, as Cree is starting to see incremental operating leverage from investments made over the last two years (hence operating profit should grow faster than revenue sequentially, and operating margin should rise). Net income is expected to be $48–55m ($0.40–0.45 per diluted share).

For fiscal 2015, Cree is targeting property, plant & equipment (PP&E) capital expenditure similar to 2014 ($200m) to support new product priorities, provide incremental capacity, and add infrastructure to support longer-term forecasted growth. "The amount we invest will vary, based on forecasted revenue demand and the degree to which we expand the use of third-party manufacturers to support our growth in lighting and LEDs," notes chief financial officer Mike McDevitt.

www.cree.com

Cree to invest $83m in 13% stake in Taiwan's Lextar

Lextar's sapphire-based mid- and low-power LEDs to allow Cree to focus on high-power LEDs

Lextar Electronics Corp of Hsinchu Science Park, Taiwan (a vertically integrated manufacturer of high-brightness LED epitaxy, chips and packages, as well as smart lighting products) and LED chip, lamp and lighting fixture maker Cree Inc of Durham, NC, USA have entered into an agreement whereby Cree will invest about $83m to purchase 83 million Lextar shares at a price of NT$30 per share. Also, the companies will enter into a long-term supply agreement for sapphire-based LED chips, as well as a royalty-bearing license agreement for certain Cree LED chip and component intellectual property. Upon closing of the investment, Cree will own about 13% of Lextar, becoming Lextar's strategic customer in the lighting market.

Lextar was founded in 2008 and is a subsidiary of TFT-LCD and solar PV manufacturer AU Optronics with nearly 3500 staff at three manufacturing sites in Taiwan and two in China (Suzhou and Xiamen). With applications including LCD backlighting, LED light modules, LED light sources and luminaires, Lextar's revenue was US$462m in 2013.

"Lextar has established a strong technology position and customer base in the mid- and low-power backlighting and lighting LED segments, while Cree has had outstanding performance in the high-power LED component and lighting markets," says Lextar's chairman & CEO Dr David Su. "This new collaboration will increase the competitiveness of our products and technology, enabling both companies continued growth in the LED lighting market," he believes. "Furthermore, the cross license of LED chip and component intellectual property will afford both Cree and Lextar the benefits from our product and technology development, thereby strengthening our mutual competitiveness in the global LED industry," he adds.

"Working with Lextar to supply high-quality mid-power LED chips enables Cree to focus its resources on the high-performance, high-power LED chips that differentiate Cree LEDs in the market," says Cree's chairman & CEO Chuck Swoboda. "This approach provides the operational and financial flexibility to help Cree achieve the best return on our people and invested capital."

The agreement has been approved by the boards of directors of both companies, and is targeted to close by the end of fiscal 2014, subject to the approval of Lextar's shareholders and the Taiwan Investment Committee, as well as other customary closing conditions.

www.lextar.com
www.cree.com

Lumileds' LUXEON CoB with CrispWhite wins LFI Innovation Award

Philips Lumileds of San Jose, CA, USA says that its proprietary CrispWhite Technology, which was on display at the LightFair International 2014 trade fair in Las Vegas (3–5 June), has been awarded the LFI Innovation Award in the category of LED/OLED Chips and Modules.

The LFI Innovation Awards are judged by an independent panel of lighting professionals — recognizing products that exemplify the best in innovative design and thinking. In 2014, there were 261 entries spanning 14 categories.

LUXEON CoB with CrispWhite Technology was developed specifically for retail applications including downlights and spotlights where the truest color representation is desired by store owners and retail customers. CrispWhite is offered throughout the LUXEON chip-on-board (CoB) line of arrays, which feature what is claimed to be the highest combination of efficacy and lumen density in the industry (with a lumen range of 1000–10,000lm and typical efficacy of 100lm/W).

Lumileds' CoB with CrispWhite LEDs

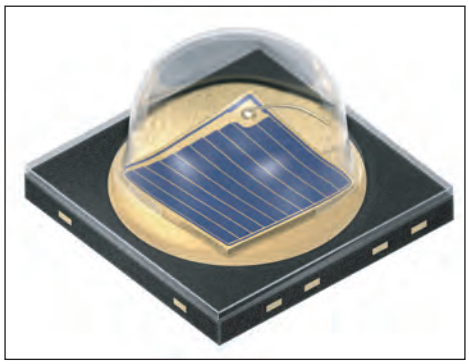
Lumileds says that thousands of show attendees (including lighting professionals and designers) got a preview of CrispWhite's light spectrum at both LightFair International and the Guangzhou International Lighting Exhibition in June. "We displayed saturated red, blue and white fabrics lit by CrispWhite next to the same fabrics lit by halogen and CDM sources," says product line director Eric Senders. "Overwhelmingly, attendees preferred CrispWhite's rendition."

www.philipslumileds.com/CrispWhite

Osram launches 48%-efficient infrared LED, boosting output by 30% for security applications

Osram Opto Semiconductors GmbH of Regensburg, Germany says that its new Oslon Black SFH 4715A 850nm-wavelength infrared LED (IRED) offers a typical electro-optical efficiency of 48% — a figure never before achieved with opto-electronic elements, it is claimed. It also achieves a substantial reduction in cooling requirements, providing much longer service life. Also, another new product in the Oslon Black family, the SFH 4716A, has a beam angle of 150°, permitting particularly narrow-angled imaging for camera-based lighting applications by using reflector optics.

The SFH 4715A's high typical electro-optical efficiency of 48% is possible due to the firm's latest chip generation and the optimized package (measuring either 3.85mm x 3.85mm x 2.29mm or 3.85mm x 3.85mm x 1.51mm). "We are not aware of any other opto-electronic component with an optical efficiency to rival this," says



Osram's SFH 4715A / 4716A IRED.

product marketing manager Sevugan Nagappan. Due to a boost in optical output to 800mW at 1A (previously 630mW), the new IRED can illuminate objects over 100m away, depending on the application and type of external optics. This higher output also generates more light, improving the image in the process. The new SFH 4715A can almost match a laser diode in terms of efficiency, allowing for greater ranges than the previous members of the Oslon Black family. "The same range can be achieved with fewer components — yielding a significant cost benefit," Nagappan says, adding that the system cooling requirements have also been reduced (thermal resistance is 11K/W maximum).

Use in camera-based outdoor security systems

The new A-version of the SFH 4715 IRED, with its much higher output and beam angle of 90°, will replace the previous Oslon Black SFH 4715. ESD (electrostatic discharge) protection for up to 2kV and extended corrosion-resistance make the new IRED suitable for outdoor applications, e.g. in CCTV systems.

150° beam angle for efficient injection into reflector optics

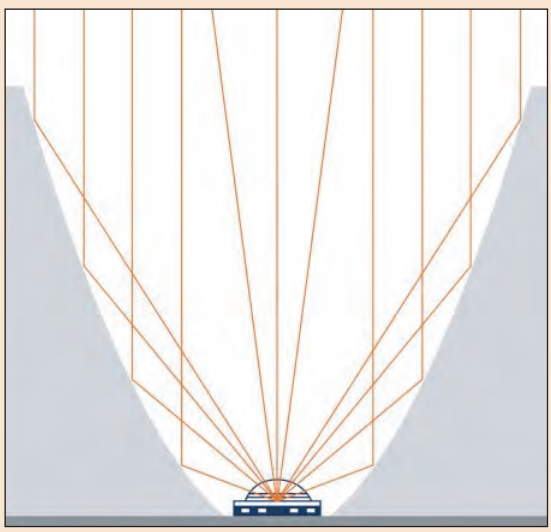
The SFH 4716A is the second new high-flux IRED in the Oslon Black family. It can inject light into reflector optics very effectively and has a beam angle of 150°. It rounds off Osram's product portfolio as a light source for applications requiring efficient imaging.

www.osram-os.com

Osram launches 940nm high-flux IRED with 150° beam angle

Osram Opto Semiconductors GmbH of Regensburg, Germany has launched the SFH 4726S, a high-power member of its IR Oslon Black product family with a wide beam angle of 150° (±75°) in a 3.85mm x 3.85mm package.

When integrated in reflector-based optics, the infrared LED (IRED) pre-shapes the light beam, concentrates it and can then focus it efficiently via other optics. As a result, smaller optics can be used, permitting generally more compact lighting solution designs. This system can replace the current conventional approach, which requires optics with a much larger optical aperture. Also, the smaller dimensions offer much greater design freedom for lighting solutions. Another advantage is



The high-flux IRED Osram Oslon Black SFH 4726S: beam shaping for reflector-based optical solutions.

the new IRED's high optical performance of 990mW at a current of 1A. Radiant intensity is 215mW/sr.

Like the SFH 4725S sister IRED product, the new Oslon Black SFH 4726S has a wavelength of 940nm. This long-wave radiation at the red end of the spectrum is barely visible to the human eye. Even the slight red glow that can be perceived at a wavelength of 850nm rarely occurs with this version. Infrared LEDs are hence ideal for discreet surveillance applications, e.g. in the main hall of a bank or at border crossings.

Other application for the IR Oslon Black family include optical vehicle security systems or gesture detection for computer games.

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POET announces results of annual meeting

POET Technologies Inc of Toronto, Canada — which, through subsidiary OPEL Defense Integrated Systems (ODIS Inc) of Storrs, CT, USA, has developed the proprietary planar-optoelectronic technology (POET) platform for monolithic fabrication of integrated III-V-based electronic and optical devices on a single semiconductor wafer — has announced the results of its Annual General & Special Meeting (AGSM) held on 12 August.

Shareholders approved all matters presented to the meeting, including the 2014 Stock Option Plan, the By-Law No. 1 amendment, the possible Share Consolidation, the Shareholders' Rights Plan and the election of the following nominees to the board of directors (as proposed in the Information Circular): Peter Copetti, Adam Chowaniec, Sheldon Inwentash, Ajit Manocha, John F. O'Donnell, Dr Samuel Peralta, Dr Geoff Taylor, and Chris Tsiofas. All directors received the required majority vote from shareholders. Shareholders also approved the re-appointment of Marcum LLP of Hartford, Connecticut as auditors for the ensuing year.

Shareholders were presented with updates by Peter Copetti, Geoff Taylor, and Ajit Manocha, Stephane Gagnon and Lee Shepherd on the status of the firm and progress of the POET technology. Each reinforced that the core of the firm's strategy is to continue to develop the POET platform.

In a subsequent meeting of directors following the AGSM, the following executive officers were re-appointed for the ensuing year:

- Peter Copetti, executive chairman & interim CEO;
- Ajit Manocha, vice-chairman of the board;
- Leon M. Pierhal, president;
- Kevin Barnes, treasurer & chief financial officer;
- Stephane Gagnon, senior VP of operations;
- Lee Shepherd, VP of technology;
- Michel Lafrance, corporate secretary; and
- Blaine Grisel, controller.

Daniel DeSimone, who has been senior VP, product development of the ODIS division since April, was also appointed chief technology officer. "Dan brings to POET a diverse background of circuit/product design and technology development experience from Fairchild Semiconductor and Tundra Semiconductor," comments chief scientist Dr Geoff Taylor. "These skills are expected to be instrumental in developing the electronic component of the POET platform."

Leon Pierhal, who did not stand for re-election as a director, will continue as president until 30 September. Afterwards, he will remain as a consultant on an as-needed basis in order to provide information and advice regarding any legacy issues that may arise from time to time. His options will remain in place for 12 months.

At the board meeting, incentive stock options were granted under the stock option plan to certain directors, officers, key consultants and employees of the firm to purchase up to an aggregate of 3,940,000 common shares, representing 2.41% of the firm's outstanding shares.

Of these options, 4.8% were granted to key technical staff related to the POET effort, 14.0% to the company's officers, 64.0% to non-officer directors, and 17.8% to directors who are also officers. The stock options are exercisable at a price of CA$1.24 per share expiring 12 August 2019. Pursuant to the TSX Venture Exchange policies, the exercise price was fixed by the closing market price of 11 August. The options will vest and be exercisable on the basis of 25% on the date of grant and 25% every six months thereafter.

The options were granted subject to provisions of the firm's stock option plan (approved by shareholders on 12 August) and are subject to the TSX Venture Exchange policies and applicable securities laws. There are currently 163,773,384 shares issued and outstanding and 26,307,750 options outstanding.

www.poet-technologies.com

ProPhotonix releases compact green laser modules for machine vision systems

ProPhotonix Ltd of Salem, NH, USA, a designer and manufacturer of LED illumination systems and laser diode modules for OEMs and medical equipment companies (as well as a distributor of laser diodes for Oclaro, Osram, QSI, Panasonic and Sony), has launched the 3D PRO Laser Green Series, an extension of its structured light laser product portfolio.

The 3D PRO Laser Green series includes the 3D PRO Green, the Adjustable Focus 3D PRO Laser Green and the 3D PRO Laser Mini Green, all available in either 19mm or 10mm diameters. The direct emission green structured light lasers deliver high uniformity, suiting a wide range of 3D imaging applications.

The 3D PRO Laser Green Series of 520nm structured light lasers come in a range of output powers and uniform line and diffractive options.

"With the launch of 3D Pro Laser Green series we have taken advantage of our position as a leading laser diode distributor to access the latest in laser diode technology, delivering a truly compact solution for our machine vision customers," says Jeremy Lane, managing director of Laser Operations.

www.prophotonix.com

Novati gains Trusted Foundry accreditation from DoD

Novati Technologies Inc of Austin, TX, USA, a development center for photonics, MEMS, 2.5D/3D, III-V-on-silicon and nanotechnology products, says that its 68,000ft^2 wafer fabrication facility has been accredited by the US Department of Defense (DoD) as a Category 1A Trusted Foundry.

DoD accreditation distinguishes Novati as a trusted manufacturer of integrated circuits for US aerospace and defense applications. Category 1A is a select designation that has been granted to only nine CMOS fabs worldwide that exhibit the highest levels of process integrity and protection.

To ensure the trustworthiness of electronic components used for critical national security systems, the Defense Microelectronics Activity (DMEA) organization administers the Trusted Foundry program on behalf of the DoD. This provides a means for the DoD to assess the integrity and confidentiality of IC design and manufacturing processes, establishing stringent requirements spanning chain of custody assurance, supply continuity, and anti-tampering and anti-counterfeiting measures.

The Trusted Foundry program ensures that the US government has guaranteed access to specialized, high-performance components. Novati's wafer fabrication facility is designed to meet this requirement, supporting high-mix fabrication on 200mm and 300mm wafers, using novel materials, state-of-the-art technologies, and niche process variants that offer the high-performance characteristics that many new DoD applications demand.

Novati fabricates micro-electro-mechanical systems (MEMS), sensors, actuators, photonic and electro-optic devices, infrared (IR) detectors, wide-bandgap electronics, non-volatile memory, power semiconductors, RF devices and 2.5D/3D devices for aerospace and defense applications.

"Today's security applications for the DoD demand suppliers who can meet the most rigorous requirements for utilizing non-traditional elements and support low-volume manufacturing," says president & CEO David Anderson. "We've proven that customers with really tough problems that require innovative materials, combinations of heterogeneous devices and high-risk processing techniques come to Novati," he adds. "We regularly help develop products from concepts that have never been built before. The Trusted Foundry accreditation reflects our focus and strong commitment to supporting aerospace and defense contractors."

www.Novati-Tech.com

Oclaro's 100G growth counteracting legacy 10G decline

Restructuring cuts losses, while 100G capacity increases target adjusted EBITDA breakeven at $100m quarterly revenue by September

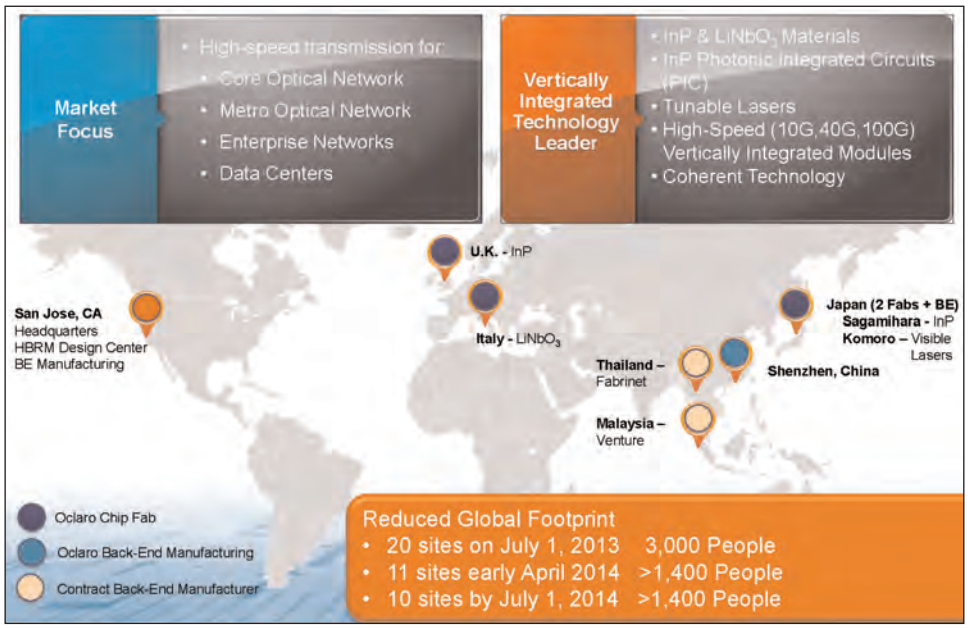
For fiscal 2014 (to end 28 June), Oclaro Inc of San Jose, CA, USA (which provides components, modules and subsystems for optical communications) has reported revenue of $390.9m, down 3% on fiscal 2013's $404.6m.

For fiscal fourth-quarter 2014, revenue was $95.9m, up only slightly on $95.4m both last quarter and a year ago, sustained mainly to continued growth in high-speed products (both the client-side and line-side of the 100G business).

Led by $3m of growth in 100G datacom and lithium niobate modulator products (including the first revenue for 100G coherent micro-ITLAs, plus three-fold sequential growth in shipments of 100G coherent modulators), sales of 40G & 100G transmission products were $48.8m, up 11% on $44.1m last quarter and up 54% on $31.7m a year ago (rising from 33% then 46% to 51% of total revenue). This was offset by sales of 10G-and-lower transmission products of $39.4m, shrinking by 10% from $43.7m last quarter and 31% from $57m a year ago (falling from 60% then 46% to 41% of total revenue).

By end-market, sales of Datacom products grew by 10% from $40.2m last quarter to $44.2m (rising from 42% to 46% of total revenue), while Telecom products shrank by 8% from $47.6m to $44m due to Oclaro exiting some products (falling from 50% to 46% of total revenue). Industrial & Consumer sales of $7.7m comprised the remaining 8% of total revenue (roughly level over the last year).

The top 10 customers contributed 82% of revenue (up from 78% last quarter), including three at greater than 10%: Coriant (formally the Optical Networks business of Nokia Siemens Networks) remained the largest, at 24% (up from 21%); Huawei at 13%; and Cisco at 11%. By region, the Americas contributed 29% of revenue, China 28%, Europe 23%, South-East Asia 14% and Japan 6%.



Overview of Oclaro's business.

On a non-GAAP basis, gross margin has rebounded partially from last quarter's sharp dip of 12.3% to 14.1%, due to increased sales of a 100G datacom product. This was despite another quarter of higher-than-usual cost of sales as Oclaro continues to fix historical business process issues. Without the higher E&O (excess and obsolete) reserves, gross margin would have instead been of 18%. Despite the drop in annual revenue, full-year gross margin has risen from 8.8% in fiscal 2013 to 14% for fiscal 2014.

Operating expenses have been cut further to $27.8m, down by 5% on $29m last quarter and down 28% on $39m a year ago, significantly reducing the firm's breakeven point.

Operating loss was $14.3m, cut from $17.5m last quarter and $28.9m a year ago. Full-year operating loss has been cut from $119.9m in fiscal 2013 to $74.7m for fiscal 2014.

Adjusted EBITDA has been cut from negative $22.1m a year ago and negative $12.3m last quarter to negative $9.4m (compared with the forecast negative $13–9m). Full-year adjusted EBITDA was cut from negative $89.9m in fiscal 2013 to negative $51.5m for fiscal 2014.

Capital expenditure (CapEx) has risen from $2.4m last quarter to about $3m. During fiscal Q4, cash, cash equivalents, restricted cash and short-term investments fell from $122m to $104.1m, due partly to a working capital drain of $10.3m (with accounts payable down as expected).

"The significant year-on-year improvement demonstrates the effective execution of our turn-around plan and validates our focus on being the market leader at 100G," says CEO Greg Dougherty. "While our work is not over, we've substantially transformed the company over the past nine months," he adds. "First, to fund our recovery we successfully sold assets which allowed us to pay off our debt and to kick off our restructuring plan that we rolled out last November. That plan called for us to lower our cost structure by reducing the number of our sites, reducing our headcount, correcting many broken

Ushio acquires Oclaro Japan's industrial & consumer laser diode and LED business

Ushio Inc of Tokyo, Japan (which makes light sources including lamps, lasers and LEDs) says that its subsidiary Ushio Opto Semiconductors Inc (established in July) has agreed to acquire the LED, red, violet and part of the infrared laser diode business of Oclaro Japan Inc (a subsidiary of optical component, module and subsystem maker Oclaro Inc of San Jose, CA, USA). The acquired activity is located primarily in Komoro, Japan and includes about 80 staff.

Since being founded in 1964, Ushio has manufactured lamps and solid-state light sources, becoming a leading manufacturer of industrial light sources. Aiming to further expand its solid-state light sources business, Ushio will take over the business related to the development and manufacturing of semiconductor lasers and LEDs (other than Oclaro Japan's optical communication business).

"Today, optical processes and applications have become more and more diversified and important in the industry," comments Ushio's president & CEO Shiro Sugata. "We at Ushio will provide a variety of light sources, including high-brightness and high-quality LEDs and LDs, as well as our existing lamp products to meet the diversified needs of our customers," he adds.

"It was critical for Oclaro Japan to find a respected partner that would provide new opportunities to our Komoro employees and continued support and innovation to our customers," says Oclaro Japan's president Tadayuki Kanno.

The transaction is expected to close in fourth-quarter 2014.

www.ushio.co.jp/en

processes, and essentially beginning to operate as one Oclaro. Secondly, we committed to continuing to invest strongly in R&D and focus our resources on the large 100G markets for telecoms and datacoms."

Oclaro has now reduced annual operating expenses by $26m (17%). By the end of fiscal Q2, it expects to have only eight major sites, down from the 20 a year ago, and to have cut its number of fabs from six to three. Headcount will fall from about 2900 a year ago to approaching 1200 when the sale of the Industrial and Consumer (I&C) business closes.

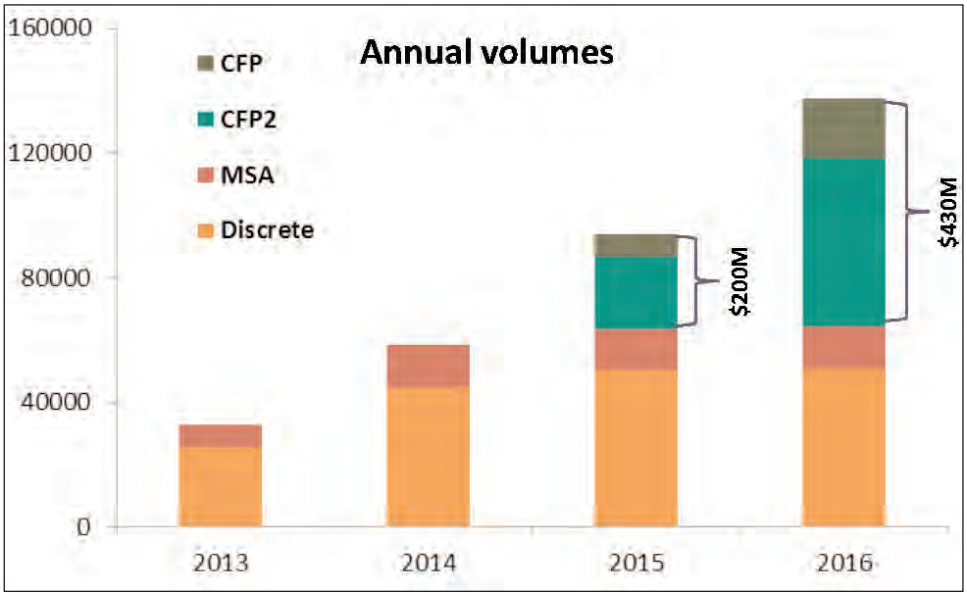
On 5 August, Japan's Ushio Opto Semiconductors Inc agreed to buy the I&C business based in Komoro, Japan (which employs about 80 staff, primarily making red and violet laser diodes for medical, measuring, printing and display applications) for ¥1.85bn ($18.5m) in cash, of which ¥1.6bn ($16m) will be paid at the closing and ¥250m ($2.5m) will be paid into escrow and released to Oclaro Japan Inc upon the earlier of six months after the closing or the completion by Oclaro Japan of certain transition services. Closing of the transaction is expected during fiscal second-quarter 2015 (ending 27 December 2014).

"The I&C business has limited synergies with the rest of our business," comments Dougherty. "It also adds a fair amount of complexity to the organization as it has different customers, different sales channels, market and technologies." Another reason for divesting the business is that it has a semiconductor laser fab that needed to be relocated after the expiration of Oclaro's lease in early 2016. "The cost to move the fab into our Sagamihara fab in Japan would have been around $10m. In addition, it would have created a significant distraction to some of our key laser personnel in our Datacom division in Japan. Instead, we will now be able to keep our Japan team focused on 100G modules for data-center application," he adds.

"The divestiture of our Industrial & Consumer business is another positive step in our ongoing plan to streamline our global operations, strengthen our balance sheet, and focus our product portfolio on the optical communications market, with the main thrust of our R&D on the large and high-growth markets for 100G," says Dougherty.

"Demand for CFP form factor for client side has peaked and we will see it decline some over the next few quarters as customers gradually transition to the new CFP2 form factor. Our focus has allowed us to successfully introduce and ramp up production of our client-side CFP2 transceiver," Dougherty continues. "We're currently the market leader in single-mode 100G products for client-side," he believes, based on seeing 30% growth in fiscal Q4, driven by China-based demand. "We intend to leverage this success into the emerging single-mode data-center opportunities. We also have begun shipping samples of our coherent CFP2 to several key customers for line-side application. This is another area where we're in a market leadership position," he adds.

"Longer term, we expect to see solid growth from 100G coherent products for transmission and from the conversion of data centers to single-mode fiber and to 100G data rates," says Dougherty. "We continue to invest substantially in R&D in these areas and are strongly positioned technically in both. We further establish ourselves as a market leader in 100G client-side products with our CFP and CFP2. We also believe that the coherent CFP2, our emerging flagship product, will serve as a growth engine for us in many years to come. In Q4, we shipped our first coherent CFP2 product to several key cus-



tomers. The system test results of these customers have been very good and have reinforced our first-to-market position and our technical differentiation. Results show the customers will be able to use coherent CFP2 for both metro and long-haul applications."

While the CFP2 is expected to be Oclaro's flagship product, it is based on a platform approach that allows customers to buy either a CFP2 pluggable module or the discrete transmit and receive components or system architectures utilizing embedded optics configuration. This platform approach leverages the firm's indium phosphide (InP) photonic integrated circuit (PIC), which allows for small size, lower power consumption and excellent performance, says Dougherty. The new pilot-production line is up and running in Caswell, UK, and will be shipping coherent CFP2 products next quarter. "We believe that the market for the coherent CFP2 will be in the hundreds of millions of dollars within about two years. We expect to be well positioned to capture a significant share of this growing market," he adds.

For fiscal first-quarter 2015 (ending 27 September 2014), which will still include a full quarter of the I&C business (about $7.7m), Oclaro expects revenue to fall to $83–91m (down by about $9m at the midpoint of this range). Despite this, gross margin should be 12–16%. Adjusted EBITDA is expected to be negative $13–9m.

"Despite a projected slower start to the fiscal year, due primarily to the decline in 40G [line-card business at AT&T] and lower-speed [10G] legacy products, we expect to continue improving our bottom line in fiscal 2015 through our lower cost structure and strong demand for new 100G products," says Dougherty. "Overall, on the 100G client-side, we expect Chinese demand to slow down a bit in Q1 [following a very good fiscal Q4/2014] and pick up again in Q2 with the next anticipated infrastructure projects from the leading service providers there. We are continuing to invest in next-generation high-speed DFB [distributed feedback] lasers, receivers and advanced packaging to address the market needs for the conversion of data centers to 100G and single-mode fiber," he adds.

"Our new 100G products will continue to ramp and become an even larger revenue contributor in the coming quarters, overtaking the legacy product revenue roll off around mid-calendar year in 2015," reckons Dougherty.

Regarding 100G coherent micro-iTLAs, Dougherty says: "While we did not ramp this quickly as we had planned, we expect to see continued growth as again we have much more demand than we can shift." Micro-iTLA product revenue is expected to grow three-fold in the September quarter and then by a further 150–200% in the December quarter. Also, after tripling from the March to June quarters, shipments of 100G coherent lithium niobate modulators are expected to double by the December quarter after significant capital investments have been made to double manufacturing capacity in the next 4–5 months, as very strong order backlog for fiscal Q1 and Q2 means that demand is currently outstripping the firm's ability to supply the products. CapEx and capital lease needs collectively are hence rising to about $5m per quarter.

Oclaro has hence decided to no longer move and/or re-qualify any more 10G InP products to its contract manufacturing partners, allowing them to helping with the expected steep production ramp of 100G products (at the cost of a one-time restructuring charge of about $3m in fiscal Q4/2014).

"Through our actions this past year to rebuild, revitalize and focus the company, we're on a much stronger financial foundation and have a healthy new product pipeline," says Dougherty. "Now that we are completely focused on the optical communications market, our strategy is clear to be a leading innovator and provider of 100G solutions for line- and client-side applications."

Since the I&C business contributed revenue of $29m, gross margin of 50% and about $8m of positive adjusted EBITDA in full-year fiscal 2014, Oclaro has revised its adjusted EBITDA breakeven model and timeline from $110m in quarterly revenue to $100m (together with 20% gross margin and 25% operating expenses) by the quarter to end-September 2015 (rather than the December 2014 quarter). However, breakeven on a non-GAAP (operating income) basis will require $105–110m in quarterly revenue (with gross margin of 25%, and operating expenses remaining at 25%), driven by revenue growth from the firm's new high-margin coherent 100G products.

www.oclaro.com

NeoPhotonics grows 13.6% in Q2 to record $77.5m revenue

Restructuring targets break-even at revenue of $85m per quarter

For second-quarter 2014, NeoPhotonics Corp of San Jose, CA, a vertically integrated designer and manufacturer of both indium phosphide (InP) and silica-on-silicon photonic integrated circuit (PIC)-based modules and subsystems for high-speed communications networks, has reported record revenue of $77.5m, up 13.6% on $68.2m last quarter and up 3.3% on $75m a year ago (and at the high end of the $73-78m guidance range).

Growth is driven mainly by 100G products. "Our new products are well positioned to continue to benefit from the rapid growth in worldwide 100G deployments," believes chairman & CEO Tim Jenks.

There were three 10%-or-greater customers, with Alcatel-Lucent falling from 13% of total revenue last quarter to 12% and Ciena falling from 14% to 13%, whereas China's Huawei Technologies rose from 35% to 39%. Correspondingly, revenue mix by geographic region was 20% Americas (level with last quarter), 5% Japan (down from 7%) and 21% rest of the world (level with last quarter), whereas China was up from 52% to 54%.

The Speed & Agility product group contributed $56.2m (72% of total revenue), up $6.4m on last quarter. Of this, High Speed products (i.e. 100G and some 40G) contributed $30.2m (39% of total revenue), up $1.9m. The Access product group contributed $16.4m (21% of total revenue), up $2.1m.

On a non-GAAP basis, gross margin has fallen from 25.1% a year ago and 22.0% last quarter to 20.8%, due mainly to lower volumes of components (notably for client-side 100G modules as the firm transitions from CFP to CFP2) and above-average inventory reserve charges.

The transition from CFP to CFP2 in 100G client-side modules caused a decrease in certain component shipments and under-utilization in that fab. "We have a vertically integrated manufacturing model and, as such, we must continue to focus on improving and optimizing production processes to increase yields and lower manufacturing costs," says chief financial officer Ray Wallin. "With lower volumes this quarter, we had the additional issue of adverse volume variances. In addition, we took above average inventory reserve charges of $0.9m, or a 1.2 percentage point impact, for certain end-of-life low-margin products," he adds. "These impacts offset gains we made through other cost reduction and productivity efforts."

Sales, general & administrative (SG&A) expenses were $11.8m (15.2% of revenue), down from $12.4m (18.2% of revenue) last quarter. Of this, G&A expenses were $8.2m (10.6% of revenue), cut from $9m (13.2% of revenue) last quarter. R&D expenses were $12.1m (15.6% of revenue), unchanged from $12.1m last quarter (17.7% of revenue) and up on $11.1m a year ago, as NeoPhotonics continued making significant investments in 100G product development despite the restructuring.

Net loss was $7.5m ($0.24 per diluted share), cut from $9.5m ($0.30 per diluted share) last quarter but up from $3.8m ($0.12 per diluted share) a year ago.

During Q2, NeoPhotonics restructured a credit line facility with its principal lender in the USA. Hence, at the end of June it reported restricted cash and investments totaling $26.4m, as required under its $21m term loan in the USA and the remaining $5.4m under its line of credit facilities in China. Hence, on a comparable basis, combined cash, cash equivalents and restricted cash and investments was $54.4m, down from $64.3m of cash, cash equivalents, short-term investments and restricted cash at end-March. Combined notes payable and debt rose from $40.8m to $48m.

"We are taking significant actions to address operational and profitability challenges while continuing our focus on key growth markets such as 100G," says Jenks. "100G deployments were a significant contributor in Q2, including in China, and we are continuing to see increases in our backlog for the third and fourth quarters of 2014," he adds. "100G long-haul deployments remain strong, as we have seen some North American carriers increase CapEx spending in this market. Industry discussions and design-win activity related to 100G deployments outside of long-haul, including metro, continue at an active pace and we remain enthusiastic about its adoption cycle, and we expect these products to ramp in 2015."

"Within the Access market, we continue to see strength over the near-term as a result of growth in China LTE backhaul and FTTx," continues Jenks. "We view the FTTx segment as a mature market with flat or declining revenue over the mid-term, while LTE backhaul is growing, giving strength to this product group."

For Q3/2014, NeoPhotonics expects revenue of $78–82m. Gross margin should rebound to 22–26%, due to the impact of restructuring changes, ongoing operational improvements and other cost reductions. Having completed its 2013 audit and restatement work, the firm expects G&A expenses to fall to $7.5–8m. Diluted net loss per share should be $0.04–0.14. CapEx is expected to be $2–3m per quarter in the next two quarters (down from $3.8m in Q2).

NeoPhotonics also expects revenue growth in the coming quarters from several of its new products. "For example, our micro-ITLA product, which represents a step-function improvement in component integration and performance, is in qualification with lead customers," says Jenks. This product should begin production shipments later this year and ramp in early 2015.

Since product mix affects profitability (due to margins ranging from greater than 40% for some high-speed products to below10% for certain mature products), NeoPhotonics is focused on increasing the contribution from higher-margin opportunities, including certain coherent100G long-haul and 100G metro deployments in the USA, Asia and Europe. "While the Metro market opportunity is still in the nascent stage, we expect the overall market opportunity over time to be as much as 3x the volume of the 100G long-haul market," notes Jenks. "We expect metro 100G, where several of our new products are targeted, to begin to ramp in 2015 and continue into 2016," he adds.

"Additionally, the transition from CFP to CFP2 in client-side 100G modules represents an opportunity both for our CFP2 modules and also for 25G lasers and drivers from NeoPhotonics Semiconductor, and we see this as a continuing trend over the next few years. In fact, we are seeing initial CFP2-related ordering and we anticipate a pickup going forward," says Jenks.

"While we are encouraged by the growing opportunities ahead of us, due to the competitive nature of our industry, we are sharpening our focus on costs and the need to reach sustained profitability in the near term," says Jenks. NeoPhotonics has hence initiated a restructuring and cost-reduction plan with the goal of reducing total operating costs.

In the initial phase, NeoPhotonics expects to cut operating costs by $10m of annual run rate during Q3 ($2.5m per quarter). "We have reduced our general & administrative expenses as we completed our restatement activities over the past several quarters, resulting in a $1m reduction per quarter (not included in the $2.5m)," says Jenks. "So far, we have taken actions to reduce manufacturing costs and operating expenses by staff reductions in operations, R&D, sales, marketing and G&A, and these cost reductions will materialize during Q3," he adds.

In a second phase, the firm will take additional actions to reduce manufacturing and operating costs by reducing manufacturing footprint in higher-cost geographies, decreasing associated manufacturing overhead costs for these facilities, and further reducing R&D spending. It expects the split of cost reductions to be about 25% in manufacturing-related costs, with the rest in operating expenses. "That said, we will continue to fully support our key 100G product platforms for next-generation networks," says Jenks. "The specific components of this restructuring initiative are aimed to reduce corporate and business unit overheads, provide operating leverage in gross margins on increasing volumes, reduce total R&D spending, and streamline decision-making efficiency," he adds.

"Looking at the full year of 2014, we continue to believe demand is favorable for NeoPhotonics products, with continued potential in high-speed and coherent products in 100G around the world," says Wallin. "We expect that this continued revenue growth, combined with the restructuring actions we are doing, will put NeoPhotonics on stable footing by year end. That is, we plan to exit 2014 with a business right-sized for our 100G opportunity, and with a cost structure in line with our size, plus new products able to deliver strong profitable growth in 2015 and beyond," he adds.

"We continue to work on increasing our content per port in 100G systems and we believe our key investments in next-generation products, our investments in production capacity and the growing adoption of coherent networks, plus the use of high-speed modules on the client side, will fuel NeoPhotonics growth in the medium term," says Jenks. "In the interim we believe our restructuring activities, volume growth and our ongoing product mix changes will accelerate our path to profitability such that, once completed, we are targeting break-even profitability at run-rate revenues of about $85m per quarter."

www.neophotonics.com

OIF adds long-reach to CEI-56G roadmap

Members of the Optical Internetworking Forum (OIF) have provided feedback to start another Common Electrical Interface (CEI) 56G project to complement the existing 400G roadmap that was started last year. The project defines 56Gb/s-generation electrical interfaces for full-sized backplane channels for long reach of up to 1m with two connectors.

"Given the lead times, development of standards for the next-generation backplane electrical links needs to start now," says David Stauffer of Kandou Bus and the OIF Physical and Link Layer working group chair and board member. "Feedback from our membership indicates that the industry needs the OIF to start the long-reach project now so that a complete roadmap can be supported."

The CEI-56G-LR specification will increase the data rate by a factor of two over the data rate of CEI-28G-LR. It will provide for one or more electrical specifications for lane operation at data rates of 40 to 56Gb/s. The reach range will be 0 to 1000mm using advanced printed circuit board materials plus two connectors.

The OIF is currently working on a full roadmap for 400G, addressing interfaces that are medium reach (MR) for chip-to-chip and mid-range backplane, very short reach (VSR) for chip-to-module, extra short reach (XSR) for chip to nearby optics engine, and ultra short reach (USR) for 2.5D/3D applications. LR is needed to complete this roadmap for chip-to-chip backplane applications with about 35dBs of loss at 14GHz.

www.oiforum.com

Emcore quarterly revenue up 33% year-on-year to $44.6m

Cost reduction in Fiber Optics to enable breakeven at $46–48m

For its fiscal third-quarter 2014 (to end-June), Emcore Corp of Albuquerque, NM, USA has reported revenue of $44.6m, up 5.5% on $42.2m last quarter and up 33% on $33.5m a year ago (and above the guidance of $40–44m).

Photovoltaics revenue was $18.4m (41% of total revenue), down by 1.2% on $18.6m (44% of revenue) last quarter but up 55% on $11.9m (36% of revenue) a year ago (and a "pretty typical revenue run rate for the current state of this business").

Driven by growth in the telecom and broadband cable TV product line, Fiber Optics revenue was $26.2m (59% of total revenue), up 10.8% on $23.6m (56% of total revenue) last quarter and up 21% on $21.6m (64% of total revenue) a year ago. In particular, in telecoms applications, revenue from 100G coherent products grew about 18% on last quarter to another record.

"We've seen significant improvement in the 100G and 400G coherent market," says chief financial officer Mark B. Weinswig. "This has led to an increase in our revenues and in our overall gross margins for our telecom products."

Fiber Optics gross margin has risen further, from just 3% a year ago to 8.2% last quarter before doubling to 16.4% this quarter, due mainly to the increase in revenue, better absorption of the fixed costs, and lower warranty costs. The improvement from the Fiber Optics business was primarily due to telecom ITLAs (integrable tunable laser assemblies) for 100Gb/s applications, despite margins being under pressure from the launch of the firm's new micro-ITLA product (for which revenue was over $2m). Although still down on 28.6% a year ago, Photovoltaics gross margin has risen from 26.5% last quarter to 27.7%, due mainly to favorable variances realized during the quarter. Total gross margin has risen further, from 12.1% a year ago and 16.3% last quarter to 21.1%.

Total operating expenses have risen from $11.7m a year ago and $12.1m last quarter to $12.5m. This is mainly due to selling, general & administrative (SG&A) expenses rising from $7m a year ago and $6.9m last quarter to $7.8m, outweighing R&D expenses falling from $5.2m to $4.7m (level with a year ago). "We continue to invest significantly in R&D and the new product development by leveraging sponsored R&D and engineering service contracts," notes president & CEO Hong Hou.

Total operating loss has been cut from $7.3m a year ago and $5.2m last quarter to $3.1m. In particular, Fiber Optics operating loss has been cut from $9m a year ago and $7.3m last quarter to $5.1m. Photovoltaics operating profit of $2m was roughly level with last quarter and up on $1.3m a year ago.

Non-GAAP net loss has been cut from $6.1m ($0.23 per share) a year ago and $2.6m ($0.08 per share) last quarter to $1.6m ($0.05 per share), due mainly to the better financial performance within the Fiber Optics segment. In particular, thanks to better absorption of fixed cost and cost-reduction efforts, the telecom division achieved the "important milestone" of positive EBITDA (excluding corporate allocations). Cash and cash equivalents stayed level during the quarter, at $18.2m. The firm's line of credit was increased to $20.9m.

Order backlog for the Photovoltaics segment at the end of June totaled a record $70.5m, up 37.2% from $51.4m as of end-March. Also, over the past few months Emcore has signed two "very significant" long-term agreements (LTAs) with its two leading aerospace clients, Space Systems/Loral (in mid-June) and Lockheed Martin Space Systems (in late July). Emcore also secured multiple contracts with other clients during the quarter worth $4.7m.

In the Fiber Optics segment, Emcore has seen signs of a recovery in cable TV infrastructure spending, especially towards the end of the quarter when it started seeing orders flowing in. "The book-to-bill was over 1.1 [for Fiber Optics] and the booking momentum into the September quarter seems to be continuing," says Hou. In addition, Emcore continues to see strong 100G coherent product demand, yielding a book-to-bill for telecom products of 1.2, driven by strong demand for 100G coherent transmission from telecom carriers. Order backlog for this product line reached a record level. Also during the quarter, Emcore started shipping transmission products that comply with the DOCSIS 3.1 standard, as leading customers have recently released their first DOCSIS 3.1 transmission products. "We are deeply engaged in product design and qualification to address DOCSIS 3.1 standard and have finished several related product releases," says Hou.

For fiscal Q4/2014 (to end-September), Emcore expects revenue of $41–45m. Fiber Optic revenue should grow (driven by the telecom division, with micro-ITLA more than doubling, driving gross margin for the product to equal that for ITLA,, for which revenue will start tapering off in the December quarter). Photovoltaics revenue should fall (consistent with seasonality in the Space business — the firm expects record Photovoltaics revenue for the full fiscal year). Based on the order backlog and current demand, Space Photovoltaic should rebound in the December quarter. The firm still targets gross margin for Photovoltaics of roughly 30%.

"We are implementing certain cost-reduction initiatives to further reduce cost and improve our personal efficiency," says Hou. "Our Fiber Optics business will be more sustainable financially once these initiatives are fully implemented," he adds. "We expect to reach breakeven at quarterly revenue of $46–48m."

www.emcore.com

Hanergy completes acquisition of Alta Devices

Plans to speed commercialization of technology for mobile power

Beijing-based clean-energy power generating firm Hanergy Holding Group Ltd (parent of thin-film photovoltaic module maker Hanergy Solar) has completed the acquisition of Alta Devices of Santa Clara, CA, USA.

Founded in 2007, Alta Devices is a development-stage company focused on improving the production economics of high-efficiency solar photovoltaics. The firm fabricates gallium arsenide PV cells in a micron-thick thin-film that it then lifts off the growth GaAs substrate (which can then be reused multiple times to amortize its high cost). The thin-film cell can then be placed on a flexible substrate.

Alta has raised more than $120m in funding from investors including August Capital, Kleiner Perkins Caufield & Byers, Crosslink Capital, DAG Ventures, New Enterprise Associates (NEA), Presidio Ventures, Technology Partners, Dow Chemical, Alberta Investment Management Corporation (AIMCo), Good Energies, Energy Technology Ventures, and Constellation Energy.

Alta's use of GaAs has allowed its single- and dual-junction solar cells to produce record conversion efficiencies of 28.8% and 30.8% respectively, as certified by the US National Renewable Energy Laboratory (NREL). On a same-surface-area basis, the firm's cells are reckoned to produce a power output 2–3 times higher than standard flexible thin-film cells, 8% higher than mass-produced monocrystalline silicon cells, and 10% higher than multicrystalline silicon cells. Alta's single-junction GaAs thin-film solar cells are already in production.

"Alta Devices' thin-film solar technology allows more energy to be produced in lower light conditions than any other type of solar cell, giving it greater potential to power a wide range of mobile devices and equipment, from phones to cars," comments Hanergy's chairman & CEO Li Hejun.

"This successful acquisition is built upon Alta Devices' and Hanergy's shared belief that flexible, thin-film solar technology represents the future of the solar industry," says Alta Devices' president & CEO Chris Norris. "The combination of our world-class solar cell R&D capability and Hanergy's technology, research and capital resources will help us further improve the performance of our technology, increase production capacity and expand applications," he adds.

Both companies' R&D teams will join forces to further develop Alta's technology to serve the mobile and wearable tech market with high-efficiency solar-power solutions. The acquisition builds on Hanergy's efforts in recent years to improve the efficiency and applicability of clean energy through the integration of thin-film solar technologies. In the last few years, Hanergy Solar has acquired three copper indium gallium diselenide (CIGS) PV firms: Germany's Solibro GmbH (from Q.Cells SE) and US firms MiaSolé of Santa Clara, CA, and Global Solar Energy Inc (GSE) of Tucson, AZ. Now, Hanergy plans to expand the application of Alta's products in mobile power applications, ranging from emergency charging of mobile phones to the automotive sector and the Internet of Things.

Following the acquisition, Alta will continue to operate independently as a subsidiary of Hanergy. Hanergy will also work with Alta to develop international markets and enhance its cooperation with key strategic customers.

In 2014 Hanergy was the only Chinese energy firm named among the 'World's Smartest Companies' by MIT Technology Review. In 2012 and 2013, the same publication named Alta Devices among the 'World's Most Disruptive Companies'.

www.altadevices.com

Emcore awarded long-term supply contract for solar cell assemblies by Lockheed Martin

Emcore Corp of Albuquerque, NM, USA has entered into a new long-term supply agreement with Lockheed Martin Space Systems to design and manufacture multi-junction coverglass interconnected cells (CICs) for Lockheed Martin's satellite program requirements.

Emcore has been a supplier of CICs for many previous space missions featuring satellites and spacecraft developed by Lockheed Martin. The CICs to be delivered under this new supply agreement are based on Emcore's latest-generation ZTJ triple-junction solar cells, which are the result of years of R&D on high-efficiency, multi-junction solar cell technology for Lockheed Martin and several other major aerospace companies.

"This agreement with Lockheed Martin is one of the most significant contract awards in Emcore's recent history and results from many years of productive collaboration between our two companies," comments Dr Brad Clevenger, executive VP & general manager of Emcore's Photovoltaics Division. "We are very pleased to enter into this next phase of our relationship and look forward to powering Lockheed Martin's next generation of programs for many years to come."

www.emcore.com

First Solar's Q2 sales up 4.6% year-on-year, despite 43% dip from Q1

Cut in operating expenditure outweighed by project delays, but full-year EPS and cash flow guidance maintained

For second-quarter 2014, First Solar Inc of Tempe, AZ, USA — which makes thin-film photovoltaic modules based on cadmium telluride (CdTe) as well as providing engineering, procurement & construction (EPC) services — has reported net sales of $544m, up 4.6% on $520m a year ago but down 43% on $950m last quarter, due mainly to achieving revenue recognition on the Campo Verde project in Q1 followed by project delays in Q2 that resulted in the deferral of some revenue recognition to second-half 2014.

Operating expenses have fallen from $101m a year ago and $97.4m last quarter to $90.8m, due to R&D expenses falling back from the spike of $38.8m last quarter to $32.6m, and selling, general & administrative (SG&A) expenses falling from $58.7m last quarter to $57.7m.

However, the reduction in operating expenses has only partially offset the effect of the Campo Verde project sale in Q1 being followed by project delays in Q2. Operating income has hence fallen from $139.3m last quarter to just $1.9m. Net income has fallen from $112m ($1.10 per fully diluted share) last quarter to $4.5m ($0.04 per fully diluted share).

Cash flow from operations was $118m. However, during the quarter, cash and marketable securities fell by $30m to $1.3bn. Net cash remains $1.2bn.

"While project delays in Q2 resulted in deferring some earnings to later in the year, we remain on track to our financial targets for the year," says CEO Jim Hughes. Since Q1, First Solar has received 812MW$_{DC}$ of new bookings, bringing year-to-date bookings to 1216MW$_{DC}$. First Solar has hence reaffirmed its full year 2014 guidance for earnings per share of $2.40–2.80 and operating cash flow of $300–500m (these had been raised from $2.20–2.60 and $250–450m, respectively, after Q1's better-than-expected results). However, the firm notes that this guidance is highly dependent on factors such as the construction progress and sales process related to certain utility-scale power plants. Any changes in expected timing of these activities would defer earnings and operating cash flow to subsequent fiscal periods and result in a substantial impact on these guidance targets.

"I am proud of the execution by the organization, as demonstrated by a new record cell efficiency and new bookings of over 800MW$_{DC}$," notes Hughes. First Solar has raised the record for thin-film PV cell efficiency from 20.4% (set by the firm in February) to 21.0%, which now exceeds the records for both multi-crystalline silicon and copper indium gallium diselenide (CIGS) thin-film technologies.

www.firstsolar.com

First Solar to develop its first photovoltaic project in India

First Solar, the world's biggest thin-film solar module maker and one of the largest developers of utility-scale solar projects worldwide (with a global project pipeline of over 2500MW), has announced its first development project in India.

Through its Indian subsidiary, the firm plans to build 45MW$_{AC}$ capacity of solar power generation in the new state of Telangana, supplying electricity through the grid to the Southern Power Distribution Company of Telangana State Ltd (TSSPDCL) at a levelized tariff of Rs6.49p/kwh for a period of 20 years.

The project will include construction at two different sites in the Mahabubnagar district, and is expected be in commercial operation by May 2015.

"The state of Telangana has an energy deficit that demands immediate creation of incremental generation capacity," says Sujoy Ghosh, country head for First Solar India. "The excellent solar resource in the state, combined with our CdTe thin-film module technology that is ideally suited for hot climates like India, allows us to bid tariffs that brings solar energy pricing to parity with diesel/gas and potentially imported coal, for the consumers across all segments," he adds. "We are optimistic that the state will enhance their plans for creating a higher deployment of solar in the overall energy mix to address the energy deficit in a sustainable manner."

The excellent solar resource in the state, combined with our CdTe thin-film module technology that is ideally suited for hot climates like India, allows us to bid tariffs that brings solar energy pricing to parity with diesel/gas

Construction of the project is expected to begin by October. On completion, the projects are expected to produce about 86,880 MW-hr of electricity each year (sufficient to meet the needs of over 92,000 average homes in Telangana).

www.firstsolar.com

First Solar fabricates record 21%-efficient thin-film PV cell

Multi-crystalline silicon and latest CIGS records both exceeded

First Solar Inc of Tempe, AZ, USA has set a record for cadmium telluride (CdTe) photovoltaic (PV) research cell conversion efficiency of 21.0%, as certified at the Technology and Applications Center (TAC) PV Lab of Newport Corp. The cell was fabricated at First Solar's manufacturing factory and Research & Development Center in Perrysburg, OH, using processes and materials designed for commercial-scale manufacturing. The record has been documented in the US Department of Energy's National Renewable Energy Laboratory (NREL) 'Best Research Cell Efficiencies' reference chart.

This certified result exceeds the previous CdTe record of 20.4%, set by First Solar in February, and is the seventh substantial rise in the record since 2011. It also places First Solar's CdTe research cell efficiency above the 20.9% efficiency of copper indium gallium diselenide (CIGS) solar cells, and well above that of multi-crystalline silicon (mSi), which peaked at 20.4% in 2004.

"We have just begun to reveal the true unrealized potential of CdTe PV," believes chief technology officer Raffi Garabedian. "Our Advanced Research team continues to deliver extraordinary results by creating practical devices capable of commercial-scale production. Not only have we now demonstrated the highest single-junction thin-film cell on record but, just as important, our record cells are based on the same scalable manufacturing processes and commodity materials that we have proven through years of volume production."

Garabedian notes that, while competing technologies are using increasingly costly materials and cell processes in order to deliver moderate performance gains, First Solar is establishing a rapid path to industry-leading energy densities, while simultaneously improving manufacturing metrics.

"Our significant investment in development of CdTe thin-film technology has enabled a rapid rate of improvement and gives us tremendous confidence in the future," says Markus Gloeckler, VP for Advanced Research. "We have made outstanding improvements in all aspects of our thin-film solar cells and are aggressively pursuing the commercialization of these advanced technologies in our product," he adds.

At an analyst briefing in March, First Solar presented a technology roadmap anticipating a research cell efficiency of 22% in 2015. The latest announcement indicates First Solar is steadily tracking to achieve that goal ahead of schedule.

First Solar says it has continued to transfer its success in the R&D lab into its commercially produced modules, increasing its average production module efficiency to 14% in second-quarter 2014, up 0.5% from Q1 and 0.7% from 2013. At the end of Q2/2014, the firm's lead line was producing modules with average efficiency of 14.1%.

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

First Solar to build, operate & maintain 52.5MW PV plant in Jordan

First Solar has signed an agreement to provide engineering, procurement and construction (EPC) services for the 52.5MW$_{AC}$ Shams Ma'an solar power plant in Jordan. The firm has also finalized a long-term operations and maintenance (O&M) contract for the project.

First Solar and Jordan's Kawar Group co-developed the project, which secured a 20-year power purchase agreement (PPA) with the country's power generation and distribution authority National Electric Power Company (NEPCO). Also, as part of its commitment to supporting additional foreign investment in the country's renewable energy sector, First Solar elected to divest its stake to a consortium of investors consisting of Diamond Generating Europe Ltd (a subsidiary of the Mitsubishi Corp); Nebras Power Q.S.C. (a subsidiary of the Qatar Electricity & Water Company); and the Kawar Group.

"Shams Ma'an has already established a new benchmark for the independent production of renewable energy in the region, demonstrating how the selection of the right technology and service providers creates considerable value, which, in turn, helps attract experienced institutional investors," comments Ahmed S. Nada, First Solar's VP for the Middle East.

The power plant (to be the largest PV facility in the Middle East) is a key component in Jordan's strategic diversification of its generation portfolio, which is intended to boost energy security. As part of the Ma'an Development Area (MDA) initiative in southern Jordan, the project will generate an estimated 500 jobs during its construction, which is expected to begin in early 2015. When completed in 2016, the facility will supply an estimated 160 million kilowatt hours (kWh) of electricity per year (equivalent to about 1% of Jordan's annual energy output).

"Every aspect of the project has been optimized for low-cost, high-energy performance in actual conditions. For instance, our advanced thin film modules will yield up to 8% more energy than an array or plant of the same power output rating using silicon-based modules, due to the high temperatures onsite," says Matthew Merfert, First Solar's technical director for the Middle East. "The First Solar Tracker will allow the plant to generate over 20% more energy than a fixed mounting system," he adds.

TU Wien creates ultra-thin solar cells from tungsten diselenide/molybdenum disulphide

Researchers at the Vienna University of Technology (TU Wien) in Austria have combined two semiconductor materials, each consisting of a layer just three atomic thick, to create a new structure that holds promise for a new kind of solar cell, it is reckoned (Furchi et al, 'Photovoltaic Effect in an Electrically Tunable van der Waals Heterojunction', Nano Lett., DOI:10.1021/nl501962c).

Several months ago, Thomas Mueller, Marco Furchi and Andreas Pospischil produced an ultra-thin layer of the photoactive crystal tungsten diselenide. Now, this semiconducting material has been combined with another layer made of molybdenum disulphide, creating a structure that could be used in future low-cost solar cells.

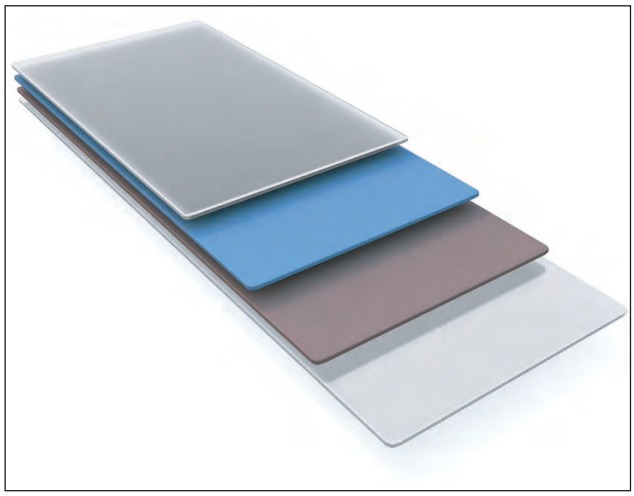
Two-dimensional structures

Like other research groups all worldwide, Mueller and his team acquired the necessary expertise to handle, analyse and improve ultra-thin layers by working with graphene. This know-how has now been applied to other ultra-thin materials.

"Quite often, two-dimensional crystals have electronic properties that are completely different from those of thicker layers of the same material," says Mueller. His team is claimed to be the first to combine two different ultra-thin semiconductor layers and study their opto-electronic properties.

Two layers with different functions

Tungsten diselenide is a semiconductor consisting of three atomic layers: one of tungsten atoms, sandwiched between two of selenium atoms. "We had already been able to show that tungsten diselenide can be used to turn light into electric energy and vice versa," says Mueller. But a solar cell made only of tungsten diselenide would require countless metal electrodes tightly spaced just a few microns apart. If the material is combined with molybdenum disulphide



The solar cell's layer system: two semiconductor layers in the middle, connected to electrodes on either side.

(which also consists of three atomic layers), this problem is circumvented. The heterostructure can now be used to construct large-area solar cells.

When light shines on a photoactive material, single electrons are removed from their original position, leaving a positively charged hole. Both the electron and hole can move freely in the material, but they only contribute to the electrical current when they are kept apart so that they cannot recombine. To prevent their recombination, metallic electrodes can be used, through which the charge is sucked away — or a second material can be added. "The holes move inside the tungsten diselenide layer; the electrons, on the other hand, migrate into the molybdenum disulphide," says Mueller. Recombination is hence suppressed.

However, this is only possible if the energies of the electrons in both layers are tuned exactly the right way. In the experiment, this can be done by using electrostatic fields. Florian Libisch and professor Joachim Burgdörfer provided computer simulations to calculate how the energy of the electrons changes in both materials and which voltage leads to an optimum yield of electrical power.

Tightly packed layers

"One of the greatest challenges was to stack the two materials, creating an atomically flat structure," says Mueller. "If there are any molecules between the two layers, so that there is no direct contact, the solar cell will not work," he adds. Eventually, this was accomplished by heating both layers in vacuum and stacking them in ambient atmosphere. Water between the two layers was removed by heating the layer structure once again.

Part of the incoming light passes right through the material. The rest is absorbed and converted into electric energy. The material could be used for glass frontages, letting most of the light in, but still creating electricity. Also, as it only consists of only a few atomic layers, it is extremely light (300m^2 weighs just 1 gram), and very flexible. The team is now working on stacking more than two layers – this will reduce transparency, but increase electrical power.

Marco Furchi, Thomas Müller and Andreas Pospischil (left to right).

http://pubs.acs.org/doi/abs/10.1021/nl501962c

www.tuwien.ac.at

Ascent receives $2.64m second tranche of funds from Asian investor in $3.96m stock issuance

Ascent Solar Technologies Inc of Thornton, CO, USA, has received the second tranche of funds from the stock purchase agreement (SPA) announced on 31 July.

Ascent entered into the SPA with an Asian-based investor to sell 12 million shares of restricted common stock with no warrants at a fixed price of $0.33 per share. The $1.32m first tranche of 4 million shares closed on 29 July. The second tranche of 8 million shares closed on 11 August, yielding $2.64m in extra proceeds.

The common stock will be restricted for resale until 6 months after the closure of the transaction. No placement agent or placement fee was involved.

Ascent Solar had planned a $32m securities purchase agreement (announced on 21 July), but that was terminated on 31 July.

www.AscentSolar.com

Ascent Solar's Q2 revenue driven by EnerPlex sales of $1m

For second-quarter 2014, Ascent Solar Technologies Inc, which makes lightweight, flexible copper indium gallium diselenide (CIGS) thin-film photovoltaic modules that it integrates into its EnerPlex series of consumer products, expects to report revenue of about $1.1m, up 45% on Q1/2014 and up about four-fold on a year ago.

Revenue from operations of the EnerPlex consumer products division grew 50% quarter-on-quarter to $1m. This represents the first million-dollar product revenue ever generated by the firm in a single quarter. Government R&D contracts and Specialty Market PV (photovoltaics) comprised the remainder of revenue.

Ascent had previously given investors revenue guidance for full-year 2014 of $5–6m. The firm continues to stand by this and expects to end the year at the higher end of the guidance.

"The acceleration of our EnerPlex growth trajectory demonstrates the success of our product and sales channel strategies," says president & CEO Victor Lee. "EnerPlex sales of $1m, which represents greater than 750% growth over our second quarter of 2013, is a significant milestone for the company. The strong momentum of EnerPlex will accelerate as we continue to roll out more innovative products in the second half of the year."

PVMC to provide technical support services to SoloPower

Partnership to accelerate commercial manufacturing ramp-up

SoloPower Systems of Portland, OR, USA, which designs, manufactures and deploys copper indium gallium diselenide (CIGS) flexible thin-film solar technology, is collaborating with the US Photovoltaic Manufacturing Consortium (PVMC) — an industry-led collaboration headquartered at the College of Nanoscale Science and Engineering (CNSE) of the State University of New York (SUNY) in Albany, NY — as a strategic technology partner. Under the agreement, PVMC will provide specialized technology services to SoloPower Systems to develop thin-film solar.

Created as part of the US Department of Energy's SunShot Initiative, PVMC has extensive experience and expertise in photovoltaic technologies, including roll-to-roll CIGS PV technology, in both research laboratory and industrial production environments. Since CIGS-based thin-film uses layers just a few microns thick, the materials can be deposited on solid or flexible lightweight substrates, offering capabilities that are more versatile than traditional solar panels. The technology could also prove to be more cost-effective to produce in high volume, SoloPower says.

Our collaboration with PVMC will accelerate the commercial manufacturing ramp-up at Systems' factory in Portland, and will further support the continuing advancement of our products," says SoloPower's chief technology officer Chris Eberspacher.

"Interest in the US Photovoltaic Manufacturing Consortium continues to grow, further supporting PVMC's mission to power the research, development, and deployment of sustainable, solar energy-focused solutions," says its chief operating and technology officer Dr Pradeep Haldar. "We welcome SoloPower to the consortium, where they will be able to tap into advanced solar energy research and expertise to enable high-tech innovation, which continues to be fueled by New York Governor Andrew Cuomo's commitment to developing next-generation, clean energy technologies," he adds.

PVMC is also developing roadmaps and standards to forge industry consensus and address broad issues related to power electronics, module advancements, building integration, testing, and reliability. Additionally, it offers a proving ground for innovative solar technologies and manufacturing processes.

www.SoloPower.com
www.uspvmc.org

Improving single photon counting at high temperature with silicon carbide

Researchers claim the first high-temperature Geiger-mode avalanche photodiode performance with low dark current.

China's Nanjing University has produced silicon carbide (SiC) avalanche photodiodes (APDs) with the lowest claimed dark count rate (DCR) at high temperatures of 150°C, compared with any other semiconductor material [Dong Zhou et al, IEEE Photonics Technology Letters, vol26, p1136, 2014].

According to the researchers, such devices could find a number of applications, including flame detection on battle fields or in gas turbines, and gamma-ray detection for down-hole gas and oil exploration. Ultraviolet detection is also important for space missions where minimum cooling budget and footprint calls for devices such as compact SiC APDs.

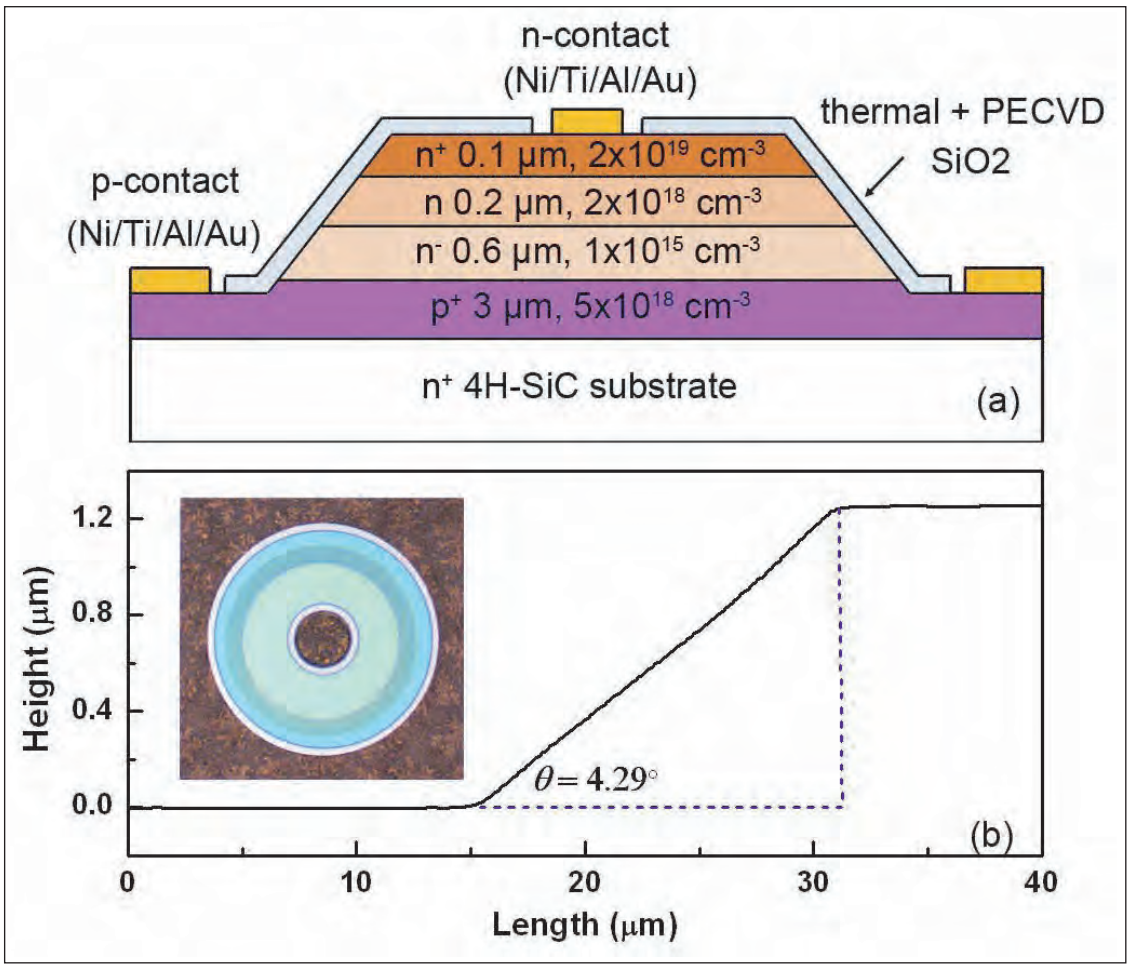


Figure 1. (a) Schematic cross-section of 4H-SiC APD, (b) profile of beveled mesa characterized by stylus profilometer; inset: top view of fabricated APD.

APDs are operated near the reverse-bias breakdown region so that incoming photons cause an avalanche of electrons. Such 'Geiger mode' operation can even be used to detect single photons with high gain. However, a low dark count rate is needed to separate the photon signal from noise.

The researchers deposited the device layers (Figure 1) on an n-type 4H polytype SiC substrate from SiCrystal.

The fabrication consisted of inductively coupled plasma etch of the mesa, passivation with 15nm thermal oxidation and 185nm plasma-enhanced chemical vapor deposition (PECVD) of silicon dioxide, opening of contact windows with a wet etch, and electron-beam evaporation and rapid thermal annealing of the metal electrodes.

The mesa was beveled to suppress edge breakdown with a shallow 4.29° slope angle using a photoresist reflow technique.

At room temperature, the device has an abrupt breakdown at 186V bias. Below 174V, the dark current is below the floor of the measurement set up — i.e. less than 0.1pA. The gain at 190V is around $2x10^6$,

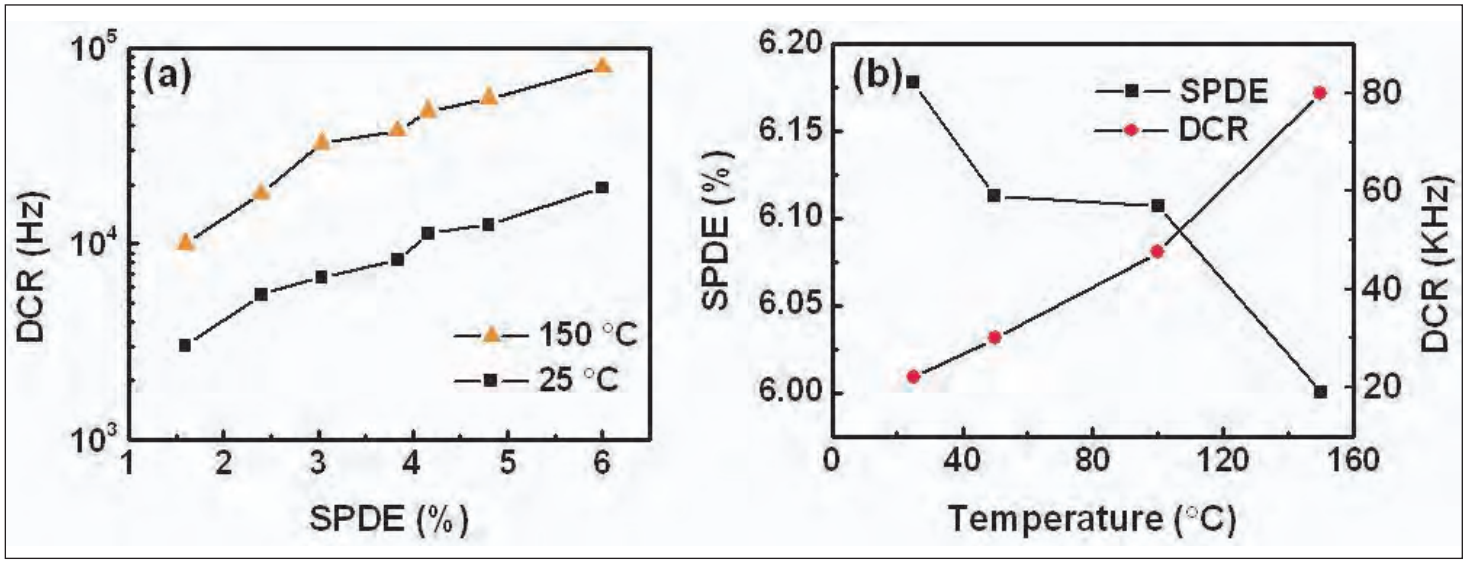


Figure 2. (a) DCR versus SPDE at 25°C and 150°C; (b) SPDE and DCR versus temperature.

where unity gain is defined to be that at 10V bias. At unity gain bias, the response curve peaked at 290nm and cut off at ~380nm, corresponding to the 4H-SiC bandgap of 3.26eV. The maximum external quantum efficiency was estimated at 53.4%.

Raising the temperature to 175°C increases the dark current before breakdown by more than three orders of magnitude. The researchers believe that the increased dark current is related to residual surface defects. The unity gain bias spectral response increased at the longer wavelengths with temperature, giving a maximum external quantum efficiency of 63.3% at 295nm in a 150°C environment. The red-shift in response is attributed to bandgap narrowing with increased temperature. The breakdown voltage increases approximately linearly with temperature at a rate of 14mV/°C.

Single photon counting was carried out with the device biased near breakdown and with the avalanche current quenched by a load resistor. Electrical pulses were detected with a high-speed oscilloscope put in parallel with a sampling resistor. The source was a 22pW 280nm ultraviolet LED delivering ~$3x10^7$ photons per second.

The single photon detection efficiency (SPDE) can be increased by varying the applied bias, but at the expense of an increased dark count rate (DCR) (Figure 2a). The SPDE decreases with temperature from 6.17% to 6.00% between room temperature and 150°C at a fixed gain of $1.3x10^6$ (Figure 2b). At the higher temperature, the DCR was 80kHz, giving a normalized DCR of 7.1Hz/μm^2.

The researchers comment: "Such low high-temperature DCR has never been achieved in APDs based on other semiconductor materials. The equivalent UV radiation density is ~5pW/mm^2 at 280nm." ■

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Author: Mike Cooke

Enabling silicon photonics through advances in III-V integration on silicon

EV Group's Dr Martin Eibelhuber discusses a wafer-level die transfer process for bonding InP laser dies to a silicon photonics wafer, allowing volume production.

Storing and processing ever increasing volumes of data at higher speeds and lower costs while decreasing energy consumption are constant goals in our communications age. Copper interconnects continue to be the standard material to enable data transport between chips, boards or racks in data centers. However, conduction-induced power losses as well as signal latency with copper are becoming more challenging to overcome, and limit increases in data communication bandwidth.

Optical data transfer — already well established for long-haul and metro networks — is able to keep up with the data transfer rates required by data centers. Silicon photonic chips designed for today's data centers have already proven transmission rates up to 40Gbit/s for a single laser [1], which can be scaled up to more than 1 terabit (Tbit)/s by multiplexing several wavelengths solely using a single optical fiber. First products on the market are already announced with transfer rates around 100Gbit/s. Thus, optical interconnects and, in particular, silicon photonics is a novel and most promising way to overcome the limitations in short-range communication. From a technological standpoint, silicon photonics combines the best of two worlds — namely the maturity of silicon (Si) technology and the superior optical properties of III-V compounds — thus enabling the integration of a fiber-optic communication platform into a single chip.

The idea of combining silicon and CMOS processing with optics fabrication was initially not seriously considered due to the indirect-bandgap properties of silicon, which inhibit efficient optical performance. Early on, it was only known that silicon has a high refractive index and is transparent at infrared wavelengths, and therefore could perform optimally as a waveguide for the desired telecommunication wavelengths of 1.3µm and 1.55µm. Subsequent years of development in CMOS-optics technology resulted in tremendous progress, and today almost all necessary elements — such as couplers, modulators and detectors — are based on the CMOS infrastructure. An overview of the performance of optical components based on different materials used in their manufacture is given in Figure 1.

Significant progress has also been made for the light source, and silicon-based lasing — once thought almost impossible to achieve — has since been proven by a Raman laser [2]. However, the performance of silicon-based lasers is still currently far behind that of III-V lasers and much work is needed to narrow the gap. As a result, today's silicon photonics still rely on III-V laser structures.

In addition, progress in epitaxial growth and new wafer bonding techniques are removing many of the restrictions of using different materials on a single chip. It has always been a desire to integrate III-V materials or other compound semiconductors on silicon in order to benefit from their different material properties.

Improvements in direct epitaxial growth on silicon have already demonstrated that the growth of high-quality crystal structures on large wafers is feasible, thus proving the concept of epitaxial heterogeneous integration of III-V materials on silicon. However, crystallo-

	Laser	Photo-detector	Modulator	Passive Devices	Wafer Level Packaging
GaAs	Good	Good	Medium	Low	X
InP	Good	Good	Medium	Low	X
$LiNbO_3$	X	X	Good	Low	X
Silicon	Poor	Medium	Low	Good	Good
Heterogeneous Integration of InP	Good	Good	Medium	Good	Good

Figure 1: Performance of optical elements related to the used material.

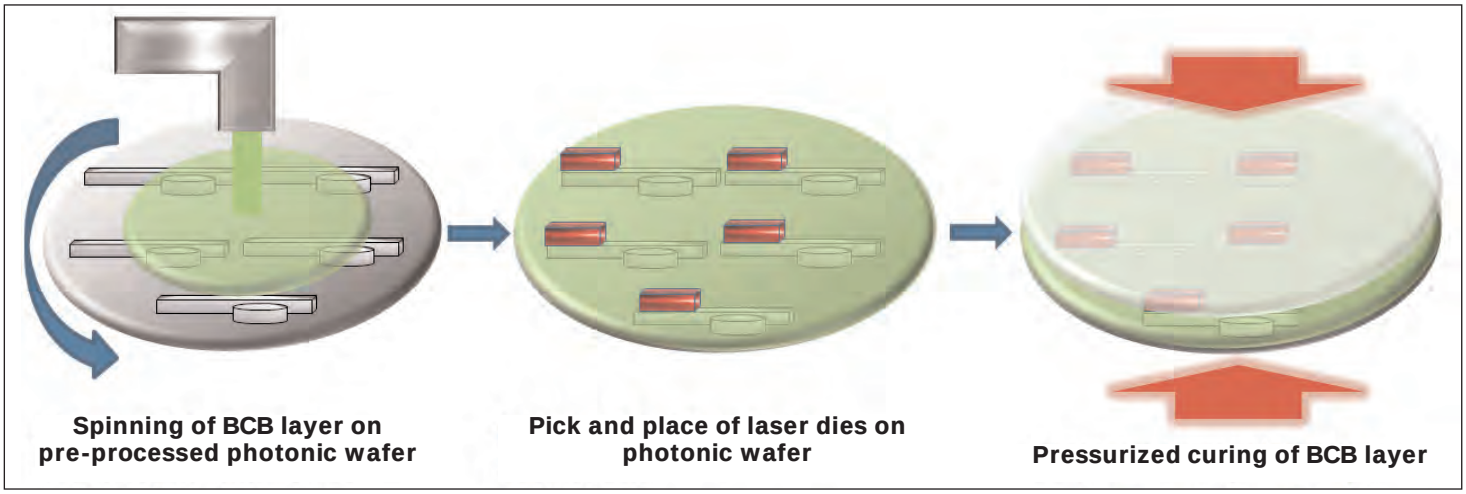

Figure 2: Process flow for adhesive bonding of vertically coupled laser dies.

graphic defects arise within the interfaces between the silicon substrate and III-V compounds as a result of the differences in lattice constant and coefficient of thermal expansion (CTE) between the silicon and III-V materials. A defect-free crystal structure can only be re-established after inserting a thick buffer layer between the materials. Efforts to reduce the thickness of this layer (such as the inclusion of dislocation filter layers) still result in a layer thickness of several microns. This is a major drawback for silicon photonics, since the most widely accepted approaches involve the vertical coupling of light to the silicon waveguide with the laser die placed directly on top of the waveguide [3] (see Figures 2 and 3). This vertical coupling requires a superior optical interface with the active region no more than a few tens of nanometers away from the silicon — at least an order of magnitude smaller than the thickness of the required buffer layer.

In contrast, wafer bonding enables optimal interfaces with few or no crystallographic defects as the materials are joined with a transparent interlayer that mitigates the effects of the lattice constant and CTE mismatch. The two leading methods of wafer bonding for this purpose are either bonding using a transparent adhesive or direct molecular bonding.

As shown in Figure 2, bonding with an adhesive has the advantage of being very simple and easy to implement. The process flow includes only a coating process to flatten the topography of the pre-processed photonic wafer, placement of the laser dies, and finally a wafer-level bonding step with thermal curing. UV curing is not an option since neither silicon nor III-V materials are transparent to UV light. In order to keep the distance between the materials constant, superior pressure and temperature uniformity are crucial to guarantee the best performance of the devices. Thus, the top bond chuck has to comply efficiently for die or wafer inhomogeneity while putting the same pressure on the single dies. Curing the adhesive at the die level carries an enormous disadvantage of requiring heating and cooling for every single die resulting in very long process times. Current roadmaps already highlight the need to economically process several thousand laser diodes on a single photonic wafer. This fast integration of the whole photonic wafer can only be enabled by wafer-level bonding.

However, even though direct bonding cannot compete with the simplicity of adhesive bonding, it is typically the preferred solution, as it enables better device performance. Despite losses within the adhesive material, the main drawback of adhesive bonding is the distance between the laser dies and the waveguide, which is the key parameter for the light coupling efficiency between the laser and the waveguide. Direct wafer bonding allows two materials to be joined with an oxide interlayer that is only a few nanometers in thickness, resulting in a higher coupling efficiency that is not achieved with adhesive interlayers.

Direct fusion bonding of indium phosphide (InP) laser diodes on silicon is challenging in several aspects. First, the topography of the pre-processed photonic wafer has to be flattened by SiO_2 deposition and chemical mechanical planarization (CMP) in order to ensure the required low surface roughness. Fusion bonding is a two-step process consisting of a room-temperature pre-bond and an annealing step. Traditional annealing processes developed for silicon-on-insulator (SOI) wafer manufacturing required an annealing temperature of 1100°C, which is far too high for CMOS and III-V technology. In particular, for bonding InP on silicon, the bond annealing temperature should not exceed 350°C, as the CTE differs significantly between these materials.

Despite these temperature restrictions, sufficient bond strength must be obtained. Low-temperature plasma-activated direct wafer bonding is a process that lowers the required annealing temperatures in order to reach high bond strength. Plasma activation of both wafer surfaces is used to modify the surface chemistry of both materials, thereby significantly reducing the annealing temperature requirements. In this way,

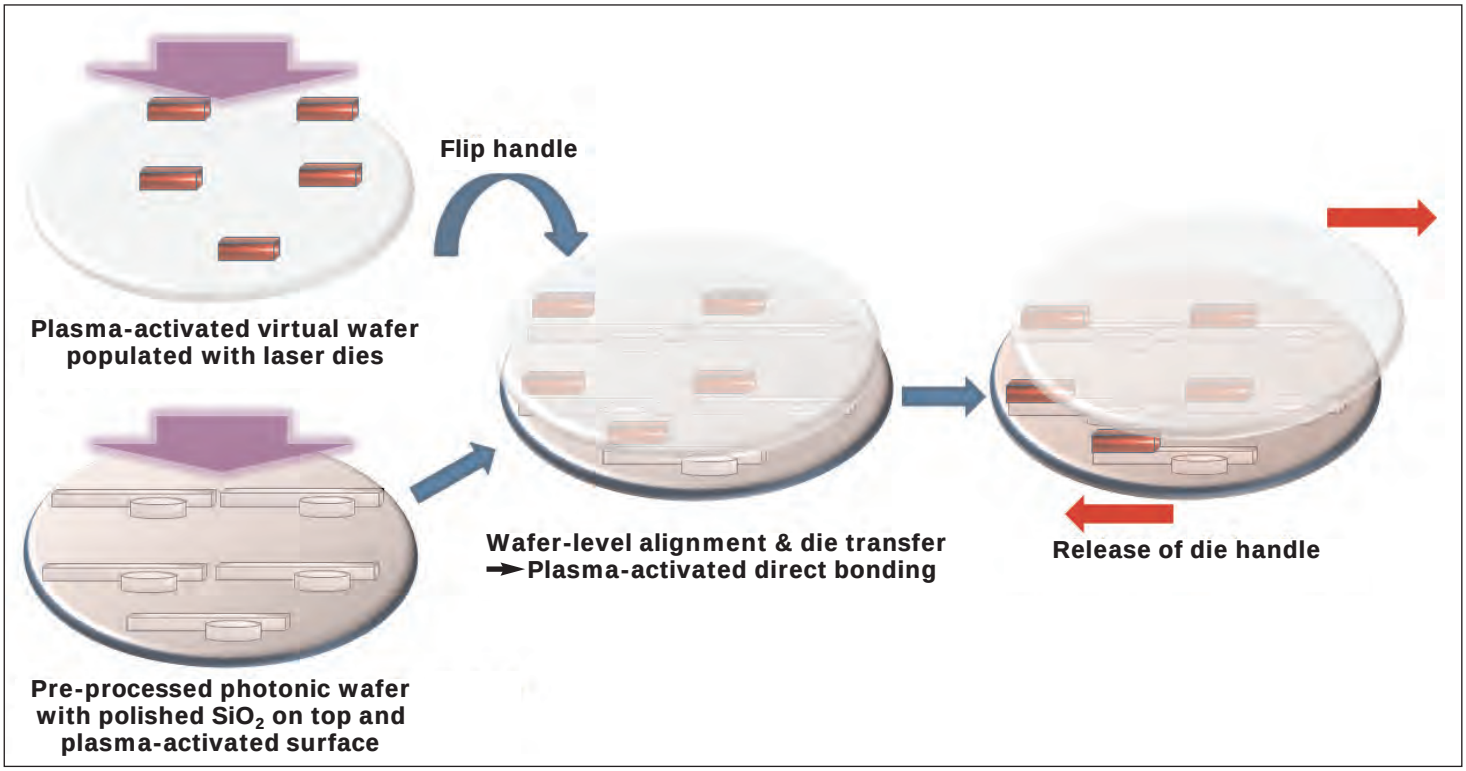

Figure 3: Wafer-level die transfer process for plasma-activated direct bonding of vertical-coupled laser dies.

materials supporting a high crystal quality of compound semiconductors can be joined with a carrier that accounts for differences in thermal expansion. Annealing temperatures below 350°C have been demonstrated using this approach for bonding InP on silicon wafers at diameters up to 150mm [4].

Since heterogeneous integration of InP is needed only on a minor part of the photonic wafer, bonding full wafers to each other is economically less attractive than placing the laser dies only in the needed areas. A die-level process enables one to overcome geometric constraints with InP wafers, since InP — which is currently only available on substrates up to 150mm in diameter — can then be scaled up to 200mm and 300mm production lines. Nonetheless, reasonable process times can only be achieved with a wafer-level process.

One way to overcome these challenges, as depicted in Figure 3, is to selectively place the laser dies on a handle wafer, creating a virtual wafer, transfer them in a single wafer-to-wafer bonding step, and finally release the handle [5]. This process flow enables dies to be placed on the handle wafer very quickly, while more time-consuming processes — such as cleaning, plasma activation and bonding at elevated temperatures — can be applied at the wafer level. In particular, cleaning of the dies is very important, since direct bonding is very sensitive to particle contamination, which can inhibit direct contact of the surfaces. As a result, this approach enables integration of III-V laser diodes directly bonded onto silicon-based photonic circuits with shorter process times and without wasting unreasonable amounts of real estate.

An alternative approach to get the light into the waveguide is edge coupling. In this case the laser diodes are placed at the same level as the photonic structures by etching pockets into the SOI substrate where the dies are placed. As a result, the facet of the laser points directly to the edge of the waveguide, which allows more power to enter the photonic circuit via a tapered waveguide. For this approach the bond interface does not need to be transparent. Hence, a eutectic bond is the preferred solution, as it allows the landing pad to be used as a bottom contact. Since the process flow of the wafer-level die transfer in Figure 3 can be applied to almost any kind of bond interface, it can also be adopted to realize edge-coupled photonic structures at the wafer level, as shown in Figure 4. For eutectic bonding, creating a virtual wafer enables one to remove undesirable oxides on the dies at the wafer level. Furthermore, the required heating and cooling ramps for eutectic bonding are far too time consuming to populate a photonic wafer with the laser dies in a reasonable time scale by serially bonding each chip to a CMOS wafer. Fast population of the handle wafer and aligned wafer-level bonding of the laser dies on the landing pads can solve this issue while still ensuring high transfer rates.

In conclusion, heterogeneous integration of InP laser diodes on silicon for silicon photonic circuits has received much attention recently. Despite the concentrated efforts to directly grow III-Vs onto silicon, dislocations are hard to control and the desired interface qualities have not been achievable. Wafer-to-wafer bonding offers an ideal solution for this problem. Nonetheless, the bonding of fully processed device wafers results in

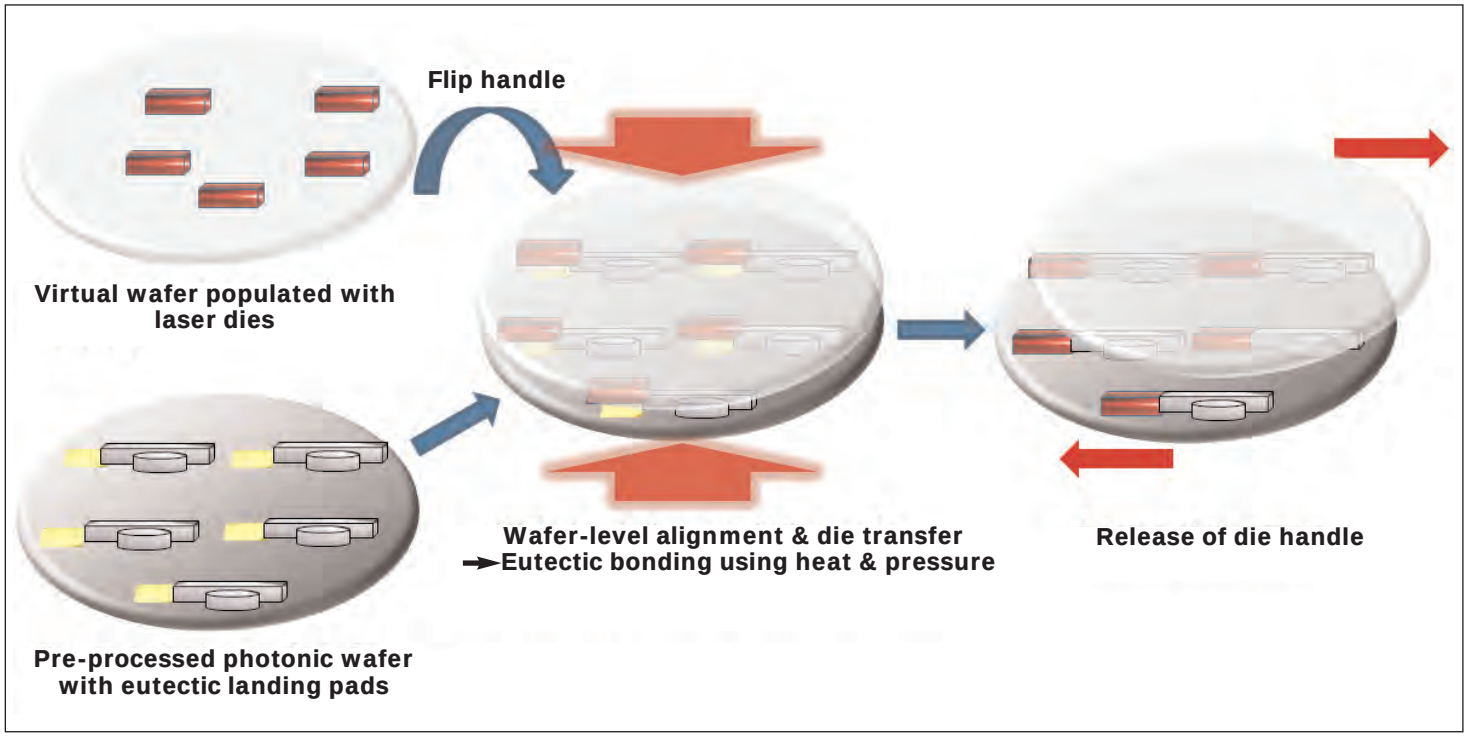

Figure 4: Wafer-level die transfer process for eutectic bonding of edge-coupled laser dies.

significant waste and loss of real estate, since only a low filling factor of the laser dies is needed. Furthermore, the usage of 200mm and 300mm CMOS production lines for InP wafers — as well as the integration of laser dies with different wavelengths in order to enable data transfer in both dedicated telecommunication bands around 1.3 and 1.55µm — would significantly aggravate this waste and lead to higher cost of ownership. Thus, in all integration schemes — be it adhesive, direct or eutectic bonding — large numbers of laser dies have to be implemented on a single photonic wafer. The key to enable reasonable time scales and to move silicon photonics into mainstream production is to implement wafer-level die transfer processes.

These advanced bonding techniques for photonic integrated circuits or heterogeneous integration in general can add tremendous benefit. The parallel processing of bonding a virtual wafer of InP die to the photonic wafer offers a substantial increase in throughput compared to serially bonding each InP die to the photonic wafer. It also solves the geometry issue, CTE mismatch, and substrate size mismatch associated with bonding an InP wafer to the photonic wafer. ■

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References

[1]Y. Vlasov, W. M. Green and F. Xia, 'High-throughput silicon nanophotonic wavelength-insensitive switch for on-chip optical networks', Nature Photonics, vol. 2, no. 4, 242–246, 2008
[2]H. Rong, A. Liu, R. Jones, O. Cohen, D. Hak, R. Nicolaescu, A. Fang and M. Paniccia, 'An all-silicon Raman laser', Nature 433, 292–294, 2005
[3]H. Park, A. Fang, S. Kodama and J. Bowers, 'Hybrid silicon evanescent laser fabricated with a silicon waveguide and III-V offset quantum wells', Opt. Express 13, 9460–9464, 2005
[4]D. Liang and J. E. Bowers, 'Photonic integration: Si or InP substrates?' Electronics Letters, vol. 45, no.12, p578, 581, June 4 2009
[5]T. Plum, 'Chip-on-Wafer Bonding — A new Fabrication Technology for High-Power Semiconductors', Annual Report RWTH Aachen, 24, 2006

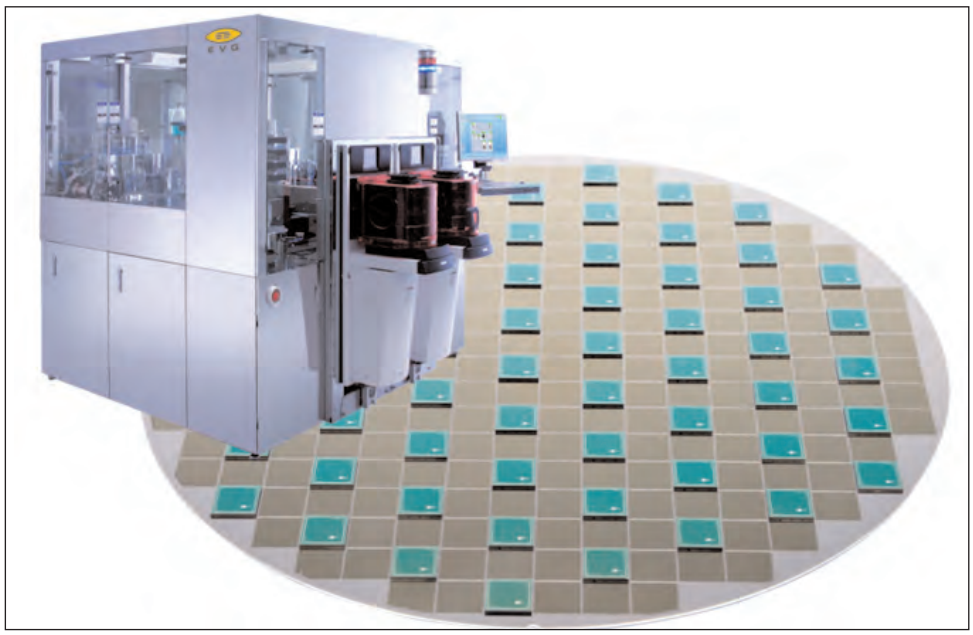

Figure 5: Advanced chip-to-wafer bonded dies on a 200mm wafer.

Simplifying zinc oxide/gallium nitride nano-rod LED fabrication

An oblique-angle RF magnetron sputtering technique could result in low-cost, reliable mass production of nano-scale optoelectronics.

Researchers in Taiwan have produced zinc oxide/gallium nitride (ZnO/GaN) nano-rod light-emitting diodes [Ya-Ju Lee et al, APL Mater. vol2, p056101, 2014]. The researchers avoided complicated polymer processing by using a shadowing effect to selectively deposit ZnO on GaN nanorods.

Often nano-rod-based devices are fabricated by filling the space between the rods with polymer and etching down to expose the tips to make an electrical contact. The team from National Taiwan Normal University, National Chiao-Tung University, National Taiwan Ocean University, and National Cheng Kung University comment that their method "allows us to overcome the constrictions of using a polymer, rendering our technique low cost and reliable for mass-production of nanoscale optoelectronic devices."

The metal-organic chemical vapor deposition (MOCVD) GaN layers consisted of 2µm undoped material on sapphire substrate,

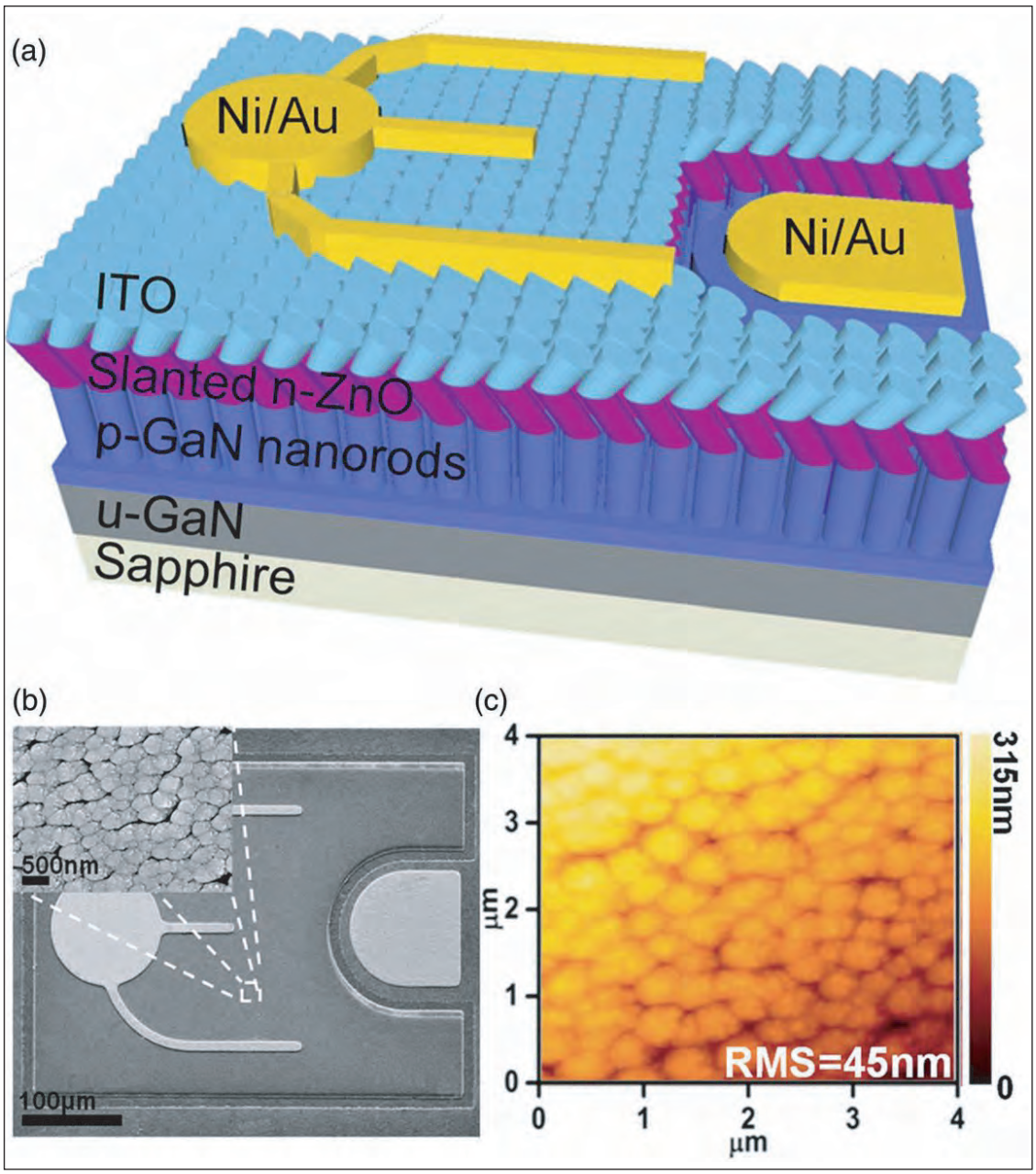

Figure 1. (a) Design of LED composed of slanted n-ZnO film on p-GaN nanorod arrays. An additional slanted ITO film interconnects slanted n-ZnO/p-GaN nanorod arrays for electrical injection. (b) Top-view SEM image of fabricated LED. Inset: enlarged top-view SEM image of surface of slanted ITO film. (c) Atomic force microscope (AFM) image of slanted ITO film.

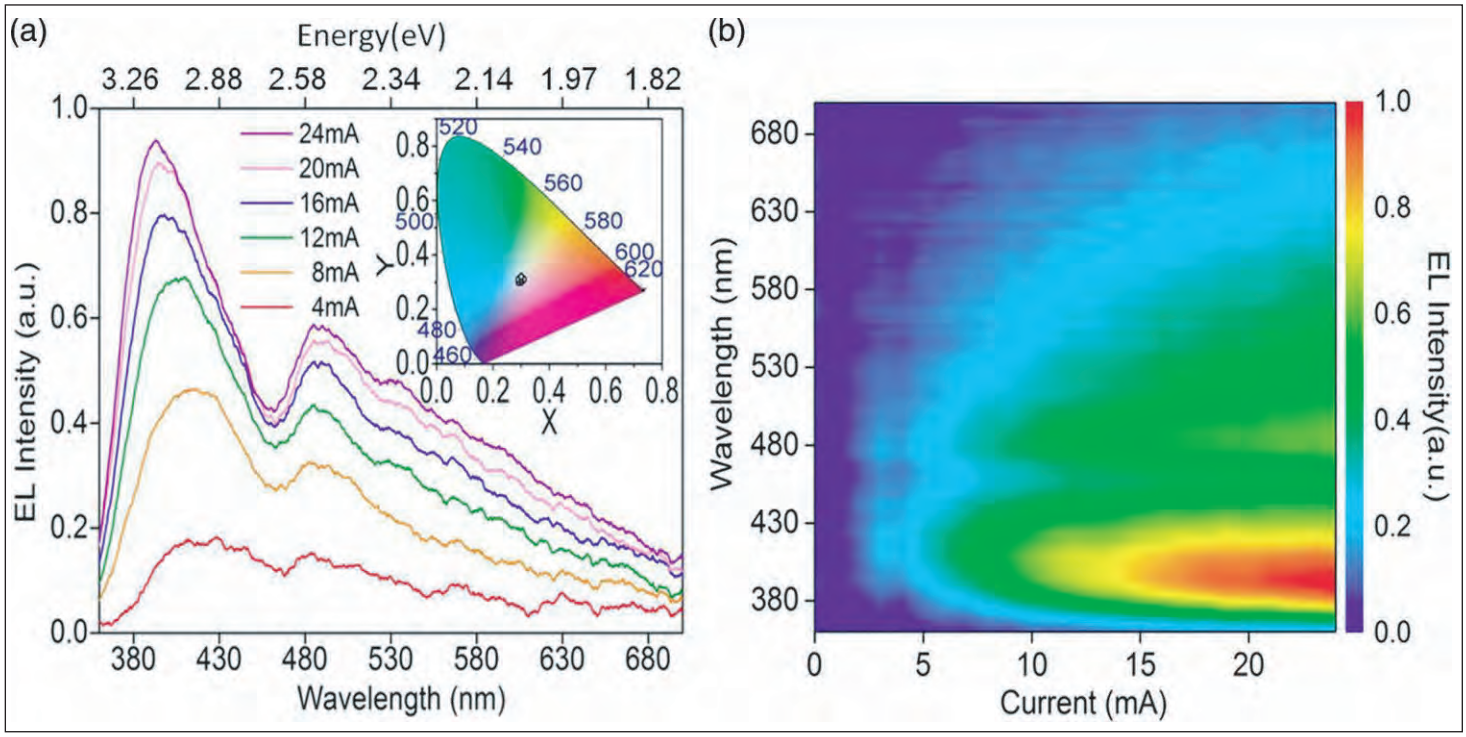

Figure 2. (a) EL spectra of slanted n-ZnO/p-GaN nanorod arrays LED for various injection currents. Inset: calculated CIE chromaticity ordinates of EL spectra. (b) Same EL spectra converted and re-plotted as 3D contour image.

followed by 400nm of p-type GaN. The hole concentration and mobility of the p-GaN were $5.5x10^{17}/cm^3$ and $6.2cm^2/V\text{-}s$, respectively.

Nano-rod random arrays were fabricated in the p-GaN by depositing self-assembled nickel clusters on the surface and etching with inductively coupled plasma. The p-contact region was protected with a photolithography-defined mask. The nano-rods were 300nm long and 100-140nm in diameter. The number density of nano-rods was estimated to be $2.2x10^9/cm^2$, representing a 17.3% volume filling.

The ZnO was deposited using oblique-angle radio-frequency (RF) magnetron sputtering at room temperature. The nano-rods were tilted at 60° with respect to the ZnO vapor flow. The p-GaN nano-rod array provides the shadowing effect so that the ZnO is deposited selectively on the nano-rod tips. The sample was annealed after ZnO deposition to ameliorate the effects of defects and surface states. The ZnO had an n-type characteristic with an electron density of $7.4x10^{18}/cm^3$ and mobility of $3.9cm^2/V\text{-}s$.

The method allows us to overcome the constrictions of using a polymer, rendering our technique low cost and reliable for mass-production of nanoscale optoelectronic devices.

The 485nm emission is probably related to the radiative interfacial recombination of the electrons from slanted n-ZnO and holes from p-GaN nanorod arrays, or to the energy transition from a shallow donor level to the VZn [zinc vacancy] level

Indium tin oxide (ITO) was then deposited by RF magnetron sputtering at a –60° tilt to provide a continuous transparent conductive contact and current-spreading layer connecting the individual n-ZnO/p-GaN nano-rod junctions together. Individual devices were fabricated with a chip size of 300µmx400µm (Figure 1).

The device showed good diode behavior with a turn-on voltage of 4.7V. The device emits a bluish-white light visible to the naked eye. The wall-plug efficiency peaks at around 4mA. The fall-off could be due to overheating of the device. The spectrum (Figure 2) was found to consist of two main peaks centered at 390nm (violet) and 485nm (green). The researchers associate the shorter wavelength to near-band-edge emission in the ZnO. They add: "The 485nm emission is probably related to the radiative interfacial recombination of the electrons from slanted n-ZnO and holes from p-GaN nanorod arrays, or to the energy transition from a shallow donor level to the VZn [zinc vacancy] level."

The CIE color coordinates were (0.3, 0.3). The researchers suggest that such structures could be developed as white-light sources. ■

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Author: Mike Cooke

Techniques for high-efficiency nitride LEDs on lithium gallate substrate

External quantum efficiency and light output power have been achieved that are comparable to best values in the field.

South China University of Technology (SCUT) has produced m-plane indium gallium nitride (GaN) light-emitting diodes on lithium gallate ($LiGaO_2$) (100) substrates [Wenliang Wang et al, Journal of Materials Chemistry C, vol2, p4112, 2014]. The researchers report that the best value of external quantum efficiency (EQE) of 50.8% is comparable to reported values of semi-polar GaN-based LEDs grown on bulk GaN substrate, and is much better than commercially available LED chips with EQEs of about 30%.

SCUT has worked for a while on growing non-polar m-plane nitride semiconductor layers on $LiGaO_2$ [see e.g. www.semiconductor-today.com/news_items/2014/JAN/SCUT-1_280114.shtml]. It is hoped that production of GaN-based LEDs with the crystal layers oriented in the m-plane direction will boost efficiency through avoiding the electric fields that arise from the polarization of material grown in the usual c-plane direction. These electric fields inhibit recombination through the 'quantum-confined Stark effect' (QCSE) pulling the electrons and holes apart, severely reducing the 'wavefunction overlap'.

Although non-polar and semi-polar bulk GaN and sapphire substrates are available, they are very expensive. A lower-cost option could be $LiGaO_2$, although up to now there have been technological barriers to adoption. The SCUT team has developed new growth techniques to enable the development to go forward.

The m-plane heterostructure wafers (Figure 1) were produced by a combination of pulse laser deposition (PLD) and molecular beam epitaxy (MBE). The PLD was used to create a 50nm m-GaN buffer/nucleation layer on the bare substrate at 200°C. The use of low-temperature PLD and $LiGaO_2$ avoids problems with thermal expansion and lattice mismatching in the early nucleation phase of the crystal growth, reducing the formation of threading dislocations. The low temperature also inhibits lithium diffusion from the substrate that has previously been a concern from the use of $LiGaO_2$ substrates.

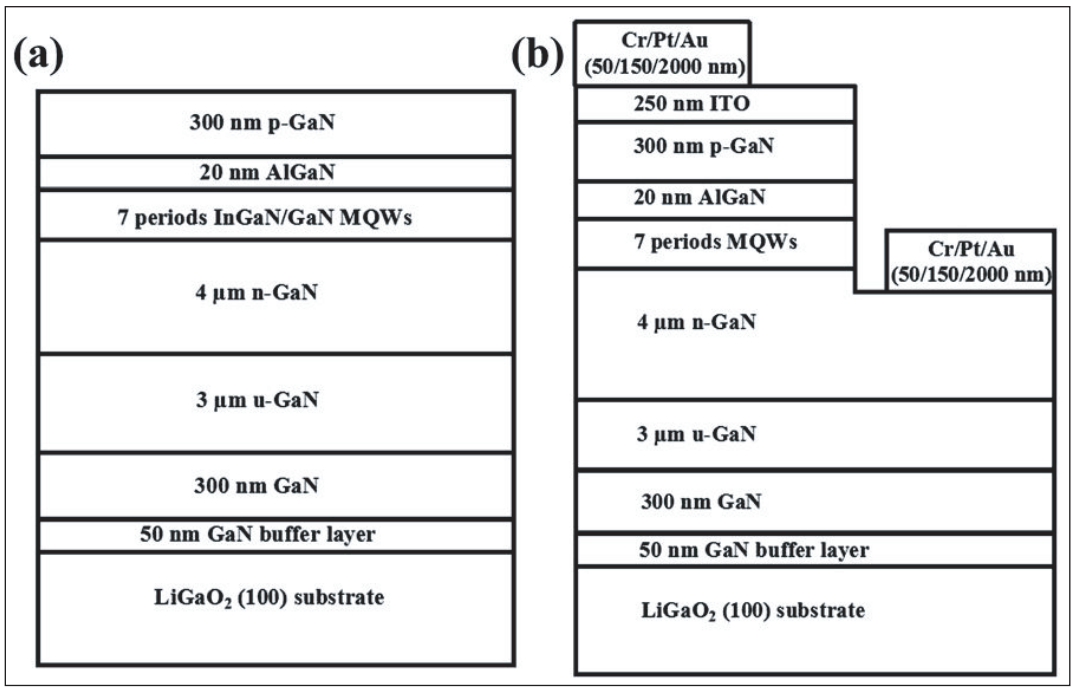

Figure 1. Schematic structures of (a) GaN-based LED wafer grown on $LiGaO_2$(100) substrate, and (b) chip.

The temperature was then raised for the further layers grown by MBE at higher temperature: 500°C (300nm GaN), 750°C (3µm GaN, 4µm n-GaN), and 700°C for the multiple quantum well (MQW), AlGaN electron-blocking, and p-GaN contact layers.

The heterostructure material was fabricated into standard LED chips using inductively coupled plasma reactive-ion etch, 700°C thermal activation of the p-GaN, evaporation of indium tin oxide (ITO) as transparent conductive p-contact, deposition of n- and p-

electrode metals, and a 1 minute 700°C anneal for ohmic contact formation. The wafers were finally singulated into 300µm x 300µm LED chips.

Scanning-electron microscope (SEM) studies comparing the m-plane material with a similar structure grown on c-plane sapphire showed more pits and black spots in the latter material. The researchers comment: "We attribute these differences to the higher Mg-doping efficiency in non-polar m-plane p-GaN layers due to its higher hole concentration. The poorer Mg-doping efficiency in p-GaN grown on c-plane sapphire would introduce many more defects, such as pits and black spots."

Hall measurements also showed improved electrical performance for the n-type and p-type regions (Table 1).

Atomic-force microscopy (AFM) gave a root-mean square (rms) roughness of 1.3nm for the m-plane structure, compared with 2.7nm for the c-plane material.

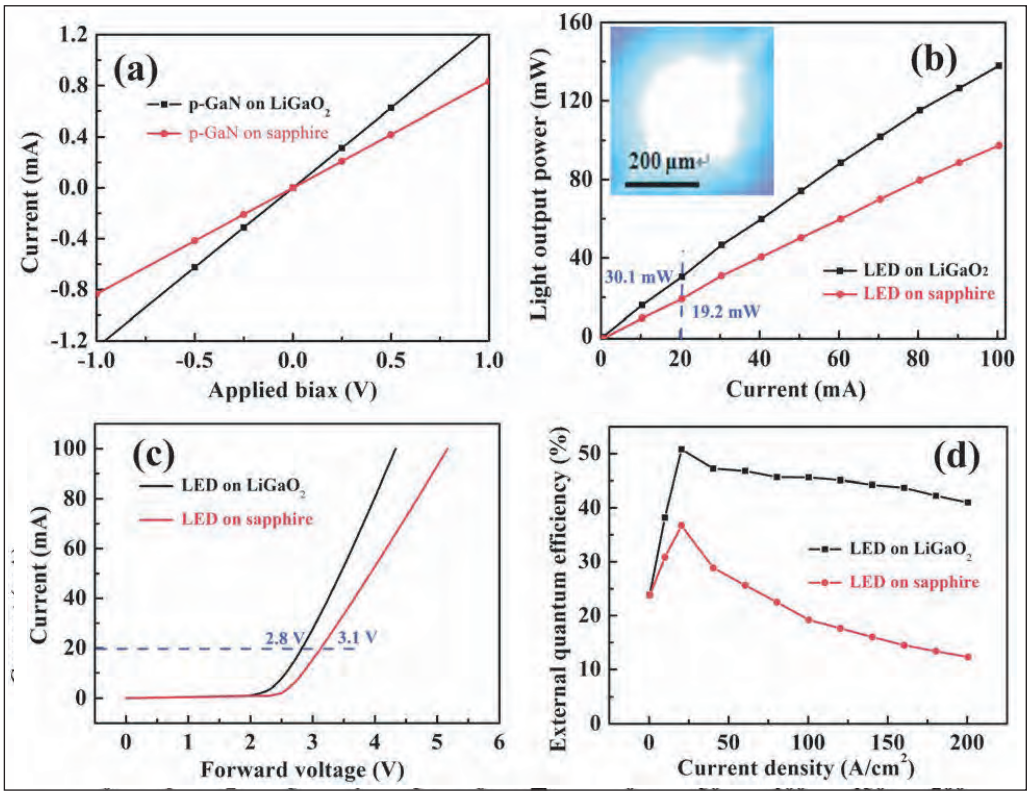

Figure 2. (a) Current–voltage characteristics of chromium / platinum / gold (Cr / Pt / Au) contacts on p-GaN grown on $LiGaO_2$(100) and c-plane sapphire substrates, respectively, measured over Ohmic pads with spacing of 3mm. GaN-based LED chip characteristics: (b) light output power versus current (L–I), (c) current versus voltage (I–V), and (d) EQE versus current (EQE–I). Inset photograph: lit-up LED on LiGaO2(100) substrate at 20mA.

Room-temperature photoluminescence also showed a stronger narrower peak for the m-plane InGaN/GaN MQWs at 446nm with full-width at half-maximum (FWHM) of 21.2nm, compared with 23.5nm for the c-plane structure.

The electroluminescence from the device blue-shifts slightly to shorter wavelengths as the current increases from 20mA to 150mA – an effect the researchers attribute to band filling where the average distance between the electron and hole states becomes wider at higher carrier concentrations, leading to higher-energy photons.

The FWHM of the spectral line remains fairly constant at ~20.5nm, in contrast to a c-plane comparison LED that has a width that increases from 21.25nm to 23.5nm over the 20mA to 150mA current range. The researchers ascribe the difference to the smaller lattice and thermal expansion contrast of the $LiGaO_2$ substrate with m-plane GaN, compared with c-GaN on c-sapphire.

The light output power at 20mA was 30.1mW, compared with 19.2mW for the c-plane LED (Figure 2). The performance of the m-plane LED on $LiGaO_2$ "is comparable to the best values ever reported for semi-polar or non-polar LEDs", according to the team. The researchers add: "This great improvement in light output power is mainly attributed to the uniformity of current spreading in the LED chip on $LiGaO_2$(100) due to the absence of the QCSEs in MQWs on $LiGaO_2$ (100) substrate, which enhances the internal quantum efficiency (IQE) and external extraction efficiency."

At the same current injection, the forward voltage is 2.8V, compared with 3.1V for the c-plane device. This indicates a reduction in series resistance from ~10Ω for the c-plane LED to ~7Ω.

Finally, the external quantum efficiency (EQE) of the m-plane LED remains relatively high at ~41% for a current injection density of 200A/cm^2. By contrast, the c-plane LED shows a severe efficiency droop. The researchers attribute the high EQE for the m-plane device to the absence again of QCSE. ■

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Table 1. Hall measurement results from van der Pauw configuration on n-GaN (silicon-doped) and p-GaN (magnesium-doped) layers.

	n-type mobility (cm^2/V-s)	n-type carrier concentration	p-type mobility (cm^2/V-s)	p-type carrier concentration
m-GaN	330	5.9×10^{18}	12.5	2.8×10^{18}
c-GaN	315	4.0×10^{18}	9.5	4.9×10^{17}

Tailored last quantum barrier achieves more efficient, powerful GaN LEDs

External quantum efficiency and light output power have been boosted by 12% at 150mA injection current for a three-step graded device.

Researchers based in Singapore and Turkey have demonstrated a last quantum barrier (LQB) structure for indium gallium nitride (InGaN) light-emitting diodes (LEDs) that improves the electron blocking and hole injection of an aluminium gallium nitride (AlGaN) barrier [Zabu Kyaw, Appl. Phys. Lett., vol104, p161113, 2014]. The team consisted of researchers from Nanyang Technological University, Singapore; Institute of Materials Research and Engineering, Agency for Science, Technology and Research (A*STAR), Singapore; and Bilkent University, Turkey.

AlGaN barriers are commonly used in GaN-based LEDs to avoid electron overflow into the p-contact region. Electron overflow tends to lead to non-radiative recombination and hence reduced efficiency. However, AlGaN electron-blocking layers (EBLs) also raise a barrier to hole injection that again reduces efficiency.

The LED epitaxial material was grown on sapphire using metal-organic chemical vapor deposition (MOCVD). The device structure (Figure 1) included a three-step InGaN tailored LQB between the multiple quantum well (MQW) active light-emitting region and the electron-blocking layer. A reference device was also produced where the tailored LQB was replaced with 17nm of GaN.

Contact	p-GaN (Mg doped	200nm
Electron block	$Al_{0.2}Ga_{0.8}N$ (Mg doped)	25nm
Step 3	$In_{0.09}Ga_{0.91}N$	3nm
Step 2	$In_{0.052}Ga_{0.948}N$	3nm
Step 1	$In_{0.015}Ga_{0.985}N$	3nm
Barrier	GaN	8nm
Multiple quantum well	$6x(In_{0.13}Ga_{0.87}N/GaN)$	3nm/12nm
Contact	n-GaN (Si doped)	2μm
Buffer	GaN	4μm
Nucleation	GaN	30nm
Substrate	Sapphire	

Figure 1. Epitaxial structure of LED with 3-step InGaN tailored last quantum barrier.

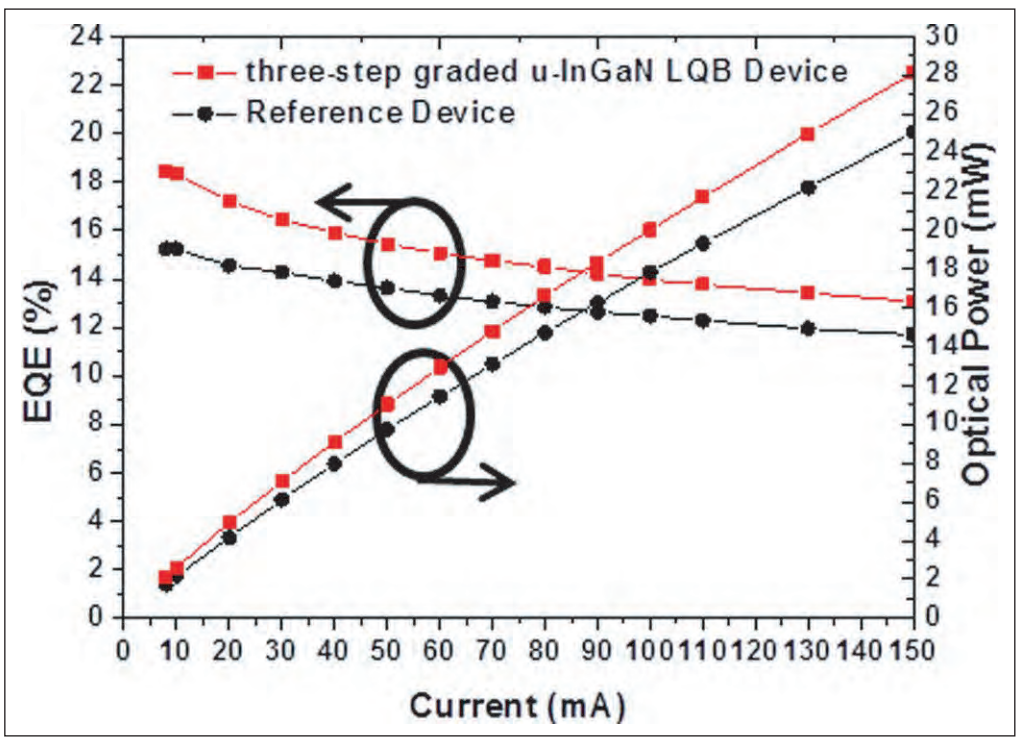

Figure 2. Optical output power and EQE versus current injection for reference and three-step graded u-InGaN LQB devices.

Table 1. Energy barrier heights computed for reference and three-step graded u-InGaN LQB devices at 20A/cm^2.

Device	LQB electron barrier	EBL electron barrier	EBL hole barrier
Reference	210meV	325meV	469meV
Three-step graded u-InGaN LQB	362meV	490meV	358meV

The epitaxial material was fabricated into 350µmx350µm mesa LEDs. A transparent conducting layer of nickel/gold was deposited on the p-contact layer. The contact pads for both the p- and n-type layers consisted of titanium/gold.

The use of a tailored LQB improved both external quantum efficiency (EQE) and output power (Figure 2). At 150mA injection current, the output power of the tailored LQB LED of 28.13mW was 12.25% higher than that for the plain GaN LQB device of 25.06mW. The EQE improvement was 11.98% at the same current injection.

The researchers comment: "This observed improvement of the optical power and the EQE is well attributed to the simultaneous reduction of the electron overflow and enhancement of the hole injection efficiency enabled by the proposed three-step u-InGaN LQB."

Simulations suggest that one factor reducing electron overflow is an increased effective potential barrier for electrons of the LQB of 362meV in the tailored LQB LED at 20A/cm^2 injection, compared with 210meV for the all-GaN LQB device. The simulations also suggest enhanced electron blocking by the EBL itself and better hole injection with tailored LQB due to an increased barrier for electrons and a reduced barrier for holes (Table 1). ■

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Author: Mike Cooke

Deep UV LED research moving performance beyond 10% efficiency

Mike Cooke reports on progress made by a number of research teams.

Deep ultraviolet light-emitting diodes are being developed for spectral analysis, photocatalysis, air and water decontamination, and material sterilization applications. More specific uses could include biological agent detection, phototherapy, optical data storage, and photolithography.

Present DUV systems involve bulky, fragile and poisonous mercury lamps. A solid-state solution based on aluminium gallium nitride (AlGaN) LEDs is desired but for the shorter UV wavelengths external quantum efficiencies plummet to less than 12% at 20mA injection current in the range 270–280nm. For the ~250nm wavelengths needed for effective killing of bacteria and viruses, the efficiency level is a measly 3%.

The poor performance is attributed to a number of factors. For example, the magnesium doping used to achieve p-AlGaN has activation energies (500–600meV) even higher than that of p-GaN (~180meV), which is already a poor performer in long wavelength LEDs. High activation energy means low carrier concentrations and hence low conductivity.

A further obstacle in DUV LEDs is that a thin p-GaN layer is added to achieve decent ohmic contact with the metal p-electrode. The DUV photons have sufficient energy to excite electrons from the valence band to the conduction band and hence these p-GaN layers absorb the light emitted by the active layers, cutting light extraction efficiency.

Here we look at recent research that attempts to tackle the problems of low efficiency in DUV devices.

Beyond 10% efficiency

A team of researchers based in the USA has described two of the main developments that has allowed them to push external quantum efficiencies beyond 10% [Max Shatalov et al, Semicond. Sci. Technol., vol29, p084007, 2014]. The team is associated with Sensor Electronic Technology Inc (SETi), US Army Research Laboratory, and Rensselaer Polytechnic Institute.

The researchers comment on one aspect of their work: "Large chip LEDs with the output power >75mW CW at 300mA pave the way for DUV semiconductor sources to be used in disinfection, decontamination, curing and medical applications."

SETi is on its third generation of DUV LED, achieving about 10% external quantum efficiency (EQE) and 4.5% wall-plug efficiency (WPE) at 20mA injection in the 270–280nm wavelength range. To achieve improvement over previous generations the researchers focused on reducing the effect of non-radiative (NR) defects and decreasing optical losses in p-GaN contact layers and through the refractive index mismatch between the device material and air.

The more recent SET devices use a short-period superlattice (SPSL) of various compositions of p-AlGaN. The technology was first developed for less challenging UV-A (400–315nm) and UV-B (315–280nm) devices and then the Al-content was increased to cross the border into UV-C (280-100nm). Factors that can be adjusted to improve performance include reducing the SL period and tuning the well/barrier compositions to align the hole ground state in the well with the acceptor level in the barrier.

At 275nm, the normal incidence optical transmission can be increased to more than 60% for a p-SPSL, compared with 5% for p-GaN contact layers. Unfortunately, the higher activation energy of the Mg acceptors in AlGaN leads to a higher operating voltage that decreases WPE at high current in small area devices.

SETi has also developed metal stack reflectors on the p-contact in its Gen II devices with 70% normal incidence reflectivity in the UV region. The researchers attribute an improvement of nearly a factor of two in light extraction efficiency (LEE) and EQE to the use of a metal reflector.

Reduced threading dislocation density (TDD) has been achieved through the application of migration-enhanced metal-organic chemical vapor deposition (MEMOCVD) on sapphire with AlN buffer layers. MEMOCVD heterostructures with AlGaN/AlN superlattice transition layers between the buffer and device layers have cut TDD from $5x10^9/cm^2$ (Gen I/II) to $2x10^8/cm^2$ (Gen III). The transition layer minimizes relaxation and avoids cracking of AlGaN layers grown over AlN templates.

The researchers believe further improvements in material quality can be achieved through growth parameter optimization to alter point defect concentration, quantum well interface sharpness, and alloy composition uniformity.

The use of low-TDD AlN templates ($2x10^8/cm^2$) allowed the researchers to achieve EQE values of more than 10% in Gen III devices (Structure B, Figure 1). This doubles the EQE of 5% achieved with Gen II devices using higher TDD templates ($3–5x10^9/cm^2$) along with LEE enhancements such as surface roughening and encapsulation (Structure A). An intermediate $5x10^8/cm^2$ TDD large-area device (Structure C) suffered from LEE problems due to optical losses in the p-SPSL contact region and absorption by n-contacts.

The lower-TDD structures B and C also exhibited earlier onset of efficiency droop at ~$5A/cm^2$ current density, compared with ~$50A/cm^2$ for structure A. The researchers suggest that the efficiency droop could be due to delocalization of free carriers at higher current densities. With higher defect densities the carriers can be bound to certain regions, inhibiting their migration to non-radiative recombination centers, delaying efficiency droop.

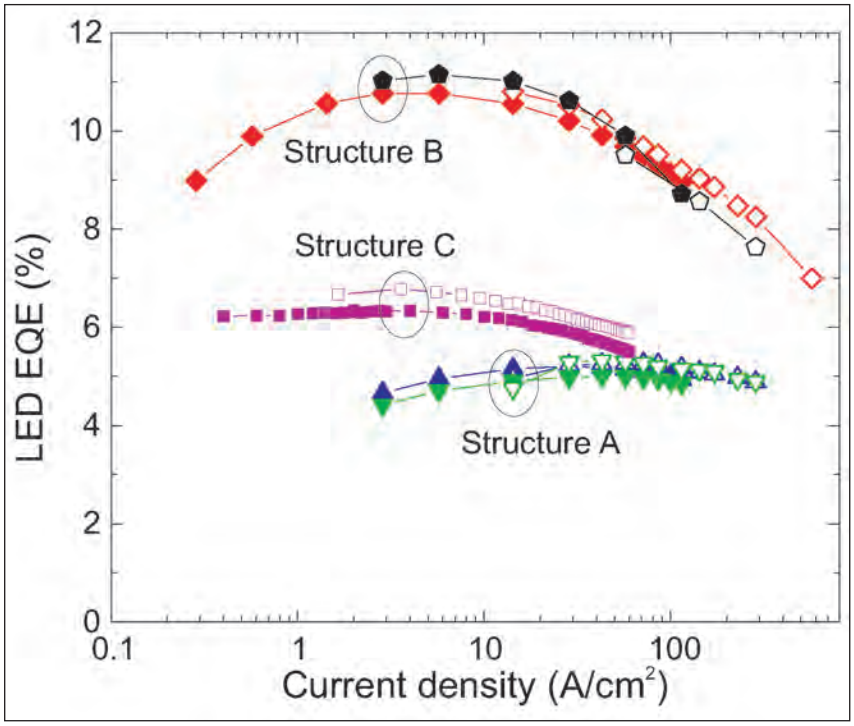

Figure 1. EQE versus current density of LED devices from structures A, B and C under CW (closed symbols) and pulsed (open symbols) pumping.

The large area device based on Structure C achieved continuous wave (CW) 275nm wavelength output powers of 27mW and 75mW at 100mA and 300mA, respectively. The corresponding EQEs were 6% and 5.5%. Using pulsed operation to avoid self-heating effects increased the output power at 300mA to 80mW. At 100mA current, the forward voltage was less than 7V, giving an electrical efficiency of ~60%.

The researchers comment: "It is evident that, for the large chip devices, use of SPSL top layer is more beneficial since the p-contact and the p-layer voltage drop contribution into the operating voltage is not as strong as in small chip devices."

Nanopipes and light extraction

The USA-based Sandia National Laboratories has recently published two papers on DUV light emitting structures that deal with different challenges for increasing efficiency.

In the first piece of work, the team sought to find ways to characterize and thus reduce performance-killing defects, in particular open-core threading dislocations or 'nano-pipes' with diameters between 2nm and 50nm [Michael Moseley et al, J. Appl. Phys., vol116, p053104, 2014].

The researchers prepared a pair of silicon-doped $Al_{0.7}Ga_{0.3}N$ templates on sapphire, using a Veeco MOCVD system. One of the templates was used for defect analysis, the other for fabricating LEDs (Figure 2). The template layer was grown on a 3.75μm AlN buffer. X-ray diffraction analysis determined that the total

Contact	p-GaN	150nm
Electron blocking	p-$Al_{0.9}Ga_{0.1}N$	
MQW	3x($Al_{0.44}Ga_{0.56}N$/ $Al_{0.55}Ga_{0.45}N$)	3x(2.6nm/4.3nm)
Contact	n-$Al_{0.65}Ga_{0.35}N$	500nm
Template	$Al_{0.7}Ga_{0.3}N$	1.3μm
Buffer	AlN	3.75μm
Substrate	Sapphire	

Figure 2. Epitaxial structure of Sandia LEDs.

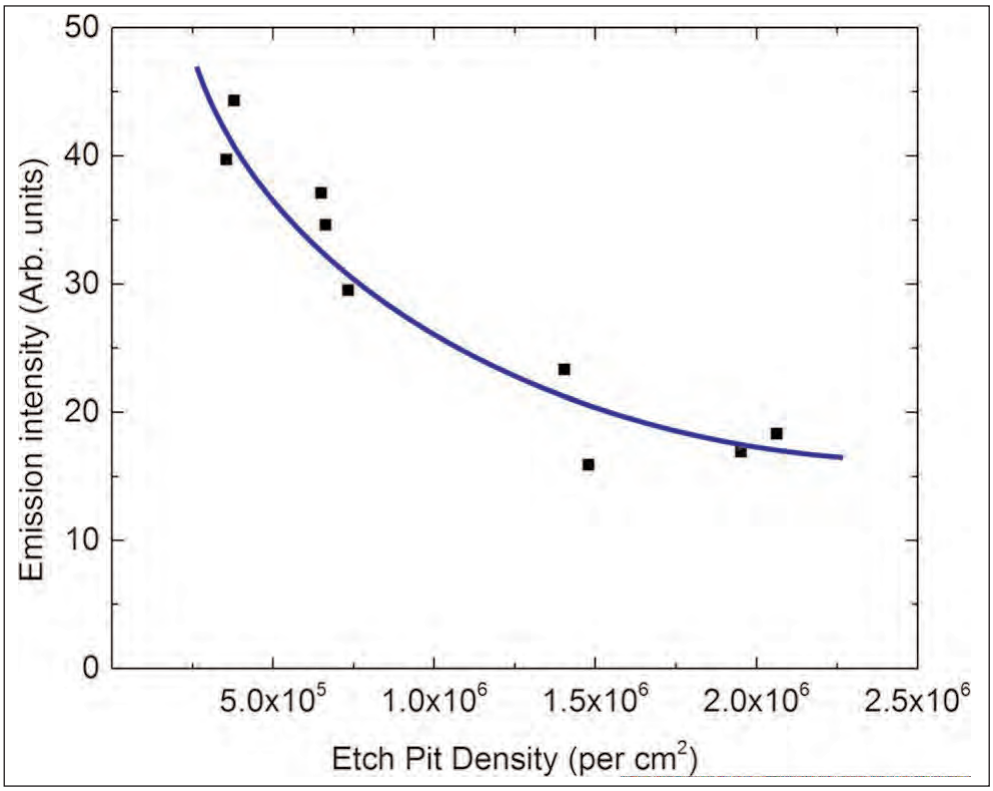

Figure 3. Relative output powers of LEDs grown on AlGaN template versus micron-scale etch pit densities at corresponding location on etched AlGaN template. Line is drawn to guide the eye.

threading dislocation density was 2–2.4x10^9/cm^2.

Before defect analysis, a further unintentionally doped 1μm AlGaN layer was grown. The analysis consisted of various atomic force microscope (AFM) scans and microscopic and AFM study of phosphoric acid etch-pits.

Among the scans, the researchers used conductive AFM (CAFM) in contact-mode to probe current leakage structures. It was found that repeatedly scanning for leakage had an unintended passivation effect whereby the current detected was reduced with each scan. Therefore multiple scanning would underestimate leakage.

Phosphoric acid etching at 160ºC for 60 seconds was used to distinguish nano-pipes. The reactants enter the pipes, dissolving material and creating 1–2μm-wide hexagonal pits. Such defects have been associated with current leakage. The growth mechanism of nano-pipes is unclear, but seems to be correlated with impurities such as silicon, magnesium and oxygen. The electrical conduction is thought to be along the walls of the pipes with the impurities creating a current path.

Comparing the etch pits with the CAFM measurements, the researchers found micron-scale etch-pits at the sites of current leakage. The team comments: "Based on the similarity in etch behavior to previous reports of nanopipe decoration in concert with the detection of current transport at these sites of hexagonal etch pits, we conclude that the source of these etch pits are open-core threading dislocations."

The researchers see these optical microscope studies of micron-scale etch pits as an efficient means to determine nano-pipe densities across wafers, in contrast to time-consuming AFM studies. Compared with the total threading dislocation density, the nano-pipe density is about four orders of magnitude lower at around 7.5x10^5/cm^2. Variation in density across the wafer was nearly an order of magnitude, between 4x10^5/cm^2 to 2.1x10^6/cm^2. Variation in total threading dislocation density was only 15%.

The Sandia team adds that recent improvements in nitridation, nucleation, and buffer growth have reduced the density of nano-pipes by almost two orders of magnitude, with etch pits providing a "crucial feedback" for process optimization.

Closed-core threading dislocations give nanometer-scale etch pits after exposure to 160º phosphoric acid for 30 seconds that can be detected using tapping-mode AFM. (The tapping mode allows finer features to be resolved.) The density of the nano-scale etch pits was estimated at 2.5x10^9/cm^2. There was found to be little variation in nano-scale etch pit density across the sample.

Having mapped out the nano-pipe density for different parts of the wafer, the researchers set out to find correlations with the performance of LEDs produced on the second sample. Previous work had convinced the team that such correlations were meaningful: "The distribution of etch pits was previously found to be similar across multiple templates produced in the same growth run."

The LEDs measured 300μm x 300μm. The emission wavelength was 270nm. The researchers found an inverse proportionality relation between relative output power and assumed micron-scale etch pit density (Figure 3). No such correlation was found between total threading dislocations and micron-scale etch pits.

The researchers comment: "This strong correlation between LED performance and micron-scale hexagonal etch pits is attributed to the electrical current leakage associated with the open-core threading dislocations. These current transport paths can shunt the quantum well active regions by carrying current directly across the junction without the opportunity to radiatively recombine."

The team therefore concludes: "These data suggest that nanopipes acting as current leakage paths can have a larger effect on LED electroluminescence than

threading dislocations acting as non-radiative recombination centers."

In the second report, the team studied the use of scattering structures to overcome poor light extraction from DUV LEDs [J. J. Wierer Jr., et al, Appl. Phys. Lett., vol105, p061106, 2014].

The epitaxial structures were produced by metal-organic vapor phase epitaxy (MOVPE) on sapphire (Figure 4). The multiple quantum well (MQW) active region consisted of the three periods of $Al_{0.44}Ga_{0.56}N$ in $Al_{0.55}Ga_{0.45}N$ barriers. The nominal well and barrier thicknesses were 2.6nm and 2.9nm, respectively, but the actual parameters varied across the epitaxial wafer. The electroluminescence peak was at 269±2nm.

The epitaxial material was processed into flip-chip UV LEDs. The p-contact consisted of a thin layer of nickel and an aluminium mirror of 60–70% reflectivity. The effectiveness of the mirror in extracting UV from the structure tends to be negated by the absorption of radiation by the relatively narrow bandgap (3.4eV, 365nm wavelength) of the p-GaN contact layer.

The scattering structures were created by etching down through the QWs to the n-contact layer. The n-contact regions were also formed at the same time. The scattering structures consisted of 5μm trenches with 70–80° sidewalls, giving hexagonal or triangular arrays. The trenches were filled with 200nm of silicon dioxide and then 200nm of aluminium. The silicon dioxide electrically isolated the trenches. The aluminium acted as both mirror and electrical connection between the isolated hexagonal or triangular areas.

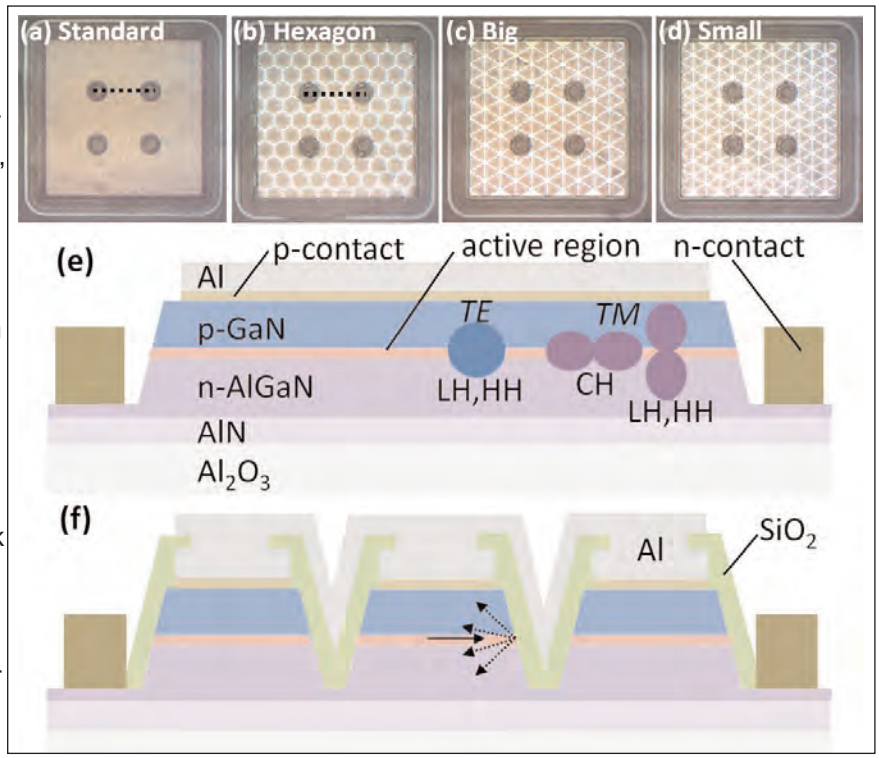

Figure 4. Optical microscope images through sapphire substrate of (a) standard, and (b) hexagonal, (c) big triangle, and (d) small triangle reflective scattering structure UVLEDs. Cross-section schematic of standard UVLED (e) showing emission patterns of TE and TM polarized light for transitions to light- and heavy-hole subbands (LH and HH, respectively) and to crystal field split-off hole subbands (CH). Cross-section schematic of UVLEDs with reflective scattering structures (f) showing scattering of in-plane light (arrows) from reflective scattering structure. Dashed lines in (a) and (b) are positions of cross-sections in (e) and (f).

The n-contact was formed by 20μm-diameter circular regions and a 20μm trace around the periphery of the device. The n-contacts were connected over the p-contact with silicon dioxide insulation and gold-based connecting and bonding metal.

The sapphire substrate, through which the light was designed to be emitted, was thinned to 250μm. The wafer was singulated into 1mmx1mm chips containing 2x2 arrays of UV LEDs. The devices were not packaged. One edge of the devices was polished to facilitate optical polarization measurements.

The effectiveness of the scattering structures was greatest when there was the largest fraction of light trapped in the plane of the LEDs. In fact, the in-plane radiation was greatest when the optical polarization of the radiation was least (Figure 5). This effect was related to details of the band structure that varied with QW thickness, etc. In longer wavelength InGaN QWs the light tends to be polarized parallel to the plane, favoring perpendicular emission into the light escape cone. For AlGaN QWs the light is polarized both perpendicular and parallel to the QW plane, resulting in more trapped light.

Nonpolar substrates

Researchers at NTT Corporation, Japan, have used nonpolar m-plane substrates to find ways to overcome the problem of optical polarization [Ryan G. Banal et al, Appl. Phys. Lett., vol105, p053104, 2014]. The team studied 4-period, 1nm to 4nm $Al_{0.56}Ga_{0.44}N$ MQWs in 6nm $Al_{0.88}Ga_{0.12}N$ barriers produced by MOVPE on c- and m-plane AlN bulk substrates. The epitaxial samples were produced under identical process conditions in the same run.

The m-plane MQWs were found to have undulations that "occurred during the MOVPE growth because of the formation of macrosteps on the surface, which could be suppressed by using appropriate growth conditions and off-cut angles of the substrate surface," according to the NTT team.

Photoluminescence at 9K showed peaks at 237.7nm

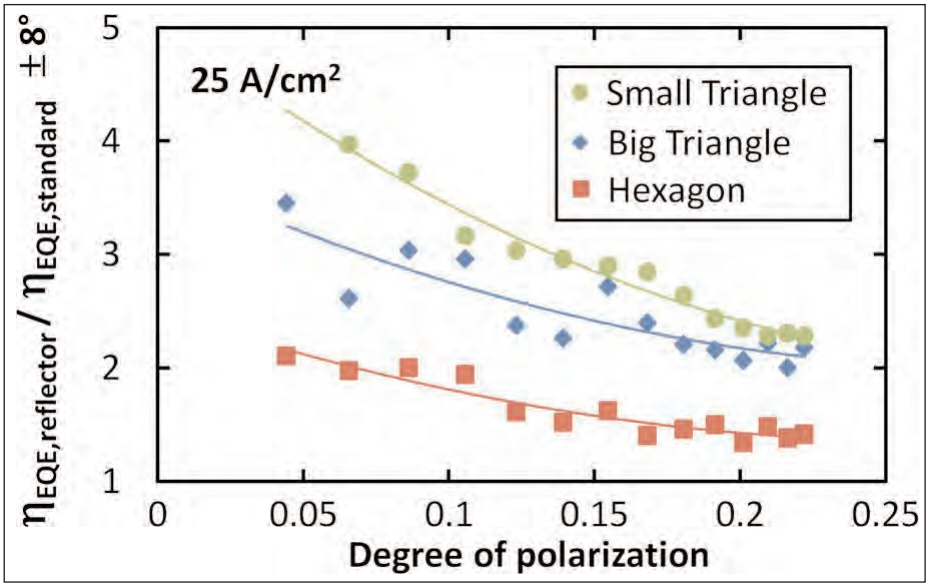

Figure 5. Ratio of EQE in ±8° collection cone of reflective scattering and standard UVLEDs versus degree of polarization at 25A/cm².

(5.216eV) and 249.8nm (4.963eV) for 4nm m- and c-plane wells, respectively. The c-plane sample also has a larger linewidth of 7.63nm (150meV), compared with 5.13nm (112meV) for m-plane MQWs. The researchers attribute this to a shoulder in the c-plane spectrum due to multiple factors such as a phonon replica peak and compositional inhomogeneity.
At room temperature, the linewidths were 6.08nm (132meV) and 9.54nm (188meV) for the m- and c-plane MQWs, respectively.

Over the range of 1-4nm well widths, both samples showed decreasing photon energy (increasing wavelength) as the well width increased (Figure 6). At all widths, the c-plane sample emitted lower energy photons

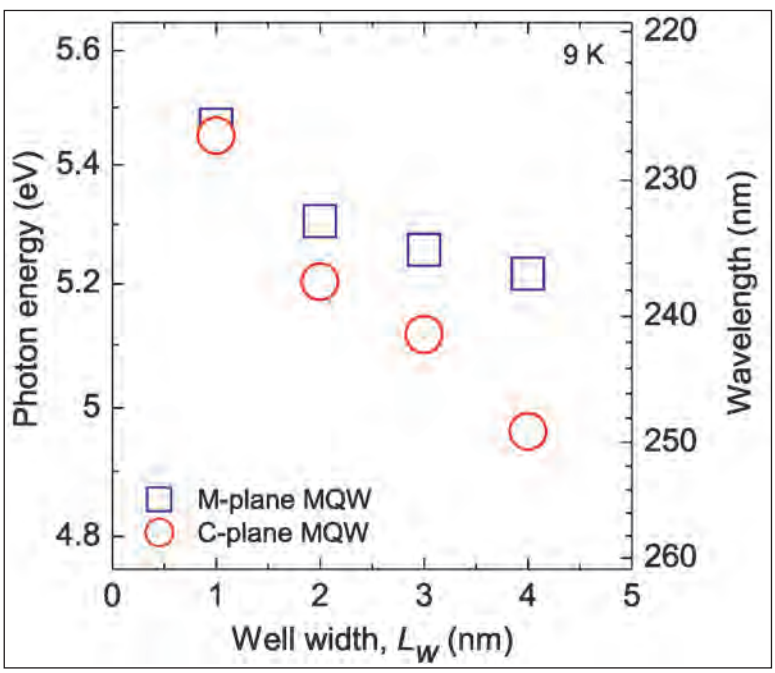

Figure 6. Peak emission energy (emission wavelength) of m- and c-plane AlGaN MQWs versus well width at 9K.

— an effect mainly attributed to the quantum-confined Stark effect (QCSE), which is not present in the m-plane samples.

Optical polarization measurements showed that the radiation with electric field parallel ($E_{||c}$) to the c-direction was stronger than that in the perpendicular direction ($E_{\perp c}$). The m-plane 4nm-well sample was more strongly polarized at –0.91, compared with –0.58 for the c-plane MQW structure. (Positive optical polarization indicates when perpendicular electric fields predominate. Negative polarization shows parallel fields.) Over the range of well widths, the m-plane polarization remains parallel, but the c-plane sample crosses over to perpendicular polarization for the narrowest wells (Figure 7).

The researchers comment: "The strong $E_{||c}$ polarization along with the absence of the QCSE in the nonpolar AlGaN MQW structures will make them a promising approach for increasing the emission efficiency of AlGaN deep-UV LEDs."

Boron nitride p-contacts

Professors Hongxing Jiang and Jingyu Lin at Texas Tech University believe that using boron nitride as the p-type contact layers in nitride semiconductor heterostructures "could ultimately pave the way toward the realization of high efficiency nitride deep ultraviolet (DUV) optoelectronic devices" [Semicond. Sci. Technol., vol29, p084003, 2014].

Jiang and Lin see the most important roadblock for DUV applications as being the poor p-type hole carrier densities and conductivity of AlGaN at the high aluminium fractions needed for short wavelengths.

Jiang and Lin have been exploring the growth of boron nitride in the hexagonal crystal structure (hBN) as an alternative to GaN. Although the lattice mismatch between hBN and wurtzite AlN is large at 19.54%, Jiang and Lin noticed that 4x the 'a' lattice constant of wAlN (4x0.3112nm = 1.245nm) is almost equal to 5x the 'a' lattice constant of hBN (5x0.2504nm = 1.252nm). The researchers comment: "This 5/4 coincidence in the hBN/w-AlN heterojunction interface reduces the effective lattice-mismatch from 19.54% to about 0.58%."

Texas Tech has not as yet reported a DUV LED with h-BN p-contact layer, but pn diodes with "decent" behavior have been demonstrated. Jiang and Lin hope use of p-hBN contact layers in DUV LEDs (Figure 8) will enhance hole injection efficiency, more effectively block electrons from entering the p-contact region, reduce contact resistance and dramatically increase

UV transparency for wavelengths longer than 230nm due to the wide ~6eV bandgap of hBN.

The p-hBN/n-AlGaN diode heterostructures were grown using MOCVD on sapphire substrates. The p-BN layer used tri-ethyl boron, ammonia and bis-cyclopentadienyl-magnesium as precursors.

A low-temperature 800ºC buffer layer was used to avoid adhesion problems and cracking. The quality of the p-hBN epilayer improved as the buffer was thinned from 140nm to 20nm.

The growth temperature of the hBN epilayer was in the range 1300–1350ºC. The hBN layer had an x-ray diffraction (002) rocking curve full-width at half-maximum of 662arcsec — larger than for hBN grown directly on sapphire. This indicates room for improvement in crystal quality.

The p-hBN was activated with a 1150ºC anneal for 45 minutes in nitrogen. When grown on an insulating substrate the p-hBN epilayer has demonstrated a 2.3Ω-cm resistivity. The researchers estimate the activation energy at 31meV based on temperature dependent resistivity measurements.

The present p-hBN epilayers have low mobility (~2cm^2/V-s) and free hole concentrations lower than expected (~10^{18}/cm^3 when doped with magnesium concentration of 10^{19}/cm^3). The researchers believe that appreciable concentrations of defects may be acting as free hole compensating centers. The source of the defects is presently unclear. Clarification should lead to larger carrier concentrations and higher mobility.

The pn diode was achieved with an inductively coupled plasma etch to expose the n-type AlGaN layer. The n-contact metals consisted of annealed titanium/aluminium/nickel/gold. The p-contact was nickel/gold. The p-contact was annealed in a variety of conditions but full characterization of the ohmic contact resistance and comparison with p-GaN remains to be performed. With 1020ºC annealing of the p-hBN/metal contact, the reverse bias leakage at –10V was 3μA. ■

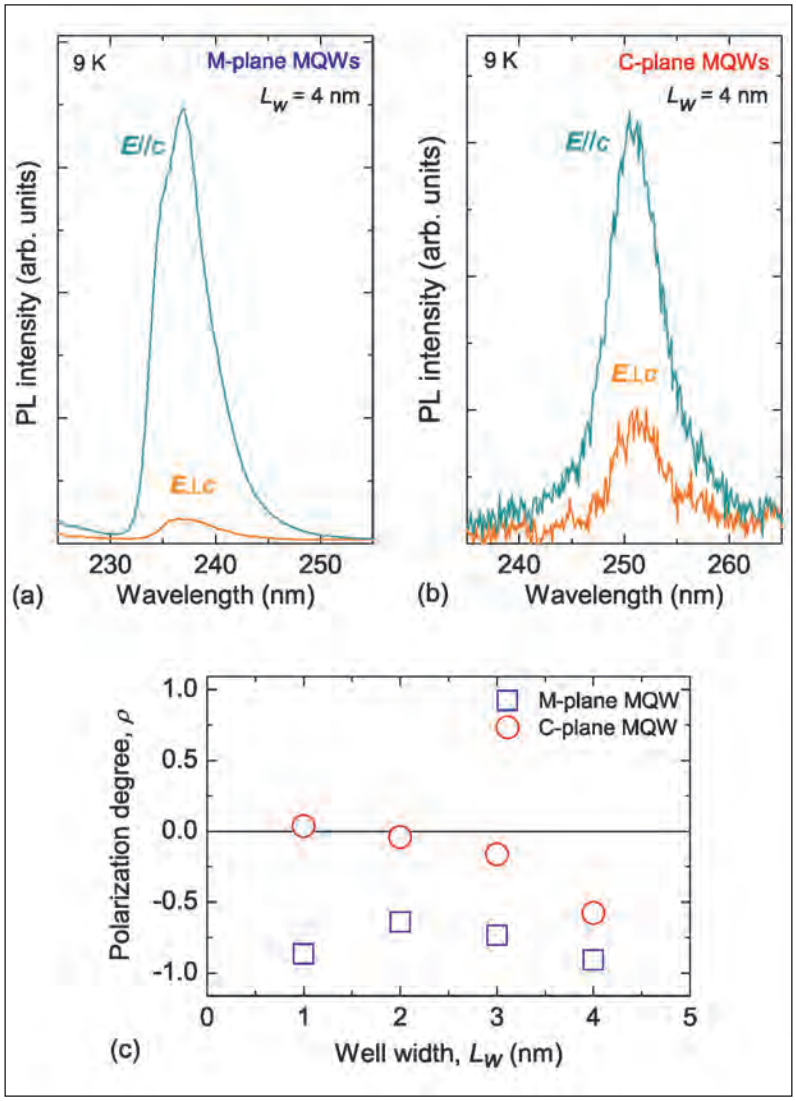

Figure 7. Polarization photoluminescence (PL) spectra at 9K from (a) m- and (b) c-plane AlGaN MQWs with 4nm wells. (c) Polarization degree (ρ) of the PL from the m- and c-plane AlGaN MQWs as function of well width.

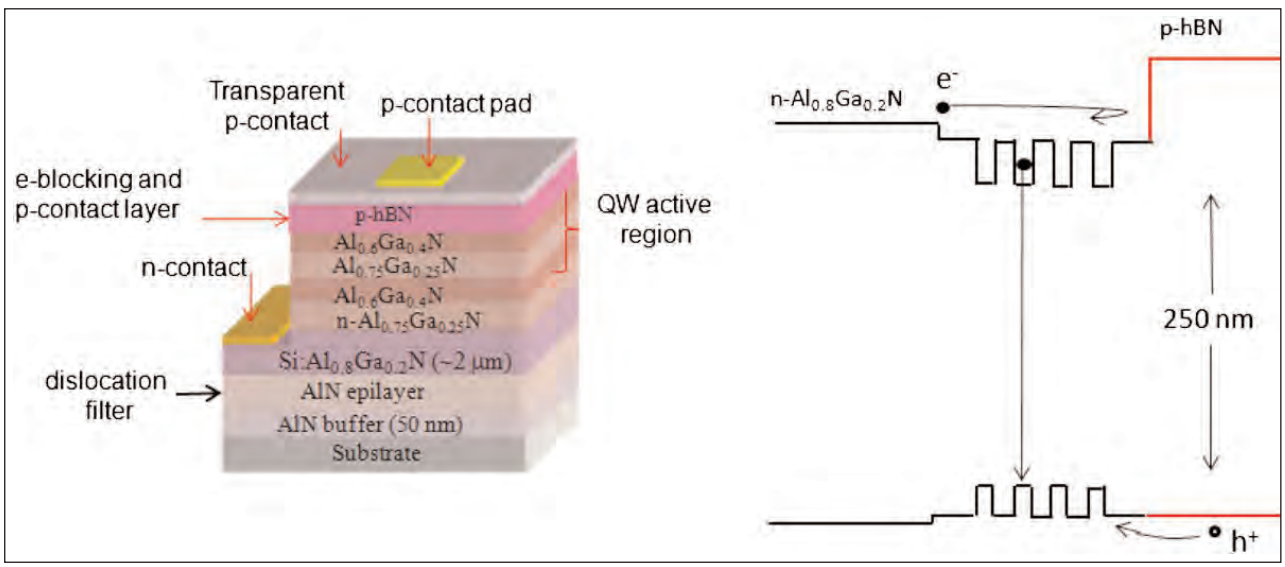

Figure 8. (a) Schematic of DUV LED layer structure proposed by Texas Tech. (b) Energy band diagram of DUV LED layer structure suggests a band alignment that blocks electrons from entering p-contact region, while posing little barrier to holes entering active region.

Optimizing ammonia-based MBE for gallium nitride electron mobility

University of California Santa Barbara and National Taiwan University have claimed the highest room-temperature bulk GaN mobility reported to date.

University of California Santa Barbara (UCSB) and National Taiwan University (NTU) have been optimizing ammonia-based molecular beam epitaxy (MBE) for gallium nitride (GaN) growth on a range of substrates [Erin C. H. Kyle et al, J. Appl. Phys., vol115, p193702, 2014].

The researchers claim their highest single-die electron mobility of 1265cm^2/Vs at 296K ('room temperature', RT) for films grown on low-threading-dislocation-density (TDD) free-standing (FS) GaN templates as "the highest RT bulk GaN electron mobility to date". To back up the claim, the paper quotes a number of results from other groups (Table 1).

The researchers used a Veeco Gen 930 molecular beam epitaxy system with an unheated showerhead injector for the delivery of purified ammonia (NH_3). The gallium, silicon and magnesium came from standard effusion cells.

The templates were isolated from the active region of the bulk GaN by a structure consisting of an intrinsic layer sandwiched between lightly and heavily Mg-doped p-type GaN regions (Figure 1). The isolation ensured that negligible current flowed through the template or re-growth interface. Heavily Mg-doped

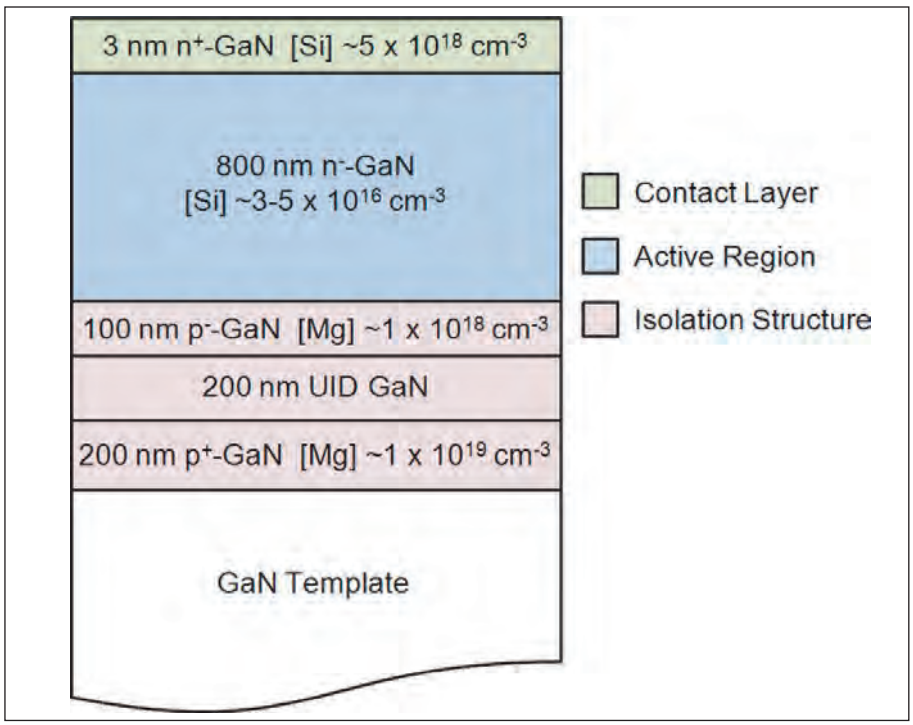

Figure 1. Schematic of UCSB / NTU growth structure.

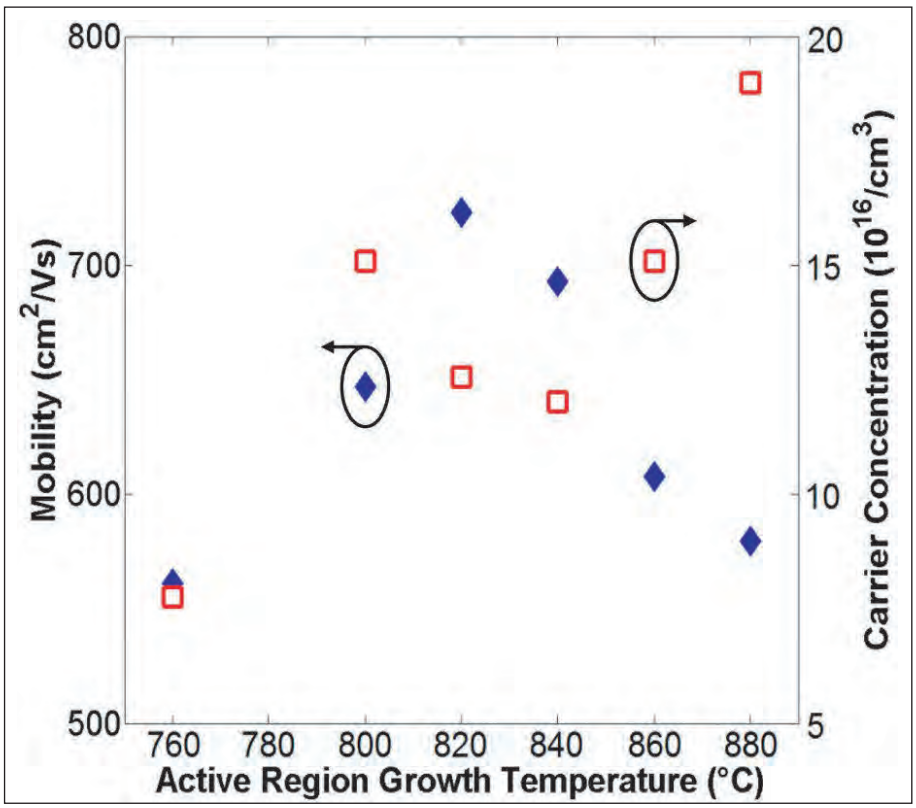

Figure 2. Average bulk electron mobility (solid blue diamonds) and average carrier concentration (red open

GaN tends to result in rough surfaces. The undoped and lightly doped top layers of the isolation gave a smooth surface for further growth.

The bulk of the structure consisted of lightly Si-doped n-type GaN with a final layer of heavily doped material "to facilitate the formation of high-quality low-resistance ohmic contacts".

The growth was optimized with respect to temperature (760–880°C) and Si-doping concentration (~$3x10^{16}$ – ~$2x10^{20}$/cm^3). Lumilog provided the semi-insulating iron-doped GaN:Fe on sapphire templates. The ammonia flow rate during optimization was 200 standard cubic centimeters (SCCM), giving a growth rate of 7.4nm/minute. The highest mobility of more than 700cm^2/V-s occurred in 820°C growth (Figure 2). The optimum silicon doping was found to be ~$3x10^{16}$/cm^3 (Figure 3). Mobility decreases with increased doping, while some doping is needed to make an ohmic contact with metal electrodes.

Further experiments (Table 2) involved growth on a variety of templates where the ammonia flow rate was 200 or 1000 (SCCM) with the aim of quantifying the effects of TDDs. Naturally, the highest-mobility results came from using free-standing GaN templates with low TDDs. The researchers carried out a wide range of experimental and theoretical analyses to explore the impact of TDDs on the electrical performance of the GaN film. ■

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Table 1. Room-temperature mobility of GaN grown by a variety of methods by different groups.

Method	Mobility (cm^2/V-s)	Year
HVPE	1245	2001
MOCVD	1005	2006
Ammonothermal	265	2007
N-rich PAMBE	1150	2007
Ga-rich PAMBE	1191	2000
NH_3-MBE	560	1999
UCSB/NTU	**1265**	**2014**

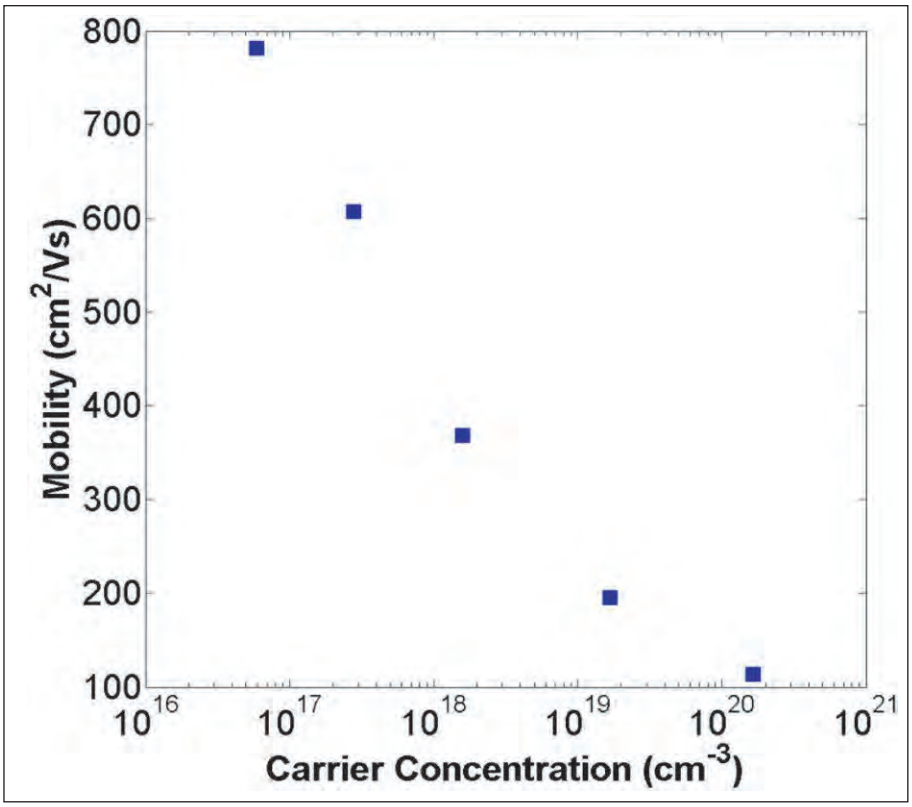

Figure 3. Effect of carrier concentration on electron mobility for GaN grown with optimized growth conditions.

Table 2. Single-die Hall measurements for 200SCCM and 100SCCM ammonia flow TDD series. Full-width at half maximum (FWHM) is for ω-scan x-ray diffraction from GaN (20$\bar{2}$1) planes.

TDD-200 Series

TDD (/cm^2)	RT mobility (cm^2/Vs)	RT carrier concentration (/cm^3)	Highest mobility (cm^2/Vs)	Highest mobility temp. (K)	FWHM (arcsec)
~$3x10^7$	1256	$4.48x10^{16}$	2948	116	225
~$5x10^8$	961	$3.50x10^{16}$	2396	115	382
~$5x10^9$	204	$4.9x10^{16}$	343	154	739

TDD-1000 Series

TDD (/cm^2)	RT mobility (cm^2/Vs)	RT carrier concentration (/cm^3)	Highest mobility (cm^2/Vs)	Highest mobility temp. (K)	FWHM (arcsec)
~$2x10^6$	1265	$3.73x10^{16}$	3327	113	90
~$5x10^8$	966	$2.09x10^{16}$	2637	112	375
~$2x10^{10}$	317	$1.33x10^{17}$	348	212	1370

Polarization-engineered high mobility of two-dimensional hole gas in GaN

P-channel heterostructure field-effect transistor with 10^8 on/off ratio shows great potential for complementary logic in harsh environments.

Researchers in Germany have developed two-dimensional hole gas (2DHG) gallium nitride (GaN) channel structures with record mobility [B Reuters et al, J. Phys. D: Appl. Phys., vol47, p175103, 2014]. Mobility for 2DHGs in GaN is usually around 10cm^2/V-s. Two-dimensional electron gas (2DEG) mobility is much higher, at around 1000cm^2/V-s.

The research by RWTH Aachen University, Forschungszentrum Jülich GmbH, Jülich Aachen Research Alliance (JARA)-Fundamentals of Future Information Technologies, and Aixtron SE resulted in one sample with a 2DHG mobility as high as 43cm^2/V-s.

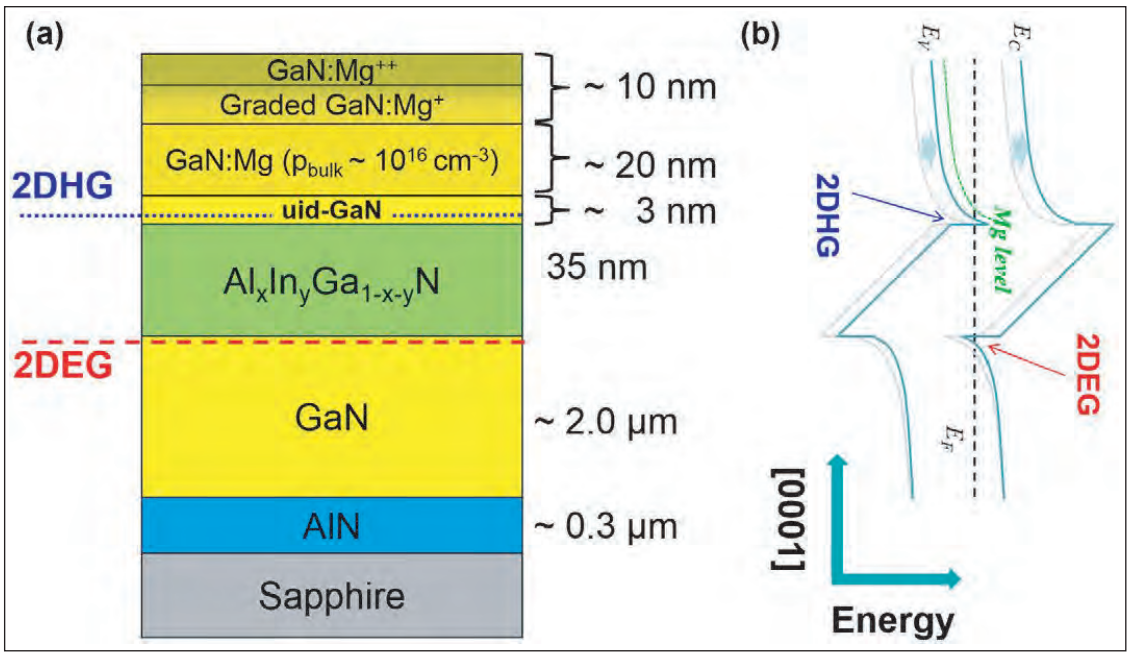

Figure 1. (a) Schematic of nitride semiconductor stack grown by MOVPE. (b) Corresponding schematic of band structure.

The researchers also produced p-type heterostructure field-effect transistors (p-HFET). Some of these devices demonstrated depletion-mode (normally on) operation. Other devices worked in enhancement mode, giving normally-off behavior that is desired for low power consumption.

Producing p-type hole conductivity in nitride semiconductors is inhibited by background impurities such as silicon or oxygen that act as donors in GaN, meaning that unintentionally doped material is n-type.

The researchers in Germany used an aluminium indium gallium nitride (AlInGaN) back-barrier and magnesium doped bulk p-GaN above the unintentionally doped channel layer. By varying the composition of the back-barrier, different polarization fields could be set up, allowing 2DHGs with different properties to be realized. The upper p-GaN layers were designed to compensate for the typical n-type behavior of the unintentionally doped (uid) GaN channel layer.

The epitaxial structures (Figure 1) were grown on 2-inch c-plane sapphire in an Aixtron horizontal-flow metal-organic vapor phase epitaxy reactor. The surface temperature and growth rate were carefully controlled using spectroscopic measurements over the wavelength range 276–775nm from a LayTec tool, in combination with true-temperature pyrometer data.

Five samples were produced with various AlInGaN compositions for the back-barrier. The composition variation was created through different growth temperatures and trimethyl-Al/Ga precursor flow ratios. The aim was to achieve different spontaneous and piezoelectric (strain-dependent) polarizations, giving control over the contrast with GaN (Table 1).

The more heavily doped p^{++}-GaN surface layer was aimed at ohmic contact formation. The magnesium acceptors were activated with a 20-minute 700°C anneal process in nitrogen.

Test structures, including a heterostructure field-effect transistor (HFET), were produced with annealed nickel/gold ohmic contacts, molybdenum Schottky gates, and gate and access region recessing through the surface p^{++}-GaN and graded p^{+}-GaN layers with a digital etch process. The gate recessing reduced gate leakage by about four orders of magnitude, according to the researchers.

Hall measurements gave 2DHG densities of between $2x10^{13}/cm^2$ and $6x10^{11}/cm^2$. A record hole mobility of $43cm^2/V\text{-}s$ was achieved for sample C at $1.3x10^{12}/cm^2$ carrier density. However, sample C also suffered from a wider spread of results compared to the other samples. Overall, sample C had a median mobility of $30cm^2/V\text{-}s$ and $2.2x10^{12}/cm^2$ carrier density.

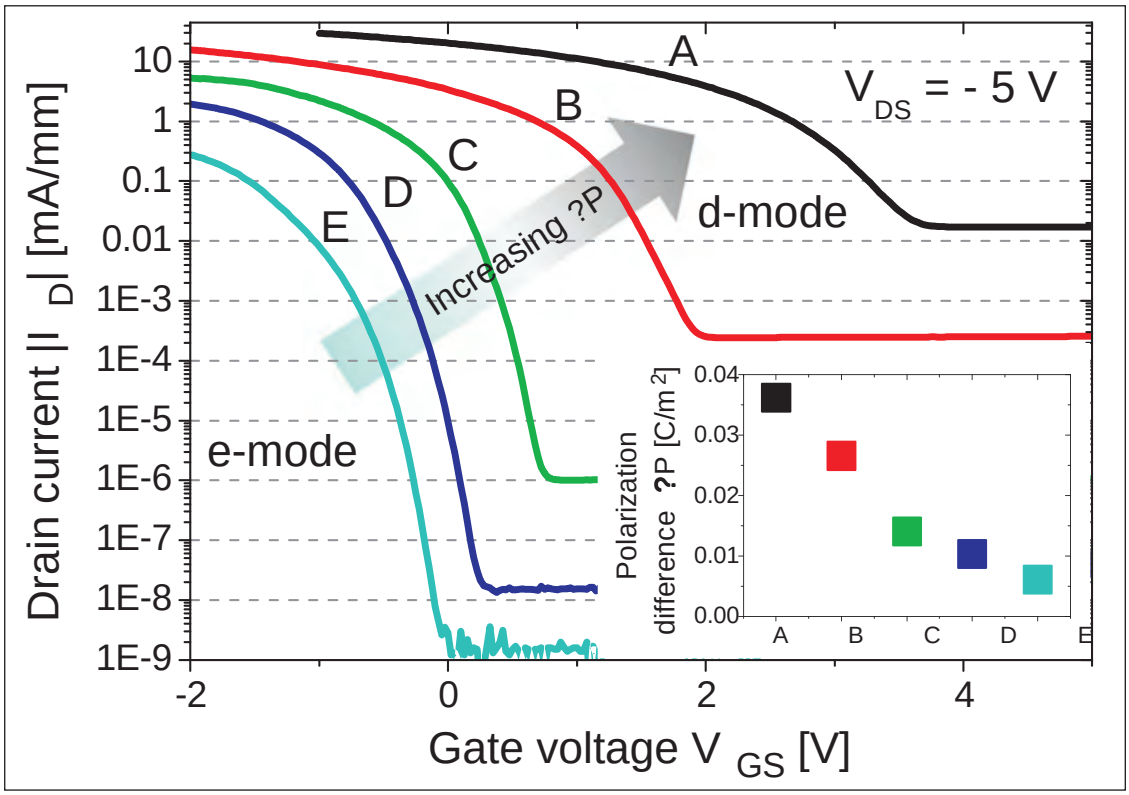

Figure 2. Absolute drain current versus gate voltage. Threshold voltage shifts from negative values (enhancement-mode) to positive values (depletion-mode) with increasing ΔP. Inset: calculated ΔP values for each sample.

HFETs with 1µm gate length and 7nm recess were fabricated. Sample A produced HFETs with depletion-mode/normally-on behavior.

The drain current reached more than 40mA/mm for a negative gate potential of –3V and drain bias 10V. A positive gate potential of 3.5V gave an off-current of 0.01mA/mm, resulting in an on/off ratio of more than 1000. Higher drain currents of more than 100mA/mm have been achieved in 2DHG HFETs, but these devices have only achieved on/off ratios of around one order of magnitude.

The peak transconductance was 9mS/mm. Frequency measurements resulted in a cut-off frequency (f_T) of 206MHz and maximum oscillation (f_{max}) of 640MHz.

Enhancement-mode performance was achieved using sample E with a low polarization difference (Figure 2). The maximum drain current and peak transconductance at 5V drain bias were 0.7mA/mm and 0.2mS/mm. These low values were offset by an even greater reduction in off-current, giving an on/off ratio 10^8, "the best value ever published for p-channel transistors," according to the researchers.

The researchers say that the on/off performance of the enhancement-mode transistor shows "great potential of these devices for applications like complementary III-nitride logics for harsh environments". ■

http://iopscience.iop.org/0022-3727/47/17/175103

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Table 1. Sample identification with, respectively, growth surface temperature, precursor Al-to-Ga molar gas phase ratio, compositions determined by Rutherford backscattering spectrometry (RBS) and high-resolution x-ray diffraction (HRXRD), spontaneous and piezoelectric polarization, and polarization difference with GaN.

Sample	T_S(°C)	TMAl/TMGa ratio	Al (%)	In (%)	Ga (%)	$-P_{sp}$ (C/m²)	$-P_{pz}$ (C/m²)	ΔP (C/m²)
A	820	2.4	54	4	52	0.058	0.012	0.036
B	815	1.2	42	3	55	0.052	0.009	0.027
C	807	0.6	25	2	73	0.044	0.004	0.014
D	798	0.4	20	2	78	0.041	0.003	0.010
E	793	0.2	14	2	84	0.039	0.001	0.006

Stress bumps improve nitride semiconductor packaged transistor performance

Flip-chip technology has been used to introduce strain-enhancement for the first time, according to researchers.

Researchers in Taiwan claim to be the first to use bumping technology to create piezoelectric-induced performance enhancement in flip-chip packaged aluminium gallium nitride (AlGaN) high-electron-mobility transistors (HEMTs) [Szu-Ping Tsai et al, IEEE Electron Device Letters, published online 29 May 2014]. Such HEMTs are being developed for high-power switching devices for automotive, cell-phone base-station system and phased-array radar applications.

AlGaN HEMTs depend on the polarization fields in the buffer GaN and barrier AlGaN to create the two-dimensional electron gas (2DEG) channel in the buffer near the barrier. These polarization fields arise as a result of the ionic nature of the bonds between the elements in the compound. The nature of the polarization field is affected by the stress state of the material, giving opportunity to improve performance through piezoelectric effects.

Some researchers have used external means to produce strain in nitride semiconductor HEMTs to enhance performance, but the team based at National Chiao Tung University and Yuan Ze University decided to use the bumping process that is used in flip-chip packaging as a means to introduce stress.

Six different bump patterns were designed on AlN substrates (Figure 1) consisting of electroplated gold. Various forms of bump were used: circular cylinders of 25μm and/or 10μm radius and 25μm height, and/or various rectangular bumps. The 'optimized' design (Figure 1f) used six rectangular bumps on the source fingers, giving a 500μm length and 18μm width.

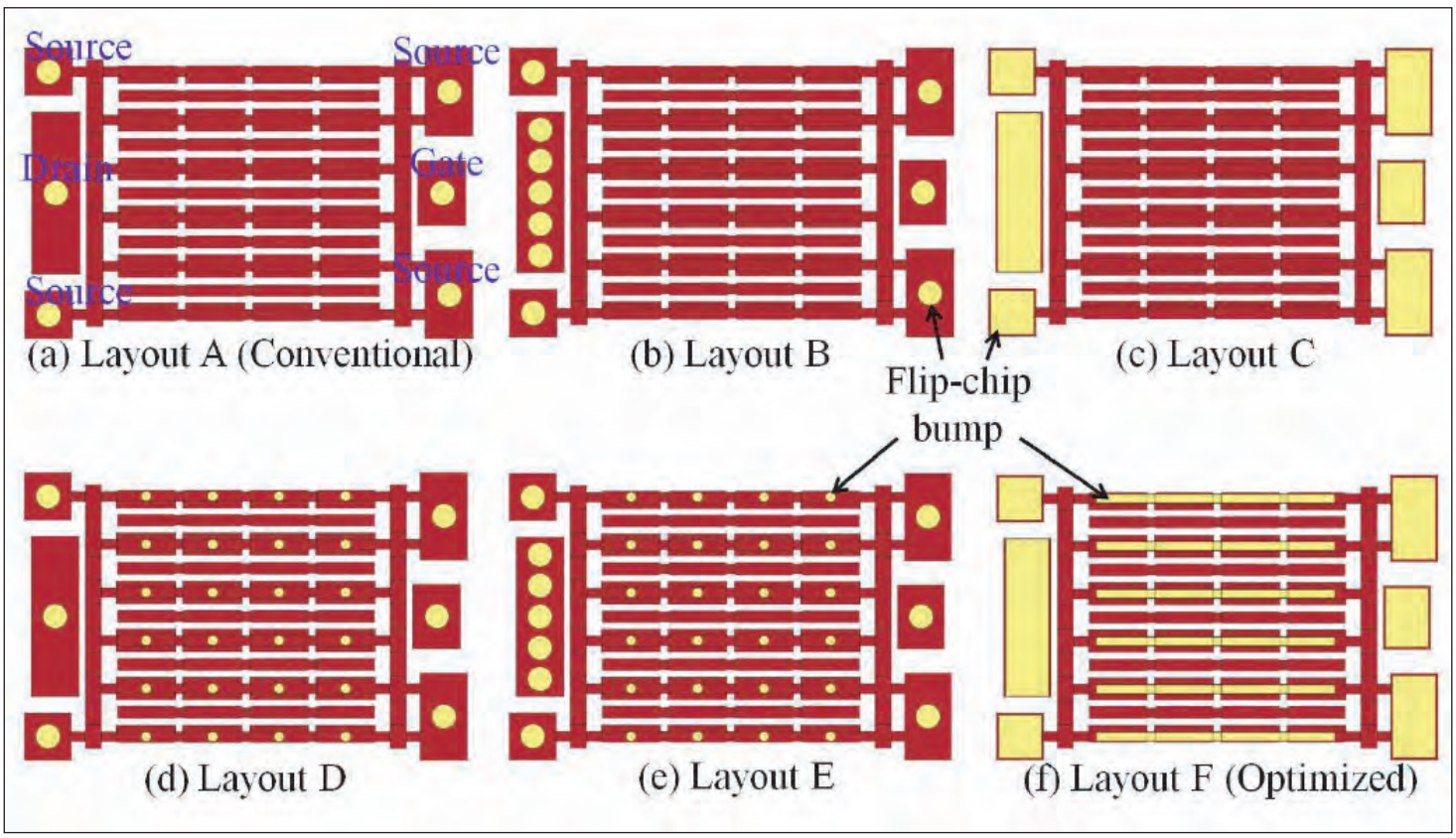

Figure 1. Layouts of six different bump patterns on AlN substrate.

The optimized design also had rectangular bumps covering the contact regions of the device.

The researchers comment: "These bump patterns were designed to induce increasing levels of tensile stress, with the optimized case giving the highest strain, as verified through numerical simulations."

The stress was designed to arise in the thermal bonding process as a result of the different coefficients of thermal expansion of gold (14.2 parts per million/°C) and GaN (5.6ppm/°C).

The HEMT heterostructure was grown by metal-organic chemical vapor deposition (MOCVD) on 1000µm-thick silicon substrate. The heterostructure consisted of a 120nm AlN buffer, 5.5µm GaN channel, 25nm AlGaN barrier, and 4nm GaN cap. The transistors consisted of 10-finger structures with 2µm gate length and 500µm gate width.

In DC measurements, the maximum drain current of the bare 5mm die was 850mA. In flip-chip packaged form the drain current for the optimized case exceeded the DC-mode 1A limit of the Agilent B1505A power device analyzer. However, this result does not reveal the strain effect, since the improvement is largely due to the improved thermal dissipation of the packaged device through the flip-chip bumps compared with the bare die.

To separate out the strain effect, the researchers performed pulsed measurements to avoid self-heating (Figure 2). The current 'improvement' over the bare die ranged from –12.7% (i.e. worse than bare die) for the conventional bump layout to +4.3% for the optimized bump design — a range of 17 percentage points. Relative to the conventional bump packaged device, the optimized bumping scheme improved the current by 19.5% (104.3/(100–12.7) = 1.195).

The researchers also found a slight negative shift of threshold voltage (~3%) with optimized strain. This is attributed to the induced piezoelectric effect, which leads to an increase in the sheet carrier density. ■

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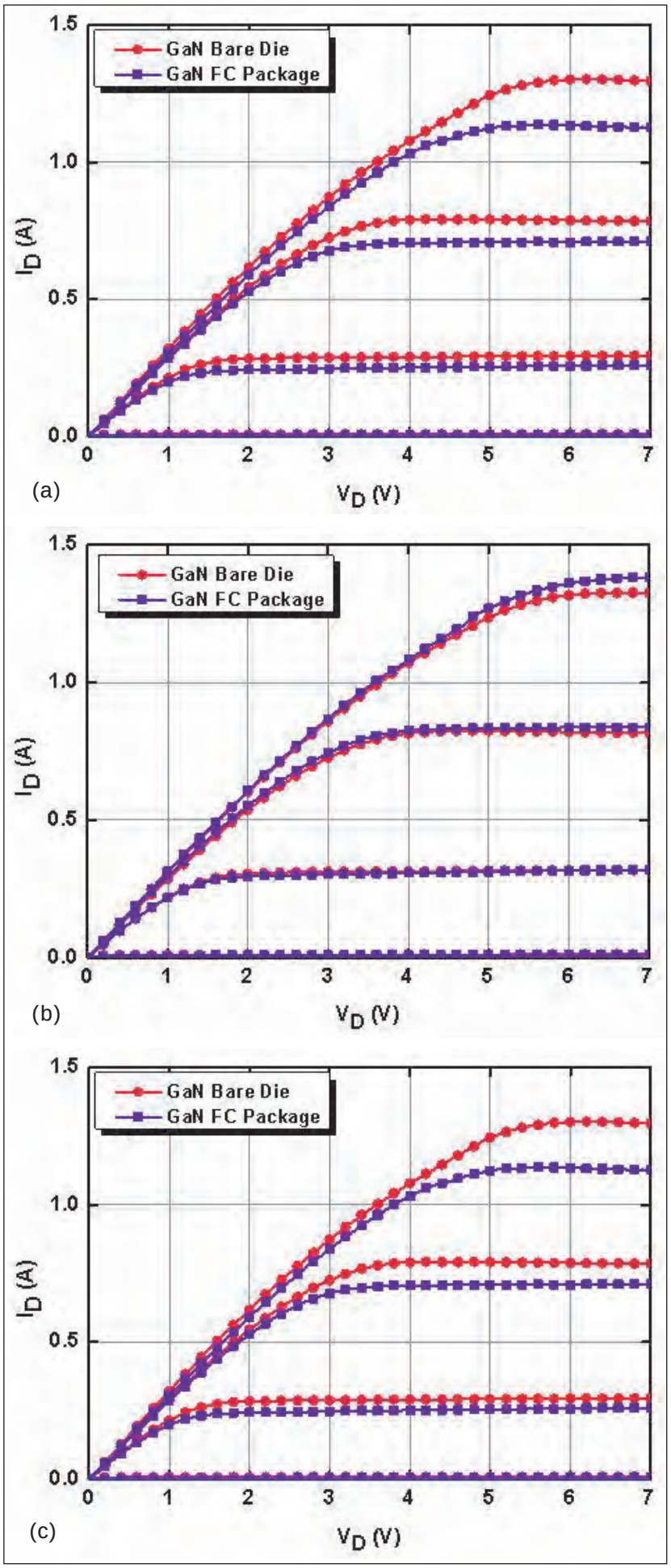


Figure 2. Pulsed measurements of drain current versus voltage for FC-bonded AlGaN/GaN HEMTs with (a) conventional bump pattern and (b) optimized bump pattern. (c) Improvements relative to bare die of maximum drain current for six different FC package bump layouts.

Nano-scale gallium oxide high-voltage transistor demonstration

Easy production of nanomembranes of wide-bandgap material motivates research towards integration into multiple platforms.

An international team of researchers has been exploring nanomembranes of beta-phase gallium oxide (β-Ga_2O_3) as a channel material for high-voltage field-effect transistors (FETs) [Wan Sik Hwang et al, Appl. Phys. Lett., vol104, p203111, 2014]. The researchers are variously associated with Korea Aerospace University, University of Notre Dame, USA, University of California Santa Barbara, USA, IBM T. J. Watson Research Center, USA, Leibniz Institute for Crystal Growth, Germany, and University of Parma, Italy.

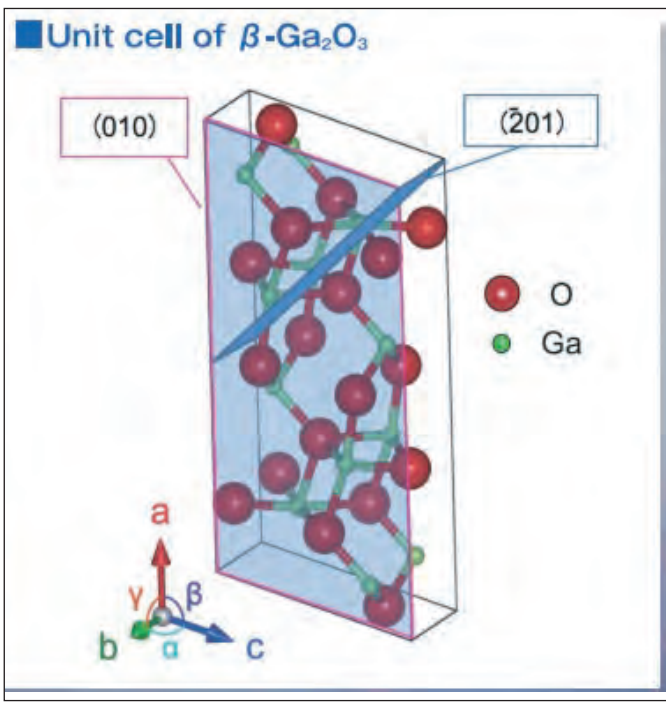
Bulk β-Ga_2O_3 has a wide bandgap energy of around 4.9eV, which should correspond to high critical fields for breakdown. This bandgap is even wider than those for materials such as silicon carbide (SiC ~3.3eV) or gallium nitride (GaN ~3.4eV) that are presently being developed for high-voltage and high-power applications.

The drawback of β-Ga_2O_3 for such applications is a low thermal conductivity of 13W/m-K, compared with 150W/m-K for Si, 150–200W/m-K for GaN, and 360–400W/m-K for SiC. For power devices, thermal management requires high thermal conductivities to enable efficient heat dissipation.

The research team believes that thin layers of β-Ga_2O_3 integrated with more thermally conductive substrates could overcome the heat dissipation problem. Such integration has been demonstrated for low-power electronics based on layered materials such as graphene and metal dichalcogenides such as molybdenum disulfide (MoS_2).

The researchers used a mechanical exfoliation technique to create nanomembranes of β-Ga_2O_3. Mechanical exfoliation with sticky tape applied to graphite is how graphene was first produced for characterization.

Although β-Ga_2O_3 does not have the layered structure of graphene that has strong in-plane covalent bonds and weak intra-plane van der Waals bonding, mechanical exfoliation nevertheless results in nanomembranes of thickness between 20nm and 100nm. The researchers suggest that, despite β-Ga_2O_3 technically being a three-dimensional crystal (Figure 1), the long



Characteristics

Crystal structure	Monoclinic a=12.23Å,b=3.04Å,c=5.8Å β=103.7°
Density	5.95×10³ kg/m³
Vickers hardness	(101): 9.7 GPa (2̄01): 12.5 GPa
Young's modulus	230 GPa
Melting point	1725°C
Thermal conductivity	[100]: 13.6 W/m · K [010]: 22.8 W/m · K
Specific heat capacity	0.49×10³ J/kg · K
Bandgap	4.8 ~ 4.9 eV
Refractive index	1.97 @450 nm

Figure 1. Crystal structure and properties from www.mtixtl.com/Ga2O3onAl2O3-101005S1-1.aspx

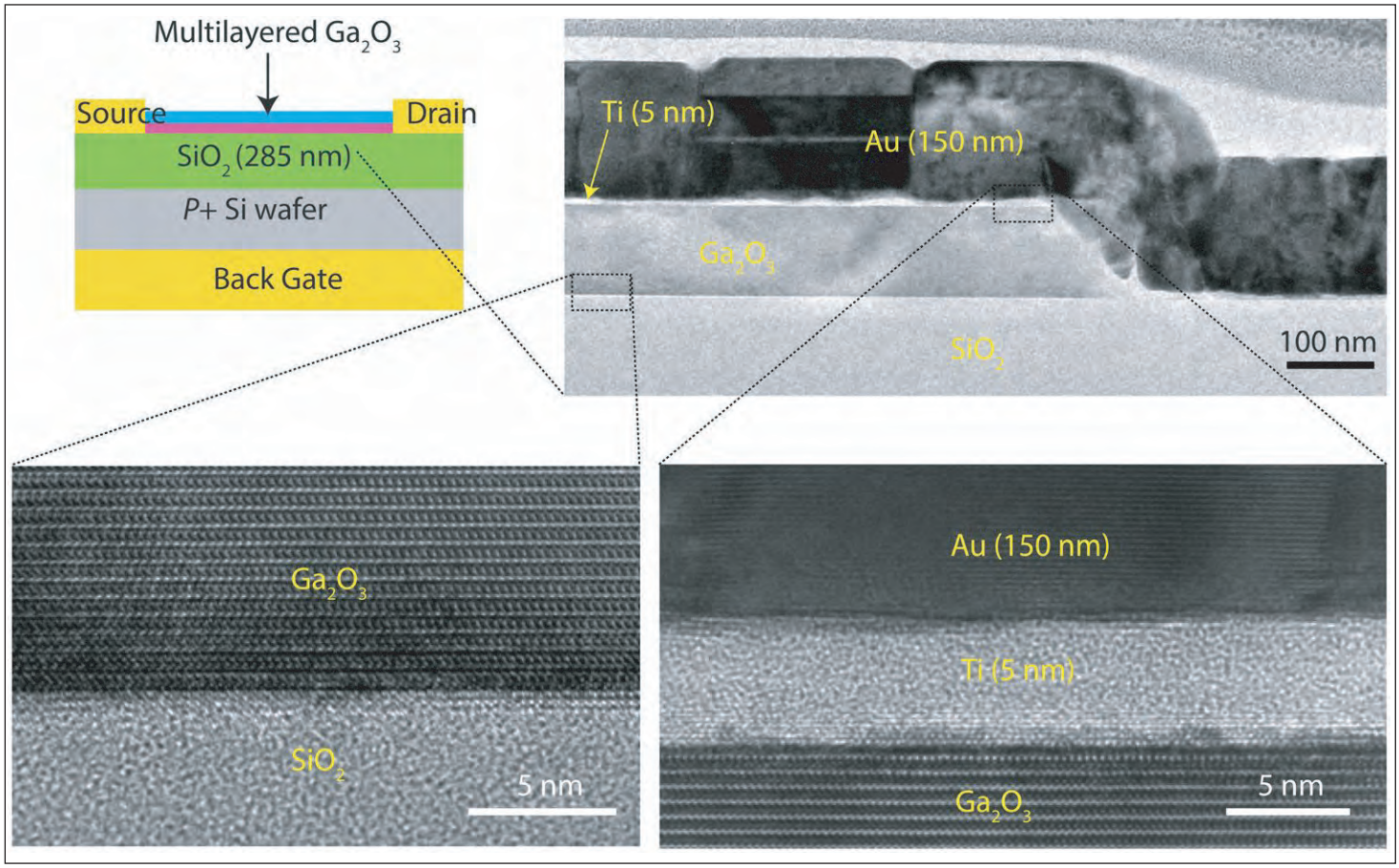


Figure 2. Cross-sectional TEM image of β-Ga_2O_3 FETs, showing a flat interface between β-Ga_2O_3 and the SiO_2 dielectrics as well as between the β-Ga_2O_3 and the Ti/Au electrode.

lattice constant in the (100) direction (a) leads to easier exfoliation than expected.

The researchers admit: "Mechanical exfoliation is indeed not a scalable method, but methods similar to smart-cut technology used in silicon-on-insulator (SOI) wafer manufacture can potentially enable controlled release of large nanomembranes of the wide-bandgap material. Such a method can potentially enable the integration of nanomembrane high-voltage transistors on multiple platforms for high-voltage switching and power management."

The 20mm-diameter single crystals of β-Ga_2O_3were produced by the Czochralski process of slowly drawing the crystal out of a melt in an iridium crucible. The melting point of β-Ga_2O_3 is 1820°C. The crystal growth was carried out in a dynamically adjusted atmosphere designed to reduce decomposition of the Ga_2O_3 while avoiding oxidation of the iridium crucible.

The researchers produced 1cm-side cubes of β-Ga_2O_3 crystal with exposed (100) planes for exfoliation and easy cleaving. Hall measurements in the Van der Pauw configuration with indium/gallium contacts gave a free-electron concentration of $5.5x10^{17}/cm^3$, mobility of $112cm^2/V\text{-}s$, and resistivity of 0.1Ω-cm.

Energy-dispersive x-ray analysis gave an optical bandgap of 4.77eV for the nanomembrane material. Band-structure calculations suggest an indirect bandgap of 4.85eV, with a slightly larger direct gap of 4.88eV at the Γ-point (k=0). The conduction-band minimum is at Γ with an almost isotropic effective mass of 0.28x the free-space mass. The valence-band maximum is located along the I–L line.

The transistor structure (Figure 2) used a back-gate. The exfoliated Ga_2O_3 nanomembrane was transferred to a thermal silicon dioxide layer on a silicon substrate. The source/drain electrodes consisted of titanium/gold annealed at 300°C for three hours in an argon/hydrogen environment. Transmission electron micrography (TEM) was used to confirm that the lattice parameters of the nanomembrane were unchanged from the bulk values "indicating minimal strain and damage in the transfer and device fabrication process". In particular, the material was unstrained in the channel, under the source/drain contacts, and at the interface with the underlying silicon dioxide.

With a high 20V drain bias, the gate was able to modulate the current by a factor of ~10^7 at room temperature. The limiting factor for the on/off current range was not the channel, but rather gate leakage. The extrinsic field-effect mobility (uncorrected for contact resistance of ~55Ω-mm) was $70cm^2/V\text{-}s$. The real 'intrinsic' mobility of the device is expected to be nearer the bulk value at ~$130cm^2/V\text{-}s$.

Although the subthreshold swing of 200mV/decade is

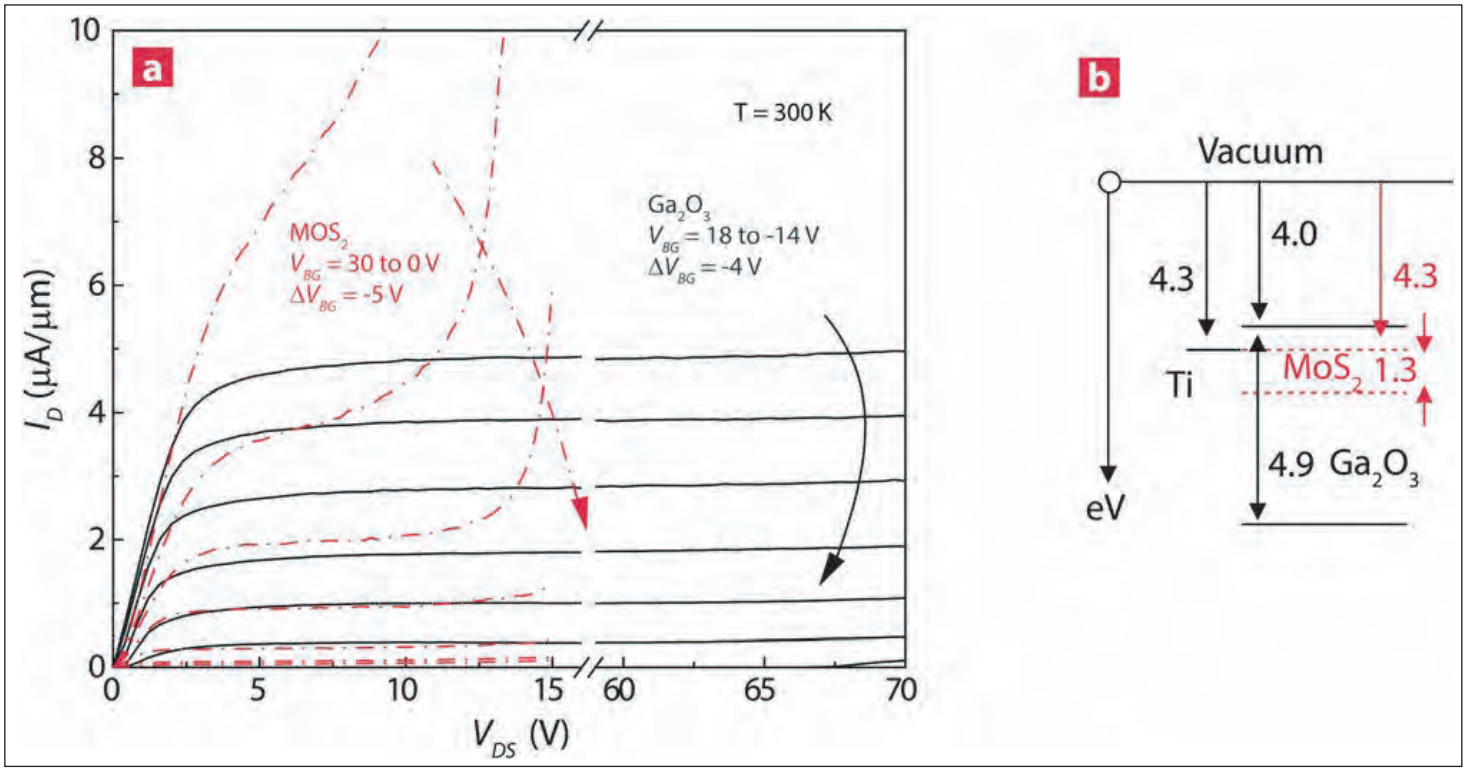


Figure 3. (a) Common-source transistor characteristics, drain current versus drain bias in linear region and current saturation under high drain bias, and comparison of breakdown voltage of β-Ga_2O_3 and MoS_2. Device widths/lengths of 1/3μm. (b) Band diagram of β-Ga_2O_3 compared with MoS_2, indicating formation of Schottky barrier contact between metal and β-Ga_2O_3.

far from the ideal 60mV/decade, the researchers comment that the value is "encouraging", given the unoptimized interfaces and the thick silicon dioxide back-gate dielectric layer. The device has an unintentional n-type (negative electron charge carriers) behavior. This could be due to atomic defects and/or impurities.

The researchers believe that the relatively high contact resistance could be improved by using metals with low workfunction or by ion implantation of dopants under the contacts. The present contact resistance performance is comparable to that obtained with MoS_2 transistors. While MoS_2 transistors tend to suffer avalanche breakdown at around 15V (Figure 3), Ga_2O_3 transistors "maintain a robust current saturation up to 70V with no signs of output conductance".

The researchers add: "This result shows that nanomembrane β-Ga_2O_3 channel transistors can sustain and switch high voltages even when integrated in thin layer forms on foreign substrates. High thermal conductivity but electrically insulating layers such as AlN or BN can be used to help circumvent the low thermal conductivity of the β-Ga_2O_3 channel. The high-thermal-conductivity insulating layers can also serve as the gate insulator for the transistor." ■

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95873 Bezons Cedex,
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www.riber.com

SVT Associates Inc
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Eden Prairie, MN 55344,
USA
Tel: +1 952 934 2100
Fax: +1 952 934 2737
www.svta.com

Temescal, a part of Ferrotec
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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
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www.logitech.uk.com
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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.

PLANSEE High Performance Materials
6600 Reutte, Austria
Tel: +43 5672 600 0
Fax: +43 5672 600 500
E-mail info@plansee.com
www.plansee.com

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,
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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.

Optical Reference Systems Ltd
OpTIC Technium,
St Asaph Business Park,
St Asaph, LL17 0JD, UK
Tel: +44 (0)1745 535 188
Fax: +44 (0)1745 535 186
www.ors-ltd.com

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)

Williams Advanced Materials
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

PLANSEE High Performance Materials
6600 Reutte, Austria
Tel: +43 5672 600 0
Fax: +43 5672 600 500
E-mail info@plansee.com
www.plansee.com

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

7–10 September 2014
24th IEEE Semiconductor Laser Conference (ISLC)
Meliá Palas Atenea, Palma de Mallorca, Spain
E-mail: m.figueroa@ieee.org
www.islc-ieee.org

7–11 September 2014
8th International Workshop on Zinc Oxide and Related Materials (IWZnO 2014)
Sheraton on the Falls Hotel, Niagara Falls, Ontario, Canada
E-mail: kriss@mrs.org
www.mrs.org/IWZnO-2014

7–12 September 2014
18th International Conference on Molecular Beam Epitaxy (MBE 2014)
Flagstaff, AZ, USA
E-mail: della@avs.org
www2.avs.org/conferences/MBE2

16–18 September 2014
The LED Show
Los Angeles Convention Center, CA, USA
E-mail: registration@pennwell.com
www.theledshow.com

21–25 September 2014
40th European Conference on Optical Communication (ECOC 2014)
Cannes, France
E-mail: contact@ecoc2014.org
www.ecoc2014.org

22–24 September 2014
LEDs and the SSL Ecosystem 2014: Lighting in the Information Age
Hyatt Cambridge in Cambridge, MA, USA
E-mail: jcarter@smithers.com
www.ledsconference.com

22–25 September 2014
SPIE Security+Defence 2014
Amsterdam RAI Exhibition and Convention Centre, The Netherlands
E-mail: info@spieeurope.org
http://spie.org/security-defence-europe.xml

5–9 October 2014
Mid-IR Optoelectronics: Materials and Devices (MIOMD-XII)
CORUM convention center, Montpellier, France
E-mail: miomd2014@miomd2014.org
www.miomd2014.org

5–10 October 2014
226th Electrochemical Society (ECS) Meeting
Moon Palace Resort, Cancun, Mexico
E-mail: meetings@electrochem.org
www.electrochem.org/meetings/biannual/fut_mtgs.htm

7–9 October 2014
SEMICON Europa
Alpexpo, Grenoble, France
E-mail: eweller@semi.org
www.semiconeuropa.org

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7–9 October 2014
Solar Power International (SPI '14)
Las Vegas Convention Center
E-mail: plangdon@solarenergytradeshows.com
www.solarpowerinternational.com

8–9 October 2014
Power Electronics Conference: the ultimate path to CO_2 reduction
ALPEXPO, Grenoble, France
E-mail: eweller@semi.org
www.semiconeuropa.org/node/2586

9–10 October 2014
Invest in Photonics
Bordeaux, France
E-mail: pitch@invest-in-photonics.com
www.invest-in-photonics.com

12–15 October 2014
23rd European Workshop on Heterostructure Technology (HeTech2014)
Justus Liebig University Giessen, Germany
E-mail: info@hetech2014.org
www.hetech2014.org

12–16 October 2014
27th IEEE Photonics Conference (IPC 2014)
Hyatt Regency La Jolla, San Diego, CA, USA
E-mail: i.donnelly@ieee.org
www.ipc-ieee.org

15–17 October 2014
LED Japan/Strategies in Light
Pacifico Yokohama, Japan
E-mail: registration@pennwell.com
www.sil-ledjapan.com

21–23 October 2014
Strategies in Light Europe
M.O.C. Event Centre, Munich, Germany
E-mail: registration@pennwell.com
www.sileurope.com

11–13 November 2014
Avionics Fiber-Optics and Photonics Conference 2014 (AVFOP)
Hyatt Regency Atlanta, Georgia, USA
E-mail: m.figueroa@ieee.org
www.avfop-ieee.org

3–5 December 2014
SEMICON Japan 2014
Tokyo Big Sight, Japan
E-mail: jeventinfo@semi.org
www.semiconjapan.org

15–17 December 2014
IEEE International Electron Devices Meeting (IEDM 2014)
Hilton San Francisco, CA, USA
E-mail: iedm@his.com
www.ieee-iedm.org

4–6 February 2015
SEMICON Korea 2015
COEX, Seoul, Korea
E-mail: semiconkorea@semi.org
www.semiconkorea.org

7–12 February 2015
SPIE Photonics West 2015
Moscone Center San Francisco, CA, USA
E-mail: customerservice@spie.org
http://spie.org/photonics-west.xml

24–26 February 2015
Strategies in Light
Sands Expo & Convention Center, Las Vegas, NV, USA
E-mail: registration@pennwell.com
www.strategiesinlight.com

2–5 March 2015
LED China 2015
Pazhou, Guangzhou, China
E-mail: led-trust@ubm.com
www.LEDChina-gz.com

17–19 March 2015
SEMICON China 2015
Shanghai New International Expo Centre, China
E-mail: semichina@semi.org
www.semiconchina.org

13–15 April 2015
CPV-11 (11th International Conference on Concentrator Photovoltaics)
Aix-les-Bains, France
E-mail: info@cpv-11.org
www.cpv-11.org

13–16 April 2015
SPIE Optics + Optoelectronics 2015
Clarion Congress Hotel, Prague, Czech Republic
E-mail: info@spieeurope.org
http://spie.org/optics-optoelectronics.xml

20–25 April 2015
SPIE DSS 2015 (SPIE Defense + Security andSPIE Sensing Technology + Applications)
Baltimore Convention Center, Maryland, USA
E-mail: customerservice@spie.org
http://spie.org/defense-security-sensing.xml

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