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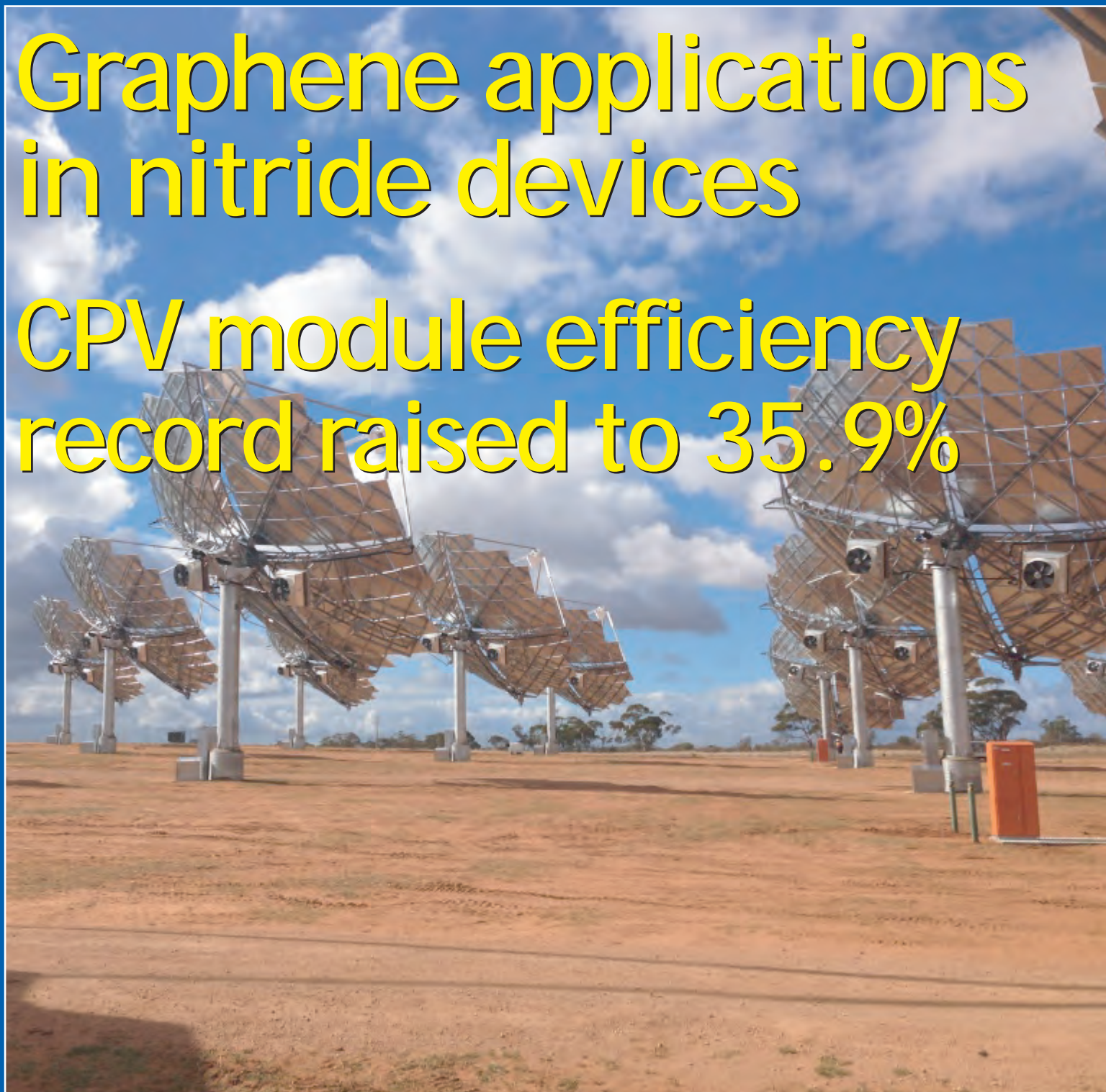
C O M P O U N D S & A D V A N C E D S I L I C O N

Vol. 8 • Issue 6 • July/August 2013

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Graphene applications in nitride devices

CPV module efficiency record raised to 35.9%



TriQuint buys CAP Wireless • Veeco launches GENxplor MBE tool
JDSU raises \$636m • Cree licenses patents to Transphorm

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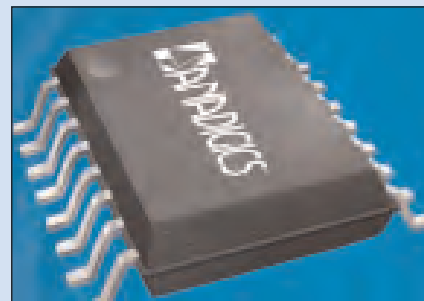
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COMPOUNDS & ADVANCED SILICON

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p10 Anadigics' new ACA2429 GaN power doubler, reckoned to be the first 1.2GHz surface-mount line amplifier.



p28 Veeco's new GENxplor MBE system, a fully-integrated MBE system for compound semiconductor R&D.



p46 Osram Opto's new RGB MultiLED has a wide blue color range, giving automotive lighting designers a wide choice of colors for ambient lighting.



Cover: Sillex's utility-scale solar power technology subsidiary Solar Systems Australia has opened its 1.5MW Mildura Solar Demonstration Facility, Australia's largest concentrated photovoltaic (CPV) power plant.

p58

LED oversupply declining, but still to be 40% in 2016

In this issue, the feature article (pages 74–75) focuses on the applications of graphene in semiconductor devices, for example as a transparent conducting layer for improving current spreading and efficiency in nitride light-emitting diodes, as an alternative to the incumbent indium tin oxide (ITO) which cuts off light transmission in the ultraviolet.

In addition, pages 68–69 reports work in China on improving deep UV LED performance by using nanopatterned sapphire substrates to improve the overlying aluminium gallium nitride material quality. The articles on pages 70–71 and 72–73 also demonstrate how patterning and shaping of both the substrate and epitaxial layers can improve nitride LED performance.

Apart from technical developments, LED markets are also picking up, as evidenced by sapphire substrate maker Rubicon Technology reporting 28% revenue growth in second-quarter 2013 (including six-fold growth in 2" and 4" core products), driven by "the strengthening LED market" (specifically the general lighting segment). Indeed, despite the increase in shipments, sapphire pricing has risen for the first time in two years (by 10% for 2" and 4" core products in Q2/2013), the firm reports.

On page 7, market analyst firm Lux Research forecasts that the market for epitaxial wafers will reach \$4bn in 2020 as the LED lighting industry grows to \$80bn. Significantly, it reckons that GaN-on-sapphire will remain the dominant technology, with GaN-on-silicon taking just 10% market share.

Meanwhile, market research firm Displaybank forecasts that demand for MOCVD precursor materials for LED manufacturing will more than double between 2012 and 2016, citing the "rising operating rate of MOCVD as the LED lighting market grows" (page 7). Shipments of MOCVD equipment are expected to rise by 17% in 2013, with the largest buyers (South Korea, Taiwan and China) accounting for about 80% of precursor demand.

This is supported on pages 66–67 by a forecast by trade association SEMI that "following declines of 45% in 2011 and 30% in 2012, LED wafer fab equipment spending will rise 17% to nearly \$1.2bn in 2014 as the LED industry is working through its over-capacity problems and will renew capital spending and capacity increases in 2014". Geographically, China will rise from 33% of global spending in 2013 to 44% in 2014, it adds.

The early stages of such trends are being seen perhaps by MOCVD system makers Aixtron and Veeco in their Q2/2013 revenues and orders (see pages 30–31 and 27–28, respectively). Compared with Q1, Aixtron's revenue rebounded by 13%, citing "rising rates of capacity utilization at leading LED manufacturers" amid a "continued reduction of production overcapacities". Veeco's MOCVD orders rose 40%, aided by winning "important deals in Korea, Taiwan and China", adding that "utilization rates at many of our key LED customers [in Asia] are high and stable: 80%, 90% or even 100%... LED lighting is ramping". However, it notes that some customers remain extremely cautious about capacity expansion, and that orders are still relatively weak.

This view is supported by market research firm IHS, which estimates that LED supply will exceed demand by 69% in both 2013 and 2014, and will decline to 61% in 2015, but that LED oversupply will still be 40% in 2016.

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Semiconductor Today covers the R&D and manufacturing of compound semiconductor and advanced silicon materials and devices

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

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

Semiconductor Today (ISSN 1752-2935) is published free of subscription charge

in a digital format 10 times per year by Juno Publishing and Media Solutions Ltd, Suite no. 133, 20 Winchcombe Street, Cheltenham GL52 2LY, UK. See: www.semiconductor-today.com/subscribe.htm

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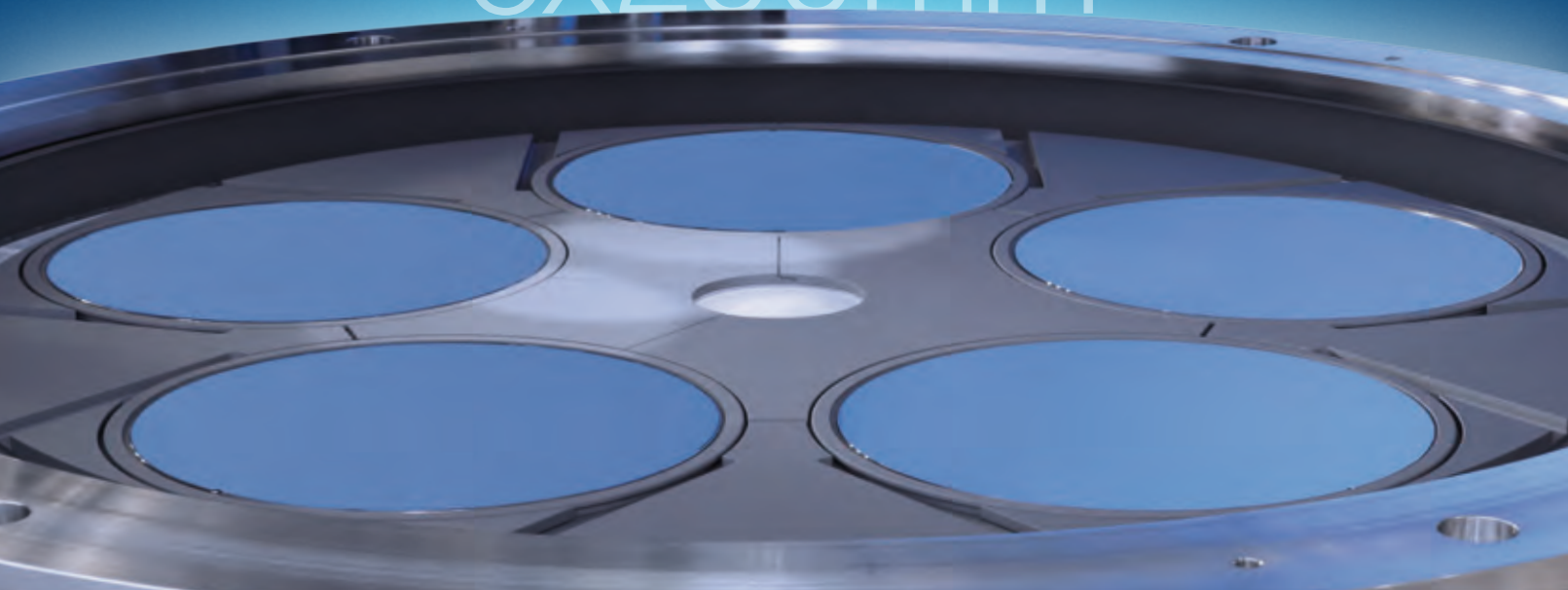
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LED oversupply to continue through 2016

Supply to exceed demand by 69% in 2013 and 2014, then decline to 61% in 2015 and 40% in 2016

Despite a major surplus in the light-emitting diode market, the top suppliers are increasing their capital spending and production because of government incentives and in order to cash in on an expected boom in the lighting business, says market research firm IHS.

Being essential for LED manufacturing, global shipments of metal-organic chemical vapor-deposition (MOCVD) systems are expected to rise by 17% in 2013, reckons Alice Tao, senior analyst, LEDs and lighting for IHS. This will be the first annual growth for the MOCVD market since 2011, and will represent a major turnaround from the 70% plunge of 2012 (see Figure 1).

At the same time that growth is being projected, factory utilization rates are increasing for major LED companies in Asia. In South Korea, for example, utilization rose to about 75% in second-quarter 2013, up from 60% in 2012. Meanwhile, utilization for some Taiwanese and Chinese firms reached 90% in Q2/2013.

The capital spending and boost in utilization rates alike are occurring despite a glut of supply that has plagued the market since 2010. The surplus began when LED suppliers made major investments in capacity in 2010 and 2011, stemming from local governments in China subsidizing MOCVD purchasing, notes IHS. Governments are helping to fund the procurement of MOCVD systems by up to 80% of the total price of the equipment.

Many of these companies are also increasing production in the belief that they can capitalize on upcoming rapid growth in the market for LEDs used in lighting, adds IHS. "The global market for LED lighting is expected to double during the

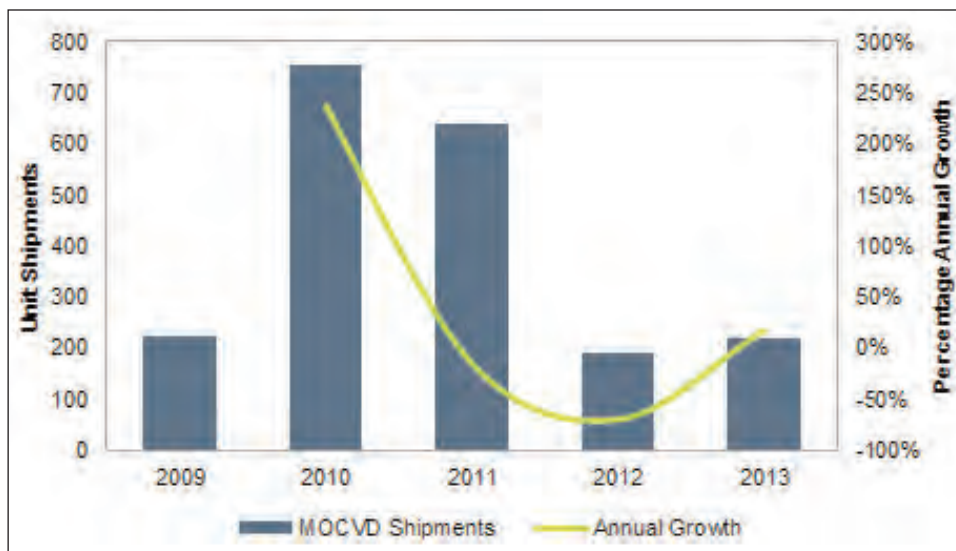


Figure 1. Global forecast of MOCVD shipments and annual growth.

next three years," notes Tao. "The prospect of this massive growth is irresistible to LED suppliers, who don't want to be caught short of supply during this expected boom. But, given the rising investments in manufacturing equipment, the acute LED oversupply already in existence is expected to continue through 2016."

Measured in terms of manufactured die, the supply of LEDs is expected to exceed demand by

69% in both 2013 and 2014 (see Figure 2). The glut will decline slightly to 61% in 2015 and then to 40% in 2016.

Market research firm IHS cites the major suppliers of LEDs as including San'an Optoelectronics and Elec-tech of China, Samsung and Seoul Semiconductor of South Korea, Epistar of Taiwan, Philips Lumileds of the USA, and Osram of Germany.

www.ihs.com

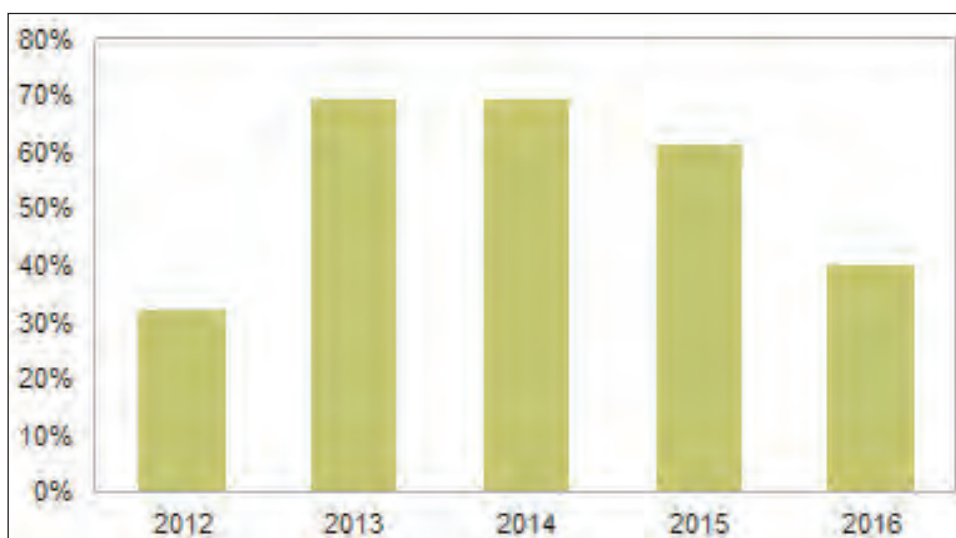


Figure 2. LED surplus (percentage of oversupply in terms of die manufactured).

Epiwafer market to reach \$4bn in 2020 as LED lighting industry grows to \$80bn

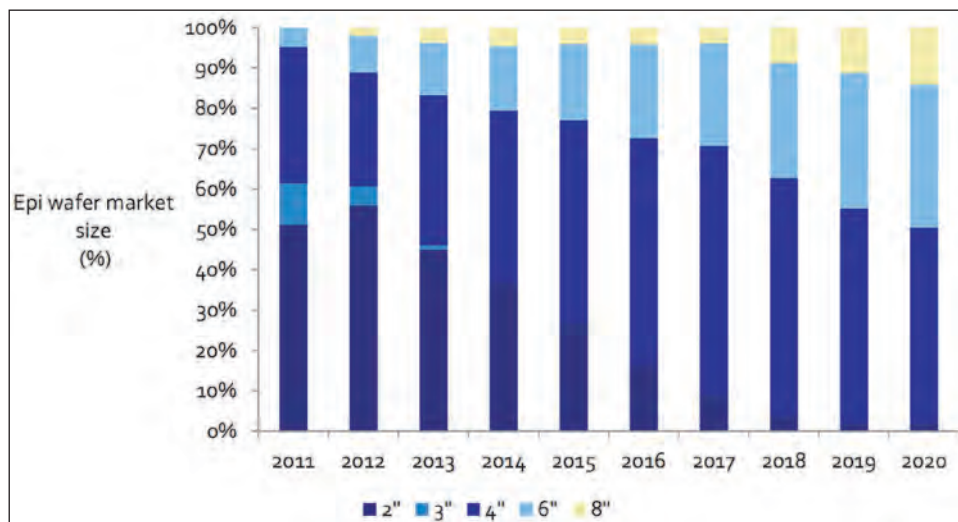
GaN-on-sapphire remains entrenched; GaN-on-Si to gain only 10% share

As LED lighting becomes an \$80bn industry, the market for the epitaxial wafers that LEDs are made from will grow to \$4bn in 2020, according to Lux Research.

The vast majority of these epi-wafers are currently gallium nitride (GaN)-on-sapphire. GaN-on-silicon (GaN-on-Si) is the leading emerging technology with a strong economic allure — silicon is just one-eighth the cost of a sapphire substrate — but technical challenges will limit it to only a 10% market share in 2020, it is forecast. GaN-on-silicon carbide (SiC), championed by Cree, will grow to 18% market share.

"Silicon is already widely used for electronics, and some LED die manufacturers are hoping to take advantage of silicon substrates," says analyst Pallavi Madakasira, lead author of the report 'Dimming the Hype: GaN-on-Si Fails to Outshine Sapphire by 2020'. "But GaN-on-Si is more prone to cracking than GaN-on-sapphire, and mitigating this mismatch is expensive," she adds.

Lux Research analysts studied the market for GaN-on-sapphire, GaN-on-SiC, GaN-on-bulk GaN, and GaN-on-Si epiwafers, evaluating each technology's economic prospects as



Breakdown of epiwafer market size by wafer diameter, over 2011–2020.

the industry moves to larger wafer sizes. Among their findings:

- Choice and cost of LEDs will determine adoption. Where GaN-on-sapphire is suited to all applications, GaN-on-bulk GaN will be relegated to niche commercial lighting, and GaN-on-Si (with unproven performance) will be better suited to cost-sensitive residential applications.

- 4-inch wafers will rule, though 6-inch wafers start to come into vogue. 4-inch wafers will peak at 62% market share with \$2.1bn in sales in 2017. Later, the LED industry

will migrate to 6" epi wafers, which will take a 35% share (equivalent to \$1.4bn) in 2020.

- Technology will advance sapphire substrates. Sapphire substrate manufacturing technology has advanced significantly, with specialists such as Rubicon and Monocrystal demonstrating substrates up to 12" in diameter. New methods like hydride vapor phase epitaxy (HVPE) will further improve throughput and cut costs, keeping sapphire highly competitive for the rest of the decade.

www.luxresearchinc.com

MOCVD precursor demand for LEDs to more than double to 69 tons over 2012–2016

Demand for MOCVD precursor materials for making LEDs will more than double from 2012 to 2016 (rising by 114% from 32 tons to 69 tons), according to a report 'Precursor for LED MOCVD — Market and Industry Analysis' from Displaybank. This reflects the "rising operating rate of MOCVD as the LED lighting market grows".

Of the major precursors, which include trimethylgallium (TMGa), trimethylindium (TMIn), trimethyl

aluminum (TMA), triethylgallium (TEGa) and C₂Mg₂, TMGa commands about 94% of total demand.

Shipments of MOCVD equipment are expected to rise by 17% in 2013. The largest buyers — South Korea, Taiwan and China — account for about 80% of precursor demand. China, which is generating the highest growth in MOCVD system installations, is expected to make up 45% of global demand for precursors in 2016.

In the nascent stage of the LED market, Dow Chemical was the unrivaled leader in the precursor market. But, with recent growth in precursor demand, new players have been investing in R&D and manufacturing facilities while aggressively breaking into the market with low prices for similar-quality product, says the report. Such developments will intensify competition among precursor makers.

www.ihs.com

RFMD's quarterly revenue rises 45% year-on-year

Cellular growth of 56% driven by expanding dollar content in handsets

For its fiscal first-quarter 2014 (ended 29 June 2013), RF Micro Devices Inc of Greensboro, NC, USA has reported record revenue of \$293m, up 4.4% on \$280.6m on last quarter and up 44.5% on \$202.7m a-year ago.

Cellular Products Group (CPG) revenue was \$237.7m, up 5.3% on last quarter's \$225.7m and up 55.8% year-on-year, led by nearly every major smart-phone, tablet and handset maker. CPG also benefited from entry-level smart-phone segment via participation in major reference designs and customer developments at Lenovo, Coolpad, Skycom and WaterWorld. Also, CPG's carrier aggregation switch portfolio was selected to enable the world's first LTE-Advanced handset.

Multi-Market Products Group (MPG) revenue was \$55.3m, up 1% on last quarter's \$54.9m and up 10.4% year-on-year. Broad-based sequential growth spanned markets including Wi-Fi, power broadband and high-reliability applications. Year-on-year, high-performance Wi-Fi grew 77%. WiFi growth was previously led by mobile devices, but this quarter was driven by expansion across consumer premise equipment (CPE) and multiple applications including routers, access points and set-top boxes.

"We are capitalizing on growing demand for data-rich mobile applications, and our products are at the heart of the high-speed data connections enabling always-on, broadband mobility, both in the devices and consumer premises equipment, and within the supporting network infrastructure," said president & CEO Bob Bruggeworth. "We are delivering on multiple opportunities to increase our dollar content generation-over-generation in the world's leading smart-phones and benefiting from increasing participation in the highest-volume entry-level platforms and reference designs," he added.

"In the emerging tier, customers want to choose between cost and performance, while being absolutely assured about supply availability and quality. As a result, we estimate that RFMD's average dollar content per handset has increased 40% in just two years, as we've expanded our dollar content from the high to the low tier," Bruggeworth continued. "It's our aim to be the industry's most diversified supplier in terms of customers, product categories, market segment and air standards," he added. "Our two largest customers are the top two smartphone manufacturers. We also support multiple customers who each are low- to mid-single digits as a percentage of revenue. These are all large accounts that can drive large volumes, and RFMD is at the heart of their next-generation product ramps, very often with a full suite of RFMD components further driving increased dollar content."

"Design activity related to our new low-cost CMOS PA is accelerating, and we expect this will improve margins in our 2G product portfolio by the end of 2013," said Bruggeworth. "With 56% year-over-year growth, our cellular sales are outpacing the underlying handset industry."

On a non-GAAP basis, gross margin has risen from 34.4% last quarter to 35.1%. Operating expenses were cut from \$76m to \$74.7m, due mainly to general & administrative expenses falling from \$12.6m to \$11.5m (though up on \$10.6m a year ago). Sales & marketing expenses were \$17m (up from \$16.7m last quarter and \$14.4m a year ago). R&D expenses were \$46.2m (up from \$40m a year ago, but cut from \$46.8m last quarter).

Net income was \$25.6m (\$0.09 per diluted share), up on \$17.1m (\$0.06 per diluted share) last quarter and just \$2.7m (\$0.01 per diluted share) a year ago.

Operating cash flow was \$7.2m (down from \$10m last quarter and

less than half the \$15.6m a year ago). Capital expenditures (including investments in duplexer capacity, assembly equipment, and tools to reduce gold consumption) were \$27.2m, with depreciation of \$11.6m and intangible amortization of \$7.2m. During the quarter, cash, cash equivalent and short-term investments fell from \$179.6m to \$159.4m.

Outlook

For fiscal second-quarter 2014 (to end-September 2013), RFMD expects sequential growth in revenue (to \$305–\$310m), gross margin, and earnings per share (to \$0.10–\$0.11).

"Good performance has resulted from three key margin drivers this fiscal year," noted chief financial officer Dean Priddy.

"First, we have signed a definitive agreement to sell our UK fab [in Newton Aycliffe — Europe's largest GaAs fab — to Compound Photonics of Phoenix, AZ, USA]. This is part of our overall flexible GaAs sourcing strategy, and it accounts for roughly half of the margin expansion goal... the full benefit of this transaction will be realized in the December 2013 quarter."

"Second, our ultra-low-cost CMOS PA has been fully released and is rapidly ramping production. We have demand for multiple millions of units in the September quarter, and that number is projected to more than double in the December quarter. This initiative represents a margin expansion of 1%.

"Third, assembly capacity has been installed in our Beijing facility and is now being qualified. We will begin to realize the full benefit of this expansion during the December quarter. This represents 0.5–1% of the margin expansion."

"Key margin improvement initiatives are all either on or ahead of schedule and we remain confident in achieving 3–4% in gross margin improvement this year," said Priddy.

www.rfmd.com

Matthew Peach, Contributing Editor

RFMD ships millionth RF7196D CMOS PA

RFMD has shipped over 1 million RF7196D CMOS power amplifiers. The firm's newest CMOS PA is in mass production in support of multiple high-volume 2G and 3G handset platforms, and shipments are expected to jump to about 10 million units by the end of the September quarter.

RFMD cites strong adoption of its CMOS PAs in next-generation handset platforms targeting emerging markets. The firm is migrating its customers of 2G PAs (both GaAs

and CMOS) to its ultra-low cost RF7196D, and expects shipments to more than double in the December quarter and exceed 100 million units worldwide in calendar 2014.

"We intend to launch a broad portfolio of innovative new CMOS products in the coming quarters, and we forecast strong growth in emerging markets across a highly diversified customer set," says Eric Creviston, president of RFMD's Cellular Products Group (CPG).

www.rfmd.com

Hittite reports rise in profit on 4.9% growth year-on-year in Q2

For second-quarter 2013, Hittite Microwave Corp of Chelmsford, MA, USA (which designs and supplies analog, digital and mixed-signal RF, microwave and millimeter-wave ICs, modules and subsystems as well as instrumentation) has reported revenue of \$68.6m, up 1.3% on \$67.7m last quarter and 4.9% on \$65.4m a year ago.

Of total revenue, 44% (\$30.2m) came from customers in the USA (versus 44.7% last quarter) and 56% (\$38.4m) came from customers outside the USA (versus 55.3% last quarter).

Gross margin has fallen from with 74.5% a year ago and 73.7% last quarter to 72.4%. Nevertheless,

operating income has risen further, from \$26.2m a year ago and \$27.1m last quarter to \$27.5m (staying steady at an operating margin of 40.1% of revenue throughout).

Likewise, net income has risen further, from \$17.2m (\$0.56 per diluted share) a year ago and \$17.6m (\$0.57 per diluted share) last quarter to \$18m (\$0.58 per diluted share). During the quarter, total cash and marketable securities rose by \$8.8m, from \$429.4m to \$438.2m.

For Q3/2013, Hittite expects slight drops in revenue to \$66.5–68.5m and in net income to \$16.7–17.7m (\$0.54–0.57 per diluted share).

www.hittite.com

Teradyne CFO Greg Beecher elected to board

In June Hittite's board of directors elected Gregory R. Beecher as a member of the board. He was also appointed to serve as a member of its Audit Committee.

Beecher has significant industry and financial expertise, says Hittite. He has served as chief financial officer of automatic test equipment maker Teradyne Inc since 2001 and as its treasurer since 2007. Previously, he was a partner at PricewaterhouseCoopers LLP,

where he had an 18-year career in public accounting. He also serves on the board of directors of MKS Instruments Inc, where he is its Audit Committee chairman. Beecher has a B.S. from the University of Hartford and M.S. in Accounting from Northeastern University.

"His experience and background is well suited to serve Hittite's needs as we implement our strategy for the future," comments chairman Franklin Weigold.

Teledyne LeCroy demos first 100GHz real-time oscilloscope as it releases new chip design to Teledyne Scientific's InP foundry

Teledyne LeCroy of Chestnut Ridge, NY, USA (a subsidiary of Teledyne Technologies Inc) has demonstrated what is claimed to be the first 100GHz real-time oscilloscope by acquiring and displaying live signals at 100GHz bandwidth (exceeding currently available capabilities). High-speed oscilloscopes are vital tools in developing high-speed digital networks, says the firm. "It reveals new phenomena, opens channels for new discoveries and paves the way for vast improvements in the field of high speed measurement," says Tom Reslewic, CEO, Teledyne environmental and electronic measurement instrumentation.

The demonstration was conducted at the research facilities of Teledyne Scientific Company in Thousand Oaks. Teledyne LeCroy and Teledyne Scientific also said they have completed the design of a jointly developed next-generation indium phosphide (InP) chip and have released the design for fabrication at Teledyne Scientific's InP foundry. The chip is the first device in an expansive chip-set planned for future generations of high-speed oscilloscopes. Teledyne acquired LeCroy Corp in August 2012 and has pursued synergies related to the development of ultra-high-speed oscilloscopes.

"We are pleased to see the 100GHz real-time oscilloscope milestone reached less than one year after the acquisition of Teledyne LeCroy," comments Teledyne's chairman, president & CEO Robert Mehrabian. "Releasing the new InP chip in collaboration with Teledyne Scientific on the very same day illustrates the breadth of our technology expertise, and our commitment to taking high-performance oscilloscopes to the next level."

www.teledynelecroy.com

Anadigics' sales up 31% to \$34.6m in Q2, driven by 138% growth in WiFi

Migration to new inter-layer dielectric products to boost profit margin

For second-quarter 2013, broadband wireless and wireline communications component maker Anadigics Inc of Warren, NJ, USA has reported net sales of \$34.6m, up 31% on \$26.4m last quarter and up 37.7% on \$25.1m a year ago.

Growth was driven by WiFi products sales of \$11.4m (up 138% on \$4.8m last quarter). Cellular sales were \$18.1m (up 10.9% on \$16.3m last quarter), driven partially by an increase in certain legacy business. Infrastructure sales were \$5.3m (down fractionally, by just 3.5%).

"This level of performance was driven by the exceptional traction we have achieved with our WiFi and Cellular products, which now power some of the most popular wireless devices in the market," says chairman & CEO Ron Michels.

"Our WiFi group has achieved exceptional growth and is positioned for continued success, broad penetration of multiple reference designs," notes Michels. "Our Cellular group has solid sales momentum with multiple design wins for ProEfficient and Penta-band solution, expanding our WCDMA market share," he adds. "Our Infrastructure group is leading the industry to support the transition to DOCSIS 3.1."

The greater-than-10% customers were Samsung, Murata and Huawei. During the quarter, Samsung selected Anadigics' WiFi and cellular

solutions for its Galaxy S 4 smart-phone, ProEfficient-Plus solutions for its new Galaxy S 4 Mini, and WiFi front-end ICs for its new Galaxy Tab 3 family, while Huawei selected Anadigics' Pentaband power amplifier for its new CPE and hotspot devices.

Capacity utilization has risen again, from 55% in Q4/2012 and 65% last quarter to about 75% (almost double the 40% a year ago). Gross margin has improved from -7.7% a year ago and 0.7% last quarter to 5.2%, driven by WiFi's growth, despite a gross margin headwind from growth in legacy Cellular products and a small decrease in Infrastructure sales.

R&D expenses fell 13.1% sequentially to \$8.6m, reflecting cost improvements previously put in place as well as more efficient development activities. Selling & administrative expenses rose slightly by 2% to \$5.3m, as Anadigics fueled Wi-Fi's sales growth. Since Q1/2013, operating expenses as a percent of revenues have shrunk considerably from over 57% to about 40%, evidencing substantial operating leverage. "We expect this trend to continue as we grow the topline," says VP & chief technology officer Terry Gallagher.

On a non-GAAP basis, net loss has been cut from \$17.9m a year ago and \$14.8m a year ago to \$12m. During the quarter, cash, cash equivalents and short- and long-

term marketable securities fell from \$50.9m to \$41m.

"We effectively managed our cost structure while ramping production to meet increasing customer demand," says Gallagher. "We continue to make operational progress by increasing yields in our manufacturing processes and transitioning our product portfolio to our more efficient ILD (inter-layer dielectric) technology," he adds. "Capital investment was \$2m and is helping expand our more efficient ILD capacity. Capital investment, combined with an increasing mix of ILD and production efficiencies being implemented, should result in an increase in available capacity."

Based on current improved bookings and revenue visibility, for Q3/2013 Anadigics expects further sales growth of 4-8%.

"As we migrate from legacy Cellular to new ILD products, we expect gross margin will improve with better incremental rates," says Gallagher. "While we anticipate higher sales volume in the third quarter, we expect that the capacity improvements will result in a lower utilization metric," he cautions.

"We anticipate continued financial improvement as we take advantage of our operating and manufacturing leverage, and increasing design-win penetration with our new, more profitable, ILD products," says Michels. "We expect solid growth into the second half of 2013."

MACOM to supply Northrop Grumman with MMIC technology

M/A-COM Technology Solutions Inc of Lowell, MA, USA is supplying Northrop Grumman with its GaAs-based MMIC technologies, aimed at enabling improvements in the capabilities, flexibility and affordability of airborne surveillance and sensor systems used across multiple

airborne platforms.

"The acute and enduring challenge facing defense contractors — higher-performance systems with improved affordability — is accelerating the pace of innovation in the defense market-space," says MA/COM's president & CEO John

Croteau. "Our collaboration with customers like Northrop Grumman has resulted in design, test and manufacturing processes that yield high performance products and a cost-effective, highly dependable supply chain."

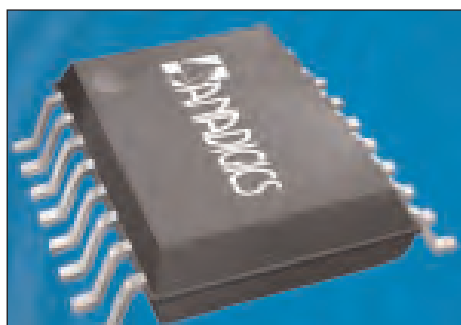
www.macomtech.com

Anadigics launches 1.2GHz GaAs & GaN amplifier family for DOCSIS 3.1 CATV infrastructure network upgrade

Anadigics has introduced a family of CATV infrastructure products that is optimized for the proposed data over cable service interface specification (DOCSIS) system standard version 3.1. The solutions are optimized to help CATV service providers increase their system bandwidth, allowing them to offer additional digital services, including high-definition television (HDTV) and video on demand (VOD), and enable higher-speed data services. The first product in the family is the ACA2429 gallium nitride (GaN) power doubler, which is claimed to be the industry's first 1.2GHz surface-mount line amplifier.

"By helping manufacturers achieve industry-leading performance and reliability in new 1.2GHz downstream equipment, we are enabling MSOs to take advantage of this upcoming standard," says Tim Laverick, VP of infrastructure products.

Anadigics' newest generation of infrastructure products will include



Anadigics' new ACA2429 GaN power doubler, reckoned to be the first 1.2GHz surface-mount line amplifier.

power doubler and push-pull line amplifiers, Edge QAM amplifiers, reverse path amplifiers, and optical receivers. They are designed to support outstanding picture quality and higher data rates by offering exceptional linearity and noise figure, ensuring high signal fidelity over extended frequencies up to 1.2GHz with a 'high-split' return path. The firm says that its DOCSIS 3.1 solutions will also deliver higher output power levels to achieve drop-in

upgrades to existing hybrid fiber coax (HFC) infrastructure systems. The new product family will leverage Anadigics' proven high-linearity GaAs process (which is claimed to have exceptional reliability and mean-time-to-failure) along with GaN high-electron-mobility transistor (HEMT) technology (for high output and optimum power efficiency).

The ACA2429 1.2GHz GaN power doubler combines Anadigics' MESFET technology with a GaN HEMT output stage, delivering 25dB gain with +60dBmV output power and only 10W of power consumption in a proven surface-mount package. The line amplifier offers what is claimed to be exceptional bit-error rate (BER), composite triple-beat (CTB), composite second-order (CSO), cross-modulation, and carrier-to-intermodulation noise (CIN) characteristics for optimal performance in a fully loaded spectrum.

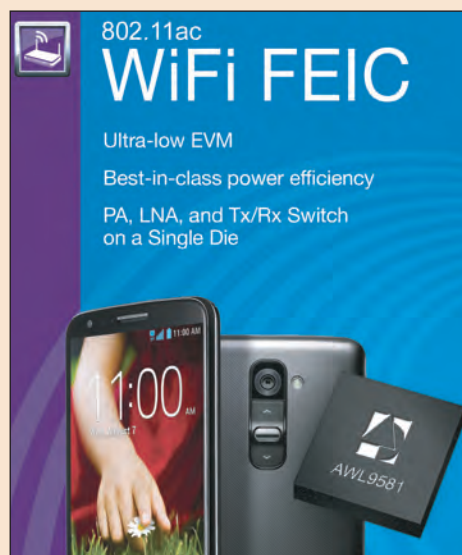
www.anadigics.com

Anadigics' 5GHz 802.11ac front-end integrated circuit enables WiFi connectivity in LG's new G2 smartphone

Anadigics says that its AWL9581 front-end integrated circuit (FEIC) is enabling 5GHz 802.11ac WiFi connectivity in LG Electronics' new G2 smartphone.

"Our 802.11ac WiFi solutions have set the standard in FEIC form, fit and function by combining industry-leading efficiency for longer battery-life and world-class linearity for greater throughput in a highly integrated, space-saving package," says Jonathan Griffith, Anadigics' VP of WiFi products.

The AWL9581 5GHz FEIC leverages Anadigics' exclusive InGaP-Plus technology and patented design architectures to combine a high-performance power amplifier (PA), low-noise amplifier (LNA), and RF Tx/Rx switch on a single die, to simplify RF design and



Anadigics' AWL9581 FEIC, used in LG's new G2 smartphone.

reduce time-to-market. The compact 2.5mm x 2.5mm x

0.4mm QFN package includes a high-accuracy, integrated power detector, and RF ports internally matched to 50Ω to reduce PCB space requirements. The complete family of 802.11ac FEICs provides outstanding error vector magnitude (EVM) and noise figure performance, enabling ultra-high data throughput, claims the firm.

This feature-rich smartphone offers a 5.2" Full HD IPS display, 13 megapixel camera, 2.26GHz quad-core processor, and Android 4.2.2 Jelly Bean operating system.

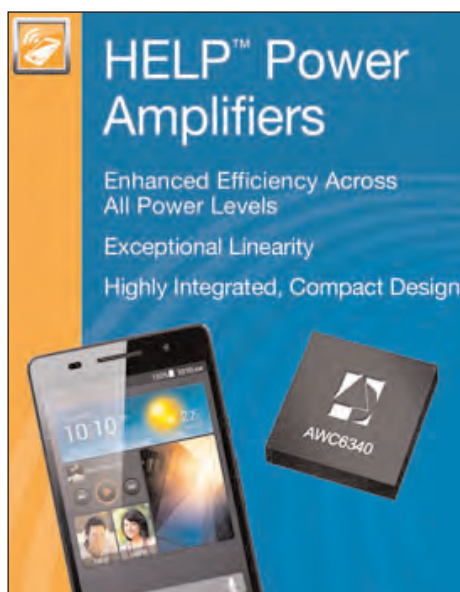
"Our value as a critical enabler for the newest-generation of WiFi-enabled devices is demonstrated by our inclusion on leading reference designs and strong traction at top-tier OEMs," says Griffith.

www.anadigics.com

Anadigics' HELP 3G PA selected by Huawei for Ascend P6 smartphone

GaAs-based broadband wireless and wireline communications component maker Anadigics Inc of Warren, NJ, USA is shipping production volumes of its AWC6340 HELP (High-Efficiency-at-Low-Power) power amplifier (PA) to Huawei for the new Ascend P6 smartphone (which features a 4.7" HD display, 1.5GHz quad-core processor, 8 megapixel camera and an Android 4.2.2 Jelly Bean operating system).

"We are very pleased to enable 3G connectivity in the Ascend P6, the world's slimmest smartphone," says Navi Miglani, director of product marketing for Cellular Products at Anadigics. "The selection of Anadigics' AWC6340 power amplifier for this flagship smartphone not only exemplifies the strength of our relationship with Huawei, but also



Anadigics' HELP PA powers Huawei's Ascend P6.

the space-saving and total battery-life benefits across all power levels

delivered by our RF solutions," he adds.

Anadigics' HELP 3G PAs use the firm's patented InGaP-Plus technology to achieve higher efficiency at low and high power levels and to minimize quiescent current, helping to extend battery life in smartphones. HELP power amplifiers also deliver what is claimed to be exceptional linearity to ensure a stable connection for clear voice and high-speed data.

In particular, the compact 3mm x 3mm AWC6340 power amplifier features an internal voltage regulator and integrated RF coupler to simplify design and phone calibration requirements. This level of integration reduces external component requirements and saves valuable PCB space, the firm adds.

www.anadigics.com

Samsung selects Anadigics' ProEfficient-Plus WCDMA power amplifiers for Galaxy Mega phablet

Anadigics Inc of Warren, NJ, USA says that its AWT6751 and AWT6755 dual-band ProEfficient-Plus WCDMA power amplifiers (PAs) are enabling wireless connectivity in Samsung Electronics' new Galaxy Mega phablet (which features either a 6.3-inch or a 5.8-inch display blending the functionality and form factor of both a smartphone and tablet). The Galaxy Mega has a dual-core processor operating at up to 1.7GHz, a 8 megapixel camera, and an Android 4.2.2 Jelly Bean operating system.

"Our dual-band ProEfficient-Plus solutions not only help to extend battery life in power-hungry, large-screen mobile devices, but also deliver space-saving integration to provide greater design flexibility," says Jerry Miller, senior VP of Cellular Products. "We look forward to powering the next-generation of feature-rich smartphones,



Anadigics' AWT6751 and AWT6755 dual-band ProEfficient-Plus WCDMA power amplifiers

phablets and tablets."

Anadigics says that dual-band ProEfficient-Plus solutions use its exclusive InGaP-Plus technology and patented design architectures to deliver high performance and integration. The power amplifiers deliver high efficiency in low-power mode for greater talk time and high-power mode for longer

data application use. This performance, combined with low quiescent current (of 6mA) without the use of a DC/DC converter, maximizes battery life in 3G mobile devices. ProEfficient-Plus power amplifiers are also compatible with average power tracking (APT) to further increase efficiency and reduce

current consumption at medium and low operating powers.

The complete family of dual-band ProEfficient-Plus solutions are offered in compact 3mm x 4mm x 0.9mm packages and feature internal voltage regulation and integrated DC blocks on the RF ports to save valuable PCB space.

www.anadigics.com

TriQuint revenue returns to year-on-year growth in Q2

Sequential growth driven by Mobile Device sales up 12%, offsetting drops in Networks and Defense segments; Q3 to return profit

For second-quarter 2013, RF front-end component maker and foundry services provider TriQuint Semiconductor Inc of Hillsboro, OR, USA has reported revenue of \$190.1m. This is up 3% on \$184.2m last quarter (although Q1 had been impacted by \$5m of cost due to a now resolved quality issue) and up 7% on \$178m a year ago (with growth in all three market segments).

End-market revenue split was 62% Mobile Devices (up from 57% last quarter), 24% Network Infrastructure (down from 28%), and 14% Defense & Aerospace (down slightly from 15%).

Mobile Devices revenue grew 5% year-on-year and 12%, sequentially while Networks Infrastructure fell by 11%, and Defense & Aerospace revenue by 3%.

Subcontract assembly firm Foxconn Technology Group was the only customer exceeding 10% of total revenue (at 22%). The second-largest customer was Samsung.

"This report marks the beginning of the next phase of growth at TriQuint," reckons president & CEO Ralph Quinsey.

On a non-GAAP basis, gross margin was 31.3%, up from 22.8% last quarter due to the absence of the now-resolved Q1 quality issue, higher revenue, improved factory utilization, and better yields. Operating expenses have risen from \$68.3m last quarter to \$69.6m, due mainly to additional engineering expense and the firm's annual sales conference. Net loss was \$10.9m (\$0.07 per share, \$0.04 better than the guidance given in April), an improvement on \$27.2m (\$0.17 per share) last quarter and \$15m (\$0.09 per share) a year ago.

Capital expenditures of \$27.9m (down from \$29.4m last quarter) related mainly to capacity expansion for premium filters. During the quarter, cash and investments fell by \$51.8m, from \$141.1m to \$89.3m.

This was due primarily to a planned increase in inventory of \$34.5m (in anticipation of a strong second half ramp) and repurchasing 7.7 million shares for \$51.1m (although these uses of cash were partially offset by \$20m hired for short-term liquidity).

Regarding technology development highlights during the quarter, TriQuint produced "the industry's first gallium nitride transistors using GaN-on-diamond wafers".

TriQuint has also accelerated its GaN offerings, with 15 new products and two new Foundry services. Also, the firm recently launched chipsets for point-to-point radios serving 3G/4G cellular backhaul. "In the year-to-date we have released 86 new products, and we're on track to double our release rate as compared to 2011," noted Quinsey.

In addition, TriQuint has doubled bulk acoustic wave (BAW) filter technology capacity compared to last year's levels.

"This third quarter is the beginning of a stronger period of performance for TriQuint, built on a differentiated strategy that is defensible and sustainable," reckons Quinsey.

"Our strategic focus is on innovation, technology and a comprehensive RF capability," he added.

"Investments in proprietary GaN, BAW and advanced surface acoustic wave [SAW filter] technology are examples of where we set ourselves apart from the competition," Quinsey says.

For Q3/2013, TriQuint expects revenue of \$245–255m (up more than 30% on Q2). Despite operating expenses rising slightly to \$70–71m, this should bring much improved gross margin (of 34–36%) and a return to profitability (net income of \$0.09–0.11 per diluted share).

"Solid results in the second quarter and our current expectation for the remainder of the year lead us to believe non-GAAP earnings of at least \$0.05 per diluted share for fiscal 2013 is a reasonable expectation," says chief financial officer Steve Buhaly.

"We have retooled our volume factor and aligned our mobile product strategy around premium filters, high-efficiency amplifiers and high-performance WLAN solutions," notes Quinsey.

"For the five years prior to Q3/2011 our company grew at compound annual growth rate of over 20%," says Quinsey. "We expect year-over-year second-half 2013 performance back to those historic levels, and I remain bullish of our 2014 prospects. TriQuint has reinforced and reenergized our product development efforts across the company."

Quinsey also detailed issues that have faced the market in recent years: "Considering amplifier technology, there has been much speculation over the last ten years around GaAs HBT [heterojunction bipolar transistors] versus silicon. The question being if and when would silicon overcome GaAs or will silicon's relatively low cost outpace the superior performance of GaAs. The reality is the cost difference between silicon and GaAs in an integrated solution has become inconsequential due to extremely small GaAs [device] sizes. GaAs HBT continues to deliver longer battery life for years and will likely remain the technology of choice for all but the very low-end entry-level phones."

www.triquint.com

Matthew Peach, Contributing Editor

Cost difference between silicon and GaAs in an integrated solution has become inconsequential due to extremely small GaAs [device] sizes. HBT will likely remain the technology of choice for all but the very low-end entry-level phones

Skyworks exceeds quarterly revenue and profit guidance

Revenue rises 12% year-on-year to \$436.1m; gross margin rises to 44%

For its fiscal third-quarter 2013 (ended 28 June), Skyworks Solutions Inc of Woburn, MA, USA (which makes analog and mixed-signal semiconductors) has reported better-than-forecast financial results. Revenue was \$436.1m, up 2.6% on \$425.2m last quarter and 12% on \$389m a year ago, and ahead of guidance of \$435m.

Gross margin was 44%, up on 42.2% last quarter and 43.2% a year ago. "Our strong margin performance reflects the strategic shift in our product portfolio toward more differentiated performance-based solutions," commented chief financial officer Donald Palette.

On a non-GAAP basis, net income was \$103.8m (\$0.54 per diluted share, exceeding guidance by \$0.01), up on \$91.9m (\$0.48 per diluted share) last quarter and \$86.1m (\$0.45 per diluted share) a year ago.

Operating cash flow was \$65m. Capital expenditure was \$33.4m, while depreciation was \$18.5m. The firm also invested \$92m to repurchase nearly 4 million shares of common stock. Altogether, Skyworks exited the quarter with \$400m in cash and no debt.

"We are on a path to produce over \$450m in cash flow from operations for the whole of fiscal 2013," noted Palette.

"We had another strong performance in Q3/2013, exceeding guidance across all key metrics," commented CEO David J. Aldrich. "I am pleased with the progress we've made towards our overall

goals of diversification and market expansion. Both of these initiatives contributed towards our outperformance in the quarter. Our growing portfolio of highly integrated, high-performance analog solutions helped to drive strong sequential margin improvement and helped to drive earning upside," he added.

"We are capturing margin-accretive content across a broad set of end-markets, spanning automotive, industrial, smart energy, home automation, medical, mobility and cloud computing," Aldrich continued. "Leading customers within each of these targeted markets are increasingly requiring always-on connectivity and enhanced power efficiency, which intersects with our core competencies," he adds. "Our system-level innovations and scale advantages are translating into accelerating top-line growth, margin expansion and, most importantly, returns well in excess of our cost of capital. Accordingly, Skyworks is well positioned to capitalize on the Internet of Things tsunami and to outpace the broader analog semiconductor market while increasing shareholder value."

Business highlights

Skyworks listed several highlights from its latest quarter, including: enabling novel home sensor networks at an emerging global home healthcare provider; launching the industry's lowest-noise amplifiers supporting GPS systems, broadband and satellite communications; and securing telematics and info-

tainment system design wins with a "strategic global automotive supplier".

Skyworks systems have also powered Belkin, Cisco and Netgear 802.11ac enterprise routers. The firm also ramped its voltage regulators across LTE data cards; and commenced shipments of wireless networking and ZigBee solutions for security sensors, smoke alarms, motion detectors and touch pads.

Other achievements included gaining connectivity and analog control IC content at Huawei, Lenovo and ZTE; capturing multiple front-end and wireless networking sockets on Qualcomm LTE reference designs; and introducing silicon-based ultra-high-speed switching technology for carrier aggregation applications.

Outlook and guidance

"Given new program launches and an expanding product pipeline, we expect a strong second half to 2013," said Palette. Specifically, for fiscal fourth-quarter 2013 (to end-September), Skyworks anticipates revenue will rise nearly 9% sequentially and 13% year-on-year to \$475m, driven by contributions from new market initiatives, program ramps and share gains. Gross margin should be 44–44.5%. Based on the outlook for strong revenue growth, gross margin expansion and operating expense leverage, Skyworks hence expects diluted earnings per share to rise to \$0.62 (up 17% year-on-year).

www.skyworksin.com

Matthew Peach, Contributing Editor

Skyworks announces \$250m stock repurchase program

Skyworks' board of directors has authorized the repurchase of up to \$250m of the firm's common stock from time to time prior to 16 July 2015 on the open market or in privately negotiated transactions.

The new stock repurchase program replaces in its entirety the \$200m

program which was approved by the board on 8 November 2012, and which had \$35.6m of repurchase authority remaining.

The timing and amount of any shares of the common stock that are repurchased will be determined by the firm's management

based on its evaluation of market conditions and other factors. Any repurchased shares will be available for use in connection with the firm's stock plans and for other corporate purposes.

Skyworks expects to fund the program using working capital.

Skyworks powers MediaTek's dual-core SoC platforms

MediaTek (a fabless semiconductor firm for wireless communications and digital multimedia) is using several Skyworks front-end solutions in its dual-core MT6572 platform, which is supporting multiple leading tier-one smartphone makers in emerging markets.

The MT6572 is the world's first dual-core, system-on-a-chip platform with high-speed-packet-access, integrated WiFi, FM, GPS and Bluetooth functionality delivered in a four-layer printed circuit board. MT6572 integrates a power-efficient, dual-core Cortex-A7 central processing unit sub-system with speeds up to 1.2GHz in 28nm. The platform also integrates MediaTek's multimode Rel. 8 HSPA+/TD-SCDMA modem, 3G graphics, support up to HD 720p video playback and record, 5Mpixel camera and qHD displays.

The fully matched, 14-pad SKY77758 power amplifier (PA) module packs full coverage for Bands I, II, V, VIII into a single, compact 3.0mm x 4.2mm x 0.9mm package. The small and efficient surface mount module meets stringent spectral linearity requirements for WCDMA, HSDPA, HSUPA, HSPA+ transmission with high power-added efficiency. A directional coupler integrated into the module eliminates the need for any external coupler. The single GaAs, MMIC contains all active circuitry in the module. The MMIC contains on-board bias circuitry, as well as input and interstage matching circuits. Output match into a 50Ω load is realized off-chip within the module package to optimize efficiency and power performance.

The SKY77590-11, SKY77590-21, SKY77590-51, SKY77590-61, SKY77593, SKY77594, SKY77595 and SKY77596 are transmit (Tx)/receive front-end modules designed in a very low profile (0.9mm) and 6mm x 6mm compact form factor for quad-band cellular handsets comprising GSM850/900, DCS1800 and PCS 1900 operation. The complete transmit VCO-to-antenna

and antenna-to-receive, surface acoustic wave filter modules consist of Tx harmonic filtering, a high linearity/low insertion loss switch, and a complementary metal-oxide semiconductor, PA control block. A custom silicon IC contains decoder circuitry to control the RF switch while providing a low current, external control interface.

Industry analysts expect future smartphone growth to come from emerging markets where con-

sumers are upgrading from feature phones to entry-level platforms. According to IDC, 1.7bn smart connected devices (tablets, smartphones and PCs) will be shipped in 2014. Of those, 1bn will be delivered to emerging markets, with smartphones and tablets comprising most units. IDC estimates emerging markets will see a compound annual growth rate of 17% from 2012–2017 for connected devices.

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Peregrine expands family of MultiSwitch STeP8 UltraCMOS antenna switches for 4G LTE-Advanced mobile wireless applications

Peregrine Semiconductor Corp of San Diego, CA, USA, a fabless provider of radio-frequency integrated circuits (RFICs) based on silicon-on-sapphire (SOS), is expanding its family of MultiSwitch STeP8 dual single-pole, seven throw (SP7T/SP7T) UltraCMOS antenna switches optimized to solve the carrier aggregation challenges of 4G mobile wireless applications (as adopted by RF front-end module suppliers such as Murata Manufacturing). The PE42128x devices support simultaneous multi-band operation of up to 14 frequency bands while delivering exceptional linearity, insertion loss performance and small size, says the firm.

"Peregrine's UltraCMOS process continues to bring innovative solutions to a highly complex and ever-increasing set of challenges in the

RF front-end," says CEO Jim Cable. "Our vision has always been to enable the wireless industry to solve the most critical RF demands, where our technology and products not only deliver but thrive," he adds. "Emerging LTE-Advanced Smartphone platforms require a unique combination of RF performance achievements that only UltraCMOS technology can bring."

The LTE-A protocol calls for carrier aggregation (or the simultaneous reception of multiple frequency bands) which improves data delivery speed to improve consumer experience. The new PE42128x antenna switches are designed to solve the challenges of carrier aggregation. Each of the new MultiSwitch devices features a combination of two SP7T switches in a single IC to support 14 different frequency

bands, including simultaneous multiband operation.

With HaRP technology enhancements, the PE42128x devices deliver high linearity with an IIP3 of +75dBm, as well as extremely low insertion loss (0.35dB @ 900MHz; and 0.45 at 1900MHz) and high isolation (38dB at 698–2170MHz; and 33dB at 2500–2690MHz). The switches also feature 2fo and 3fo for LTE of less than –80dBm at 700MHz. High linearity and isolation performance are critical in LTE-Advanced Smartphones to ensure that radio signals don't spill into other bands during multi-band operation.

The flip-chip PE42128x switches are available in RoHS-compliant, chip-scale packaging for SMD placement. Samples and volume-production quantities are available.

Peregrine introduces new CMOS RF switches

Peregrine claims it has set new standards of performance for high-frequency CMOS RF switches with the launch of the SPDT PE42520 and PE42521 devices.

Based on Peregrine's UltraCMOS technology, the new, high-linearity switches support operation at 13GHz, combined with high power handling of +36dBm, enabling performance previously thought to be impossible with CMOS. The devices suit high-frequency applications that require high power handling, such as signal-path and filter bank switching in the test & measurement, wireless backhaul, and military markets, says the firm.

"Peregrine has, once again, set new levels of performance, achieving high-frequency and high-power capability without compromising the core capabilities of UltraCMOS," says Dave Shepard, VP of Peregrine's High-Performance Solutions



The SPDT PE42520 and PE42521 devices.

business unit. "The PE42520 and PE42521 switches, along with our new PE43704 DSA, are the first in our line of high-frequency, high-power products," he adds. "We look forward to continuing to support applications that require broad-band performance of 13GHz and beyond."

The PE42520/21 switches support operation up to 13GHz at 36dBm

and feature HaRP technology, resulting in IIP3 of 66dBm and IIP2 of 115dBm. The PE42520 supports frequencies down to 9kHz, while the PE42521 is a fast-switching variant that operates down to 100MHz. Both devices have low gate lag (key for test & measurement applications). The insertion loss of the PE42520 and PE42521 is 0.7dB at 7.5GHz. Both devices have isolation of greater than 41dB at 7.5GHz.

In addition, Peregrine has also unveiled the PE42520 and PE42521 Evaluation Kits, to enable designers to evaluate the new switches in their applications.

The PE42520 and PE42521 RF switches are available in a 16-lead, 3mm x 3mm QFN package, priced at \$3.98 each in 10k-unit quantities.

www.psemi.com

RFaxis ramps up volume production of pure-CMOS-based SP3T Wi-Fi/Bluetooth RF switch for smartphones and mobile devices

Fabless semiconductor firm RFaxis Inc of Irvine, CA, USA, which designs RF semiconductors and embedded antenna solutions for the wireless connectivity and cellular mobility markets, says that it has started volume production of its RFX333 single-pole triple-throw (SP3T) antenna switch, which is developed and manufactured in bulk CMOS technology and is pin-compatible with incumbent solutions that use more expensive gallium arsenide (GaAs) or silicon-on-insulator (SOI) processes.

The RFX333 is optimized for wireless applications requiring high linearity and low insertion loss, such as WLAN IEEE 802.11b/g/n and Bluetooth in the 2.4GHz frequency range. It has simple and low-voltage CMOS control logic, and requires minimal external

components. All DC-blocking capacitors are integrated on-chip to minimize PCB footprint. Assembled in an ultra-compact, low-profile 1.6mm x 1.6mm x 0.45mm 12-pin quad flat no-lead (QFN) package, the RFX333 provides an RF switch suitable for handset, smartphone, tablet and other mobile platforms.

"With Qualcomm's recent announcement of its RF360, the global RF industry is undoubtedly witnessing an accelerated acceptance of

We are now offering our Wi-Fi SoC partners and ODM/OEM customers with pin-compatible, alternative RF switch solutions based on pure CMOS

CMOS-based RF front-end components including PAs [power amplifiers] and switches," reckons chairman & CEO Mike Neshat.

"We saw GaAs pHEMT switches displaced by SOI on many platforms in the last couple of years. We are now offering our Wi-Fi SoC partners and ODM/OEM customers with pin-compatible, alternative RF switch solutions based on pure CMOS at a significantly reduced price," he continues.

"By adding RFX333 to our portfolio, RFaxis is rapidly becoming a one-stop shop for high-performance, and yet the most cost-effective RF solutions for wireless connectivity products, including complete RF front-end ICs (RFeIC), high-power PAs and now switches."

www.rfaxis.com

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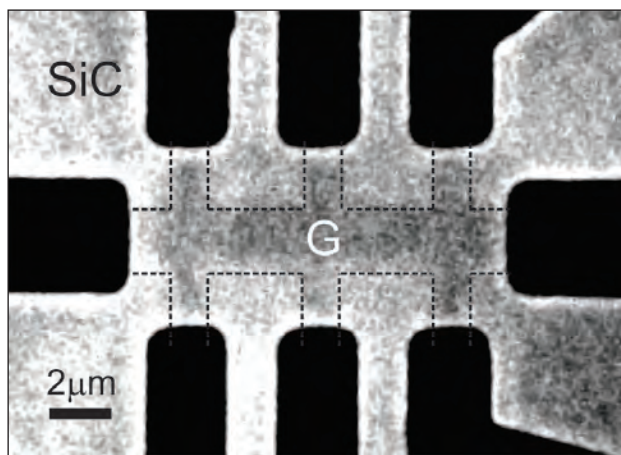
Express tool developed for quality control of epitaxial graphene on silicon carbide

Optical microscopy provides faster and more economic nanoscale inspection without perturbing graphene layer

In a European collaboration within the project ConceptGraphene, researchers at Chalmers University of Technology in Sweden have developed a method for fast and inexpensive quality control of graphene grown on silicon carbide (SiC). The technique, based on optical microscopy, is used to understand the effect of the silicon carbide substrate on the quality of the graphene layer and paves the way for optical microscopy as an industrial quality control tool of epitaxial graphene on silicon carbide.

The unique and superior properties of graphene (a single layer of carbon atoms) promise a revolution in electronics. Several processes have been developed to produce graphene on a large scale, and a strong contending technology is the growth of graphene on the surface of silicon carbide at high temperature. Also called epitaxial graphene on silicon carbide, this material often requires quality control, because the surface of the silicon carbide reconstructs during graphene growth. Steps and defects in the substrate may lead to the appearance of stepped terraces and the formation of areas with many layers instead of a single layer. These unwanted features limit the performance of the electronic devices and large-scale integration.

Now, in collaboration with colleagues at Sweden's Linköping University and the UK's National Physical Laboratory (NPL), researchers at Chalmers have shown that graphene on silicon carbide can be quality-controlled at the nanoscale by using simple inspection with an optical microscope (published online on 13 August in Nano Letters; DOI: 10.1021/nl402347g). Their technique is said to allow simple and accurate identification of even a



A Hall bar device (black areas) positioned on monolayer graphene using the optical method.

single graphene layer (0.3nm thick) and nanometer-scale steps on silicon carbide.

Until now, it was believed that graphene on silicon carbide has too little contrast to be observed directly by optical microscopy. But, by cross-checking optical data with electrical measurements, it was found that a single layer of graphene on silicon carbide reflects about 1.3% of light — faint but sufficient to be detected in an optical microscope.

As an illustration of the power of the technique, researchers have applied it to fabricate graphene devices on specific parts of the substrate, identified using optical microscopy. It is shown that stepped terraces on silicon carbide are not as detrimental as multi-layer-graphene domains. Also, they



Sergey Kubatkin.

show that, positioned on monolayer areas, the devices have characteristics that are truly given by the unique properties of graphene. Apart from facilitating fun-

damental studies, the technique can also have an industrial impact.

"Our findings will help the advancement of epitaxial graphene research and technology on the way towards wafer-scale production and achieving control of graphene quality at the nanoscale," believes professor Sergey Kubatkin about the usefulness of the method. "Optical microscopy of epitaxial graphene delivers similar

information to that obtained by other well-established but more complex techniques such as low-energy electron microscopy (LEEM) and scanning probe microscopy (SPM), not only in a much faster and economic way but also without perturbing the graphene layer," he adds.

The optical microscopy technique is already used as a tool in producing epitaxial graphene at Linköping University spin-off Graphensic AB, of which professor Yakimova (co-author of the study) is co-founder & CEO. "It is a fantastic tool for production evaluation of our material," says Mikael Syväjärvi, who works with production protocols at Graphensic.

The research work was supported by ConceptGraphene (a collaborative project funded by the European Union within its 7th Framework Program), the Swedish Research Council and Foundation for Strategic Research, The Knut and Alice Wallenberg Foundation (KAW), and the IRD Graphene Project of the UK's National Measurement Office.

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TriQuint buys CAP Wireless and its Spatium technology

GaN MMIC expertise to be added to RF power combining technology

RF front-end component maker and foundry services provider TriQuint Semiconductor Inc of Hillsboro, OR, USA has acquired CAP Wireless of Newbury Park, CA and its patented Spatium RF power combining technology, which replaces travelling-wave tube amplifiers (TWTAs) in communications and defense systems. TriQuint estimates that the TWT market opportunity will be about \$600m by 2015.

The acquisition leverages TriQuint's expertise in gallium nitride plus CAP Wireless' expertise in high-power RF solid-state amplifier systems. The combined firm can now offer a wider selection of high-power/high-frequency products, with CAP Wireless' Spatium technology adding to the bandwidth, efficiency and ruggedness of TriQuint's product portfolio.

Spatium technology improves broadband RF power efficiency through the use of patented coaxial

spatial combining techniques. TriQuint says that other performance advantages include solid-state reliability, smaller form factors, higher power densities and reduced weight compared to either TWT-based systems or conventional planar power combining products. It adds that Spatium can provide faster time-to-market and incorporate the performance of GaN MMICs while reducing product lifecycle costs.

The acquisition of CAP Wireless merges a unique approach to high-power RF amplifier system design with the benefits of TriQuint GaN device technology, notes TriQuint's VP & general manager for Infrastructure and Defense Products, James L. Klein. "CAP Wireless initially developed its Spatium amplifier platform using gallium arsenide (GaAs)-based MMICs," he adds. "GaN-based products from TriQuint can elevate Spatium to new levels of efficiency, power density,

frequency coverage and output power."

CAP Wireless' Spatium products are currently being sold and designed into several U.S. and international defense and commercial programs. TriQuint will focus Spatium technology development as a solution for high efficiency power applications in commercial and defense markets, including electronic warfare (EW), communications and radar. TriQuint's reliable supply of high-performance MMICs, combined with its volume manufacturing expertise will benefit immediate and long-term customer requirements for Spatium-based and conventional amplifier products.

TriQuint is continuing operation of CAP Wireless product sales and contracts while it develops new devices based on Spatium technology using TriQuint GaN and GaAs MMIC amplifiers.

www.capwireless.com

TriQuint's board approves inducement awards

TriQuint's board of directors' Compensation Committee (which consists solely of independent directors) has approved stock options and restricted stock unit (RSU) awards in conjunction with the firm's acquisition of CAP Wireless Inc of Newbury Park, CA, USA (announced on 7 August).

The directors approved 67,900

stock options and 46,760 RSU awards to former CAP Wireless employees under the TriQuint 2008 Inducement Plan. The awards were granted on 7 August, in accordance with NASDAQ Listing Standard 5635(c)(4). The stock options expire on 7 August 2023 and will vest 25% on 7 August 2014 with the remaining

75% vesting quarterly over the next three years, and have an exercise price equal to 100% of the closing price of TriQuint's common stock on 7 August 2013. RSUs will vest 25% on 1 August 2014, with the remaining 75% vesting annually over the next three years.

www.triquint.com

L&K Tech appointed as Korea distributor for RF solutions

TriQuint has appointed Seoul-based L&K Tech Inc as distributor in Korea for its entire RF product portfolio.

"We see Korea as a significant market for growth so it is imperative for us to select a partner with a successful track record," says S.J. Kim, TriQuint Korea country manager. "L&K has an excellent reputation for working closely with its partners and customers to

quickly resolve problems and meet customers' unique needs. We believe L&K's strong sales and support team will lead to significantly increased revenues and market share for both TriQuint and L&K," he adds.

"We look forward to partnering closely with TriQuint to deliver the benefits of its technology to customers throughout our region."

says L&K Tech's CEO Young-Ik Hwang.

L&K Tech delivers products, engineering services and customized technical solutions based on its application design team. With the new partnership, TriQuint says that its customers in Korea now have an expanded channel to access the company's RF product lines.

Diamond Microwave launches compact high-power X- and Ku-band GaN solid-state power amplifiers

Diamond Microwave Devices Ltd of Leeds, UK, which was spun out in 2006 from the diamond electronics team of Element Six and specializes in gallium nitride (GaN)-based microwave solid-state power amplifiers (SSPAs), has launched an ultra-compact high-power SSPA operating in the X- and Ku-bands, suiting use in demanding defence, aerospace and communications applications.

The solid-state power amplifiers are based on gallium nitride (GaN) devices, and offer high pulsed power

performance coupled with a power-to-volume ratio that the firm believes to be among the highest in the industry for such products. Pulsed power output levels of up to 150W have been achieved. The designs are flexible in layout and architecture, and are fully customizable to meet individual specifications for electrical, mechanical and environmental parameters, says the firm. Amplifiers with pulsed power outputs in excess of 1kW, and with multi-octave bandwidths, are also under development.

At June's 2013 IEEE MTT-S International Microwave Symposium (IMS 2013) in Seattle, WA, USA, Diamond Microwave displayed an example of a Ku-band amplifier with a peak pulsed output power of 125W at 16.5GHz and a 1dB bandwidth of 1.5GHz in a space outline that is similar in size to a smartphone. "Our amplifiers are really pushing boundaries with their compact size and high output powers," says managing director Richard Lang.

www.diamondmw.com

Cree licenses nitride materials, HEMT and Schottky diode patents to power conversion device maker Transphorm

Power conversion device maker gains access to nitride materials, HEMT and Schottky diode patents

Cree Inc of Durham, NC, USA has signed a non-exclusive worldwide patent license agreement with Transphorm Inc of Goleta, near Santa Barbara, CA, USA (which designs and delivers power conversion devices and modules) that provides access to Cree's family of patents related to gallium nitride high-electron-mobility transistor and GaN Schottky diode devices for use in power conversion devices.

The licensed family of patents addresses various aspects of making GaN power devices including nitride materials, HEMT and Schottky diode designs and processing technology. While GaN HEMTs are already used extensively in RF markets by Cree and others, their use in power conversion markets has been targeted by Transphorm and other firms.

"Over the last 17 years, Cree has invented technology that enabled

the successful introduction of reliable GaN HEMT devices in the RF market," says John Palmour, Cree's chief technology officer, Power & RF, and one of Cree's co-founders. "Many of these inventions can and are expected to be used by others to manufacture devices in the burgeoning area of GaN power management systems."

www.transphormusa.com

www.cree.com

GaN Systems appoints VP, product management

GaN Systems Inc of Ottawa, Ontario, Canada, a fabless provider of gallium nitride (GaN)-based power switching semiconductors for power conversion and control applications, has appointed Larry Spaziani as VP, product management effective. Spaziani will head the firm product team and be responsible for driving forward acceptance of GaN Systems' unique technology.

"Larry's experience in technical development and successful track

record in marketing and new product launches will drive this important growth phase for our breakthrough device designs in gallium nitride high-power transistors," says CEO Girvan Patterson.

Spaziani joins GaN Systems from International Rectifier, where he was executive director, Enterprise Power Business Development, responsible for managing its new product development team and forging relationships with external business partners and

technology leaders.

Prior to IR, he was VP marketing & business development at CHIL Semiconductor, where he managed the Applications and FAE teams and oversaw 43 new product launches in three years.

Spaziani also held senior positions at Unitrode and Texas Instruments, where he was responsible for off-line and isolated power products. He also has an MSEE from Boston University.

www.gansystems.com

Silvaco joins SEMATECH to co-develop modeling tools for next-generation technologies

TCAD and EDA software to speed new materials optimization for silicon, non-silicon and beyond-CMOS technologies

Silvaco Inc of Santa Clara, CA, USA, a provider of technology computer-aided design (TCAD), circuit simulation and electronic design automation (EDA) software tools, has joined SEMATECH of Albany, NY, USA (the international research consortium of semiconductor device, equipment, and materials manufacturers) to collaboratively develop advanced modeling and simulation tools.

As the microelectronics industry develops emerging and future products, new and improved methods will be needed to meet the associated manufacturing challenges, says SEMATECH. Through their collaboration, SEMATECH will use Silvaco's TCAD and EDA software tools to perform advanced device simulations. Additionally, Silvaco will work with SEMATECH to develop new design, modeling and simulation methods

that will address thermal, mechanical and reliability issues for next-generation technologies.

"As the industry considers numerous new materials, there is a need to develop new modeling infrastructure for those materials and structures," says Paul Kirsch, director of SEMATECH's Front End program.

"We will work together to accelerate the investigation and verification of new materials modeling and optimization for silicon, non-silicon and beyond-CMOS technologies."

Silvaco's TCAD and EDA tools provide R&D capabilities for

process and device simulation, circuit simulation and design of analog, mixed-signal and RF integrated circuits. Such methodologies and technologies will be used to address the scalability of materials, processes, equipment and subcomponents for next-generation wafers and devices.

"Silvaco will provide simulation solutions that address mechanical stress and the reliability challenges for vertical chip integration, as well as meeting the simulation challenges presented by nanometer-scale FinFET devices," says Silvaco's CEO David Halliday. "This partnership will enable Silvaco to provide additional unique solutions to our customers requiring simulation tools for the next generation of wafers and devices," he expects.

www.silvaco.com

www.sematech.org/research/materials

Agilent expands business relationship with Gradient Design Automation

Agilent increases financial commitment in exchange for greater access to Gradient's technology

Agilent Technologies Inc of Santa Clara, CA, USA has announced a new agreement that expands its business relationship with Gradient Design Automation Inc of Palo Alto, CA, a provider of electro-thermal simulation technology used to identify hazards and improve performance in integrated circuits subject to temperature variations during operation.

As part of the agreement, Agilent has increased its financial commitment in exchange for increased access to Gradient's technology. In 2012, Agilent introduced a version of Gradient's

technology integrated within its Advanced Design System software as part of a comprehensive multi-technology solution for RFIC and MMIC development.

"After we selected Gradient's technology and launched an integrated solution last year, our customers responded so enthusiastically we decided to expand our relationship with Gradient," says Todd Cutler, general manager of Agilent EEsof EDA, a suppliers of electronic design automation software for microwave, RF, high-frequency, high-speed digital, RF system, electronic system level, circuit, 3D electromagnetic,

physical design and device-modeling applications. "With thermal issues now one of the toughest challenges facing our customers working on power amplifier IC designs, electro-thermal simulation technology has become a critical part of our product portfolio," he adds.

"In addition to system-on-chip and custom IC applications that Gradient has traditionally targeted, this agreement further validates the benefits of our technology for high-frequency applications," says Gradient's president Ed Cheng.

www.agilent.com/find/eesof-ADS
www.gradient-da.com



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HBTs pHEMTs BiFET/BiHEMTs

SAES Pure Gas agrees to support customers of Johnson Matthey Gas Purification Technology

SAES Pure Gas Inc of San Luis Obispo, CA, USA (a member of the SAES Group) has reached an agreement with Johnson Matthey Gas Purification Technology to provide support to customers who own Johnson Matthey gas purifiers. With the recent closure of the Johnson Matthey Gas Purification Technology business, customers will now be able to contact SAES Pure Gas for ongoing support.

"Following Johnson Matthey's announcement [on 28 March] of the closure of their Gas Purification

Technology business, we were approached by many customers asking for our support," says SAES Pure Gas' CEO Tim Johnson.

"Johnson Matthey offered a full line of palladium membrane hydrogen purifiers, and we recognize this as a critical technology for manufacturing high-brightness LEDs and other high-purity applications," he adds. "We understand the importance of providing ongoing support for customers using this technology. This agreement builds on our recent acquisition [in April] of the

palladium hydrogen purifier business from Power + Energy and establishes SAES Pure Gas as the leading supplier of palladium purifiers."

SAES Pure Gas is now the authorized supplier of both warranty and non-warranty support or replacement for Johnson Matthey HP series, V-purge, HTG, GPT and PSH Series palladium membrane hydrogen purifiers.

www.saespuregas.com

www.pureguard.net

www.powerandenergy.com

Keithley launches source measure unit instrument with interactive touchscreen display

Electrical test instrument and system provider Keithley Instruments Inc of Cleveland, OH, USA has introduced what it says is the first benchtop source measure unit (SMU) instrument with a capacitive touchscreen graphical user interface. According to the firm, the Model 2450 SourceMeter SMU's design offers a fundamentally new way for users to interact with test and measurement instruments. It is based on the firm's 'Touch, Test, Invent' design philosophy.

The new design philosophy reflects recent market changes, including shrinking product design/development cycles and fewer personnel devoted exclusively to test engineering tasks. At the same time, the profile of the typical instrument user has evolved. To accommodate these market and user changes, the Model 2450 incorporates numerous ease-of-use features, including a context-sensitive help function, 'Quickset' modes that speed instrument configuration, and on-screen

graphing capabilities that quickly turn raw data into usable results.

The Model 2450 combines the functionality of a power supply, true current source, 6-1/2-digit multimeter, electronic load, and trigger controller in one tightly integrated, half-rack instrument. With all of these capabilities, the Model 2450 integrates the capabilities of I-V systems, curve tracers, and semiconductor analyzers at a fraction of their cost.

www.keithley.com

SAMCO's stock transferred to Tokyo Stock Exchange

Japan's SAMCO Inc, which supplies etch, chemical vapour deposition (CVD) and surface treatment systems for the semiconductor industry, says that its stock listing has been transferred from the TSE JASDAQ (Standard) market to the Second Section of the Tokyo Stock Exchange market (TSE). SAMCO says that it represents the first transfer of a listing since consolidation of the Tokyo Stock Exchange (TSE) and the Osaka Securities Exchange (OSE) on 16 July.

SAMCO specializes in manufacturing thin-film deposition (PECVD), etching (ICP, RIE, DRIE) and surface treatment (plasma and UV-ozone cleaning) systems for the production of compound semiconductor, optoelectronics, MEMS and other electronic components, including next-generation power devices and LEDs. Since the company was founded in 1979, for the past 33 years it has maintained continual profitability.

In May 2001, SAMCO went public on the Japan Securities Dealers

Association over-the-counter market (now TSE JASDAQ – standard). However, SAMCO determined it was best to switch to the main market of the TSE in order to improve its performance in developing new fields and expanding into global markets. The company hence obtained approval from the TSE to switch to the Second Section of the TSE.

SAMCO adds that it aims to be listed in the First Section of the TSE in the near future.

www.samcointl.com

AXT's revenue grows 4.5% in second-quarter 2013

CPV-driven doubling of Ge substrate revenue outweighs drop in GaAs

For second-quarter 2013, AXT Inc of Fremont, CA, USA has reported revenue of \$23.8m, down 5.5% on \$25.2m a year ago but up 4.5% on \$22.4m last quarter. "Our results for the second quarter came in within our guidance range, with revenue improving modestly from the prior quarter," says CEO Morris Young.

"We continued to see an evolution of our business as our revenues further diversified across our substrate product portfolio," notes Young.

Gallium arsenide (GaAs) substrate revenue was \$10.6m, down 9.4% on \$11.7m last quarter and 29% on \$14.9m a year ago.

Indium phosphide (InP) substrate revenue was \$2m, up 11% on \$1.8m last quarter and up 54% on \$1.3m a year ago.

Germanium (Ge) substrate revenue was \$5.3m, doubling from \$2.6m last quarter and \$2.4m a year ago.

Raw materials sales were \$5.8m, down about 9% on \$6.3m last quarter and \$6.5m a year ago.

"While the wireless market remains soft, germanium substrates showed strong growth," says Young. "Germanium substrates are gaining momentum with increasing demand from CPV [concentrating photovoltaic] terrestrial solar applications," he adds.

"As we continue to work through challenges in the gallium arsenide substrate side of our business, it is encouraging-

While the wireless market remains soft... germanium substrates are gaining momentum with increasing demand from CPV terrestrial solar applications

ing to see growth in other areas in which we have invested over the past two years."

Nevertheless, gross margin has fallen further, from 29.8% a year ago and 15.6% last quarter to 12.9%. Operating expenses were \$5.2m, up from \$4.7m last quarter and \$4.9m a year ago. Net loss has been cut from \$2.4m (\$0.08 per diluted share) last quarter to \$2m (\$0.06 per diluted share), although this compares with net income of \$1.3m (\$0.06 per diluted share) a year ago. During the quarter, cash and cash equivalents fell further, from \$25.8m to \$22m.

"We continue to manage our expenses carefully and plan our business conservatively in order to weather the near-term environment and position ourselves for success as the market improves," says Young.

www.axt.com



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IN BRIEF

KaiStar ramps LED manufacturing with multiple Veeco MaxBright M MOCVD systems

In second-quarter 2013, Veeco received an order for multiple TurboDisc MaxBright M metal-organic chemical vapor deposition systems from KaiStar Lighting Co Ltd of Xiamen, China, a joint venture between Taiwan's Epistar Corp and China's Shenzhen Kaifa Technology Co Ltd that began LED production in 2012. The systems will be added to KaiStar's current installed base of Veeco MOCVD systems as part of the joint venture's 2013 capacity expansion plan.

"This latest capacity expansion is based on our customers' growing demand for LEDs for backlighting and general illumination applications," says Epistar's president MJ Jou. "We have been delighted with the performance of Veeco's production-proven MOCVD systems, which provide high productivity and low cost of ownership," he comments.

"We are gratified that KaiStar has again chosen Veeco as their MOCVD supplier of choice as they ramp production," says Veeco's executive VP William J. Miller Ph.D.

Veeco reckons that its TurboDisc MaxBright M GaN MOCVD multi-reactor system is the industry's highest-footprint-efficiency MOCVD system designed to manufacture high-brightness light-emitting diodes (HB-LEDs), providing up to 15% improved footprint efficiency and easier serviceability as well as offering flexible layout configurations compared to the original MaxBright.

www.veeco.com/mocvd

Sanan expands LED production capacity with Veeco MaxBright M MOCVD systems

In third-quarter 2013 China's largest LED maker Sanan Optoelectronics Co Ltd placed a multi-tool order for Veeco TurboDisc MaxBright M metal-organic chemical vapor deposition (MOCVD) systems.

The multi-reactor systems will be used to ramp production of LEDs in its fab in Xiamen, China, for applications including backlighting and general illumination.

"Veeco has been and remains our MOCVD supplier of choice," says Sanan's CEO Zhiqiang Lin. "As we were selecting equipment for our new phase of expansion, it was evident that the MaxBright M would give us the best footprint efficiency to maximize space and productivity in our Xiamen fab," he comments. "Veeco has been a great partner for us since as we have solidified our



Veeco's TurboDisc MaxBright M MOCVD system.

position as the top LED manufacturer in China and as we have increased our business outside of China as well," he adds.

According to LED market analyst firm IMS Research, China remains the largest region in LED chip production, with the most potential for adoption across all lighting applications, notes Veeco's executive VP William J. Miller Ph.D. "We believe Sanan is well positioned to capitalize on that growth."

www.sanan-e.com/en

Veeco receives NASDAQ notice regarding late filing for second-quarter 2013

Epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA says that on 14 August it received a letter from The NASDAQ Stock Market LLC notifying it that it is not in compliance with NASDAQ Listing Rule 5250(c)(1) because its quarterly report on Form 10-Q for second-quarter 2013 was not filed on time with the US Securities and Exchange Commission (SEC).

Previously, the firm's annual report on Form 10-K for 2012 and Form 10-Q reports for third-quarter 2012 and first-quarter 2013 were also not filed on time. This is because Veeco is reviewing the timing of recognition of revenue and related expenses on the sale

of certain of its products. The accounting review was announced on 15 November 2012.

On 17 July, the NASDAQ Listing Qualifications Panel informed Veeco that its request for continued listing on The NASDAQ Stock Market until 4 November had been granted. On or prior to 4 November, Veeco must regain compliance with all applicable requirements for continued NASDAQ listing, including filing its outstanding annual and periodic reports with the SEC.

Veeco says that it continues to conduct its review and intends to file its Forms 10-Q and 10-K as soon as reasonably practicable after the accounting matters have been resolved.

Veeco's orders rebound by 21% to \$85m in Q2, driven by MOCVD orders rising 40%

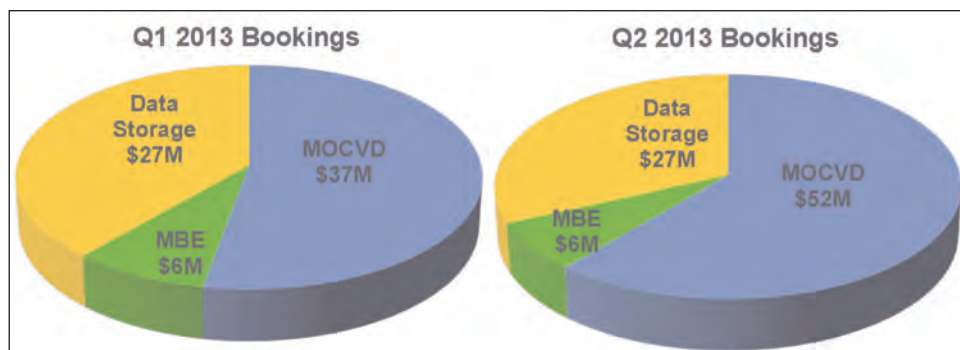
But MOCVD orders remain choppy and MBE production orders slow

Epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA has reported selected financial metrics and business highlights for second-quarter 2013 (excluding revenue and earnings, due to the firm's ongoing review of revenue recognition, announced last November).

Compared with first-quarter 2013, shipments were up sequentially for metal-organic chemical vapour deposition (MOCVD) but flat for both molecular beam epitaxy (MBE) and Data Storage. "While [overall] shipments were up sequentially, we continued to experience weak business conditions," commented executive VP & chief financial officer David Glass.

"We are experiencing the most challenging business conditions since 2009, and this downturn has persisted longer than anyone predicted," continued Glass. "Business conditions have been weak across all our end markets for well over a year now." Veeco says that, since there are so few deals available in MOCVD, it continues to experience significant competitive pricing pressure, which is having an adverse impact on margins and the breakeven level. "We continue to focus on carefully managing our operating expenses and we have installed strong inventory and working capital disciplines to continue to fund our R&D at high levels," noted Glass. During the quarter, Veeco's unaudited cash balance fell slightly from \$588m to \$585m. "We are maintaining a strong financial base [in terms of cash] from which to weather this storm," he added.

"We made only a small backlog adjustment of under \$2m during the latest quarter," said Glass. Order bookings were \$85m, rebounding by 21% from \$70m last quarter (following a 24% drop from \$92.3m in Q4/2012). This comprised



Data Storage orders of \$27m (level with last quarter) and LED & Solar orders of \$58m, rebounding by 35% from \$43m last quarter (following a 43% drop from \$75.4m in Q4/2012). Of LED & Solar orders, \$52m were for MOCVD (rebounding by 40% from \$37m last quarter, following a 42% drop from \$62.8m in Q4/2012) and \$6m were for MBE (level with last quarter, following a drop of 51% from \$12.6m in Q4/2012).

"MOCVD orders improved by about 42% sequentially to \$52m as we won important deals in Korea, Taiwan and China," said chairman & CEO John Peeler. "Data Storage and MBE business conditions remain muted as customers continue to manage their capital expenditures tightly, so second-quarter orders were flat on a sequential basis."

Market trends are still mixed. "In MOCVD, utilization rates at many of our key LED customers [in Asia] are high and stable: 80%, 90% or even 100%," said Peeler. "All the reports indicate that LED lighting is ramping... Many of Veeco's top customers are reporting strong demand for mid-power LEDs for indoor replacement bulbs and high-power LEDs for outdoor lighting. Some customers are optimistic in moving to increase capacity, while others are holding out and waiting before committing more capital... They remain extremely cautious about capacity expansion," he commented. "While orders were up 42% sequentially,

they're still relatively weak. MOCVD order patterns are likely to remain choppy because of the timing of large, multi-unit deals, and have a significant impact on our quarterly bookings level," added Peeler.

"In the latest quarter, we had our first multi-unit capacity buy from Korea in three years — one of the world's top LED manufacturers, which is adding capacity to support LED demand growth in tablets and lighting applications," Peeler noted. "We have also booked a multi-unit order from KaiStar [a Chinese joint venture of Taiwan's largest LED chip and epiwafer maker Epistar]. We've performed well in their Xia-men fab, and they have now selected Veeco for their increased capacity needs." Also in July, Veeco booked a large multi-unit deal with China's largest LED maker Sanan. Both KaiStar and Sanan, selected Veeco's TurboDisc MaxBright M multi-reactor MOCVD systems.

Looking ahead, "While our quoting activity has increased from earlier in the year, the conversion process from quotation to purchase order is slow," cautioned Peeler.

In the meantime, during Q2, two customers selected Veeco for substantial MOCVD service contracts. "While business is challenging, we remain focused on all aspects of our strategy to get Veeco growing again," stated Peeler. "We're growing our services business to maintain our edge as the preferred supplier to top industry players."

► “In MBE, the production side of the business continues to be slow,” noted Peeler. “But on the R&D side of the business, our deal funnel is improving and we booked our first order for new-generation systems for R&D customers this quarter. While we’re seeing some customer pull from the research market, it’s clear that the US Government sequester is having an impact on our customers’ research funding.”

“We’re seeing signs of life in the market for LEDs and elsewhere, and we continue to invest in next-generation product development, both to expand our strong leadership positions and to enter into new growth markets,” summarizes Peeler. *Matthew Peach, Contributing Editor*

MOCVD/LED:

- Utilization rates stable at high levels
- Increased quoting and pick-up in customer confidence
- But caution remains and orders still low

MBE:

- Deal funnel is improving for R&D; starting to increase our win rate
- Wireless market still digesting capacity; focused on growing Services

Data Storage:

- Little capacity buying
- Customers making strategic investments for HAMR and other next-gen technology



Current trends in Veeco's various markets.

Veeco launches GENxplor MBE system for compound semiconductor R&D

Fully integrated design combining reactor and electronics aids usability and flexibility

Epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA has introduced the GENxplor molecular beam epitaxy (MBE) deposition system, which is said to be the industry's first fully-integrated MBE system for the compound semiconductor R&D market. The GENxplor creates epitaxial layers on substrates up to 3" in diameter and is suitable for research on a variety of materials including gallium arsenide (GaAs), nitrides, and oxides.

“The compound semiconductor R&D community asked for a more affordable, flexible, and easy-to-use MBE system and Veeco has delivered with the GENxplor,” comments Jim Northup, Veeco's VP & general manager. “We have repackaged Veeco's industry-leading MBE technology into a novel ‘all-in-one’ design that combines the reactor and electronics on a single frame. It will change the way researchers use MBE,” he reckons.



Veeco's new GENxplor R&D MBE system.

The GENxplor uses Veeco's proven GEN10 growth chamber design and incorporates process flexibility that makes it suitable for materials research on emerging technologies such as UV LEDs, high-efficiency solar cells, and high-temperature superconductors. Its efficient single-frame design combines all vacuum hardware with on-board electronics to make it up to 40% smaller than other MBE systems, it is reckoned, saving lab space. Because the

manual system is integrated on a single frame, installation time is reduced, says the firm. The GENxplor's open architecture design also improves ease-of-use, provides convenient access

to effusion cells, and allows easier serviceability compared with other MBE systems, the firm adds. Coupled with Veeco's recently introduced retractable sources, the GENxplor system facilitates oxide materials research.

Veeco says that, in recognition of the growing influence and importance of China in the field of MBE research, it is launching the GENxplor at this week's China MBE Conference in Shanghai.

www.veeco.com/genxplor

LayTec and Nanometer Structure Consortium develop real-time quantitative monitoring of III-V nanowire growth

LayTec AG of Berlin, Germany, which makes in-situ metrology systems for thin-film processes, focusing

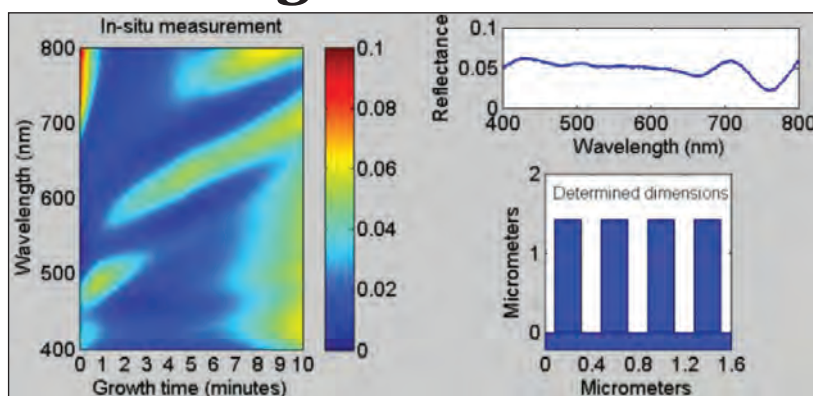


Fig. 1: Software display after a complete nanowire growth run. In the plot (left), the reflectance is given by the color.

on compound semiconductor and photovoltaic applications, and Sweden's Nanometer Structure Consortium at Lund University have jointly developed a solution for real-time quantitative monitoring of III-V nanowire growth.

First results were presented by Martin Magnusson of Lund University at LayTec's in-situ seminar on 3 June. Professor Lars Samuelson and his team used LayTec's spectroscopic in-situ reflectometer EpiR to monitor the nanowire epitaxial process in an Aixtron 200/4 reactor. Figure 1 shows a metal-organic vapour-phase epitaxy (MOVPE) run sequence where InP shells were grown on InP core nanowires.

The data of previous ex-situ analysis by SEM (see Figure 2) and spectroscopic reflectance [1] were used by Nicklas Anttu of Lund University to develop numerical algorithms for deduction of the average length and diameters of the growing nanowire ensemble (N. Anttu et.al, 'Optical Far-Field Method with Subwavelength Accuracy for the Determination of Nanostructure Dimensions in Large-Area Samples', Nano Lett., 2013, 13 (6), p2662).

Together with these algorithms, the in-situ spectroscopic measurements by EpiR provide information on the evolution of nanowire length and diameter already during growth.

"The first results are very impressive," says Nicklas Anttu of Lund University. "EpiR enables effective process optimization, speeds up development and paves the way to future process transfer for industrial nanowire growth," he adds. "We are confident that in-situ metrology will be a must in nanowire applications in the near future."

Nanowires (or nanorods) are becoming increasingly attractive for next-generation LED and solar cell applications, says LayTec. One of the reasons is that epitaxial III-V nanowire arrays combine one-dimensional electronic states with additional degrees of freedom for strain relaxation and resonant electromagnetic interaction.

www.laytec.de/nanowires

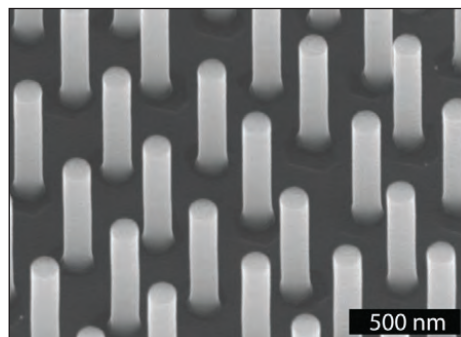
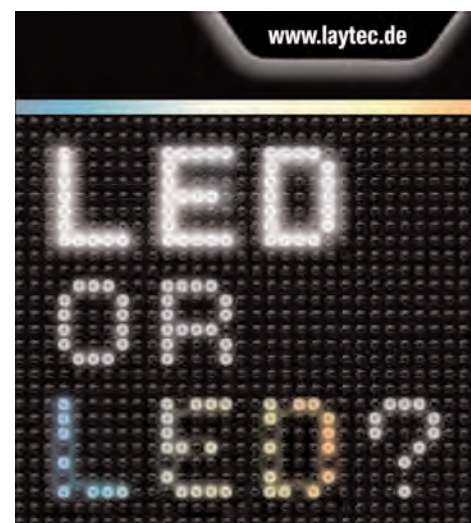


Fig. 2: SEM image of InP nanowires structured with gold particles by nanoimprint lithography. Courtesy: Lund University.



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Aixtron cuts losses as revenue rebounds 13% in Q2

5-Point-Program yields progress in efficiency and cost reduction

For second-quarter 2013, deposition equipment maker Aixtron SE of Aachen, Germany, has reported revenue of €45.3m, down 1.7% on €46.1m a year ago but up 13% on €40.2m last quarter. Aixtron also recorded improvements in its gross profit and operating result (EBIT).

The firm said that this development reflects "the first positive impacts" from its 5-Point-Program, which commenced in Q1/2013. It added that efficiency improvements and cost-cutting measures resulted in reductions in both cost of sales and operating expenses.

However, investment demand from LED makers remained subdued despite a continued reduction of production overcapacities in the market. This was also reflected in only modest development of order intake (from €29.9m in Q1 to €30.5m in Q2).

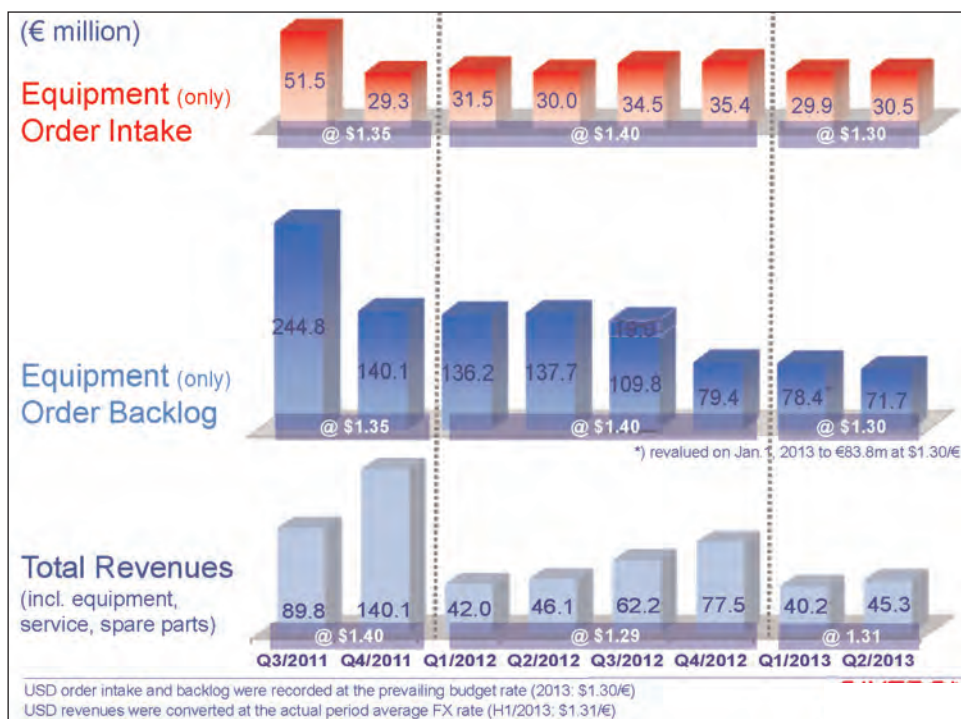
Earnings before interest and taxes (EBIT) of –€9.8m improved on both –€16.5m a year ago and –€76.3m last quarter. The sequential development reflects the initial success of the '5-Point-Program', which began in Q1/2013, the firm says.

Despite a cash outflow of –€3.7m in Q2, free cash flow in first-half 2013 was €5.6m (due to + €9.3m in Q1). As of end-June, Aixtron recorded cash and cash equivalents (including bank deposits with a maturity of more than three months) were €215.9m (down from €219.9m at the end of March, but up from €209.5m at the end of 2012).

5-Point-Program: initial success

The program, presented by the CEO in May, consists of a number of targeted individual projects, designed to address the following five topics: (1) a focus on customer benefits; (2) utilization of technology and product portfolio; (3) processes; (4) attention to financial targets; and (5) strengthening of Aixtron's corporate culture.

In particular, after planning and implementing an improved product



Aixtron's 24-month business development, showing recovery in revenue from Q3/2011 to Q2/2013.

development process, a specific initiative for the optimization of Aixtron's supply chain has been started. The aim is to increase efficiency on a global scale in procurement, logistics and inventory-management.

Aixtron is also continuing to develop its 'customer-specific' measures, such as increasing output and yield of the installed base. Another major objective of the program is to cut operating expenses by 20%.

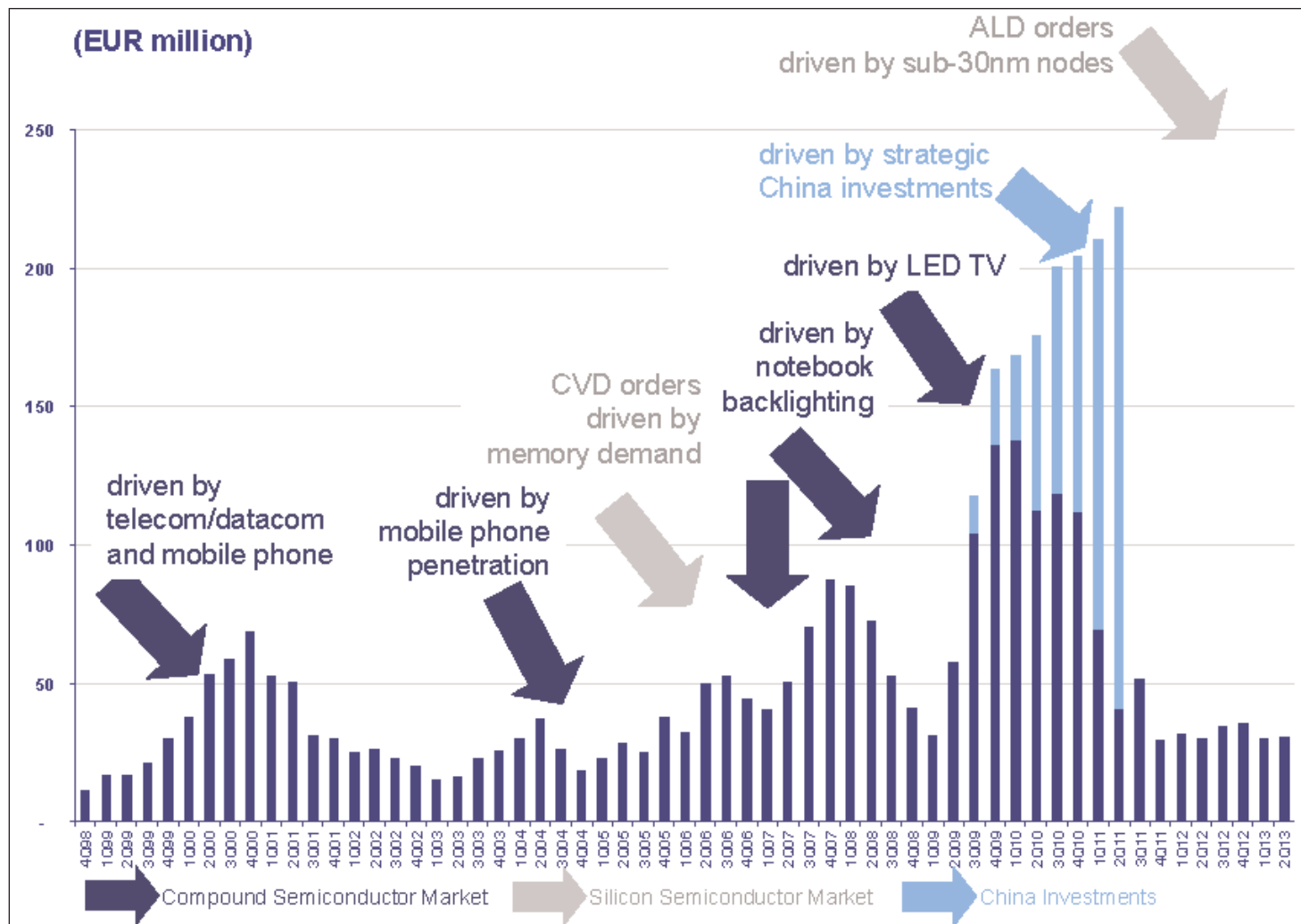
"With our 5-Point-Program we are on track to regain sustainable profitability," says Martin Goetzeler (president & CEO since 1 March).

"Our main focus is on innovative technology solutions, increasing the production efficiency of our customers as well as the efficiency of our own core process flows," he adds. "This is valid for all of our targeted growth markets, including applications beyond LED, such as next-generation memory chips. Our Q2 figures show first positive results of the successful implementation of our 5-Point-Program," Goetzeler continues.

Outlook

For first-half 2013, equipment order intake of €60.3m was broadly unchanged year-on-year, down 2% on €61.5m. Sequentially, equipment order intake remained "rather subdued", rising just 2% from €29.9m in Q1 to €30.5m in Q2. Total equipment order backlog at the end of June 2013 was of €71.7m, down 48% on €137.7m at end-June 2012 and down 14% on the 2013 opening backlog of €83.8m (revalued as of 1 January at the exchange rate of \$1.30: €1.00, valid at the time).

"The rising rates of capacity utilization at leading LED manufacturers give reason to believe that the overcapacity in the market for MOCVD equipment for the production of LEDs continues to diminish," commented Goetzeler. "However, it remains difficult to predict, when and to what extent this will translate into significant new equipment orders. Due to this continuing low visibility, our management remains unable to give precise guidance on the company's revenues and EBIT



Aixtron's quarterly equipment orders, showing flat levels since the end of 2011.

margin for the current financial year," he adds.

"However the prospects for the deposition technologies offered by Aixtron remain positive. The initi-

ated measures contained in the 5-Point Program will contribute to a further stabilization of the company's cost and earnings situation in the second half of 2013," Goetzler

concludes. "The executive board still expects Aixtron not to require any bank financing in the foreseeable future."

Matthew Peach, Contributing Editor

HG Genuine expands optical component production capacity with additional MOCVD system

China-based optical component maker Wuhan Huagong Genuine Optics Tech Co Ltd (HG Genuine) has ordered an Aixtron 6x2"-wafer Close Coupled Showerhead (CCS) epitaxial deposition system for production of light-emitting and detection devices on indium phosphide (InP) substrates.

Aixtron's CCS 6x2" system is designed for research and production. Processes developed using the CCS systems can be easily scaled up for deployment on the larger mass-production CRIUS platforms,

says the firm. The three-zone heater of the CCS provides best temperature uniformity standards.

"This repeat order reflects our complete satisfaction with the performance of Aixtron's technology," says HG Genuine's chief scientist Zhaozhong Wang. "Our existing system has demonstrated versatility, ease of operation and reproducibility," he adds. "With the new system we will be able to carry out our planned expansion of capacity and to develop high-quality epitaxy products. I am looking forward to

another smooth ramp-up as well as the excellent service, installation and operation we have come to expect from Aixtron's service team."

HG Genuine possesses complete mass production lines for epitaxy, chip fabrication, devices, optical modules and subsystems. The product range covers semiconductor laser and detector chips, active devices and transceivers (widely applied in digital communication, analog communication and optical sensors).

www.aixtron.com

IN BRIEF

Oxford Instruments and Cornell co-host seminar

On 20–21 August, Oxford Instruments co-hosted a seminar 'Nanoscale Plasma Processing' with Cornell University.

Invited guest speakers included professor Peter Ashburn of Southampton University, UK ('Application of plasma processing to nanowire biosensors for the diagnosis of respiratory disease') and Caltech professor Axel Scherer ('3D etching of Silicon Devices at Scales below 10nm').

Speakers from Cornell, and process and applications experts from OIPT, spoke on topics including: ALD, deep silicon etch, compound semiconductor etching, HBr silicon etching, dielectric etching at the nanoscale, polymer etching and other topics during the two-day programme.

University of Glasgow receives £3m in funding for engineering research using tools manufactured by OIPT

The University of Glasgow has been awarded a £3m share of £85m in government funding for equipment to support pioneering research to improve the efficiency of electronic and optical components, which includes developing advanced processes on multiple commercial micro- and nano-fabrication tools manufactured by UK-based etch, deposition and growth system maker Oxford Instruments Plasma Technology (OIPT, part of Oxford Instruments plc).

The award from the Engineering and Physical Sciences Research Council (EPSRC) will support work undertaken by researchers from the University of Glasgow's College of Science and Engineering in collaboration with OIPT, the National Physical Laboratory, the National Microelectronics Institute and Gas Sensing Solutions.

The funding will be used by the university to purchase new equipment including several Oxford Instruments Plasma Technology tools to etch semiconductor materials and deposit electrically insulating layers, techniques which are used to fabricate electronic and optical devices including transistors, LEDs and lasers.

OIPT's tools will support a range of new research projects, including:

- The development of more efficient power electronics.
- Improving efficiency and durability of solar collection technology.
- Development of a 'superspectral' imaging camera which will integrate visible, infrared and mid-infrared imaging sensors on a single chip for the first time (with applications for security and medical sensing technology).

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For more information, please contact Oxford Instruments Plasma Technology:

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www.oxford-instruments.com/plasma



China's AMEC granted Validated End-User status by US Department of Commerce

Advanced Micro-Fabrication Equipment Inc (AMEC) of Shanghai, China has been granted Validated End-User (VEU) status by the US Department of Commerce. AMEC makes dielectric and through-silicon via (TSV) etch systems, and at March's SEMICON China show in Shanghai it launched the Prismo D-Blue multi-reactor metal-organic chemical vapor deposition (MOCVD) cluster tool for nitride-based high-brightness LED production.

The VEU program aims to enhance high-tech civilian trade between the US and VEU-eligible firms in China, reducing licensing burdens on industry by allowing US exporters to ship designated items to pre-approved entities under a general authorization instead of individual export licenses. These entities now include AMEC.

The qualification process is lengthy and rigorous, says AMEC, with only those that have shown rigid standards of conduct and accountability relevant to the use of the designated products being approved. Fewer than 20 China-based companies are VEU-approved, and most are large enterprises with extensive teams to implement the necessary internal controls.

AMEC says that critical parts used to build its micro-fabrication equipment are sourced from tier-one

AMEC says that critical parts used to build its micro-fabrication equipment are sourced from tier-one US suppliers

US suppliers, which are often the sole viable and/or highest-quality vendor of such parts. As a VEU-approved company, AMEC can now purchase parts with reduced licensing-related delays, while its US suppliers can expedite sales to a trusted China-based customer.

"Although we are headquartered in Shanghai, our customers are to be found worldwide," says VP & general counsel Matthew P. Ruby. "They are accustomed to buying advanced equipment made with highest-quality parts and materials," he notes. "Today's development removes certain export licensing burdens and helps us deliver the exceptional technology they require by broadening our sourcing options."

www.amec-inc.com



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ClassOne expands European operations to support Semitool equipment

Offices in Norwich and Grenoble to focus on sales and field service

ClassOne Equipment of Atlanta, GA, USA (which supplies refurbished wafer fabrication equipment) has increased its presence in Europe with the opening of new facilities committed to the sales and support of the wet chemical processing products of both ClassOne Equipment and its new subsidiary ClassOne Technology (the firm's Design and Development Center in Kalispell, Montana, opened in July). This includes ClassOne's traditional products such as remanufactured Semitool SATs, SSTs, and Equinox tools, as well as new products such as the field-retrofitable Polaris controller that extends the life of existing tools by 10 years or more.

The first new office in Europe, located in Norwich, England, will be engaged primarily in sales, while the second, in Grenoble, France, will provide field service. These facilities supplement ClassOne's existing office in London, which

continues to focus on ClassOne's three other divisions: SPTS Plasma Etching & PECVD, Suss/EVG Mask Aligners, and KLA-Tencor Wafer Inspection & Metrology.

"The European market is extremely important for emerging technologies such as MEMS, nanotech, LED and RF power devices, particularly since the vast majority of these devices are produced on 75–200mm substrates," says ClassOne's president Byron Exarcos. "There exists a large installed base of Semitool wet processing equipment in the region, and our products and services are in high demand. The expansion of our European operations will certainly enhance ClassOne's growth, but more importantly it will benefit our customers by providing the tools, upgrades, parts, and service that their success depends on," he adds.

"With the acquisition of Semitool by Applied Materials (AMAT) in

2009, it appears that the interest in supporting the Semitool batch tool product line has declined," says ClassOne Technology Europe's director Bill Tutte. "Customers have reported that they have struggled to receive good technical support at a commercially viable cost since then. With the opening of our new offices we believe that we are well placed to succeed and reverse this apparent trend," he adds. "Our new offices are 100% dedicated to Semitool equipment expertise and are led by myself, for sales from the UK, and another former Semitool employee, Jon McGinn, in France. Between us we have over 30 years of Semitool experience."

The new offices are now open for business and are can be contacted directly with inquiries for equipment, spare parts, field repairs, lift & rotate refurbishments, or service contracts.

www.ClassOneEquipment.com

Bilkent University upgrades ALD system with Meaglow's hollow cathode plasma source

Meaglow Ltd of Thunder Bay, Ontario, Canada, a privately held firm that produces migration-enhanced afterglow epitaxy equipment and molecular beam epitaxy (MBE) and metal-organic chemical vapour deposition (MOCVD) accessories as well as providing specialized thin films, has announced the installation of a hollow cathode plasma source for the group of professor Necmi Biyikli of the Institute of Materials Science and Nanotechnology at Bilkent University in Turkey. The plasma source is being used to upgrade the group's atomic layer deposition (ALD) system by replacing an inductively coupled plasma source. Meaglow says that the enhancement will

reduce the oxygen contamination in the ALD system and increase the quality of the nitride thin films that are grown.

"The Bilkent system was easy to retrofit and the Meaglow Plasma source was the perfect solution for their oxygen contamination problem," says Meaglow's chief scientist, Dr Butcher.

Initial results show a significant reduction of oxygen content in compound nitride films. Results will be presented at the 224th ECS (Electrochemical Society) Fall Meeting in San Francisco, CA, USA (27 October — 1 November) at an invited talk presented in the symposium on 'Atomic Layer Deposition Applications'.

Meaglow is focused on commercializing its hollow cathode plasma technology (which has the advantage of scalability to large deposition areas), and is seeking additional ALD system owners and suppliers interested in removing the oxygen contamination in their films. The Plasma source can be used to retrofit existing systems or can be integrated with equipment manufacturers. It can also be utilized in applications including MBE, and low-pressure metal-organic chemical vapor deposition (LP-MOCVD). Interested parties can e-mail science@meaglow.com.

www.electrochem.org/meetings/biannual/224

www.meaglow.com

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Atlas Copco Group to acquire Edwards

Vacuum and exhaust-abatement equipment maker Edwards Ltd of Crawley, UK and Atlas Copco Group of Stockholm, Sweden, a provider of industrial productivity solutions, have entered into a definitive merger agreement in a transaction valued at up to about \$1.6bn (£1m), including the assumption of debt.

A subsidiary of Atlas Copco will acquire Edwards for up to \$10.50 per share, which includes a fixed cash payment of \$9.25 at closing and an additional payment of up to \$1.25 per share post-closing, depending on Edwards' achievement of 2013 revenue within the range £587.5–650m and achievement of a related adjusted EBITDA target within the range £113.9–145m. The deal is due to close in Q1/2014.

Depending on the amount of any additional payment, the merger represents a premium of 11–26% to Edwards' 30-day-average closing share price of \$8.33 up to 16 August (the last trading day prior to the merger announcement). Edwards priced its initial public offering on

The NASDAQ Global Select Market on 10 May 2012 at \$8.00 per share.

Edwards' shareholders representing about 84% of the current shares outstanding have entered into voting agreements with Atlas Copco to vote in favor of the merger, subject to the conditions set out in the voting agreements.

It is reckoned that the benefits of greater scale will help to accelerate Edwards' growth strategy and provide more opportunities for its staff. Upon completion of the deal, a new Vacuum Solutions Division will be formed within the Atlas Copco Compressor Technique business area, with headquarters in Crawley, UK.

"This strategically and financially compelling transaction provides the opportunity for our stockholders to receive an attractive premium for their shares," says Edwards' CEO Jim Gentilcore. "On top of the cash payment at closing, analyst consensus for the full year and our strong start to the third quarter leads us to believe it is realistic for us to achieve the results that would

deliver an additional cash payment towards the upper end of the range to our shareholders," he adds.

"The two companies share very similar strategic goals, strong brands and leading market positions," says Gentilcore. "The Edwards brand and reputation will benefit from the support, expertise and financial strength that Atlas Copco will bring."

The merger, which has been unanimously approved by the boards of directors of both companies, is subject to shareholder approval, anti-trust clearance, and customary closing conditions.

Founded by F.D. Edwards in 1919, Edwards High Vacuum International became part of The BOC Group in 1968, and was named BOC Edwards in 1997. The Linde Group acquired The BOC Group in September 2006. In March 2007, Linde Group sold the component business (vacuum pumps and semiconductor equipment) of BOC Edwards for €685m (£460m) to private equity firm CCMP Capital.

www.edwardsvacuum.com

SEMI-GAS' Auto-Guard prevents accidental gas release

SEMI-GAS Systems, a division of Applied Energy Systems Inc of Malvern, PA, USA and a manufacturer of ultra-high-purity gas source and distribution systems, offers a controller-activated cylinder connection cover that the firm says enhances safety in gas delivery environments. Auto-Guard protects gas technicians from exposure to hazardous production materials as well as the integrity of process gas and related equipment by controlling access to active gas cylinder connections.

Auto-Guard enhances specialty gas operations by preventing accidental disconnection of a hazardous gas cylinder from a gas source manifold. An extended shroud on the guard clearly indicates that it is unsafe to attempt to disconnect a cylinder, preventing access to the CGA or

DISS nut. A retracted shroud on the guard indicates that the system is in a safe state and allows the operator access for disconnection. Auto-Guard remains in this retracted position until a cylinder change and/or leak test has been successfully completed, says the firm.

The Auto-Guard cover is 100% pneumatically actuated and does not include any springs or mechanical components. Via an automatic controller, pneumatic signals open and close the device. In the event of an electrical failure or pneumatic pressure loss, the connection cover shroud remains in the same position prior to when the failure occurred.

"The industry has experienced numerous accidental hazardous gas releases due to the operator either trying to disconnect the wrong cylinder or trying to disconnect the

cylinder before it has been properly purged," said Applied Energy Systems' president, Steve Buerkel. "The Auto-Guard connection cover prevents these errors, taking safe operation of gas cabinets to a new level."

The Auto-Guard connection cover is recommended for use with all hazardous production materials (HPM) and access-restricted gases. It can be installed with minimal downtime on most standard cylinder connection pigtailed, typically without any equipment modifications.

Auto-Guard is constructed of 302-series stainless steel, anodized 6061-T1 aluminum and corrosion-resistant Viton O-Rings. It is a standard option for use with all SEMI-GAS Centurion Gas Cabinets and GigaGuard PLC controllers.

www.semi-gas.com

CRAIC introduces automated version of 20/30 Perfect Vision UV-visible-NIR microspectrophotometer

UV-visible-NIR microscope and microspectrometer manufacturer CRAIC Technologies of San Dimas, CA, USA has launched an automated version of its flagship product, the 20/30 Perfect Vision UV-visible-NIR microspectrophotometer.

The new system is designed to be fully programmable to automatically analyze microscopic samples with UV-visible-NIR spectroscopy and microscopy. Imaging and spectroscopic analysis of samples can be done by absorbance, reflectance and fluorescence from the deep UV to far into the near infrared. Applications include contamination analysis of hard disk components, thin film measurement of semiconductors, and microcolorimetry of flat panel displays.

"The automated 20/30 PV microspectrophotometer is the ideal tool for a laboratory or factory due its cost effectiveness for analyzing many samples quickly and accurately," claims president Dr Paul Martin.

The automated 20/30 PV microspectrophotometer integrates CRAIC's Lightblades spectrophotometer technologies with custom-built UV-visible-NIR microscope and powerful, easy-to-use software. Incorporating fully programmable automation features, touchscreen controls and advanced software control, the instrument is designed to acquire data from microscopic samples by absorbance, reflectance or even emission spectroscopy. By including high-resolution digital imaging, the user is also able to use the instrument as an automated UV, color and NIR microscope. Sophisticated software, ranging from image analysis, spectral analysis, film thickness determination and even colorimetry are all available to enhance the capabilities of the automated 20/30 PV microspectrophotometer.

www.microspectra.com



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The Business of Science®

Rubicon's revenue rises 28% in Q2, driven by strengthening LED market

Sapphire pricing rises for first time in two years

For second-quarter 2013, Rubicon Technology Inc of Bensenville, IL, USA (which makes monocrystalline sapphire substrates and products for the LED, RFIC, semiconductor and optical industries) has reported revenue of \$10.6m, down 38% on \$17m a year ago but up 28% on \$8.3m last quarter due to revenue for 2" and 4" core products rising six-fold from \$1m to \$6m. Growth was driven by the strengthening LED market (with the general lighting segment playing a key role in the increasing demand for LED chips), offset partly by revenue for 6" wafers almost halving, from \$6.1m in Q1 to \$3.2m — most of which was sold to the sapphire-on-silicon (SoS) market — due to high inventory levels at the firm's two main 6" customers resulting in reduced orders.

Rubicon began scaling back crystal growth production in Q1 to reduce boule inventory levels. Utilization of crystal growth facilities is hence currently only 45%. However, the lull in 6" sales has led to utilization of the firm's polishing operations falling to just 10%. Idle plant costs have hence risen from \$2.3m to \$3.7m (a significant contributor to gross loss almost doubling from \$3.4m to \$6.4m). "Keeping crystal growth utilization low has allowed us to begin converting boule inventory into cash," says president & CEO Raja Parvez. "However, the resulting idle capacity is currently having a significant impact on our margin." The increased mix of smaller-diameter sales, with prices currently below total cost, has resulted in additional pressure on profit margins.

Net loss of \$5.9m (\$0.26 per share) is up from \$3.4m (\$0.15 per share) last quarter and \$1.3m (\$0.06 per share) a year ago. Despite this, during the quarter, cash and investments rose from \$36m to \$41m due to reducing total inventory by

\$5.8m, aided by strong accounts receivable collections.

Despite the greatly increased shipments, pricing for 2" and 4" core products still rose by about 10% in Q2. "This is the first time in two years that sapphire pricing has increased," notes Parvez. "The strengthening LED market is absorbing the excess global slide of sapphire which has kept sapphire pricing at record lows for the past two years."

Changes in market pricing are usually reflected in Rubicon's financial results in the following quarter due to the lead time on customer orders, so changes in market pricing in Q2 will be reflected in Q3's financial performance. Rubicon reports that demand for 2" and 4" core products remains robust, with pricing in Q3 up by at least an extra 10% presenting further evidence of the strengthening market. "While pricing for 2" and 4" core is still below our total cost, current market pricing for those products is near breakeven, and we believe we will see the pricing environment for those products continue to improve in the coming quarters," says Parvez.

Overall demand from the LED market has been improving, driven by increasing adoption of LEDs for general lighting applications. Rubicon expects LED demand to continue to strengthen, given the momentum in the LED general lighting segment. Also, non-LED applications for mobile devices (such as camera lens covers, portions of the face plate to allow for biometrics like fingerprint recognition and

smart watches) have the potential to add considerable demand for sapphire next year.

"We expect improvement in 6" wafer orders later this year, and we are on schedule to begin offering 4" and 6" patterned sapphire substrates (PSS) by the end of the year," Parvez says. "The PSS product will allow us to capture more revenue and margin on the same surface area of sapphire. It could also help facilitate 6-inch adoption among chip manufacturers, as there will be one less process to scale up before migrating to a larger platform," he adds.

"Based on the large core volumes we are currently shipping, we expect our boule inventory levels to decrease quickly [approaching a more normal level by the end of this year] and anticipate re-engaging idle crystal growth capacity early next year," says chief financial officer William Weissman. "Utilization of our polishing operations will improve with the strengthening of 6" wafer orders and the start of patterned substrate production [which will begin to absorb capacity]," he adds. Capital expenditure was \$2.9m in Q2. "We expect to spend \$7–10m over the rest of the year, primarily on building our PSS wafer capability, and enhancing our polishing platform to further reduce wafer cost," forecasts Weissman.

"The LED market will continue to strengthen, and we expect pricing for 2" and 4" cores to be higher in the third quarter," says Weissman. "It will take another quarter or two to see a meaningful improvement in 6" wafer orders and there will likely be additional price pressure on that product in the near-term," he believes. Q3's revenue is hence expected to be similar to Q2's.

"Idle plant costs will remain high in the third quarter, but we should see some improvement in prof-

Demand from the LED market has been improving, driven by increasing adoption of LEDs for general lighting applications

itability with pricing increases for 2" and 4" cores and product cost reductions, offset partially by lower 6" wafer volumes and pricing," adds Weissman. Rubicon hence expects loss per share to be cut slightly to \$0.20–0.24.

"Clearly, we need to expand the 6" wafer user base in order to change the dynamics," says Parvez. "We are offering wafers with very tight certification at very effective pricing as an additional incentive to chip manufactures contemplating a move to 6"," he adds. "We do

believe that we will finally begin to see greater adoption of 6" wafers among major LED chip manufacturers within the next year."

"With the stronger demand from 2" and 4" core, we are shipping significant volumes of sapphire while maintaining a low utilization over crystal growth operation. As a result our total inventory levels are declining, contributing to cash flow," says Parvez. "We expect sales volume of 2" and 4" core to remain high throughout the year which should deplete most of our

boule inventories by the end of the year," he adds. "Based on this outlook, we expect to begin increasing utilization of our crystal growth facilities early next year."

"While we expect another couple of challenging quarter ahead, the improving pricing environment for smaller-diameter products and the expected increase in our factory's utilization, particularly going into next year, should allow us to significantly improve financial performance," Parvez concludes.

www.rubicontechnology.com

BluGlass awarded \$3m Australian clean tech innovation grant

Continued development of RPCVD technology targets cut in greenhouse-gas emissions during LED production

As part of its Clean Technology Innovation Program, the Australian Federal Government has awarded BluGlass Ltd of Silverwater, Australia \$2,999,255 in funding for its project 'Versatile prototype deposition machine for higher efficiency, energy saving, lower cost LEDs on various substrates including silicon'.

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

The support for the firm's continued development of its RPCVD technology represents "an enormous commitment from the Commonwealth Government and demonstrates their continued belief in our ability to bring our breakthrough technology to market," says CEO Giles Bourne.

The project aims to significantly reduce the amount of greenhouse-gas emissions generated in the production of LED devices. BluGlass

claims that its unique low-temperature RPCVD technology offers performance and cost advantages to device makers. They estimate that, for each RPCVD tool put into production, there could be a reduction in greenhouse-gas emissions of more than 39,000 tons of CO₂ equivalent (based on 3.5 million LED lamps per annum).

The funding will allow BluGlass to expedite R&D into GaN-on-silicon substrates. The low cost and large diameter of silicon substrates is currently limited in LED material growth applications because the high temperatures of conventional metal-organic chemical vapor deposition (MOCVD) growth generally lead to bowing of the substrate, resulting in poor manufacturing yields. In contrast, RPCVD is a low-temperature process that is potentially better suited to the growth of GaN-on-silicon substrates, says BluGlass. It is anticipated that this will result in a revenue stream for the firm, as currently GaN-on-Si is not competitive with the industry-standard substrate (sapphire) despite its commercial appeal as a low-cost solution for LEDs.

www.bluglass.com.au

IN BRIEF

Kyma demos nSPEC

Nanotronics Imaging LLC of Cuyahoga Falls, OH, USA says that in May it installed an nSPEC system at Kyma Technologies of Raleigh, NC, USA after the firms established a collaborative partnership following an initial meeting in early 2013.

The nSPEC is an automated, optical, inspection device geared toward defect detection and characterization of semiconductor wafers, dies and devices. As a scanning optical microscope fully integrated with patented image analysis processing, it enables Kyma to inspect its wafers via image analysis software, including the ability to store high-resolution images, capture particular features and areas of interest while translating the acquired visual information into quantifiable data.

"We are very pleased with the kinds of inspection that the nSPEC is giving us, which has already given us significant new insight into our processes," says Kyma's president & CEO Keith Evans.

Kyma is opening its doors for people to see the nSPEC in action, presenting an opportunity for semiconductor groups and universities in the south-eastern USA to learn about its capabilities.

www.nanotronicsimaging.com
www.kymatech.com

SemiLEDs' revenue falls 27% from quarter to quarter

Expenses cut, but one-time charges worsen margins and losses

For its fiscal third-quarter 2013 (to end-May), LED chip and component maker SemiLEDs of Hsinchu, Taiwan has reported revenue of \$3.5m, down 27% on \$4.8m last quarter and 62% on \$9.2m a year ago.

Founded in 2005, SemiLEDs' makes proprietary blue, green and ultraviolet (UV) LED chips under the MvpLED (metal vertical photon LED) brand for sale mainly to chip-packaging customers in China, Taiwan and other parts of Asia such as Korea, or to distributors who sell to packagers. It also packages chips into LED components for sale to distributors and end-customers in selected markets (mainly for general lighting applications, including street lights and commercial, industrial and residential lighting, along with specialty industrial applications such as UV curing, medical/cosmetic, counterfeit detection, and horticulture).

Gross margin has worsened further, from negative 11% a year ago and negative 69% to negative 129%. Likewise, operating margin has worsened further, from negative 87% a year ago and negative 145% last quarter to negative 278%. Margins were negatively impacted by the drop in revenue, excess capacity charges for the firm's LED chips, and goodwill impairment charges (of \$1.1m) and intangible assets that arose from the acquisition of a majority owned subsidiary in August 2011.

R&D expenses have been cut from \$2.2m a year ago to \$1.15m (up only slightly from \$1m last quarter). Selling, general & administrative (SG&A) expenses have fallen further, from \$3.2m a year ago and \$2.6m last quarter to \$2.2m. However, including goodwill impairment charges and impairment of long-

lived assets, total operating expenses have risen from \$3.6m last quarter to \$5.2m (although this is still down on \$6.9m a year ago).

On a non-GAAP basis, net loss was \$6.6m, cut from \$8m a year ago but up on \$5.4m last quarter. Cash used in operating activities was \$2.3m. During the quarter, cash and cash equivalents fell from \$43.9m to \$41.4m.

"Unfortunately the combination of a series of one-time events greatly impacted our business performance this quarter," says chairman, president & CEO Trung Doan. "Despite this brief set-back, we remain confident we have the right strategy in place, focusing on profitable market segments where the performance and quality of our products continues to differentiate us," he concludes.

www.semileds.com

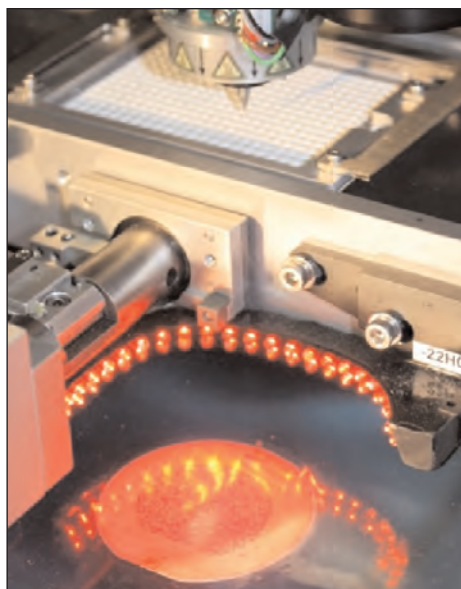
First SMD UVTOP LEDs roll off SETi's high-volume line

New volume pricing enables commercial viability in consumer-type applications

UV LED maker Sensor Electronic Technology Inc (SETi) of Columbia, SC, USA has completed product qualification and shipped the first SMD-packaged UVTOP devices from its high-volume manufacturing line.

The milestone is the result of the first phase of SETi's growth, begun in October 2011 with a \$20m investment into a new dedicated volume production facility and an expansion of its Advanced Technology Center. The first LEDs delivered from the new line were UVC LEDs operating at 275nm for disinfection applications, giving customers access to germicidal UVC LEDs intended for consumer markets.

Mainstream disinfection markets are very cost sensitive, but SETi says that it has set a new pricing structure for standard SMD UV LEDs manufactured through the new line to compete with traditional



light sources. "The new volume production facility has allowed SETi to focus a part of its business solely on manufacturing, which has reduced costs through operational methods and yield improvements,"

says president & CEO Dr Remis Gaska. "We are passing these savings directly to the customer to enable new market opportunities," he adds. UVC LEDs are now available as standard SMD products at prices similar to conventional white LEDs, enabling new product opportunities to take advantage of UV LEDs and enter new consumer markets, reckons SETi.

"We have been working with manufacturers of consumer products for the past few years, and soon we will see UV LEDs in our homes disinfecting water, air and surfaces and keeping our food fresher for longer," comments Gaska.

Additional wavelengths are being qualified through SETi's high-volume manufacturing line, and 310nm LEDs are expected to be available by fourth-quarter 2013.

www.s-et.com

Second law firm files class action suit against SemiLEDs

Law firm Pomerantz Grossman Hufford Dahlstrom & Gross LLP has filed a class action lawsuit in US District Court, Southern District of New York, against LED chip and component maker SemiLEDs Corp and certain of its officers, on behalf of a class consisting of all persons or entities who purchased or otherwise acquired SemiLEDs' securities between 9 December 2010 and 12 July 2011 (the class period).

The class action filed by Pomerantz seeks to recover damages against the firm and certain of its officers and directors as a result of alleged violations of the federal securities laws pursuant to Sections 10(b) and 20(a) of the Securities Exchange Act of 1934 (specifically Rule 10b-5).

Previously, in mid-July law firm Shareholders Foundation Inc filed a lawsuit in the same court alleging violations of federal securities laws by SemiLEDs by making false and misleading statements over the same period.

The complaint by Pomerantz alleges that, throughout the class period, defendants made materially false and misleading statements regarding SemiLEDs' business prospects, and operations. Specifically, it alleges that SemiLEDs misrepresented and failed to adequately disclose that:

(a) it was experiencing known, but undisclosed, pricing pressures for its products which were reasonably likely to result in a material adverse effect on SemiLEDs' future revenues and operating income;

(b) it failed to disclose known events or uncertainties (including the reduction in demand for its products, the loss of a large customer, and the decline in value of its inventory) that had or were reasonably likely to cause SemiLEDs' financial information not to be indicative of future operating results; and

(c) it had filed a false and misleading Registration Statement and Forms 10-Q with the US Securities and Exchange Commission (SEC).

On 10 July 2011, for fiscal third-quarter 2011 (to end-May) SemiLEDs reported revenue of \$5.6m (down 43% year-on-year) and a net loss of \$5.1m (\$0.19 per diluted common share). Results were adversely impacted by a \$1.1m inventory charge during the quarter (equal to more than 7% of the firm's total inventory at 28 February 2011). On 12 July 2011, the firm's stock price fell by nearly 11% (\$0.71 per share) to \$5.87 per share.

Pomerantz says that shareholders who purchased SemiLEDs securities during the class period have until 9 September to ask the court to appoint them as Lead Plaintiff for the class. A copy of the complaint can be obtained from Pomerantz's web-site.

www.pomerantzlaw.com

www.semileds.com



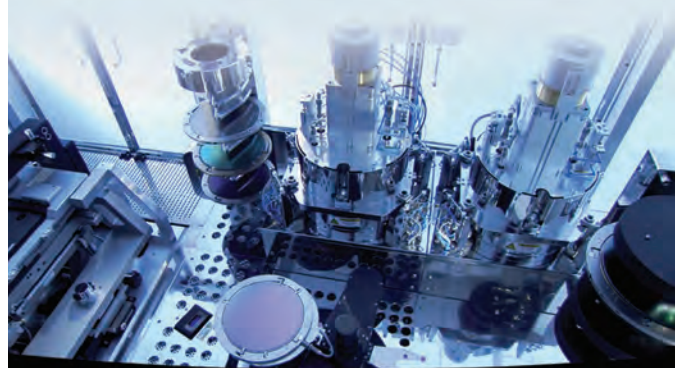
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Cree's quarterly revenue rises 7% to a record \$375m

Growth driven by Lighting product sales; LED bulb manufacturing cost reductions to boost margins

For its fiscal fourth-quarter 2013 (to end-June), LED chip, lamp and lighting maker Cree Inc of Durham, NC, USA has reported record revenue of \$375m, up 7% on \$348.9m last quarter and 22% on \$306.8m a year ago, due mainly to strong sales of the Cree LED bulb and LED components.

By sector, Lighting product revenue grew 33% year-on-year to \$134m; LED product revenue grew 17% to \$217m; and Power & RF product revenue grew 14% to \$24m.

On a non-GAAP basis, gross margin has risen from 36.3% a year ago to 38.2% (at the low end of the targeted range due to the shift in product mix to Lighting products, for which margin is just 25.1% compared to 45.7% for LED products and 53.7% for Power & RF products).

"We made great progress ramping up the Cree LED bulb and implementing a series of cost reductions during the quarter," says Swoboda. "Although the LED bulb gross margin is lower than our overall lighting segment margins, it is improving."

Operating expenses were \$92m, lower than targeted due to reduced sales commissions on lower lighting fixture sales plus lower-than-targeted IP litigation costs.

Net income has risen from \$29.2m (\$0.25 per diluted share) a year ago and \$40.8m (\$0.34 per diluted share) last quarter to \$45.6m (\$0.38 per diluted share).

Cash from operations was \$61m and capital expenditures were \$27m (including \$5m related to patents), yielding free cash flow of \$34m. Depreciation and amortization was \$39m. During the quarter, cash and investments rose by \$86.9m to \$1bn.

"Our fiscal fourth quarter was a strong finish to a great year, with record revenue and good earnings growth in line with our targets," says chairman & CEO Chuck Swoboda.

For full-year fiscal 2013, revenue was a record \$1.39bn, up 19% on \$1.16bn for fiscal 2012. This was driven by Lighting product revenue growing 48% to \$495m, whereas LED product revenue grew just 6% to \$801m. Power & RF product revenue grew 22% to \$89m.

Net income has risen from \$109.2m (\$0.95 per diluted share) for fiscal 2012 to \$155.4m (\$1.32 per diluted share). Cree generated \$285.2m of operating cash flow (up from \$242.3m a year ago) and \$186.9m of free cash flow (up from \$130m a year ago).

"After only 5 years, we created one of the largest lighting businesses in the USA," notes Swoboda. "We grew our LED component product line to \$801m by leveraging our innovative SC3 LED Technology to more than 50% of our LED sales in Q4," he adds. "We utilized our technology lead in Power & RF to open a new generation of applications for these products as we grew sales 22% to \$89m for the year."

Cree listed a range of recent highlights from the latest quarter's activities, including launching:

the XSPR LED residential street light (described as "the first \$99 LED street light targeted to compete with low-cost traditional street lights in residential applications"); its new UR Series LED Upgrade Kit (said to deliver payback in under two years for upgrading from linear fluorescent lamps); the XLamp XH Series of mid-power, ceramic LEDs; and the Cree LED BR30 Flood Light (an extension of its series of LED bulbs). Cree also expanded its CXA

LED family with new 95-CRI options. The firm also announced that the University of North Carolina General Administration has selected LED lighting by Cree as part of its ongoing efforts to reduce energy usage by at least \$25m over seven years.

Business outlook

"Total company backlog is ahead of this point last quarter, as we see good order momentum in our LED lighting product lines and LEDs are tracking in a similar range," says Swoboda. "We are currently targeting solid growth in LED lighting in Q1, driven primarily by our fixture products, as well as incremental growth in LED bulb sales," he adds.

For its fiscal first-quarter 2014 (ending 29 September 2013), Cree expects rises in revenue to \$380-400m and gross margin to 39%.

"Our targeted margin increase is based primarily on incremental lighting improvement due to an increased mix in higher-margin LED fixture sales and LED bulb cost reductions that we implemented during Q4," says chief financial officer & executive VP Michael McDevitt. "This target is based on a number of factors that could vary, including overall demand, product mix, factory execution and a competitive environment," he adds.

Operating expenses are targeted to rise by about \$3m sequentially, due to: incremental R&D spending (to support new product development and cost-reduction programs), higher sales commissions (from a higher targeted revenue) and increased general & administrative (G&A) cost, offset partially by lower marketing spending. Net income is expected to be \$44-50m (\$0.36-0.41 per diluted share).

"Our new products have opened new applications, improved payback, and fuelled growth in LED lighting," comments Swoboda.

www.cree.com



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Cree launches first \$99 LED street light as direct replacement for residential street lights

LED chip, lamp and lighting fixture maker Cree Inc of Durham, NC, USA has launched the XSPR LED Residential Street Light, which delivers better lighting while consuming over 65% less energy at an initial cost as low as \$99 for common applications.

Cree says that the XSPR street light is suitable as a replacement for municipalities and cities using outdated high-pressure sodium fixtures up to 100 watts and can deliver payback in less than one year (based on municipal usage of 12 hours per-day and the US national average of \$0.11 per kWh electric costs).

"With the low initial price of the XSPR street light and the dramatic energy savings, wholesale replace-

ment of existing street lights becomes a simple choice," reckons Al Ruud, Cree vice-chairman, lighting. "Utilities and city managers can now improve the lighting in their neighborhoods, save energy and see payback in less than a year," he adds.

Extending the technical breakthroughs of the XSP Series LED Street Light portfolio, the 25-watt and 42-watt XSPR street light is designed to replace up to 100-watt high-pressure sodium street lights, reducing energy consumption while improving lighting performance. Cree says that its NanoOptic Precision Delivery Grid optic technology achieves better optical control than traditional street lighting fixtures and efficiently delivers

white uniform light. In addition to a low initial cost and significant energy savings, the XSPR street light is backed by Cree's 10-year warranty.

"Street lighting is our city's largest single energy-related cost, and the XSPR street light appears to dramatically change the economics of LED relative to traditional lighting technologies," comments Dan Howe, assistant city manager, City of Raleigh, NC, USA. "This breakthrough technology can change the total cost of ownership equation, encouraging municipalities to transition sooner to LED with less risk, and redirect resources to other important community needs," he reckons.

www.cree.com/lighting/XSPR

Cree launches 4000 lumen LMH2 LED module to replace 70W ceramic metal halide lamps

Cree has launched the 4000 lumen LMH2, which is claimed to be industry's highest-performance LED module, producing the same or better-quality light as 70-watt ceramic metal halide (CMH) lamps while consuming half the power and lasting three times longer.

Cree says that the LMH2 LED module lets lighting manufacturers quickly and easily add LED options to their existing lighting portfolio — addressing different applications with lumen levels ranging from 650 to 4000 lumens with just one set of tooling and one optical design.

The new module family delivers system efficacy of up to 108 lumens-per-watt with a color rendering index (CRI) of more than 90 in all available color temperatures. The LMH2 module family enables manufacturers to leverage one product platform to create an entire product portfolio, delivering the investment protection necessary to quickly and cost-effectively address more lighting applications,



LMH2 LED module with flat (left) and dome (right) lenses.

says Cree.

"They provide LED lighting solutions with low design risk," comments Mike Wang, VP, lighting engineering, at Edison Price Lighting. "The LMH2 LED module delivers all the best features of lighting technology — light output, efficacy, quality of light and long lifetime — in a stable format."

The LMH2 module family is available in a range of lumen (850, 1250, 2000, 3000 and 4000),

color temperatures (2700K, 3000K, 3500K and 4000K) and driver options, including Digital Addressable Lighting Interface (DALI) and DALI touch dimming driver options.

Designed for 50,000 hours

of operation and dimmable to 5%, the LMH2 module comes with Cree's five-year warranty. Luminaire makers seeking ENERGY STAR qualification will have access to specification and performance data, including LM-80 reports, which can speed regulatory approvals.

Samples and production quantities are available with standard lead times from Cree distributors.

www.cree.com/lmh2



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IN BRIEF

Sharp and Osram enter into LED and laser diode patent cross-licensing agreement

Japan's Sharp Corp and Osram GmbH of Munich, Germany have entered into a patent cross-licensing agreement covering light-emitting diodes and laser diodes.

The agreement grants each party the right to use inventions related to LEDs and laser diodes covered by the patents owned by the respective companies around the world. Both firms expect that this will spur their R&D and contribute to further advances in LEDs, laser diodes, and related industries.

Sharp began the mass production LEDs in 1970, followed by the world's first production of infrared laser diodes for CDs in 1982. Sharp says that, with these LED and laser diode technologies built up over the years, it has recently unveiled numerous unique devices, including a high-efficiency, high-brightness 100W-class LED for lighting and a red laser diode that can be used as a light source for displays.

Under the new agreement, the companies' mutual licensing of patents will allow each party to complement its respective technologies. Sharp and Osram believe this will accelerate development of high-performance LEDs and laser diodes and have a positive effect on the creation of devices that match the needs of worldwide markets.

www.osram.com

www.sharp-world.com

This will accelerate development of high-performance LEDs and laser diodes

Osram's multi-chip MultiLEDs give auto designers more color options

With colors playing an increasingly important role in the automotive sector, the interior lighting can also be tailored to a customer's individual taste. Osram Opto Semiconductors GmbH of Regensburg says that, due to the wide blue color range of its new RGB MultiLED, lighting designers have a virtually unlimited choice of colors for ambient lighting, including customer-specific colors. Color design now covers cluster lighting to an increasing extent, notably in combined instruments such as speedometers and RPM indicators, in infotainment and GPS displays, as backlighting for switches, and in accent, ambient and trim lighting. Vehicles are fast becoming objects of individual design, the company adds.

The main feature of the new MultiLED is a broad blue color range with a wavelength of 447–476nm and high brightness. Due to the use of a red chip, a green chip and a blue chip (RGB), deep saturated blue tones can now be produced. Other properties of the MultiLED, such as its integrated ESD (electrostatic discharge) protective diode (2kV), its improved corrosion resistance, and its longtime market availability, make the LEDs suitable for use in automobiles.

All shades of blue

At 370 millicandelas (mcd), the blue is much brighter than in other multi-chip LEDs on the market, it is claimed. This brightness is a significant advantage because the sensitivity of the human eye causes the color blue to be perceived as darker than it actually is, notes the firm. "The new LED can offset this darker perception so that customer brightness requirements can be met for all color ranges," says David Rousseau, LED product marketing manager. "What's more, a short-wave blue color has a pleasant saturated appearance," he adds. "We have now succeeded in implement-



Osram's new RGB MultiLED.

ing this color range in an RGB LED version."

Due to their finely defined grouping (binning), the three independently controllable blue, red and green LED chips in the MultiLED are available in different brightness groups, which can be individually combined to produce a large color spectrum. The blue and green chips are the product of Osram Opto's UX:3 technology while the red chip is the product of its latest thin-film technology. The light is extracted from the chip with high efficiency, resulting in high luminous intensity, claims the firm. For example, in the upper blue wavelength range, at an operating current of 20mA a level of up to 560 millicandelas is achieved (where luminous intensity in candelas corresponds to luminous flux in lumens (lm) emitted by a light source in a particular solid angle). The typical thermal resistance between the chip and the solder point is 127K/W for blue and green, and 96K/W for red.

The standard SMT package measures 3.3mm x 3.0mm x 1.8mm and has the same footprint as the predecessor version. Since it was developed specifically for applications in the automotive sector, the MultiLED meets all the requirements of an automotive-certified component, says Osram Opto.

www.osram-os.com

Duris S 8 multi-chip LED for interior lighting retrofits

Osram Opto Semiconductors GmbH of Regensburg, Germany has launched the Duris S 8, a new, multi-chip, high-power member of its Duris S LED series. The close grouping of the LED permits good color consistency in combination with high luminous flux, says the firm. The new Duris S is for use primarily in directional and omni-directional retrofits, as well as in LED spots in indoor lighting. It is particularly suitable for directional lighting in office and business premises, as well as in the home.

The color consistency (color binning) in the directional retrofits is achieved through the close grouping of the LEDs, which corresponds to the coverage of a 5-step MacAdam ellipse. Also available is 3-step MacAdam grouping for applications requiring very good color homogeneity. The Duris S 8 is grouped by color coordinates at the junction temperature of 100°C instead of at room temperature, as is customary. The Duris S 8 has a color rendering index (CRI) of more than 80. "An even higher CRI will be the next step," says Janick Ihringer, product manager SSL at Osram Opto.

The firm says that the new Duris S, measuring just 5.8mm x 5.2mm, emits a great deal of light from a small surface, permitting efficient optical solutions. The LED is available in two versions: GW P9LMS1.EM with six chips or GW P9LRS1.EM with eight chips. Due to the luminous flux at 200mA of 390lm (6-chip) or 500lm (8-chip), a directional retrofit is possible even with the 8-chip version. "Compact, low-cost driver modules are available on the market for the forward voltage between 20V and 30V," says Ihringer. "Moreover, their technical characteristics, such as a longer service life of 25,000 hours or operating temperatures of 110°C, are perfectly tailored to the target applications."

The Duris S 8 can also reduce the

Osram Opto's
Duris S 8
LED



system costs of lighting systems, the firm claims: the Duris S package consists of an innovative plastic housing material that is not only particularly resistant to ageing at high temperatures and in short-wave light, but also costs less than the ceramic housings that are frequently used.

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Special Strategic Committee recommendations endorsed POET Development Alliance to be established; scaling to 100nm targeted for fourth-quarter 2013

POET Technologies Inc of Toronto, Ontario, 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 — says that its board of directors has endorsed the next phases of the company's commercialization plan put forward by the Special Strategic Committee (SSC), which was established in June and is chaired by executive director Peter Copetti.

The multi-pronged approach is based on discussions with potential industry partners and advisers regarding the company's two key markets, consisting of the military and commercial sectors, that have been identified as potential early adopters of the POET platform. The firm says that currently, while POET's incorporation in military projects is proceeding well and should provide value in several key verticals, significant value exists in adapting POET for mass production within a commercial semiconductor fab environment. The firm recognizes that it must rapidly move to the next phase of its commercialization plan, which includes addressing feature size and scalability requirements for commercial fabs.

The board has therefore endorsed, and authorized the SSC to proceed on, the following recommendations:

● **Establishing a POET Development Alliance (PDA)** — The firm aims to establish relationships with

one or more industrial partners looking to jointly adapt POET to commercial-scale III-V implementation. Partners will provide key input including intellectual assets, technical staff, manufacturing capability, and foundry resources. As well as optimizing device parameters and yields, a near-term goal is to establish comprehensive design rules and a device parameter library for POET, proliferating licensed designs in a POET device ecosystem.

● **Drive for reduction of feature size to 100nm range (100NM)** — The firm will re-prioritize its technical roadmap by introducing specific milestones associated with reducing feature size from the sub-micron to the 100nm range in scale, targeting fourth-quarter 2013. Consequently, the milestone for full optoelectronic integration on a single die will be re-scheduled to Q2/2014. Even without this full integration milestone, the 100nm goal anticipates the cadence of commercial III-V foundry capabilities. This roadmap will focus the firm's ODIS subsidiary on developmental work that will allow for scalable production within existing commercial fabs.

● **Adoption of a Shareholder Rights Plan (SRP)** — The firm will be structuring a special SRP to protect the potential value of the firm, for all shareholders, during the period where discussions with potential partners may be taking place regarding PDA-related agreements, and as progress on the 100NM project continues.

"This move crystallizes the company's strategy for unlocking the

value of our intellectual property," says Copetti. "A development alliance with the right partners will definitely shorten time-to-market, and help evolve a design ecosystem for POET in the marketplace."

Further SSC actions will be endorsed by the board depending on the status of the above initiatives.

"While the new feature-size milestone is a challenge given our commitment to projects in our delivery pipeline, I believe the POET team is more than capable of achieving this goal," comments Copetti. "There is no doubt that POET can demonstrate its n- and p-channel capability to be a viable and scalable complement to silicon CMOS," he reckons.

The POET platform has demonstrated monolithic fabrication of integrated circuit GaAs-based devices containing both electronic and optical elements on a single wafer. The firm reckons that, by offering components with the potential for increased speed, density, reliability and lower costs, it offers the semiconductor industry the ability to push Moore's Law to the next level, overcoming current silicon-based bottlenecks and potentially changing the roadmap for a broad range of applications.

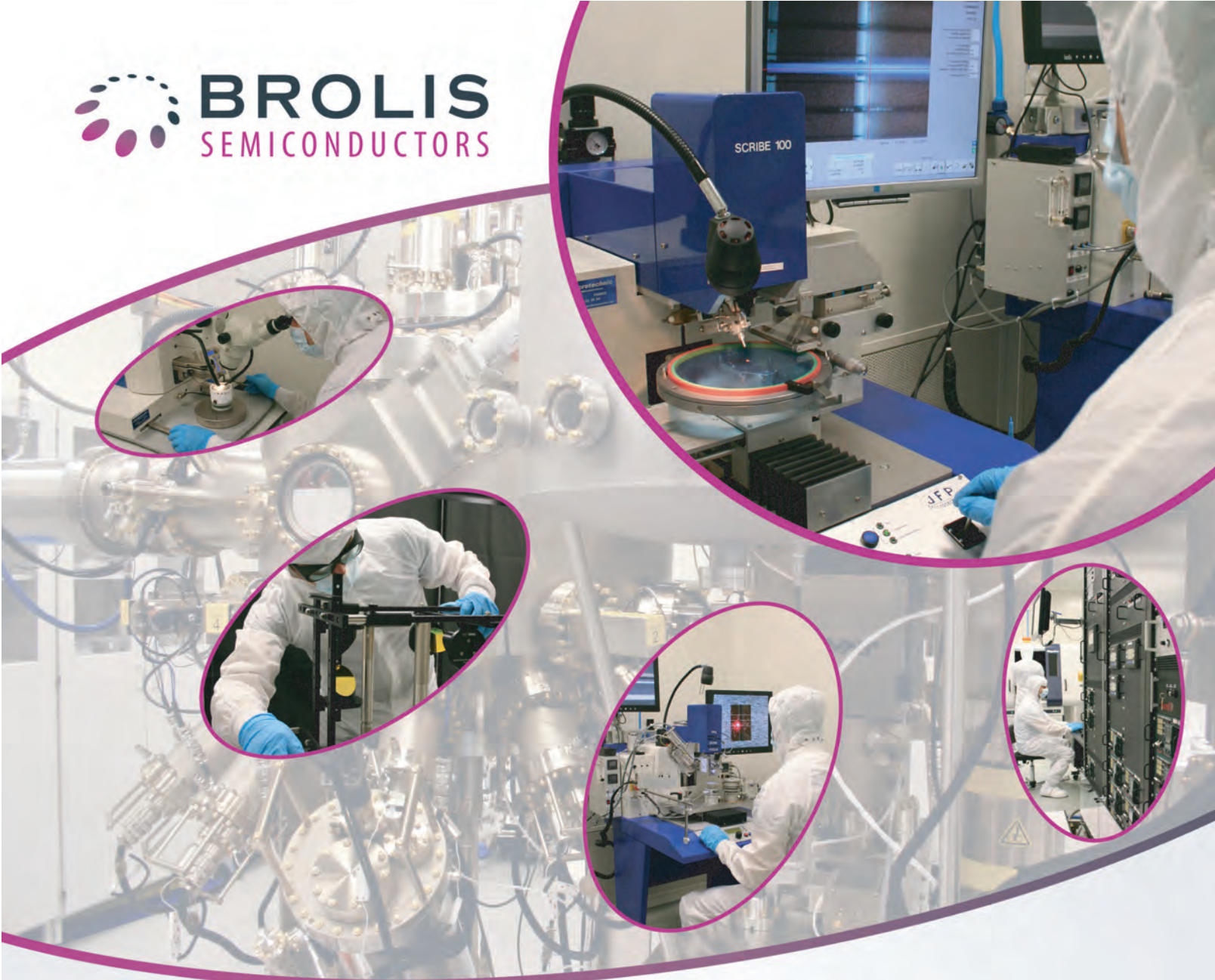
The POET platform is currently the basis for a number of key projects, including optical code division multiple access (OCDMA) devices for avionics systems, combined RF/optical phased arrays, optoelectronic directional couplers, and ultra-low-power random access memory (RAM).

www.poet-technologies.com

POET has granted further incentive stock options under its stock option plan to purchase up to an aggregate of 3,280,000 common shares (2.47% of its outstanding shares). Of these options, 14.6% were

granted to key technical staff related to the POET effort, 19.8% to company officers, 64% to non-officer board members and 1.5% to consultants. The options are exercisable at CA\$0.49 per share (the

closing market price of 12 August), expiring 13 August 2018. The options will vest and be exercisable on the basis of 25% on the date of grant and 25% every six months thereafter.



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GigOptix reports Q2 revenue down 29% year-on-year but level with Q1

Revenue to rebound 5% in Q3 and grow further in Q4

For second-quarter 2013, GigOptix Inc of San Jose, CA, USA (a fabless supplier of analog semiconductor and optical communications components enabling high-speed end-to-end information streaming over optical fiber and wireless networks) has reported revenue of \$6.8m, down only slightly on \$6.9m last quarter but down 29% on \$9.6m a year ago.

On a non-GAAP basis, gross margin remained a record 65%, flat on last quarter but up from 54% a year ago.

Excluding about \$0.7m in stock-based compensation, \$0.5m in special litigation-related expenses, and \$0.3m in amortization of intangible assets, net income was \$0.1m (\$0.00 per diluted share), down from \$0.2m (\$0.01 per diluted share) last quarter and \$0.4m (\$0.02 per diluted share) a year ago. Adjusted EBITDA has fallen from \$1.2m a year ago to \$0.7m (flat on last quarter).

"We achieved our second consecutive quarter of non-GAAP profitability while maintaining record non-GAAP gross margin in spite of the continued challenging conditions we faced in several of our served markets," says chairman & CEO Dr Avi Katz.

"We continued to make important progress during the second quarter with the joint development programs (JDP) we have with major tier-1 OEMs, with JDP revenue again exceeding \$1m in the quarter," Katz notes. "We are on track to deliver customized reference design platforms for next-generation telecom products, customized transimpedance amplifiers (TIA) and drivers, and applications for the consumer electronics market, including key components to be used in gesture recognition devices," he adds.

"These JDP contracts are important to our long-term growth as they support deployment of production parts towards the end of 2013 and the beginning of 2014."

"While market conditions have been tough for an extended period, I am increasingly optimistic that revenue in the second half of 2013 will be higher than the first half," comments Katz. "My confidence is supported by what appears to be a gradual improvement in our telecom business, primarily in the fast-growing 100 gigabit segment, where we command a roughly 50% share of the 100Gbps coherent driver market, which is being led by the introduction of our next-generation TIAs and drivers," Katz adds.

"In addition, we see continued improvement in the datacom market, where we have established a market leadership in optical engines for active optical cables (AOCs)," Katz says. "In our Industrial business, we are confident that revenue should increase later in 2013 as design wins with new products go into production."

"Now that we are seeing the beginning of a recovery in the telecom market, along with improvement in other parts of our business, our board of directors believes that this is the right time to reinstate the compensation and benefits for the company's employees to the levels they were at prior to the across-the-board reductions implemented early this year in response to the challenging times," Katz says. "We want to personally thank all of the GigOptix team for their shared sacrifice in helping support the company's cash position and to

get us back to profitability in such a short period of time." During Q2, cash and cash equivalents held steady at \$9.5m, after falling from \$10.1m to \$9.5m during Q1.

With a better outlook in its 100Gbps telecom business, continued strength in the datacom market, and a ramp of new products into both existing and new markets later this year, GigOptix expects third-quarter 2013 revenue will be up about 5% on Q2. "Based on our current expectations, we believe that revenue will continue to grow in the fourth quarter," says senior VP & chief financial officer Curt Sacks.

Litigation against M/A-Com Tech (Optomai)

"As we prepare to head to trial on 26 August in our lawsuit against defendants M/A-COM Technology Solutions Inc [of Lowell, MA, USA (which makes semiconductors, components, and subassemblies for RF, microwave and millimeter-wave applications)], its subsidiary Optomai Inc [a fabless semiconductor firm that develops ICs and modules for 40Gbps and 100Gbps fiber-optic networks] and three former GigOptix employees, we are continuing to incur expenses in support of this lawsuit," notes Katz. "This investment in the litigation is warranted by the evidence which we have obtained through the forensic and other discovery which we have conducted, as well as the process to date in the judicial system," he believes. "Most recently, this past week, the Superior Court of Santa Clara County, California, after considering the evidentiary record, denied motions filed by the defendants to stay the lawsuit, which followed a ruling last month against the defendants preserving our right to bring to trial all of our claims against the defendants," Katz adds.

www.gigoptix.com

These JDP contracts are important to our long-term growth as they support deployment of production parts towards the end of 2013 and the beginning of 2014

MACOM files patent infringement suit against GigOptix

M/A-COM Technology Solutions Inc of Lowell, MA, USA (which manufactures semiconductors, components, and subassemblies for RF, microwave and millimeter-wave applications) has filed a patent infringement suit in the US District Court for the Northern District of California against GigOptix Inc of San Jose, CA, USA (a fabless supplier of analog semiconductor and optical components for optical fiber and wireless networks).

The complaint alleges that GigOptix makes, uses, imports, offers to sell and/or sells in the USA electro-optics polymers containing chromophores that infringe two MACOM patents, including certain GigOptix Mach-Zehnder modulator products that GigOptix markets or promotes as containing 'Thin Film Polymer on Silicon (TFPS)' technology. MACOM is seeking injunctive relief barring the infringement, as well as monetary damages, including treble

damages based on allegedly willful infringement by GigOptix, attorney's fees and costs of suit.

"MACOM has built a substantial patent portfolio through investment in innovation, and will defend that investment vigorously when required," says MACOM's optoelectronics product line manager Ray Moroney. "We look forward to a just resolution of this matter through the legal process."

GigOptix comments that the new lawsuit was filed without any prior demands or notice by MACOM to GigOptix, even though the GigOptix lawsuit in the Superior Court of Santa Clara County, California against MACOM, its subsidiary Optomai Inc (a fabless semiconductor firm that develops ICs and modules for 40Gbps and 100Gbps fiber-optic networks), and three of GigOptix' former employees (for misappropriation of confidential information and trade secrets and

breach of the contractual and legal obligations to GigOptix of the former employees) is scheduled for a jury trial on 23 September, after the Superior Court has just denied motions filed by the defendants to stay the GigOptix lawsuit on the basis that certain individual defendants employed by MACOM and previously employed by GigOptix are being investigated by the US Attorneys' Office for the Northern District of California.

GigOptix says it has not been served with a copy of the complaint filed by MACOM, but intends to vigorously defend its innovations in various optical communication areas, including the use of polymer thin films for light modulation. After GigOptix has been served with a copy of the complaint, it will review the claims made by MACOM and assess its response.

www.gigoptix.com

www.macomtech.com

Advanced Photonix's revenue rises 18% quarter-on-quarter

For its fiscal first-quarter 2014 (to 28 June 2013), Advanced Photonix Inc of Ann Arbor, MI, USA (which designs and makes APD, PIN, and FILTRODE photodetectors, HSOR high-speed optical receivers, and T-Ray terahertz instrumentation) has reported net sales of \$7.1m, up 14% on \$6.2m a year ago and up 18% on \$6m last quarter. This is attributed to increased telecom infrastructure spending and the acquisition by Advanced Photonix Canada (APC) of Montreal-based Silonex Inc, which designs and manufactures optoelectronic devices and sensor solutions based on cadmium sulphide (CdS) for vertical markets including industrial controls, banking, vending, medical and telecoms.

Gross margin has rebounded from a low of 35.8% last quarter to 41.4%, up on 36.1% a year ago, aided by cost reduction efforts and a favorable mix.

Operating expenses were \$3.45m (48.8% of sales), up on \$3.3m last quarter and \$3.2m a year ago (51.8% of sales) due mainly to operating expenses assumed when Advanced Photonix Canada (APC) acquired the net operating assets of Silonex.

Adjusted EBITDA (earnings before interest, taxes, depreciation, amortization and stock compensation) was -\$68,000, recovering from -\$572,000 last quarter and -\$456,000 a year ago. During the quarter, cash reserves fell from \$619,000 to \$581,000. The firm drew about \$922,000 on its line of credit. Net working capital fell from \$4.9m to \$4.2m.

"We continue to believe that our fiscal year 2014 revenues will exceed last year's revenues by over 35%," says chairman & CEO Richard Kurtz.

"As I stated in our annual report, we have begun to include our

industrial sales as part of the Test & Measurement market. In the past we had combined our telecommunication transmission product sales and communication test & measurement (Comtest) product sales as telecommunication revenue," says Kurtz. "Going forward we have split this out so that the telecommunication revenues includes solely the transmission revenues. We have included the Comtest product sales in the Test & Measurement category along with the previous Industrial sales and our Terahertz nondestructive test and process control sales," he adds. "When looked at this way, over 50% of API's revenues come from using optoelectronics to solve our customer's need to test and measure key elements in their applications that can only be done through optical sensing. We look forward to establishing API as a leader in the test and measurement market."

www.advancedphotonix.com

NeoPhotonics' revenue grows 34% to a record \$75m in Q2 LAPIS acquisition contributes 20% growth to record 40/100G revenue

For second-quarter 2013, NeoPhotonics Corp of San Jose, CA, a vertically integrated designer and manufacturer of both indium phosphide and silica-on-silicon photonic integrated circuit (PIC)-based modules and subsystems, has reported record revenue of \$75m. This is up 34% on \$56.1m last quarter and up 19% on \$63m a year ago (and at the top end of the forecast range of \$70–75m).

"NeoPhotonics continues to be a solid leader in 100G optical products for next generation networks, with our portfolio of products once again driving record quarterly revenue," says chairman, president & CEO Tim Jenks. "We are pleased with our integration of the acquisition of the optical component unit of LAPIS Semiconductor, which closed on

29 March 2013, and is now referred to as NeoPhotonics Semiconductor," he adds. "The NeoPhotonics Semiconductor product portfolio includes several products used in 100G networks, and added approximately 20% to our 40/100G revenue in the second quarter."

On a non-GAAP basis, gross margin was 25%, down from 25.8% a year ago but up from 23.1% last quarter (and at the top end of the forecast 21–25%). Loss from continuing operations was \$3.5m (\$0.11 per diluted share), up from \$1.7m (\$0.06 per diluted share) a year ago but an improvement on \$4.4m (\$0.14 per diluted share) last quarter. Adjusted EBITDA was \$1.2m, down from \$1.8m a year ago but an improvement on a loss of \$1.7m last quarter.

During the quarter, total cash, cash equivalents and short-term investments fell from \$99.8m to \$74.7m, reflecting repayment of part of the firm's bank debt outstanding (cut from \$40m to \$26.3m).

For third-quarter 2013, NeoPhotonics expects revenue of \$72–78m, gross margin of 24–28%, diluted loss per share from continuing operations of \$0.04–0.14 (excluding about \$5.3m of expenses related to the expected amortization of intangibles, the one-time step-up in the fair value of assets acquired from LAPIS Semiconductor, and the anticipated impact of stock-based compensation: of these expenses, \$3m is estimated to relate to cost of goods sold).

www.neophotonics.com

NeoPhotonics and Inphi announce production shipments of high-dynamic-range ICR for 100G colorless coherent transmission

NeoPhotonics and Inphi Corp, a provider of high-speed mixed-signal ICs for the communications and computing markets, have announced shipments to multiple customers of a new high-dynamic-range integrated coherent receiver (HD-ICR) in production volumes.

The HD-ICR couples the high-dynamic-range, low-noise and high-input-current-handling capabilities of Inphi's IN3250TA TIA (transimpedance amplifier) with the high sensitivity of NeoPhotonics' photodiodes, and is designed to deliver the high performance needed for next-generation 100G colorless coherent transmission systems.

NeoPhotonics says that 100G coherent networks are rapidly moving towards more efficient 'colorless' operation, meaning that add and drop ports are not limited to fixed pre-determined wavelength channels, and any wavelength channel can enter or exit any port. Colorless operation improves the

efficiency and cost of coherent transport networks, but places additional requirements on receiver performance. For colorless applications where the remaining channels are not filtered out optically, the incoming signal power can vary significantly depending on how many other channels are present, resulting in up to 100 times higher optical power falling on the receiver than in the single-channel case. For this case, NeoPhotonics integrates a PIC variable optical attenuator (VOA) that is designed to set the incoming optical power at the optimum point to avoid saturating the detector, while the high dynamic range and low noise of Inphi's IN3250TA enables the desired signal to be reproduced with high fidelity.

For the case where a single wavelength enters the receiver, the high sensitivity of the HD-ICR may eliminate the need for an optical pre-amplifier in front of the

receiver, reducing cost and simplifying operation.

"We are pleased to add the HD-ICR to our extensive line of PIC-based intradyne coherent receivers, and we feel that working closely with Inphi has effectively made available to our customers the high performance of both companies' technology," says NeoPhotonics' chairman & CEO Tim Jenks. "Our next-generation 100G optical solutions, coupled with Inphi's 100G electronic chips, can help us meet the needs of our customers in next-generation 100G systems and beyond," he adds.

"Inphi remains uniquely positioned to deliver 100G solutions with its portfolio of CMOS PHY ICs and high-performance TIA and driver products, which will allow for faster deployment of next-generation 100GbE optical solutions in enterprise, data center and service provider networks," says Inphi's president & CEO Ford Tamer.

www.inphi.com

Finisar's preliminary revenue, margin and profit exceed guidance

Growth driven by sales of 10G, 40G and 100G Ethernet transceivers for datacom applications

Fiber-optic communications component and subsystem maker Finisar Corp of Sunnyvale, CA, USA says that, on the basis of preliminary financial results, it expects to report revenue of about \$266m for its fiscal first-quarter 2014 (ended 28 July 2013), compared to guidance of \$245–260m provided on 19 June.

The revenue results are preliminary and subject to adjustment. However, in the absence of material adjustment, first-quarter revenue will set a new record for the firm and will be the fourth consecutive quarter of sequential revenue growth. The growth came primarily from increased sales of 10G, 40G and 100G Ethernet transceivers for datacom applications. About \$2m of the revenue growth over the prior quarter was from products for telecom applications.

Due to the higher-than-expected revenue, a favorable product mix

and increased operating leverage, Finisar expects non-GAAP gross margin to be 34.5–35%, exceeding the previous guidance of about 33%. Earnings per share are expected to be \$0.30–0.31, exceeding the forecast \$0.22–0.26. A complete assessment of cost of

In the absence of material adjustment, Q1 revenue will set a new record for the firm and will be the fourth consecutive quarter of sequential revenue growth

revenues and operating expenses is not yet available, but results under GAAP are expected to include additional non-cash and infrequently occurring charges.

Finisar expects to release its full fiscal first-quarter results close on 5 September.

www.finisar.com

Infinera and DANTE set record for long-haul transmission capacity provisioning

Infinera Corp of Sunnyvale, CA, USA, a vertically integrated manufacturer of digital optical network systems incorporating its own InP-based photonic integrated circuits (PICs), and DANTE (Delivery of Advanced Network Technology to Europe), an operator of networks for research and education, have achieved a record for the fastest rate of multi-Terabit optical capacity provisioning.

Infinera and DANTE installed and activated 8Tb/s of long-haul super-channel optical capacity across the GÉANT production network.

The record was set using an Infinera Intelligent Transport Network, featuring the DTN-X packet optical transport networking platform, deployed on the GÉANT backbone across a long distance link from Vancis Amsterdam, The Netherlands to GlobalConnect Hamburg, Germany.

The DTN-X platform provides transmission capacity using 500Gb/s super-channel line-cards which need only two fiber connectors each:

16 such cards and 32 fiber connections were deployed at each end of the link. Once the super-channels were in operation, a 100 Gigabit Ethernet (GbE) service was provisioned over the link. The total time from the insertion of the first super-channel line-card to the activation of the 100GbE service was 19 minutes and 1 second (a provisioning rate of 26.02Tb/s per hour).

The test was completed using the DTN-X platform, which delivers the industry's only production-ready long-haul 500Gb/s FlexCoherent super-channels based on 500Gb/s PICs, engineered to be upgradeable to 1Tb/s super-channels in future. The DTN-X converges five Terabits of non-blocking OTN switching into the same platform, resulting in more efficient network utilization when compared to conventional WDM architectures, says the firm.

www.infinera.com/go/gwr

JDSU's private offering raises \$636m

In a private offering to qualified institutional buyers, optoelectronic chip and module maker JDSU of Milpitas, CA, USA has completed the sale of \$650m aggregate principal amount of 0.625% senior convertible debentures due 2033 (\$575m, plus \$75m related to the initial purchasers' over-allotment option, which was exercised in full). Net proceeds totaled about \$636m after deducting the initial purchasers' discounts and estimated offering expenses.

"Completion of this senior convertible offering further strengthens JDSU's balance sheet, with cash and short-term investments now in excess of \$1bn," says executive VP & chief financial officer Rex Jackson. "The opportunity to raise additional funds with favorable

terms provides JDSU with increased financial flexibility as we execute our growth strategy."

JDSU has the right to redeem the notes beginning 20 August 2018. Holders of the notes may require JDSU to repurchase the notes on 15 August 2018, 15 August 2023, and 15 August 2028.

JDSU used \$100m of the net proceeds to repurchase shares of its outstanding common stock in privately negotiated transactions. The remaining net proceeds will be used for general corporate purposes, including potential strategic transactions.

JDSU has also terminated its \$250m revolving credit facility (which had no amounts outstanding).

www.jdsu.com

Emcore's revenue falls 20.8% quarter-on-quarter Stake in Suncore JV divested; September-quarter revenue rebound and cost-cutting to yield near-breakeven

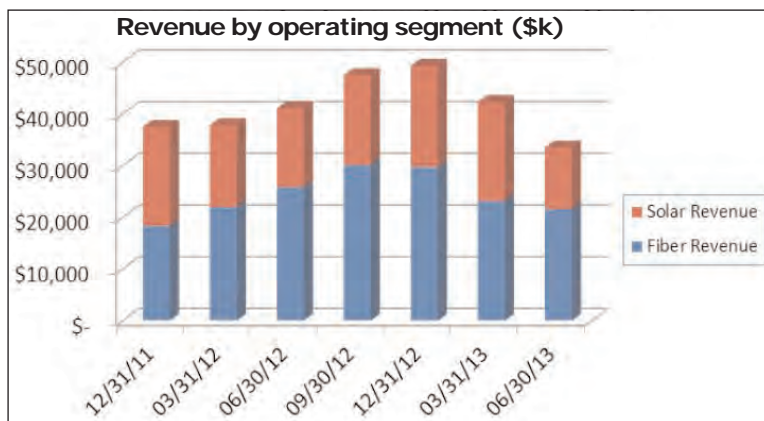
For fiscal third-quarter 2013 (to end-June), Emcore Corp of Albuquerque, NM, USA, which makes compound semiconductor-based components and subsystems for the fiber-optic and solar power markets, has reported revenue of \$33.5m. This is down 20.8% on \$42.3m last quarter and 18.5% on \$41.1m a year ago (and below the guidance of \$35–\$39m).

Fiber Optics revenue was \$21.6m (64% of total revenue), down 6.8% on \$23.1m last quarter (55% of total revenue) and 16.5% on \$25.8m a year ago (63% of total revenue).

Photovoltaics revenue was \$11.9m (36% of total revenue), down 37.8% on \$19.1m last quarter (45% of total revenue) and 21.8% on \$15.3m a year ago (37% of total revenue). This was due mainly to a large international order (worth a few million dollars) that was expected to ship during the quarter, but approval was not received prior to end-June (the order has subsequently shipped to the customer, and revenue should be recognized in the September quarter).

Overall gross margin was 12.1%, up from 10.7% a year ago but down from 18.5% last quarter. Although up from the 13% a year ago, Photovoltaics' gross margin of 28.6% is down from 32.5% last quarter. Fiber Optics' gross margin has fallen further, from 9.3% a year ago and 7% last quarter to 3% (although, without an excess on obsolete inventory charge of almost \$1m, this would have been closer to 7%). It also incurred a negative impact of about \$2m from the tunable XFP transceiver product line through lower-than-targeted yield during production ramp-up.

"We experienced lower-than-expected orders in our broadband [cable TV] business due to an unusual reduction in MSO [multi-system operator] capital expenditure (CapEx) and delayed revenue



contribution from new product, tunable XFP, due to production ramp-up challenges," commented CEO Hong Hou. "The engineering team was able to fully understand the root causes for the low yield and implemented corrective actions. We expect yield and throughput for the September quarter will demonstrate a marked improvement and reach a desirable yield and throughput level by the December quarter. At that level, we expect positive contribution margins from this product line," he adds.

"We expect our gross margins in the Fiber Optics segment to improve in future quarters as we complete the ramp up of our new product line and our contract manufacturer and our Fiber Optics revenues increase," says chief financial officer Mark Weinswig. "We continue to believe that this business' target gross margin is 30%."

Operating expenses were \$11.7m, up on \$10.9m last quarter (due mainly to R&D expenses rising from \$4.1m to \$4.7m). Going forward, operating expenses should be about \$11.5m per quarter.

On a non-GAAP basis, net loss was \$5.9m (\$0.22 per share), an improvement from \$7.4m (\$0.31 per share) a year ago but down from just \$33,000 (breakeven on a per-share basis) last quarter. Depreciation was \$1.7m and CapEx was up to \$1.6m. During the quarter, cash and cash equivalents and restricted cash balance rose from \$6.2m to \$6.6m.

Exiting Suncore JV
This excludes \$4.8m in proceeds from the sale (agreed in June) of Emcore's 40% equity stake in its China-based Suncore ter-

restrial concentrated photovoltaic (CPV) component- and system-making joint venture to partner San'an Optoelectronics Co Ltd of Xiamen. Closing is subject to customary conditions, including Chinese regulatory approvals. Payment in exchange for the equity transfer is expected in fiscal Q4.

"Due to the dramatic change in the market dynamics and the competitive landscape of solar power industry, the joint venture needed to expand its business scope into project development and, in some cases, even as a project owner operator. This business direction is beyond the current and planned scope of Emcore's business," says Hou. "We will continue to be the primary supplier to Suncore for concentrated solar cells. However, Emcore now has minimal exposure to the risks of the solar power market," he adds.

Cost reduction

"In July, in order to continue to drive our breakeven revenue level down further, we implemented a head-count reduction and cost-reduction effort," notes Weinswig. Hou adds that the latter includes "discretionary spending reduction in our broadband business in addition to other concerted efforts to focus on revenue growth and process improvement on new product introductions in our telecom component business".

In addition, after Emcore's CapEx has been higher than normal due to ramping up tunable XFP produc-

tion, in future it will be closer to the normal \$1–1.25m per quarter.

"We now have a sustainable cost structure that will return us to profitability in the near future," believes Hou. The goal is to reduce the break-even quarterly revenue run rate from \$48–50m currently to \$46–48m.

Outlook

"The Space Photovoltaics division still generated more than \$1.3m net profit in the June quarter, indicating that this business has an effective cost structure and continues to be a positive capital-generating entity," says Hou. During the quarter, the division won more than 10 separate contracts (worth over \$35m). Order backlog for Space Photovoltaics rose by 59% from \$36.5m to a record \$58.1m, due mainly to large international orders. "With the recent bookings in Q3 and expected bookings in our Q4, our outlook for the

next four quarters for this division looks very solid," Hou says.

Revenue for CATV broadband business is expected to show a marked improvement. "Beginning in June, our cable TV broadband customers stated that their inventory has been reduced to a reasonable level due to a demand uptick from their customers," says Hou. "Compared to the March quarter, their June quarter CapEx spending increased over 20% in the infrastructure upgrade category, which is most related to our business," he adds. "As a result, the booking activity from our customers in the broadband business started to show a significant improvement. The largest MSO in the US reported a plan of about 10% more CapEx spending for the second half of the year than the first half. Therefore, we are optimistic about the rebound of the

cable TV demand for the September quarter and this December quarter."

With improvement expected from both the Space Photovoltaics and Fiber Optics segments, for fiscal Q4 (to end-September) Emcore expects revenue to rise to \$42–45m, nearing Emcore's new (reduced) revenue breakeven level of \$46–48m.

"We feel that we are coming out of our trough with significantly improved revenue outlook, improved engineering yield and reduced cost base," Hou concludes. "Our focus this quarter is on completing multiple new product line and new product introductions for our cable TV business and ramping up the revenue contribution from the tunable XFP product line," he adds. "We expect a strong September quarter and have an even more optimistic outlook for the December quarter."

Matthew Peach, Contributing Editor

Emcore launches 1550nm directly modulated CATV transmitter

Emcore has introduced its Medallion 8000 series 1550nm directly modulated DWDM cable television (CATV) transmitter.

The Medallion 8000 is the latest addition to Emcore's 1550nm CATV fiber-optic transmitter portfolio and is designed for wideband applications that require both CATV and Satellite-Intermediate Frequency (SAT-IF) signals to be transmitted over fiber lengths up to 30km. This facilitates network designs that use a single transmitter to carry multiple signals, while lowering costs, system complexity and rack space requirements, says the firm.

The transmitter supports 79-channel NTSC analog signals and/or a combination of quadrature amplitude modulation (QAM) and SAT-IF signals with a reduced number of CATV analog channels. It features fixed fiber length options of 0–10km, 5–15km, 10–20km and 15–25km with a maximum 18dBm stimulated Brillouin scattering (SBS) suppression. It is also available with a selectable fiber-length option, allowing the Medallion 8000 to be

set for best optimized CSO (composite second order) distortions at any fiber length from 0–30km in 1km increments with a maximum SBS suppression of 20dBm.

The Medallion 8000 family of transmitter products is designed to support various CATV transmitter applications with a common platform. A 75Ω CATV RF video input supports frequencies up to 1002MHz. Design features including low chirp control, noise suppression circuitry, and patented pre-distortion technology that provides outstanding performance with Emcore's wide range of cooled broadband directly modulated lasers. A second 75Ω RF input supports frequencies up to 2700MHz for FTTP (fiber-to-the-premises), SAT-IF, and wireless applications.

"The new Medallion 8000 directly modulated transmitter family builds on the strengths of our popular Medallion 6000 externally modulated series and augments our offering for concurrent transmission of CATV and SAT-IF signals over fiber," says Jaime Reloj, VP of business devel-

opment. "Network providers are demanding high-quality, economical delivery of video to their customers, while extending capacity and improving network management intelligence. The Medallion 8000 series transmitters are ideal for extending traditional hybrid fiber coaxial CATV systems, for RF overlay for FTTP, and for RfOG (radio frequency over glass) projects in countries around the world."

Monitoring and configuration of the Medallion 8000 is supported by Emcore's latest-generation Web GUI, Telnet and Simple Network Management Protocol (SNMP) software via a convenient front-panel display, RS-232 port, and Ethernet port. The Medallion platform is mechanically designed for flexibility and space efficiency including universal rack-mount features, modular front panel design for private label convenience, and optional front and rear port placement. Dual-redundant field-replaceable fans and power supplies are standard.

www.emcore.com

Solar Junction surpasses its previous record with certified 44.1% cell efficiency on IQE's production-qualified wafers

Record set using high-volume production equipment

Epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK says its high-volume, production-qualified material has been independently certified as achieving 44.1% photovoltaic cell efficiency by the US National Renewable Energy Laboratory (NREL), surpassing Solar Junction's previous world record for a standard triple-junction concentrated photovoltaics (CPV) cell.

Produced using IQE's high-volume MBE tools, wafers were processed by IQE's strategic partner Solar Junction Corp of San Jose, CA, USA, which makes III-V multi-junction solar cells for CPV based on dilute-nitride materials. The standard three-junction solar cells are reckoned to set a new record for production-scale CPV wafer technology and demonstrate improved efficiency over Solar Junction's previous record of 44% reported in October 2012.

"Breaking a world record is a major achievement, but improving on our most recent record using high-volume production equipment produced in conjunction with our manufacturing partner IQE, and Solar Junction's fabrication line in Sunnyvale, CA, is dramatically more significant," reckons Solar Junction's CEO Vijit Sabnis. "This result is a testament to our close partnership with IQE, Solar Junction's dilute nitride technology and our exceptional team," he adds.

Earlier in August, Solar Junction completed the process transfer and full qualification of IQE's high-volume 4" and 6" CPV technology.

Solar Junction completed the process transfer and full qualification of IQE's high-volume 4" and 6" CPV technology

"Improvements in CPV cell efficiencies translate to highly significant overall cost reduction in terms of installation and energy generation in utility-scale solar farms," says IQE chief executive Dr Drew Nelson. "The fact that this has been achieved on production-qualified platforms is a major milestone," he adds. "Furthermore, the transfer of wafer production to IQE's manufacturing tools enables the Solar Junction team to focus on further improving efficiencies on lattice-matched, multi-junction CPV solar cells using a combination of their unique dilute nitride technology, combined with pre existing IQE IP. This will facilitate seamless technology transfer into high-volume manufacture of ultra-efficient CPV cells as the conversion efficiency improves further."

www.iqep.com
www.sj-solar.com

Alstom and Soitec agree to create a French alliance for CPV power plants

Power generation and transmission firm Alstom and Soitec of Bernin, France, which makes engineered substrates — including silicon-on-insulator (SOI) wafers and III-V epiwafers — as well as concentrating photovoltaic (CPV) solar systems, have signed a cooperative agreement to provide CPV power plants.

The agreement follows the call for tender issued by the French Energy Regulation Commission in March, seeking to exploit solar power plants using CPV technology (whole or in-part) for a total power capacity of 100MW.

In order to propose a complete and competitive offer, Alstom and Soitec intend to combine their

experience in delivering turnkey power plants and in providing integrated solutions and main equipment for power generation on the one hand, and CPV technology, on the other hand. Soitec says that its high-efficiency solar modules are well suited to the solar power production in the South of France.

Alstom and Soitec are seeking to create a sector of excellence that will create jobs and be ready to meet the challenges of the French energy transition. The prospective power plants would also showcase and promote CPV power plants internationally.

"This cooperation with Soitec demonstrates Alstom's wish to develop its offer and technologies

for renewable energies," says Jerome Pécresse, president of Alstom Renewable Power. "With Solar CSP (concentrated solar power, or solar thermal) we are able to deliver equipment for large-capacity units. Thanks to our cooperation with Soitec in concentrating photovoltaic, we will propose a perfectly complementary offer for high-efficiency power plants with flexible capacity and rapid deployment," he adds.

According to the International Energy Agency (IEA), solar energy (including both CSP and PV) could account for 25% of global electricity by 2050 and cover a third of global energy demand after 2060.

www.alstom.com

IQE's CPV materials qualified for volume production by Solar Junction

Epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK says that its strategic partner Solar Junction Corp of San Jose, CA, USA, which makes III-V multi-junction solar cells for concentrated photovoltaics (CPV) based on dilute-nitride materials, has completed the process transfer and full qualification of IQE's epitaxial materials for production-ready, high-volume manufacturing.

Qualification required extensive validation of IQE's manufacturing processes, product quality and reliability. Solar Junction is now production-ready and at an advanced stage in qualifying its cells with leading global CPV systems makers. Solar Junction expects to receive initial high-volume orders over the coming months.

As a result of a joint development agreement in February with Solar Junction, Amonix Inc of Seal Beach, CA, USA (said to be the leading worldwide installer of CPV systems) is already testing solar cells produced with IQE epitaxy and observing improved performance.

"The qualification of our production-ready 42% median efficiency solar cells produced by IQE and our new fabrication line could not have come at a better time for Solar Junction and the CPV market," reckons Solar Junction's VP of business development Jeff Allen. "Solar Junction's key customers are highly impressed with the 2+ % cell efficiency advantage over our competitor's cells, which translates to an estimated reduction in total installed CPV system cost of approximately 5%," he adds, citing rapid adoption of the firm's technology in the USA, China and Middle East.

A recent independent industry report estimates that the target market for CPV will exceed 5GW over the next few years, with more than 750MW to be installed by 2015.

Initial deployment will be in southwestern USA, southern Europe around the Mediterranean, Middle East and Northern Africa (MENA), southern Africa, Chile, Australia and China.

"Successful qualification is attributable to the close partnership of the team responsible, from Solar Junction and IQE, over the past 12 months," says Solar Junction's chief executive Dr Vijit Sabnis. "The IQE epitaxial materials are fabricated at Solar Junction's 4" and 6" production facility, partially funded by the US Department of Energy SUN-PATH contract, in Silicon Valley," he adds. "Solar cells are currently out for independent third-party verification of efficiency results, with performance anticipated to be equivalent to that produced by our internal pilot line."

IQE says that Solar Junction's qualification continues to demonstrate the value of its dilute nitride materials. In October 2012, Solar Junction achieved record solar energy conversion efficiency of 44% for a standard 3J cell at a concentration of 942 suns.

"Qualification of IQE's production-scale epiwafers for CPV marks a key milestone in bringing Solar Junction's advanced technology to market," comments IQE's chief executive Dr Drew Nelson. "Median efficiencies from our large-volume 4" and 6" platforms are at least as good as have been previously achieved in small-scale demonstrations," he adds. "The performance and manufacturing advantages of Solar Junction's 3J solar cell technology will accelerate adoption of CPV and position IQE to become the key epiwafer supplier to the global utility-scale CPV solar market," he believes. "These achievements clearly demonstrate the success of our strategy to invest in Solar Junction and enter into an exclusive, worldwide license for the technology."

IN BRIEF

Amonix achieves record 35.9% PV module efficiency Record raised from 34.9% set in April

Amonix Inc of Seal Beach, CA, USA, which makes utility-scale concentrator photovoltaic (CPV) solar power systems using III-V multi-junction solar cells, says that it has achieved a National Renewable Energy Laboratory (NREL) efficiency rating of 35.9% under recently adopted CPV IEC (International Electrotechnical Commission) test conditions of 1000W/m² and 25°C cell temperature. Data for the rating was generated by an Amonix module under outdoor test at NREL from late February to April of this year.

Amonix says that the latest result is the highest ever independently rated module efficiency for any PV technology, and that this is the first time that NREL has quantified the rating for a concentrator module with cells at 25°C instead of at operating temperature. Amonix helped NREL to mature the measurement process.

In April, Amonix set a module efficiency record of 34.9% at CSOC (concentrator standard operating conditions). Previously, in May 2012, it was first to exceed 33% CSOC module efficiency.

"This 35.9% IEC CSTC module efficiency is a direct comparison to PV module efficiencies, which are often reported at IEC standard test conditions," says Amonix's founder & chief technology officer Vahan Garboushian. "With the advent of higher-efficiency cells from companies like Solar Junction, Amonix anticipates achieving considerably higher module efficiencies and breaking our currently standing world records in the very near future," he adds.

www.amonix.com

Solar Systems opens Australia's largest CPV solar plant

Utility-scale solar power technology firm Solar Systems Pty Ltd of Melbourne, Australia (a subsidiary of Sydney-based Silex Systems Ltd) has officially opened its 1.5MW Mildura Solar Demonstration Facility, Australia's largest concentrated photovoltaic (CPV) solar power plant.

The opening was attended by guests including The Hon. Nicholas Kotsiras MP, Victoria Energy and Resources Minister, who also toured the new facility. The 1.5MW plant, in Mildura, north-west Victoria, has received AUS\$10m in funding from the Victorian State Government.

The CPV plant — consisting of 40 individual 'Dense Array' dish systems, each fitted with 100 mirrors — is now connected to the national grid and can provide enough electricity (under a power purchase agreement signed with Diamond Energy in 2012) to power up to 500 average-sized homes while removing 4200 tonnes of CO₂ emissions per year.

The Mildura facility is a demonstration plant designed to establish, over extended operational periods, that Solar Systems' 'Dense Array' CPV dish technology can reliably and cost-effectively produce electricity — essential for validating the technology's bankability before proceeding with larger-scale plants, says the firm.

"We are extremely grateful for the support that the Victorian and Federal Governments have given our solar projects to date," states Silex's managing director & CEO Dr Michael Goldsworthy. As well as AUS\$10m for the 1Mildura demonstration plant plus AUS\$5m from the Victorian State Government for a previous 16-dish test facility in Bridgewater, the firm has additional funding pledged (conditional upon successful due diligence outcomes) to expand Mildura to a utility-scale, 100MW facility (featuring about 2000 dishes and providing peak power output sufficient for up to 40,000 homes): AUS\$75m (US\$70m) from the Federal Gov-



Solar Systems' 1.5MW dense array CPV dishes.

ernment under the Low Emissions Technology Demonstration Fund (now under the Australian Renewable Energy Agency – ARENA); and AUS\$35m (US\$33m) from the Victorian State Government's Energy Technology Innovation Strategy (ETIS) fund.

Construction of Mildura Stage 2 is expected to begin in late 2014, subject to successful operation of the 1.5MW facility, the securing of a power purchase agreement, and finalization of the funding arrangements. Once built, the 100MW Mildura Solar Facility is expected to be the largest solar plant in Australia.

The firm says that it continues to investigate other major project opportunities in the 10-50MW range in Australia and key offshore markets, including the Middle East and the USA. Also, construction of a 28-dish 1MW demonstration facility in Nofa, Saudi Arabia, is well advanced and expected to be completed by the end of 2013. Solar Systems says that complete operation of the Mildura and Nofa demonstration facilities will be a key step towards "establishing bankability" for wider commercial deployment of Solar Systems' technology.

The commercialization strategy for Solar Systems' Dense Array CPV technology hence includes the following steps over the next two years, all of which have already commenced:

- operation of the Mildura and Nofa demonstration facilities to validate performance efficiency, energy yields and reliability;
- cost-reduction activities to drive the levelized cost of energy (LCOE) down to the key target of AUS10c (US9c)/kWh (or lower); commencement of the Mildura Stage 2 100MW solar power station project (subject to AUS\$110m in government funding contributions);

- securing other opportunities (up to 10–50MW range) in Australia (with pre-feasibility of prospective sites in Queensland already underway); and
- securing other solar power station projects in key off-shore markets such as Saudi Arabia and the USA.

"Our long-term vision is to deploy our technology commercially within the burgeoning global utility-scale solar power station market, which is forecast to continue to grow rapidly over the next two decades," Goldsworthy says. "As a country highly dependent on coal to supply our energy needs, solar can provide clean energy security for Australia into the future, provide secure, long-term green jobs and reduce our carbon emissions," he adds.

Goldsworthy says that investment in utility-scale solar power stations is growing rapidly as the technology improves. Global installations of utility-scale (10MW and over) solar facilities has now exceeded 14GW (14,000MW), with over 4GW of capacity installed in 2012 alone — up from less than 1GW in 2009. This currently represents an annual market of about \$15bn, with strong growth set to continue for the next two decades. "We anticipate investment in CPV solar will continue to rise as its feasibility as a cost-effective clean energy solution becomes entrenched," he adds.

www.silex.com.au

Saudi Aramco chooses Soitec's CPV solar technology

Saudi Arabian investment company Khaled Juffali Company (KJC) and Soitec of Bernin, France, say that the Saudi Arabian Oil Company (Saudi Aramco), a global petroleum and chemicals company owned by the Kingdom of Saudi Arabia, has decided to use Soitec's concentrating photovoltaic (CPV) solar systems for a 1MW solar-energy pilot plant in Saudi Arabia's northwestern Tabuk region. This project with the world's largest oil producer is the first business win for KJC and Soitec since the two firms signed a joint agreement in April to cooperate in driving solar-industry growth in Saudi Arabia and the Middle East.

Saudi Aramco's two-fold objective for the project is to complete the work on schedule while testing the performance of CPV technology to better assess its levelized cost of energy (LCOE) advantage for future utility-scale installations.

"This win is a major breakthrough in the solar market and a great testimony to the ability of Soitec's highly performing solar technology to deliver the highest competitive advantage under desert conditions,"

said KJC founder & chairman Sheik Khaled Juffali. "Being successful in winning this project with Soitec lays the groundwork for some additional very exciting projects as we establish a baseline of support for developing a solar-energy market in Saudi Arabia."

"We have made dedicated efforts in recent months to position ourselves in Saudi Arabia and to bring to the country a strong offering. We are very proud to have been selected in this first CPV tender and we look forward to a fruitful cooperation with Aramco," said Gaetan Borgers, executive VP of Soitec Solar Division. "This proof of confidence by the largest worldwide oil producer confirms Soitec's leading-edge technology and is further evidence of our company's technological and business innovations."

Utility-scale solar power plant firm BELECTRIC Saudi Arabia LLC has developed the project based on Soitec's technology and will build the plant. BELECTRIC has connected more than a gigawatt of utility-scale solar power plants worldwide, including building Saudi

Arabia's largest solar power plant at Saudi Aramco's headquarters.

CPV is the most efficient technology in the photovoltaic industry, achieving current energy-generating efficiencies of 30% — about twice that of conventional photovoltaic technologies, says Soitec. Soitec's CPV modules incorporate a durable glass-glass design and Fresnel lenses to concentrate sunlight 500 times onto small, highly efficient multi-junction solar cells. Additionally, the firm's systems use dual-axis tracking and achieve passive cooling without water consumption, which is advantageous in dry and clear-sky locations including the Middle East.

Saudi Arabia's government reckons demand for electricity in Saudi Arabia should exceed 120GW in 20 years. To meet this growing need, the Kingdom intends to introduce a significant amount of alternative sources into its energy mix. According to K.A. CARE, the institution established by King Abdullah to implement the national renewable-energy policy, solar will account for 41GW of the country's installed capacity by 2032.

www.soitec.com

Alta Devices enables UAVs to fly as long as Sun is shining

During a speech at the Small Unmanned Systems business expo in San Francisco, CA, USA, Christopher Norris, president & CEO of Alta Devices of Santa Clara, CA, said that small unmanned aerial vehicles (UAV) are no longer constrained to limited flight times and are now able to fly as long as the sun is shining.

In the past, solar solutions for powering these vehicles were either too heavy or unable to produce enough power for long-range flight. However, a small UAV outfitted with Alta Devices' mobile power technology can produce enough power, while adding practically no weight, to fly indefinitely under the sun, says the firm.

Alta claims it manufactures the

world's thinnest, most flexible, and most efficient solar material. In the case of a typical small UAV with a 9-foot wingspan, Alta's material, which weighs about 125g (about 4.5 ounces), can generate roughly 125W of power. In many cases, this is enough to sustain flight and keep an on-board power source fully charged.

"A broad range of civil unmanned systems will benefit from extended range and endurance," says Norris. This is expected to have economic value for agricultural, public safety, wildfire mapping, search & rescue, law enforcement, and industrial applications. "For example, when a UAV is used to map a wildfire, or on a human search and rescue mission, it is critical to have flight

times that are as long as possible."

For agricultural use, the ability to extend the range of a UAV and shorten the task of monitoring a large area by avoiding stops to recharge, has significant economic benefit to the farming community. According to a report published by the Association for Unmanned Vehicle Systems International (AUVSI), precision agriculture and public safety represent over 90% of the potential for civil UAS use and will result in an economic benefit to the USA of \$82bn between 2015 and 2025.

"Enabling all-day flight times for small UAVs will change the game for civil use and represents a significant market opportunity," says AUVSI executive VP Gretchen West.

www.altadevices.com

First Solar's sales fall 31% to \$520m in Q2/2013

For second-quarter 2013, First Solar Inc of Tempe, AZ, USA — which manufactures thin-film photovoltaic modules based on cadmium telluride (CdTe) as well as providing engineering, procurement & construction (EPC) services — has reported net sales of \$520m. This is down \$235m (31%) on \$755m last quarter (due mainly to lower systems business project revenues as well as lower module-only sales volume to third-parties) and \$438m (46%) on \$957m a year ago (due mainly to lower systems business project revenue as initial revenue recognition for AVSR [Antelope Valley Solar Ranch] and the sale of Silver State North were both achieved in Q2/2012, partially offset by higher sales volume to third-party module-only customers in Q2/2013).

As a previously highlighted possibility, the sale of the ABW (Anherstburg, Belmont and Walpole) projects in Ontario, Canada was not completed in Q2/2013, although it is due to complete in second-half 2013.

On a non-GAAP basis, net income was \$35.3m (\$0.39 per fully diluted share), down from \$61.5m (\$0.69 per share) last quarter (due mainly to lower revenue recognition for AVSR and lower sales volumes to third-party module-only customers) and \$111m (\$1.27 per share) a year ago (due mainly to lower systems business revenue recognition, partially offset by higher manufacturing utilization and higher module sales to third-party customers).

Cash flow from operations was \$222m, compared to \$66m last quarter. During the quarter, cash and marketable securities rose by \$273m to \$1.3bn. Net cash grew by \$580m to \$1bn.

First Solar also announced the acquisition of all of GE's CdTe solar intellectual property and entered into a technology collaboration agreement with GE, with the aim of advancing thin-film solar cells and modules. Under the agreement, First Solar acquired GE's CdTe solar

intellectual property, and in exchange GE received 1.75 million shares of First Solar stock.

Also, First Solar has acquired a 1.5GW pipeline of US and Mexico development assets from Element Power. The portfolio includes geographically diverse projects in various stages of development.

First Solar has also updated its full-year 2013 financial guidance ranges to reflect the following: (1) a reduction in expected net sales associated with the decision to hold two system projects through construction and selling such projects after construction is completed, which is expected to result in improved project economics; (2) incremental cost at AVSR due to delays related to the county approval process for materials used in construction, partially offset by an improvement in gross margin due to better-than-expected project economics for ABW, Campo Verde and Imperial Valley; (3) the impact of expected higher operating expenses associated with the newly announced GE technology partnership; and (4) the per-share impact associated with the 18 June closing of the equity offering of 9,747,000 common shares and the impact of the issuance of 1,750,000 common shares to GE as part of the IP acquisition.

The updates to the guidance are as follows: net sales reduced from \$3.8–4bn to \$3.6–3.8bn; gross margin raised from 20–22% to

22–23%; operating expenses raised from \$380–400m to \$390–410m; operating income reduced from \$430–460m to \$405–435m; and earnings per share reduced from \$4.00–4.50 to \$3.75–4.25 (or \$3.50–4.00, including the equity offering and GE shares). Guidance remains the same for operating cash flow of \$0.8–1bn; capital expenditures of \$350–400m; and an expected decrease in working capital of \$50–200m.

"Although we worked diligently in the quarter to close the sale of the ABW projects, the sale was delayed and consequently, as we highlighted on our first quarter of 2013 earnings call, such delay caused a decline in our net sales and earnings for the second quarter from expectations," says CEO Jim Hughes. "We still expect the closing of the ABW sale to occur in the current year, resulting in a corresponding increase in net sales and earnings in the second half of 2013," he adds. "The acquisition of GE's CdTe intellectual property and the formation of the new strategic collaboration partnership with GE, coupled with the growing pipeline of potential booking opportunities and continued improvements we are making on our module technology, provide incremental value and confidence for our shareholders and demonstrate the progress we are making in achieving our strategic goals of delivering industry-leading PV power solutions to sustainable markets globally."

Former Deloitte executive chairman Allen appointed to board

First Solar has appointed Sharon Allen to its board of directors, sitting on the board's Audit and Technology Committees.

Allen served as US chairman of Deloitte LLP from 2003 to 2011, retiring from that role in May 2011. She is the only woman ever to serve as chairman of a large, private US professional services organization.

Spending her entire professional career at Deloitte, Allen was the first female board member in the firm's history and the first executive chairman of Deloitte LLP.

Allen is now an independent director of Bank of America Corp, serving on its Audit Committee and Corporate Governance Committee. www.firstsolar.com

First Solar to be first EPC firm to install 1GW in a year

Cadmium telluride (CdTe) thin-film photovoltaic (PV) module maker First Solar Inc of Tempe, AZ, USA is expected in 2013 to become the first PV engineering, procurement & construction (EPC) firm to install 1 gigawatt worth of solar power systems in a single year, according to market analyst firm HIS in its quarterly EPC & Integrator Market Share & Project Market Tracker.

First Solar is forecast to install 1.1GW of solar systems in 2013, more than double the 516MW in 2012. This high growth rate will allow First Solar to maintain its leadership in the EPC business for the year, despite even faster growth from Chinese rivals, including second-ranked China Power Investment Corp (CPIC) and third-ranked GD Solar.

As system integrators, EPC firms are vertically integrated contractors that build large-scale solar projects. Firms like First Solar are capable of a full range of installation tasks, including designing installation

projects, procuring materials and building assignments. First Solar and a number of companies build projects developed in-house, generating revenue from the sale of completed PV power plants. Others focus on EPC for third-party developers, sometimes in combination with in-house development.

First Solar's growth is built on its strategy to cultivate a pipeline of PV projects, in which it takes on major undertakings, sells them to other firms and then uses the proceeds to buy other large-scale installations.

For example, in May First Solar announced the sale of the Campo Verde Solar Project, which is under construction in Southern California. Campo Verde will have a nameplate capacity of 139MW of alternating current (MW_{ac}) when completed at the end of 2013. With the money it made from the sale, First Solar expanded its pipeline with the acquisition of three other projects

under development with a total capacity of 260MW_{ac}, due for completion by the end of 2015.

With the company's solar module business suffering because of falling prices, this is turning out to be a winning approach, comments IHS. "First Solar's successful strategy of acquiring, installing and divesting projects will keep the company among the world's leading solar system integrators over the next years," says Josefin Berg, senior analyst for downstream solar research at IHS. "This approach not only offers a sales outlet for modules, but more importantly also generates project-sales revenue that cushion the company when seeking new growth markets."

In January, First Solar took a major step toward expanding its business outside the USA when it acquired Chilean PV developer Solar Chile and its early-stage 1.5GW project.

www.ihs.com

US and Mexico 1.5GW project portfolio acquired from Element Power

First Solar has acquired a pipeline of US and Mexico development assets from Element Power. Owned by global private equity firm Hudson Clean Energy Partners (which invests in renewable power, alternative fuels, and energy efficiency and storage), Element Power develops, acquires, builds and operates utility-scale solar and wind power projects. The 1.5GW pipeline includes geographically diverse projects in various stages of development. Terms of the deal were not disclosed.

Included in the pipeline are projects in California, Arizona, Texas, Georgia, North Carolina, Colorado, Louisiana and Illinois. First Solar says that the projects are competitively positioned in their respective markets and have secured site options and interconnect queue positions, and are at various stages of

environmental screening and permitting.

"These US assets are an excellent complement to our existing project pipeline," says Tim Rebhorn, First Solar's senior VP of business development for the Americas. "The mix of projects in emerging US regions and an optimized pipeline in established markets will better position First Solar to secure customer off-take agreements."

The portfolio also includes several Mexican projects in the State of Sonora that are in a position to take advantage of the emerging utility-scale PV market in Mexico.

"The Mexican project pipeline strategically positions First Solar for our entry into the market," says Rebhorn. "We are excited by the opportunity to explore new relationships with CFE [the state-owned electric utility company] and with commercial and industrial customers

and the Mexican government, and to establish a strong initial presence in the region," he adds.

"This sale of projects from our portfolio demonstrates a relationship that brings together the strengths of each company to add high-quality solar assets to the energy mix in the US and Mexico," says Element Power's president & chief operating officer Raimund Grube. "As a key component to delivering competitive renewable energy, we look forward to maintaining strong relationships with companies like First Solar who consistently demonstrate a lead position in the industry through successful acquisition, development and construction of solar projects."

Key staff from Element will support the transition of project development activities to First Solar's project development team.

www.elpower.com

www.firstsolar.com

First Solar and GE announce technology and commercial partnership to speed CdTe PV module development

GE swaps its CdTe solar IP portfolio for stake in First Solar

First Solar Inc of Tempe, AZ, USA and GE (General Electric) have announced a technology partnership to advance thin-film solar cells and modules. First Solar has acquired GE's global cadmium telluride (CdTe) solar intellectual property portfolio. As part of the transaction, GE received 1.75 million shares of First Solar common stock, which GE has agreed to retain for at least three years.

In April 2011, GE acquired PrimeStar Solar Inc of Arvada, CO, USA, which was founded in Golden, CO in 2006 to develop CdTe PV modules using technology from NREL (which is based in Golden). After acquiring a minority stake in September 2007, GE's power generation division GE Energy of Atlanta, GA, USA took a majority stake in PrimeStar in 2008.

The combination of the two firms' complementary technologies and First Solar's existing manufacturing

capabilities are expected to accelerate the development of CdTe solar module performance and improve efficiency at manufacturing scale. In addition, GE Global Research and First Solar R&D will collaborate on future technology development to further advance CdTe solar technology.

GE, which has 34GW of renewable energy installed globally, will enhance its presence in solar through access to purchasing and branding First Solar's modules for future global GE deployments, in addition to its investment in inverters, controls, balance of plant and ownership of utility scale systems.

Additionally, GE and First Solar have formed a commercial relationship around solar inverter technology. First Solar will continue to purchase inverters from GE Energy Management for use in its global solar deployments to optimize elec-

trical balance of plant. By combining complementary technologies, the collaboration is expected to lead to an improvement in solar grid integration, more competitive cost structures and a roadmap for combined electrical equipment.

"We are creating an exciting synergy with this deal," believes First Solar's CEO Jim Hughes. "The addition of GE's PV thin-film technology and R&D resources will advance our technology roadmap, while realizing cost reduction in our manufacturing process," he adds.

First Solar's existing manufacturing sites will be used to further advance CdTe technology and achieve an increasingly competitive cost position. GE has decided to discontinue the build-out of its solar manufacturing facility in Aurora, Colorado.

www.ge-energy.com

www.firstsolar.com

Business development team expanded for Middle East & North Africa

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 expanded its regional business development capabilities, with the appointment of Dr Raed Bkayrat as VP of business development for the Kingdom of Saudi Arabia. Additionally, Ahmed S. Nada, VP of business development for the Middle East, will also oversee the firm's commercial growth in North Africa. Raed and Ahmed will report to Christopher Burghardt, VP of business development for Europe, the Middle East and Africa (EMEA).

"Our decision to expand our business development team is a reflection of the tremendous potential that we see in the region," says Burghardt. "Both Ahmed and Raed

bring extensive experience to their roles and there is no doubt in my mind that, together, they will successfully lead efforts to grow our presence across the Middle East and North Africa."

With over 15 years of experience, Raed joins First Solar from the King Abdullah University of Science and Technology (KAUST), where he was responsible for establishing the institution's Industry Collaboration Program (KICP). During his four years at KAUST, he also created a demonstration and testing program for solar and other clean energy technologies. Prior to that, he was part of the core team behind Direct Drive Systems, a US-based start-up that was acquired by an oil and gas major, and previously spent eight years in various roles at Siemens. Raed holds a Ph.D. and a Master of Science (MS) in Electrical

Engineering from the Arizona State University and a Bachelor of Science from the University of Jordan.

Ahmed joined First Solar from General Electric in January and was tasked with leading the firm's business development efforts across the Middle East, excluding Saudi Arabia. As VP of business development for the MENA region, he will now also be responsible for a number of fast-growing markets, including Morocco, Algeria, Tunisia and Egypt, in addition to his existing remit.

"First Solar is focused on partnering with the region to develop solar power into a sustainable, viable and affordable energy resource," says Nada. "With rapid growth expected in North Africa, we are keen to leverage our expertise and experience in order to help the region progress its solar ambitions."

First Solar and Ingenero to collaborate on commercial and off-grid PV projects in Australia and Asia Pacific CdTe firm diversifies to medium-scale projects

First Solar Inc of Tempe, AZ, USA and Ingenero Pty Ltd of Brisbane, Australia have announced a new collaboration arrangement to provide a joint offering to the commercial and off-grid solar markets. The partnership will combine Ingenero's design, development and integration experience with First Solar's CdTe thin-film PV module technology and track record in utility-scale projects to meet market requirements within Australia and the Asia Pacific region.

Ingenero has an established footprint in the commercial and off-grid space, having constructed Australia's largest rooftop solar PV system at the University of Queensland in Brisbane plus ground-mounted PV systems in Queensland, the Northern Territory and the Pacific Islands. First Solar has international experience in constructing utility-scale solar projects, including Australia's first utility-scale solar farm (Greenough River) and has established a local supply chain in Australia. The collaboration aims to combine both

firms' capabilities to increase the number of ground-mounted solar projects in Australia. They will also jointly target diesel fuel replacement opportunities in Australia's off-grid sector, reducing operating costs for mining firms and providing an alternative power generation source for communities throughout regional Australia and the Pacific Islands.

"A collaboration agreement with First Solar and the opportunity to utilize its thin-film PV module technology brings with it the increased capability and flexibility needed to be successful in a growing market," says Ingenero's CEO Steve McRae. "This year we made the leap into the international solar market, building a complex hybrid off-grid solar power plant on the island of Vava'u, Tonga. These kinds of off-grid applications, as well as commercial and utility-scale applications, hold significant growth opportunities internationally," he adds. "Partnering with a company of this calibre means Ingenero will continue to

grow its commercial and utility solar business within Australia and broaden its international footprint," McRae continues.

Jack Curtis, First Solar's Asia Pacific VP of business development & sales, said the new partnership will leverage the synergies between the two firms. "In collaborating with Ingenero, Australia's leading integrator in the small- to medium-scale solar sector, First Solar is better positioning itself to meet the needs of the commercial and off-grid solar markets in Australia and Asia Pacific," he adds. "First Solar's primary focus has been utility-scale projects... This collaboration will provide us with additional origination and execution diversity in medium-scale projects that will allow us to broaden our accessible demand pool across the region and meet the needs of customers that are looking to utilize our thin-film PV module technology in these types of applications."

www.ingenero.com.au
www.firstsolar.com

First Solar to deliver 155MW of PV projects in New South Wales

Sydney-based AGL Energy Ltd (Australia's largest private owner and operator of renewable energy assets) has achieved financial close for two utility-scale solar PV projects for which First Solar has been contracted to supply engineering, procurement & construction (EPC) services. First Solar will also provide maintenance support for five years after the solar farms are operational.

AGL has engaged First Solar to construct a 102MW_{AC} plant at Nyngan and a 53MW plant at Broken Hill, both in New South Wales (NSW). The projects are supported by \$166.7m of Commonwealth Government funding through the Australian Renewable Energy Agency (ARENA) as well as an

extra \$64.9m in funding from the NSW Government. Total project cost is about \$450m.

"The Nyngan and Broken Hill solar projects will be Australia's largest utility-scale solar projects, respectively, and demonstrate that utility-scale solar is a proven, bankable source of power generation in Australia," says Jack Curtis, First Solar's VP of business development for Asia Pacific. "Projects will play an important part in the growing acceptance of utility-scale solar."

The Nyngan construction is due to start in January, for commercial operation by mid-2015. Construction of the Broken Hill project will start about six months later, in July 2014, and should reach commercial operation before the end of 2015.

On completion, the projects should produce about 360,000MW-hr per year (sufficient for over 50,000 average homes in NSW).

The plants should add nearly 2% to the gross regional product of both the Nyngan and Broken Hill communities. With over 100 local contractors attending subcontractor forums in Dubbo, Nyngan and Cobar, First Solar is engaged with local firms looking to become involved in the projects. The projects will create about 300 construction jobs in Nyngan and 150 in Broken Hill."

"Te will provide the experience and commercial stability to help ensure the successful construction of the two solar plants," says AGL's managing director Michael Fraser.

www.agl.com.au

IN BRIEF

Ascent Solar closes \$3m second tranche of \$6m financing; regains Nasdaq compliance

Ascent Solar Technologies Inc of Thornton, CO, USA, which makes lightweight copper indium gallium diselenide (CIGS) thin-film photovoltaic modules that it integrates into its EnerPlex series of consumer products, has announced the second closing of Series A Preferred Stock announced in June (when it closed a \$1m first tranche through a private placement with an investor in Asia). The second closing yielded proceeds of \$3m for the sale of 375,000 shares of preferred stock and 1,312,500 warrants exercisable at \$0.90 per common share. Tranche 3 is expected to close in August with proceeds of \$2m (making \$6m in total).

"We are pleased to complete the second closing on this previously announced vote of confidence in our continued paradigm shift and strategy for growth," says president & CEO Victor Lee.

Ascent said in June it will use proceeds to fund the expansion of retail channels for its EnerPlex products in the USA, Europe and Asia; brand building; and the launch of additional EnerPlex products.

Also, Ascent has regained compliance with the Nasdaq Stock Market Listing Rules that require maintenance of a minimum \$1 bid price. On 5 August, the firm was notified by The Nasdaq Listing Qualifications department that it had regained compliance with the minimum bid price requirement after maintaining a closing bid price equal to or in excess of \$1 for 20 consecutive trading days and that noncompliance (announced on 7 December 2012) had been rectified.

www.AscentSolar.com

Stion's modules demonstrate zero degradation in first year

In April 2012, Stion Corp of San Jose, CA, USA, which makes nanostructure-based CIGS (copper indium gallium sulphur-diselenide) thin-film photovoltaic panels, installed a 60kW demonstration array in Hattiesburg, MS consisting of some of the first CIGS modules produced at Stion's high-volume factory in Mississippi. After a year of field production in the hot and humid Mississippi delta, Stion's modules show zero degradation in power output.

A random sample of modules was removed from the array and tested; they performed at or above the STC (irradiance=1000W/m², air mass =1.5, module temperature=25°C) flash test result that was recorded at the time of production. In contrast, with silicon-based modules the norm is a power loss of at least

1–2% in just the first year.

Stion says that the stable performance confirms that its modules match the stability seen in CIGS modules that have been stable for nearly 8 years in a test array at the US National Renewable Energy Laboratory (NREL).

Stion's CIGS modules have a dual glass/glass construction, providing significantly improved moisture resistance and lifetime durability over the traditional polymer-based backsheets used in traditional PV modules, the firm claims. The modules are resistant to potential-induced degradation, light-induced degradation, and provide a durable solution engineered to survive in harsh environments and outperform in non-ideal situations, the firm adds.

www.stion.com

PacWest secures invitation from Brazilian Government to bring its line of solar manufacturing equipment to Brazil

Government officials in Brazil have invited PacWest Equities Inc of Sacramento, CA, USA to bring its copper indium gallium diselenide (CIGS) line of solar manufacturing equipment (acquired in a deal some analysts valued in excess of \$55m) to Brazil to open a multi-product suite of solar products for production and distribution in Brazil and other South American countries.

Based on the firm's technology and the acquisition of DayStar Technologies Inc's 51 patents, patents pending, international patents, and intellectual property, Brazilian officials feel that PacWest Equities is uniquely positioned to help propel the country forward in terms of solar photovoltaic product production.

The technology, which cost over \$100m to develop (with \$67m going to R&D, \$12m to build the prototype line, and \$27m going to the actual production line now in physical possession of PacWest Equities) addresses the construction market's need to replace typical tinted window panes in high-rise buildings with solar glass panels that generate electricity at the same time as functioning as a window, a skylight, or any other type of building cover.

With the amount of solar potential in Brazil, combined with the country's high electricity rates and desire to preserve the environment, Brazil is uniquely positioned for rapid growth in this sector, it is reckoned.

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LED equipment spending to rebound in 2014

China to rise from 33% of spending in 2013 to 44% in 2014 as MOCVD reactor sales rise nearly 50%, says SEMI.

Following declines of 45% in 2011 and 30% in 2013, LED wafer fab equipment spending will rise 17% to nearly \$1.2bn in 2014 as the LED industry is working through its over-capacity problems and will renew capital spending and capacity increases in 2014, according to the SEMI Opto/LED Fab Forecast quarterly on high-brightness light-emitting diode (HB-LED) front-end wafer fabrication plants.

Equipment spending trends also reveal a new era in the LED industry, as equipment spending now is concentrated among the industry leaders — and aspiring survivors — rather than widely distributed among new entrants to the industry or new technologies.

Following the explosion in LED interest sparked by the LED TV boom and exuberant optimism for the long-term growth in solid-state lighting (SSL), the LED industry dramatically expanded worldwide capacity over the past three years, fueled partly by lucrative government subsidies in China. Total worldwide capacity rose 49% in 2011 and 39% in 2012 and continued to grow by 19% this year, the report notes. Driven by national and provincial subsidy and incentive programs, China-based LED manufacturing rose from about 100,000 4"-equivalent wafers per month in 2010 to an astounding 620,000 4" wafers per month this year.

Much of this capacity expansion was driven by extremely optimistic forecasts in 2010 and 2011 that the LED market would grow to over \$20bn as soon as 2015. However, current market forecasts for the packaged LED market in 2015 hover around \$15bn, with a compound annual growth rate (CAGR) below 5%. The principle reasons for the decline in growth forecasts are the greater efficiency (i.e. improved light guides in displays) in using LEDs, the greater efficacy of packaged LEDs, and the minimum size of a replacement market for LED lamps.

According to market research firm Strategies Unlimited, the average cost per kilo lumen has declined from \$13 in 2011 to less than \$3.65 today. The number of LEDs used in TVs has fallen by one-third, and many SSL luminaires require less than half the LEDs used just a few years ago. LEDs in mobile devices and notebook computers have also declined. Automotive remains a growth market, but represents only around 10% of the market.

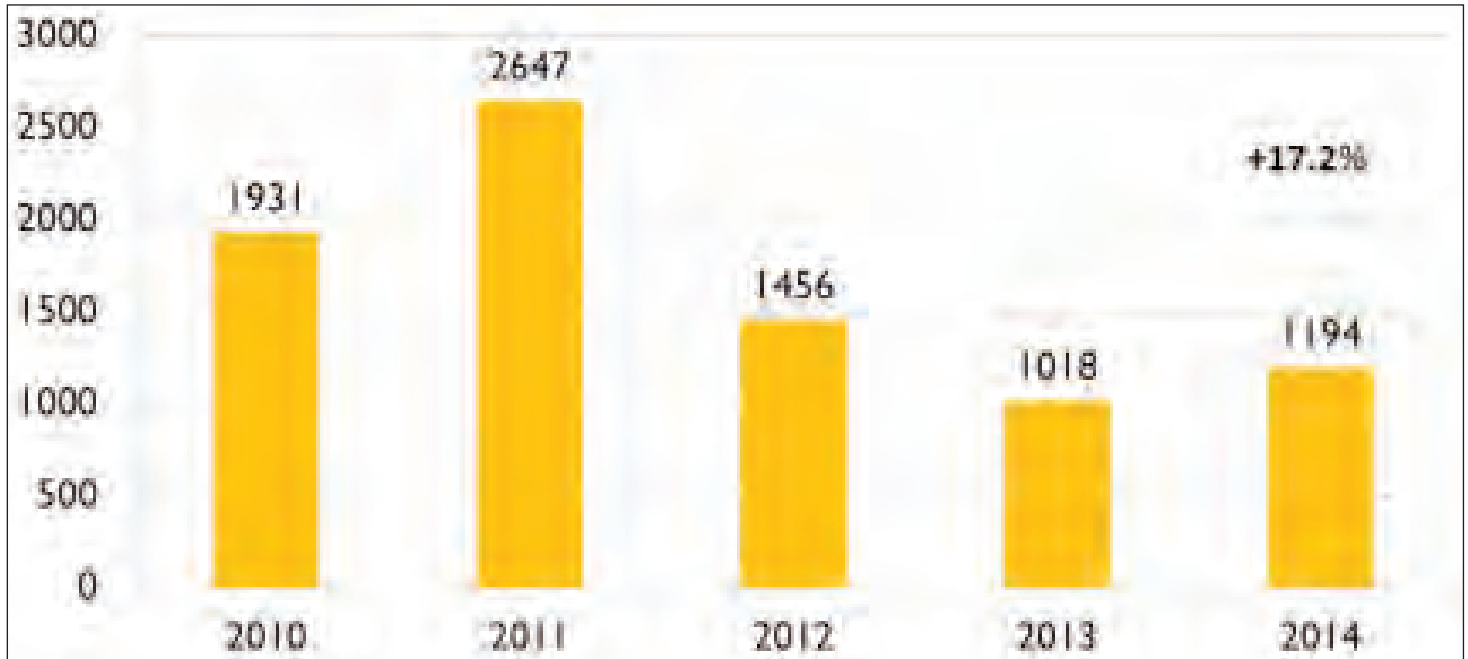
With so much new capacity, new entrants and declining growth rates, the prices for packaged LEDs has declined dramatically in recent years, creating severe financial hardship for many, especially new entrants and those restricted to the lower-margin mid- and low-power segments, notes the report. Fab utilization has fallen worldwide, especially in China. Sales for metal-organic chemical vapor deposition (MOCVD) systems — the critical production tool for LED epitaxial operations — plummeted. The leading MOCVD system makers Veeco and Aixtron, who saw sales triple in 2010, watched revenues plummet by nearly the same amount in 2012.

Compensating for some of the decline in packaged LED prices are the steep declines in sapphire wafers, which are used by over 80% of the LED industry. Sapphire prices for 4" wafers are now about \$32 (down from their peak of \$130 in 2011) and 6" sapphire prices are now below \$300 (down from \$450 eighteen months ago). Patterned sapphire substrates (PSS) have rapidly become standard at 2" and 4" diameters and are promising for 6" wafers.

Declining sapphire prices and the continued competitiveness of silicon carbide (SiC) have dampened prospects for the penetration of GaN-on-silicon in LEDs (once thought likely, if not inevitable). A new report 'Dimming the Hype: GaN-on-Si Fails to Outshine Sapphire by 2020', by market research firm Lux Research sees SiC and sapphire continuing to dominate the LED market, benefitting from added capacity and continued technology improvements. The report says that "new methods like hydride vapor phase epitaxy (HVPE) will further improve throughput and cut costs, keeping sapphire highly competitive for the rest of the decade".

The global LED industry now appears to be stabilizing as leading manufacturers invest in 6" wafer production systems and associated equipment purchases to deliver improved yield and throughput, reckons the SEMI report. Recent LED manufacturing investment has centered on the move to 6" wafers by Cree (silicon carbide) and Philips Lumileds and Osram (sapphire).

Japan's Nichia continues to invest in capacity and technology improvements, and Taiwan's Epistar, Formosa Epitaxy, and Genesis Photonics all made significant manufacturing investments this year. Nearly all



LED equipment spending (in \$millions). Source: SEMI Opto/LED Fab Forecast, July 2013 (preliminary).

leading manufacturers appear to be modernizing their production systems, with increased investments in metrology, automation, etch and lithography.

China will resume its MOCVD purchasing in 2014 in the absence of government subsidies. SEMI forecasts an increase of nearly 50% in purchases of MOCVD reactors in 2014, up from 150 reactors purchased in 2013. At the same time, many LED fabs will close or be repurposed in China as the market consolidates and non-competitive players disappear, SEMI adds.

China's San'an with over 120 MOCVDs and ETi

(Elec-Tech) with 90 reactors are operating at increasing fab utilization rates and appear to be emerging as significant players. Some medium-size LED fabs in China such as Canyang Opto and HC Semitek are also operating at near full capacity and are optimistic for their future. China will represent about 44% of total equipment spending in 2014, up from 33% in 2013. More information will be available at LED Taiwan 2013, which is co-located with the SEMICON Taiwan show in Taipei, on 4–6 September.

The global LED manufacturing market appears to be stabilizing and working through its rapid capacity expansion of 2010–2012.

Significant packaged LED price declines have been partially offset by wafer cost reduction, yield improvements and wafer size increases.

China market shakeout has begun and the survivors look to have staying power for long-term competitiveness

In conclusion, says SEMI, the global LED manufacturing market appears to be stabilizing and working through its rapid capacity expansion of 2010–2012. Significant packaged LED price declines have been partially offset by wafer cost reduction, yield improvements and wafer size increases. Leaders like Nichia, Cree, Philips, Osram and LG Innotek have continued to modernize their production operations for improved yield and throughput. China market shakeout has begun and the survivors look to have staying power for long-term competitiveness.

With the overall LED market appearing to have modest growth rates for the next five years, and with many firms being vertically integrated lighting manufacturers, the incentives for significant investments in manufacturing to gain cost advantage and market share are not high. In addition, many mid-power packaged LEDs are migrating to lighting applications once thought reserved for advanced high-power products, opening up market opportunities for Chinese companies.

However, after many years of dynamic technology change, many lighting manufacturers are looking to reduce parts count (die sizes, package and phosphor types) and stabilizing their product lines, limiting the demand for new suppliers and product-types. It seems that the stakes for success in the LED marketplace have revealed themselves and it remains to be seen how competition drives further manufacturing investments in the coming years, concludes the SEMI report.

Tom Morrow, VP & chief marketing officer at SEMI, is speaking at the conference LEDs and the SSL Ecosystem 2013 in Boston, MA, USA (28–29 October). ■

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Nanosphere-patterned sapphire improves deep UV LED performance

Light output power almost doubled and external quantum efficiency reaches 3.45% at an injection current of 20mA.

Researchers in China have been developing nanopatterned-sapphire substrates (NPSS), achieved with nano-sphere lithography (NSL), as a basis for the production of superior aluminium gallium nitride (AlGaIn) semiconductor material for deep ultraviolet (UV) light-emitting diodes (LEDs) [Peng Dong et al, Appl. Phys. Lett., vol102, p241113, 2013].

"We have demonstrated the first high-performance AlGaIn-based deep UV-LEDs fabricated on NPSS that is prepared by NSL and wet etching," says the team from Chinese Academy of Sciences' Institute of Semiconductors, Tsinghua University, and State Key Laboratory for Artificial Microstructure and Mesoscopic Physics at Peking University.

Proposed applications of deep UV LEDs include disinfection, sensing, water purification, bio-medical, and communication. It is also hoped that efficient deep UV LEDs would provide more energy efficient compact solutions compared with the present fragile and hazardous mercury vapor lamps. Improved material quality is key to achieving these aims.

Sapphire patterning was achieved by photolithography through a mask consisting of polystyrene nanospheres that were then removed using deionized water (Figure 1). The pattern in the developed photoresist was transferred to an underlying hard mask layer of 200nm silicon dioxide using inductively coupled plasma etch. Finally, the sapphire was wet etched using a mix of sulfuric and phosphoric acid solutions. The silicon dioxide was removed using hydrofluoric acid.

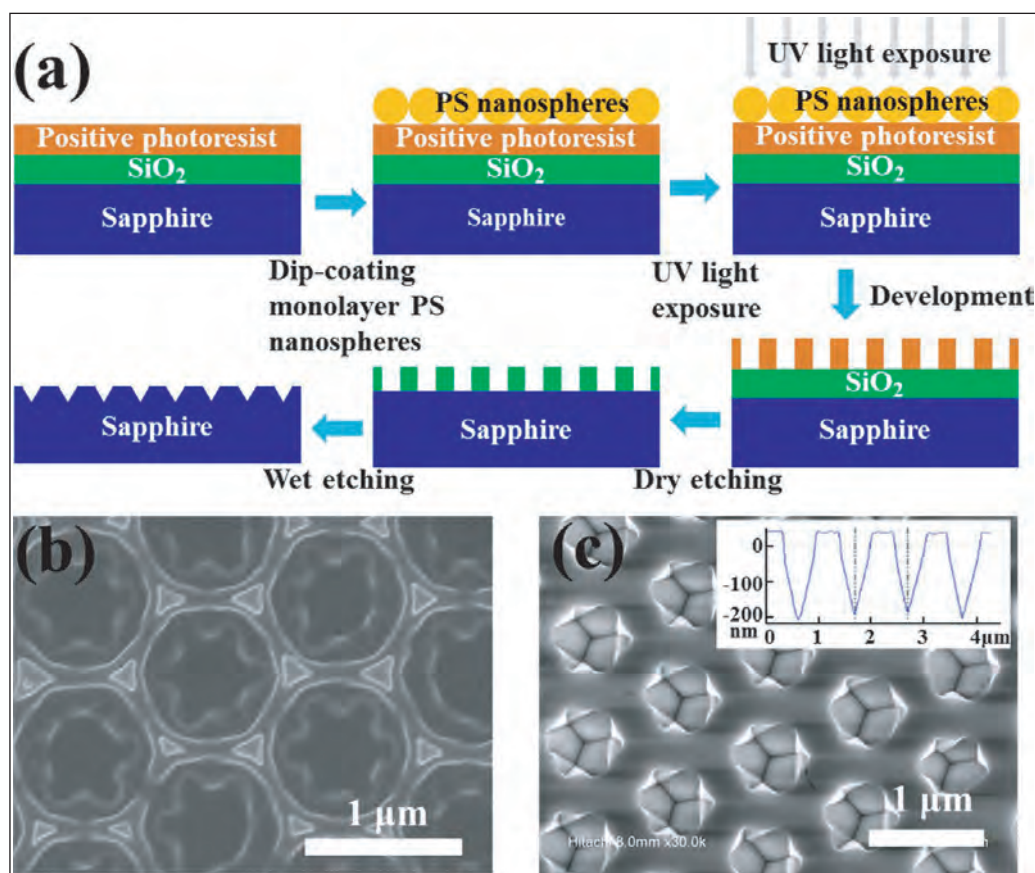


Figure 1. (a) Schematic of fabrication process flow to create nano-patterns on a sapphire substrate (NPSS). SEM images of the patterned photoresist (b) and wet-etched NPSS (c). Inset in Figure 1(c) shows line profile of patterns of NPSS by AFM measurement.

The pattern consisted of 230nm-deep concave triangular cones set in a hexagonal pattern of period 900nm. The unetched region between the cones was 400nm wide.

The growth of the UV LED epitaxial structure was through low-pressure metal-organic chemical vapor deposition (LP-MOCVD) with trimethyl-aluminium, trimethyl-gallium, and ammonia precursors, respectively, for the Al, Ga, and N species. The structure began with 25nm of low-temperature 550°C AlN, before the whole 4µm AlN template was completed at 1200°C in nitrogen-rich conditions.

Contact	p-GaN	150nm
Cladding	p-AlGaIn	50nm
Electron blocking	p-Al _{0.65} Ga _{0.35} N	
Multiquantum well	5x (Al _{0.4} Ga _{0.6} N well/ n-Al _{0.5} Ga _{0.5} N barrier)	3nm/12nm
Contact	n-Al _{0.55} Ga _{0.45} N	3.5μm
Superlattice	20xAlN/AlGaIn	
Template	AlN	4μm/1μm
Substrate	NPSS/FSS	

Figure 2. Deep UV LED structure.

The AlN was found to coalesce after only 3μm. This is much sooner than other epitaxial layer overgrowth (ELOG) techniques using micro-stripe patterning that only coalesce after 10μm growth. Atomic force microscopy (AFM) over 5μm x 5μm fields gave a root-mean-square roughness of 0.15nm. The AFM analysis also indicated a step-flow growth mode. X-ray analysis gave estimates for screw and edge dislocation densities of $1.6 \times 10^7/\text{cm}^2$ and $1.2 \times 10^9/\text{cm}^2$, respectively.

This AlN template material was used in further growth of the UV LED structure (Figure 2). The same structure was grown on flat sapphire with a 1μm AlN template layer. The n-AlGaIn layer was found to have pure edge and mixed threading dislocation densities on NPSS and FSS substrates of $\sim 1.6 \times 10^9/\text{cm}^2$ and $\sim 3.4 \times 10^9/\text{cm}^2$, respectively. The reduced density layer on NPSS was attributed to the higher-quality AlN template. The superlattice regions were also designed to have dislocation filtering effects.

Temperature-dependent photoluminescence studies at 10K and 300K suggested an internal quantum efficiency of 45% for the NPSS LED structure, compared with 28% for the FSS AlN template epitaxy.

The epitaxial materials were formed into 380μm x 380μm devices. Mesas for the devices were etched using inductively coupled plasma. The n-contact metal stack consisted of titanium/aluminium/titanium/gold annealed at 850°C in nitrogen. The p-contact was nickel/gold annealed in air at 500°C.

The chips were flip-chip mounted on silicon sub-mounts with gold-bump bonding. The majority of light in deep UV LEDs is expected to emerge through the sapphire substrate, since the p-GaN layer is absorbing of the radiation due to it having the narrowest bandgap in the structure. The device testing was performed with the sub-mounted chips attached to metal-core

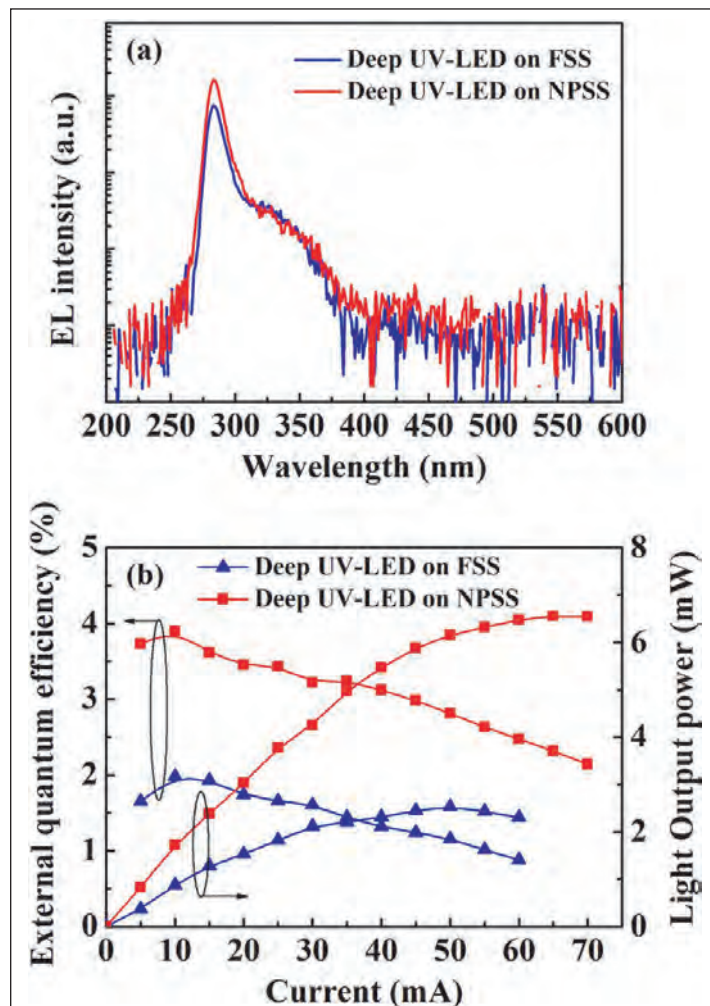


Figure 3. (a) EL spectra and (b) LOP-I-EQE curves of deep UV LEDs grown on NPSS and FSS.

circuit boards with silver paste to improve heat dissipation.

The main electroluminescence (EL) peak occurred at 282nm with a weak shoulder peak near 330nm (Figure 3). It is thought that recombination in the electron-blocking layer was responsible for the shoulder peak. Hence, "further optimization of the electron-blocking layer is needed to suppress electron overflow into the p-cladding layer," the researchers write.

The light output power (LOP) at 20mA current (I) was 3.03mW with external quantum efficiency (EQE) of 3.45% for the NPSS-based device. This was almost double that of the FSS-based LED. The saturation LOP for the NPSS LED was 6.56mW at 60mA current. The FSS device saturated at 2.53mW with 50mA injection.

Since the internal quantum efficiency does not account for all the improvement in performance, the researchers believe that "the light scattering at the AlN/NPSS interface decreases the total internal reflection and the absorption in the p-GaN layer, and increases the photon's escape opportunity from the sapphire backside." ■

<http://link.aip.org/link/doi/10.1063/1.4812237>

Author: Mike Cooke

Combining Al₂O₃ and SiO₂ for nitride semiconductor LED passivation

Patterning of a silicon dioxide/aluminium oxide passivation layer has improved LED light output power by more than 20% at 60mA.

Researchers in China have developed a silicon dioxide (SiO₂) on aluminium oxide (Al₂O₃) passivation for nitride semiconductor light-emitting diodes (LEDs) that offers more than two orders of magnitude reduced current leakage under reverse bias [Hao Guo et al, Appl. Phys. Express, vol6, p072103, 2013]. Further, by patterning the SiO₂ layer with an array of hemispheres, the light output power (LOP) is increased by up to 22% at 60mA.

The research was based at Chinese Academy of Sciences' Institute of Microelectronics, Southeast University, and Nanchang University. The epitaxial material was grown using metal-organic

Table 1. Measured surface etching profiles of patterned SiO₂/Al₂O₃ passivation layer under different reflow conditions.

Sample	Reflow temperature (°C)	Reflow time (min)	Hemisphere height (nm)	Hemisphere base diameter (µm)
A	0	0	491	1.56
B	160	5	476	1.58
C	160	7	456	1.63
D	160	9	347	1.69
E	160	11	205	1.86

chemical vapor deposition (MOCVD) on patterned sapphire. The pattern of 2.1µm diameter, 0.9µm height and 0.9µm separation was created using photolitho-

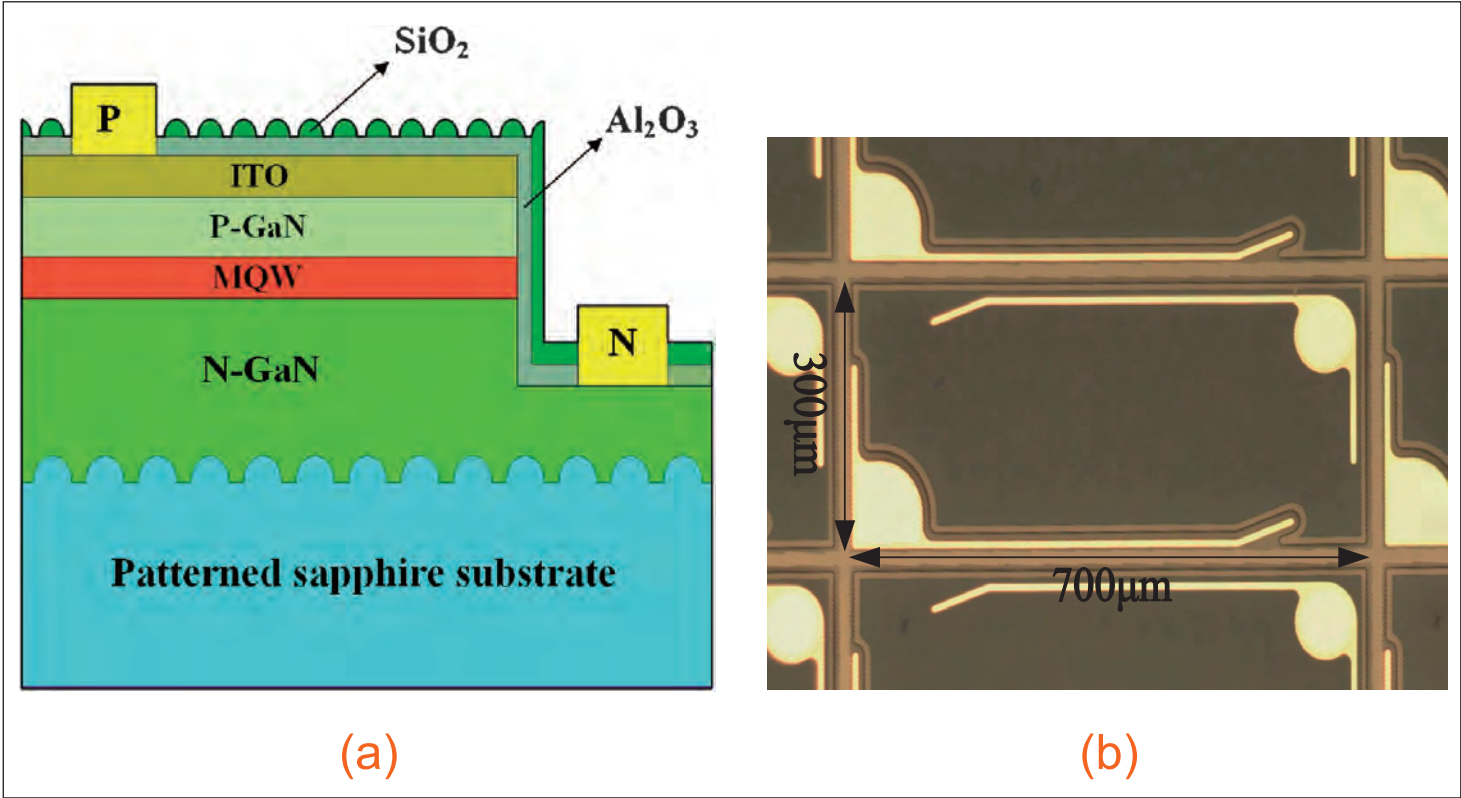


Figure 1. (a) Schematic of LED on patterned sapphire with patterned SiO₂/Al₂O₃ passivation. (b) Photograph of fabricated 300µm x 700µm LED chips.

graphy and inductively coupled plasma (ICP) etch.

The LED nitride semiconductor layers consisted of a 30nm GaN buffer, 4.5µm n-GaN contact, six-pair InGaN/GaN multi-quantum-well active region, and 0.9µm p-GaN contact. These layers were followed by 240nm of indium tin oxide (ITO) as a transparent conducting layer on the p-contact. Chromium/platinum/gold metal layers for the electrodes were deposited on the n-GaN and ITO. The devices emitted at wavelengths of around 460nm. The fabricated LED devices measured 300µm x 700µm.

After experimenting with various Al₂O₃, silicon nitride and SiO₂ passivation layers for the LED, the researchers decided to develop a combined SiO₂/Al₂O₃ oxide process. The Al₂O₃ was found to have a good surface passivation effect, as evidenced by a very low reverse bias (–5V) leakage current of -9.3×10^{-10} A when applied using atomic layer deposition (ALD). The surface passivation offered by plasma-enhanced chemical vapor deposited (PECVD) SiO₂ was relatively poor, with a reverse bias leakage of -1.8×10^{-7} A. However, the light output power (LOP) from the LED was 45.4mW with SiO₂ passivation, compared with 42.7mW for the Al₂O₃ layer.

The effect of the Al₂O₃ passivation is believed to be a decreased trap density near the surface. Such surface traps provide routes for reverse leakage currents and for non-radiative surface recombination.

In the combined SiO₂/Al₂O₃ passivation (Figure 1), the top SiO₂ was also patterned into a triangular array of 2µm-diameter hemispheres spaced by 1µm, designed to reduce total internal reflection and hence increase light extraction. The Al₂O₃ layer was 10nm and the SiO₂ 500nm.

The hemispheres were formed by photolithography into a soft resist, which was then transferred into the SiO₂ via inductively coupled plasma etch. The hemispherical shape was achieved by reflowing the patterned photoresist, i.e. the photoresist is melted and the surface tension of the liquid pulls the material into hemispherical shapes. By varying the reflow time and temperature, different diameters and heights could be achieved (Table 1).

The resulting LEDs had very similar current–voltage characteristics. At 60mA, the forward voltage was 3.1V for all six devices.

However, the light output from sample D was greatest (Figure 2): at 60mA, the LOP for samples A–E were, respectively, 49.2mW, 52.9mW, 53.5mW, 55.2mW, and 50.9mW. A reference device with conventional SiO₂ passivation had an LOP at the same current of 45.4mW. The sample D value of 55.2mW was 21.6%

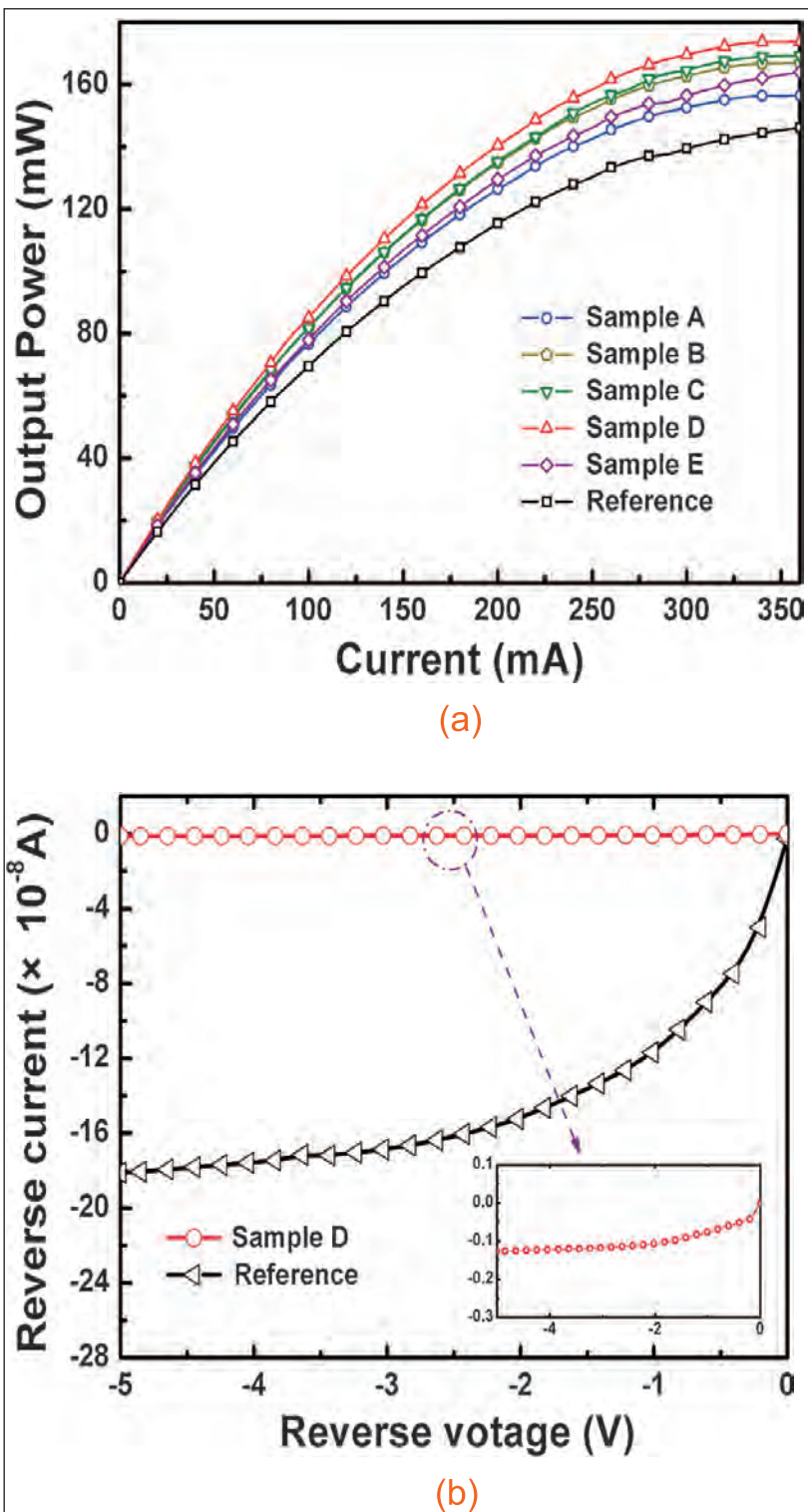


Figure 2. (a) LOP of fabricated LEDs as function of injection current. (b) Reverse leakage current characteristics of sample D and reference.

greater than that of the reference.

Another reflection of the improved performance with Al₂O₃ was increased electrostatic discharge resilience under 2000V reverse voltage stress that yielded 93.67% functioning devices for sample D, compared with 82.69% for the reference device. ■

<http://apex.jsap.jp/link?APEX/6/072103>

Author: Mike Cooke

Laser sculpting increases nitride LED extraction by up to 46%

Researchers in China have used a truncated pyramid structure to reduce back-reflection at the LED's air interface.

Researchers in China have used laser micromachining to boost light extraction efficiencies of nitride semiconductor light-emitting diodes (LEDs) by up to 46% [Bo Sun et al, J. Appl. Phys., vol113, p243104, 2013]. The team was based at Chinese Academy of Sciences' Institute of Semiconductors and Tsinghua University.

Light extraction is restricted in nitride semiconductors due to the large difference in refractive index compared with air. For gallium nitride (GaN) the escape cone is restricted to an angle of around 24°. The rest of the light is reflected back into the material.

The epitaxial structure for the LEDs (Figure 1) was grown on 2-inch low-defect-density free-standing GaN substrate using metal-organic chemical vapor deposition (MOCVD). The 1mm x 1mm device mesas were etched with inductively coupled plasma. The walls of the mesa were passivated with a silicon dioxide layer. The top p-electrode consisted of a reflective metal stack of nickel-silver-platinum-gold. The structure was then annealed at 550°C for 5 minutes in air. The n-contact consisted of titanium-aluminium-titanium-gold.

The GaN substrate was then sculpted into a truncated pyramid using laser micromachining (Figure 2). The

p-contact	p-GaN	150nm
Electron blocking	$\text{Al}_{0.15}\text{Ga}_{0.85}\text{N}$	20nm
Multiple quantum well	InGaN/GaN	
Buffer	n-GaN	2μm
Substrate	2-inch freestanding GaN	

Figure 1. Epitaxial structure with indium gallium nitride (InGaN) wells and aluminium gallium nitride (AlGaIn) electron-blocking layer.

chips were then flip-chip submounted on silicon.

The aim of the shaping was to improve light extraction by optimizing the positions of the escape cones from the various light emission surfaces with respect to the generation process. The researchers used two-dimensional finite difference and Monte Carlo ray tracing simulations to achieve this. The researchers simulated a range of set ups including different

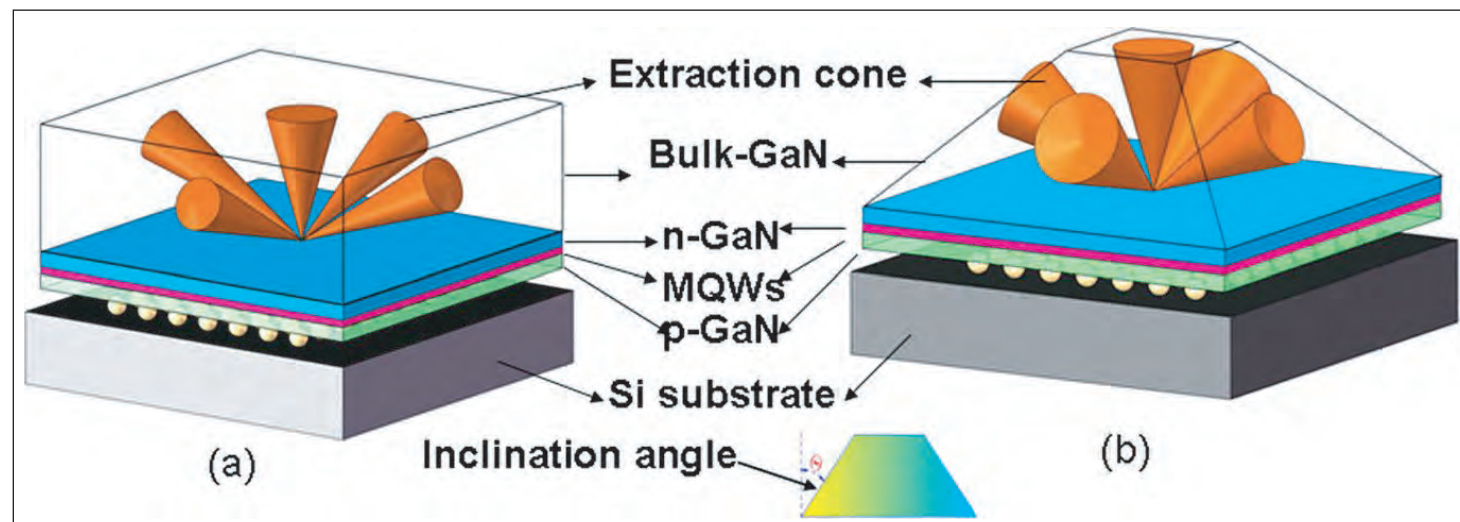


Figure 2. Schematics of conventional flip-chip bulk-GaN LEDs (a) and truncated-pyramidal-shaped flip-chip bulk-GaN LEDs (b).

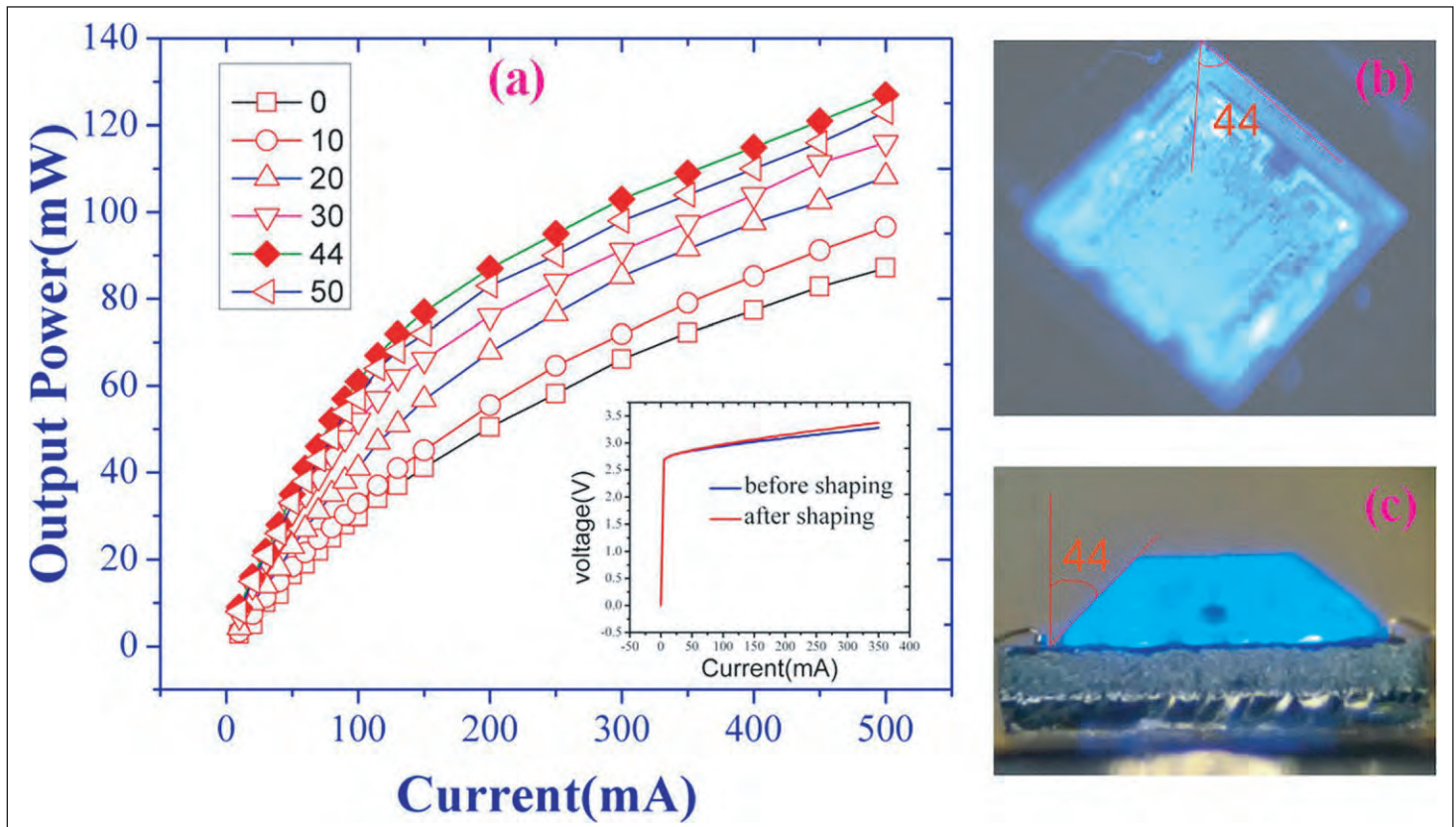


Figure 3. (a) Light output power versus current (L-I) characteristics of truncated-pyramid-shaped LEDs (from inclination angle 0° to 50°) and reference LEDs. Inset current versus voltage (I-V) curve of LEDs before and after laser shaping. (b) Tilt and (c) cross-section views of optical micrographs (with inclination angle 44°) at 5mA injection current.

inclination angles of the truncated pyramid, chip size and chip shape (rectangle, triangle or hexagon).

With the actually constructed chips, the light output power increased with inclination angle up to 44° (Figure 3). The researchers say that this result was consistent with their simulations. Further, the 44°

truncated pyramid shape gave up to a 46% enhancement over a non-shaped chip. The researchers also found that the angular distribution of the radiation was in "good agreement" with the simulations. ■

<http://link.aip.org/link/doi/10.1063/1.4812464>

Author: Mike Cooke

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Exploring graphene applications in nitride semiconductor devices

Researchers are working hard to find commercial uses for graphene in existing and future devices. **Mike Cooke** reports.

The creation of graphene layers in the past few years has created a landslide of ideas about how the material could be used in a wide range of nanotechnology applications. Although commercial applications where the material is used as the basis for active electronic devices seem some way off, there are possibilities for nearer term employment in auxiliary functions.

One use could be as transparent conducting layers (TCLs) in light-emitting and -absorbing devices. Presently, the material of choice is often indium tin oxide (ITO), which increases in price with indium supply shortages. Also, the transmission of light across ITO TCLs cuts off in the ultra-violet range. The optical transmittance of graphene extends further into the UV than ITO.

TCLs are used to improve current spreading and efficiency of wide-bandgap LEDs, generally for emission in the range from green (~520nm) to deep ultraviolet (~250nm and shorter) wavelengths, based on indium aluminium gallium nitride (InAlGa_N) semiconductor alloys.

Much work is being done to apply graphene TCLs in nitride LEDs, but with mixed success. One problem is that the very thinness of graphene leads to reduced conductivity compared with much thicker ITO layers. On the other hand, increasing the number of graphene layers to improve lateral conductivity/current spreading reduces the transmission of light.

An additional problem for graphene TCLs is a large work-function mismatch with the p-GaN that is normally used as the p-contact in nitride semiconductor LEDs. The mismatch results in a high forward voltage needed to drive current through LEDs with graphene TCLs. High forward voltage means power

losses and hence lower efficiency.

Here we look at some developments of graphene applied as TCLs in III-nitride LEDs. However, first we discuss a new use of graphene as an underlayer for the growth of nitride semiconductor material.

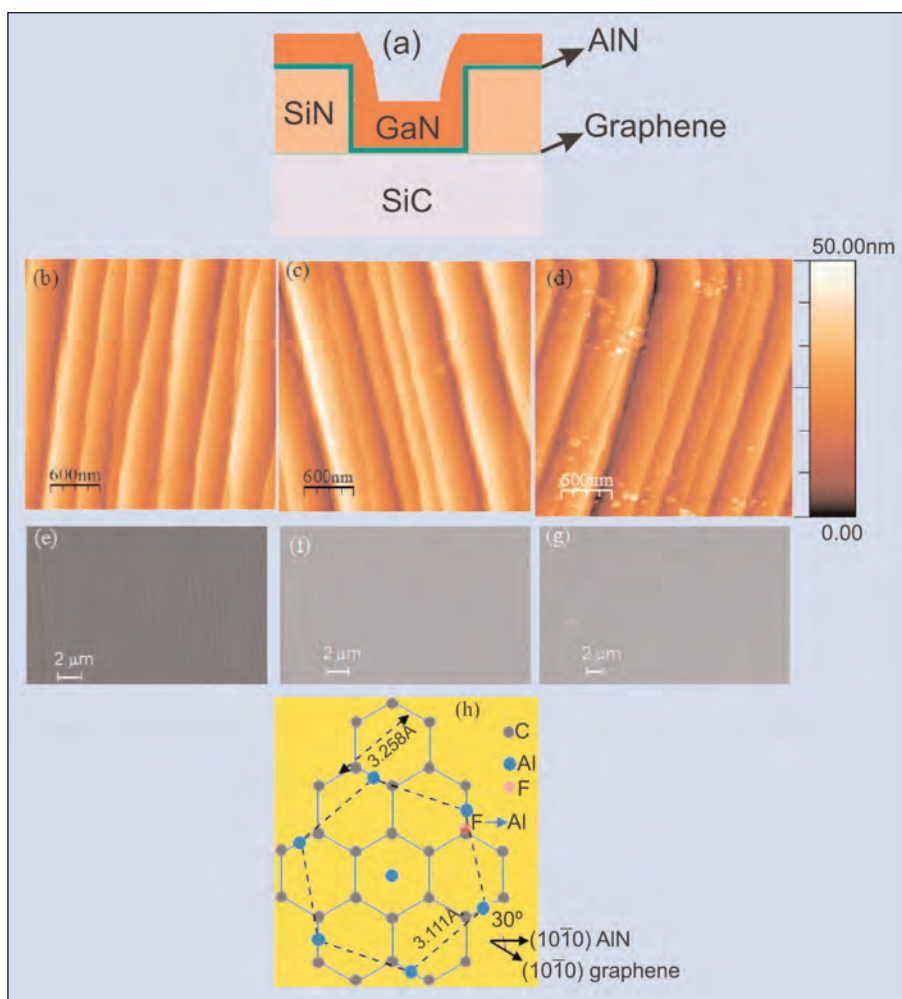


Figure 1 (a) NRL's GaN/AlN/graphene/SiC layered structure. (b) Atomic force microscope (AFM) image of as-synthesized epitaxial graphene, (c) AFM 1.2nm ALE AlN/graphene, (d) AFM GaN/graphene, (e) scanning electron microscope (SEM) image of pristine graphene, (f) SEM 1.2nm ALE AlN/graphene, (g) SEM GaN on ALE AlN/graphene. (h) Al atoms replace F atoms creating AlN nucleation site on graphene resulting in proposed crystalline alignments.

Looking towards 1THz performance

The US Naval Research Laboratory (NRL) in Washington DC has developed a method to grow epitaxial nitride semiconductors on graphene [Neeraj Nepal et al, Appl. Phys. Express, vol6, p061003, 2013]. The researchers hope that this could lead to high-speed current-switching applications using devices such as hot-electron transistors (HETs).

Existing HETs use heavily doped semiconductor or metal base regions. Heavy doping hampers ballistic transport due to impurity and carrier-carrier scattering effects. Metal base regions suffer from electron reflection effects at the base-collector interface. The NRL team believes that using graphene as the base region, in conjunction with nitride semiconductors, could lead to devices with cut-off frequencies greater than 1THz (1000GHz).

Up to now, the growth of nitride semiconductors on graphene has resulted in non-uniform GaN crystallites and not a continuous film.

The NRL method includes a functionalization step that produces "for the first time" nitride semiconductor layers of a quality similar to that obtained by traditional growth methods on conventional sapphire substrates. In fact, the crystal quality is achieved with thinner layers of less than 1 μ m compared with layers on other substrates.

The researchers comment: "These results support a successful demonstration of electronic-quality, heteroepitaxial wurtzitic GaN on graphene that is currently unavailable and can improve the performance of present state-of-the-art devices such as HETs."

The initial epitaxial graphene (EG) layer was prepared on 4° off-axis 4H-polytype silicon carbide (1.6mm x 1.6mm squares) using silicon sublimation. Silicon nitride was then applied using plasma-enhanced chemical vapor deposition (PECVD). The silicon nitride was patterned into discs of various diameters between 50 μ m and 500 μ m.

The exposed graphene was 'functionalized' by subjecting it to six 30 second pulses of xenon difluoride (XeF₂) plasma. The functionalization consists of creating fluorine-carbon bonds at 6–7% of sites. The bonds are semi-ionic and have been found to preserve the structural and electrical integrity of the graphene, and at the same time to provide nucleation sites for high-quality material deposition.

The nitride semiconductor deposition process must initially ensure that the fluorine atoms are not dislodged, so a low-temperature nucleation is needed. Unfortunately, standard techniques such as molecular beam epitaxy (MBE) and metal-organic chemical vapor deposition (MOCVD) require temperatures of more than 500°C up to around 1300°C.

The NRL nitride deposition began instead with 280°C atomic layer epitaxy (ALE) of 11nm of aluminium

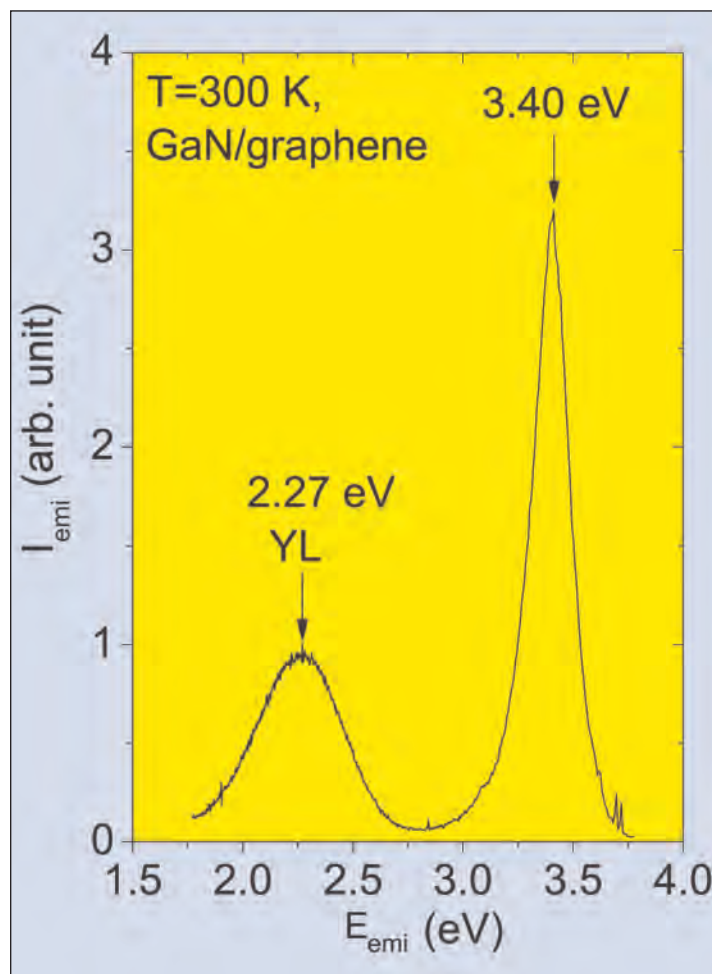


Figure 2. Room-temperature photoluminescence spectra of NRL's GaN on AlN/graphene/SiC stack. Near-band-edge emission is at 3.40eV, broad yellow line at 2.27eV.

nitride (AlN) as a nucleation layer. The lattice mismatch between graphene and AlN is 4.5%, compared with the 13% difference between AlN and sapphire.

The ALE was performed using a 'Fiji' reactor from Cambridge NanoTech. The first five pulses of precursor were of pure trimethyl-aluminium (TMA), designed to promote reaction with the fluorine atoms.

The researchers suggest that the reaction of TMA molecules with the surface fluorine atoms results in a substitution of aluminium for fluorine and the creation of reaction sites for subsequent AlN growth.

Further growth consisted of TMA and nitrogen gas pulses in argon carrier. Unreacted chemicals were purged between pulses with argon. The 11nm AlN layer was grown using 150 cycles. The thickness was determined from an AlN layer grown in the same chamber on a (111) silicon 'witness' substrate. Further growth of 800nm gallium nitride (GaN) semiconductor was performed using MOCVD in a CVD Inc. system.

The material structure (Figure 1) was subjected to a large range of measurements and characterizations during processing. Raman spectroscopy was used to confirm that the growth preserved the graphene underlayer. ➤

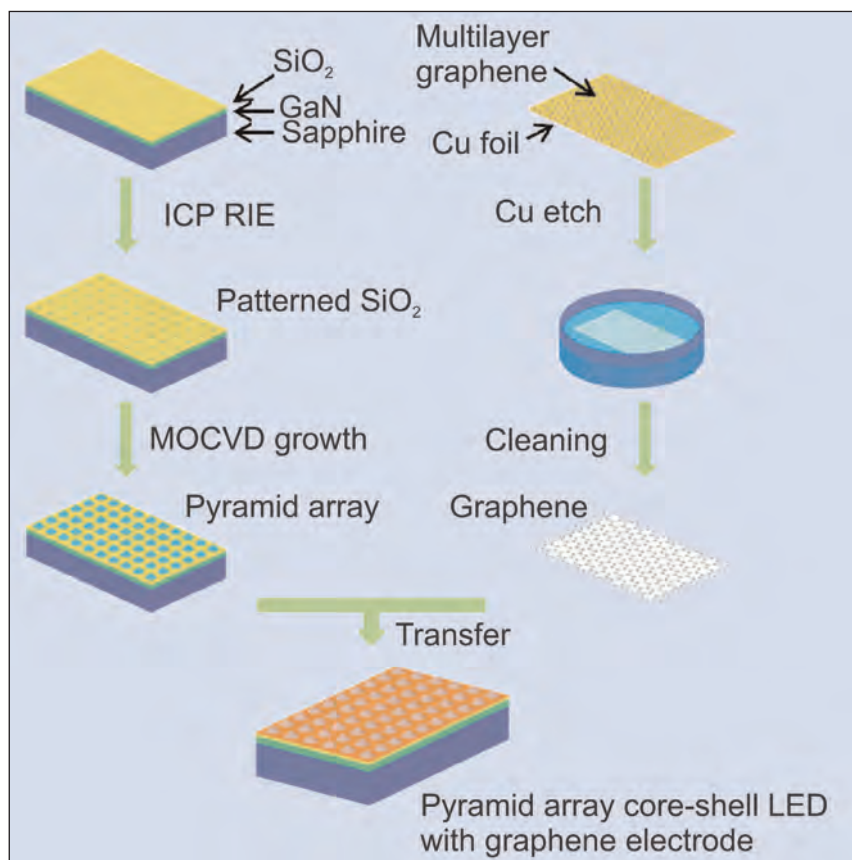


Figure 3. Schematic of key fabrication steps for IOS/Tsinghua pyramid array core-shell LED with graphene electrodes.

► X-ray diffraction studies showed the GaN to have a wurtzite structure, with rocking curve full width at half maximum (FWHM) values of 544 and 461 arcsec for the (0002) and (0004) peaks, respectively. These are similar to those obtained with 5µm GaN on sapphire with a 16% lattice mismatch. “The similarity of these FWHMs for an order of magnitude thinner GaN film may indicate that a better crystalline quality material on EG can be achieved,” the researchers comment.

Photoluminescence (PL) spectra show a 3.40eV band edge and a broad yellow line at 2.27eV (Figure 2). The band edge emission could be either due to exciton (electron–hole bound pair) or direct interband recombination. The researchers believe that the yellow line is due to a Ga-vacancy/oxygen complex point defect.

The researchers conclude: “The heteroepitaxial growth of GaN on ALE AlN/EG resulted in a less strained, high-crystalline-quality GaN material under optimized growth conditions. Hence, the optimum properties of both GaN and graphene can be utilized for device applications such as HETs.”

Pyramid-array LEDs

Moving on to TCL applications, Chinese Academy of Sciences’ Institute of Semiconductors (IOS) and Tsinghua University claim “the first proof-of-concept experimental demonstration of the current-driven pyramid array InGaN/GaN core–shell LEDs intercon-

nected with graphene electrodes”. [Junjie Kang, et al, Appl. Phys. Express, vol6, p072102, 2013].

Pyramid array InGaN/GaN core–shell LEDs have been proposed as a way to reduce quantum-confined Stark effects (QCSE) and efficiency droop. Both QCSE and efficiency droop are affected by the presence of electric fields arising from the polar nature of the III-nitride bond. The polar bond gives rise to strain-dependent (piezoelectric) and spontaneous polarization fields.

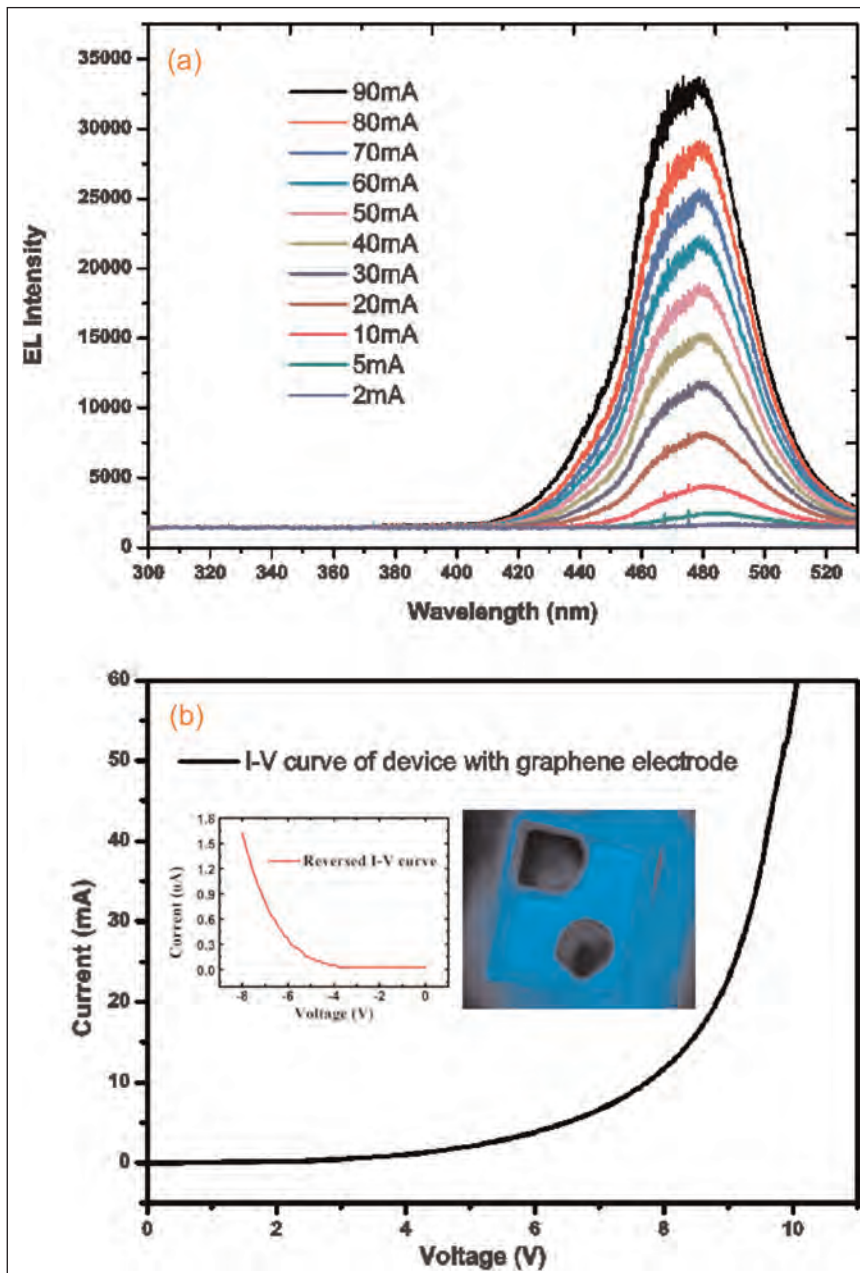
By combining the pyramid LEDs with graphene transparent conductive electrodes (TCEs) for current spreading and injection, the researchers hoped to demonstrate the use of the latter for non-planar or 3D optoelectronic and photovoltaic devices. The graphene and nitride semiconductor structures were initially processed in two separate branches (Figure 3).

The nitride epitaxy began with MOCVD of silicon-doped n-GaN on c-axis sapphire. This n-GaN template was then prepared for further growth with silicon dioxide used as a photolithographic mask for the growth of the pyramid structures. The mask was prepared with 1µm holes spaced by 1µm.

The light-emitting structures consisted of GaN pyramids grown by MOCVD for 10 minutes, multiple quantum wells (MQWs) of three-pairs of InGaN/GaN on the (11̄01) semi-polar facets of the pyramids, and a 200nm layer of p-GaN. The final pyramid structures were 1.5µm diameter and 1.5µm high. The pyramids had six (11̄01) facets. It has been found that such structures filter out dislocations that can thread up from the template. By growing the MQWs on the semi-polar facets, the polarization field effects leading to QCSE are reduced.

Multilayer graphene was prepared on copper foil by chemical vapor deposition using methane precursor. The graphene was spin-coated with poly(methyl methacrylate) (PMMA) and the copper removed by an iron chloride (FeCl₃) solution wet etch. The graphene was then transferred to the nitride semiconductor structure and the PMMA removed in acetone. The graphene transfer process was carried out three times to improve the coverage of the pyramids. Separate measurements on graphene on glass indicated that the transmittance of such multi-layer graphene was around 95% in the visible range.

The LEDs were fabricated using a mesa etch, and application of chromium-platinum-gold contacts. The LED chips measured 177µm x 228µm. In the process graphene was removed selectively using photolithography and oxidation.



The electroluminescence of the devices peaked around 478nm "with no noticeable spectral shift as the injection current is increased from 2 to 90mA" (Figure 4). This is in contrast to conventional LEDs built from polar c-plane (0001) nitride semiconductors, where QCSEs cause a shift in the peak wavelength.

The width of the emission lines is quite broad, attributed to fluctuation in the indium composition of the MQWs. The current versus voltage behavior shows a reverse current of 1.6 μ A at -8V. The researchers believe that this indicates that such devices would demonstrate good reliability.

TCL foam

Researchers in Korea have used three-dimensional (3D) graphene foam as transparent conductor for the p-GaN contact of blue LEDs [Byung-Jae Kim et al, Appl. Phys. Lett., vol102, p161902, 2013]. The team consisted of engineers from Korea University, Sunchon National University, and Hongik University.

The effect of using graphene foam was to reduce the forward voltage by 26% and to increase light output by 14%. Both factors

Figure 4. (a) Room-temperature electroluminescence spectra of IOS/Tsinghua pyramid array core-shell LEDs at various current injections. (b) Current versus voltage (I-V) curve of LEDs with multilayer graphene electrode. Inset: photograph of light emission from single LED chip and reversed bias current-voltage curve.

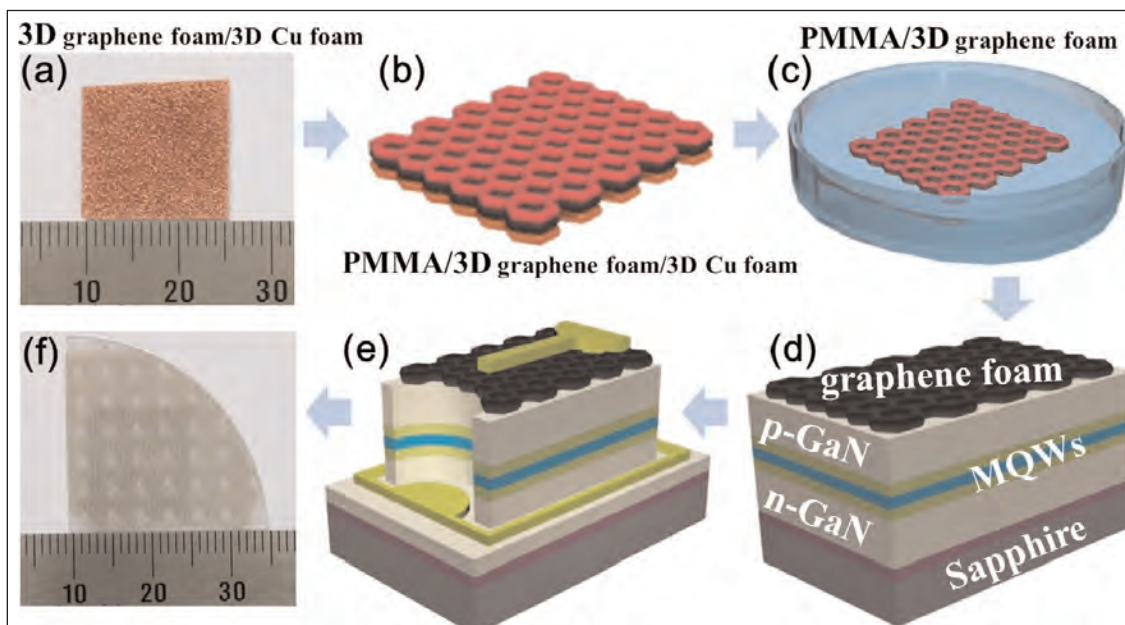


Figure 5. Korea University et al's fabrication of blue LEDs with 3D graphene foam-based TCEs: (a) 3D graphene foam grown on 3D Cu foam; (b) spin-coating with PMMA; (c) wet etch of copper; (d) transfer of 3D graphene foam to p-GaN layer of blue LED material and removal of PMMA; (e) and (f) blue LED devices fabricated with standard processes.

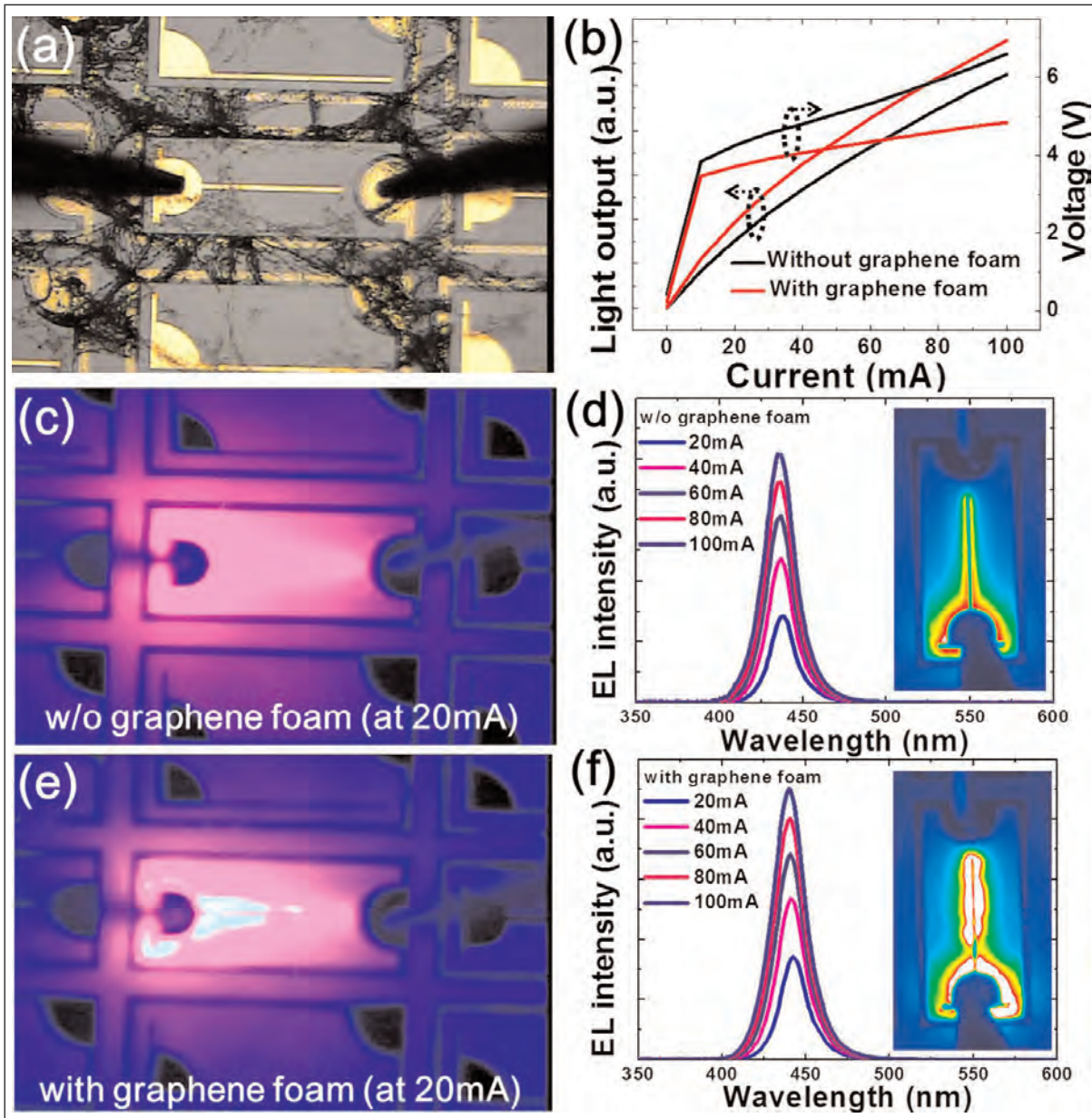


Figure 6. (a) Korea University et al's optical microscope image of blue LED devices with graphene foam TCE. (b) Light output and current versus voltage (L-I-V) characteristics of blue LEDs with/without graphene foam. (c) Electroluminescence (EL) image of blue LED device without graphene foam at 20mA. (d) EL spectra of blue LED without graphene foam in 20–100mA range. (e) EL image of blue LED with graphene foam at 20mA. (f) EL spectra of blue LED with graphene foam in 20–100mA range. Insets of (d) and (f) are optical light emission images from beam profiler without/with graphene foam.

suggest improved power efficiency. Before this research, graphene foam had not previously been applied to light-emitting or -absorbing devices (e.g. solar cells).

Commercial 3D graphene foam was used, produced on 3D copper foam using chemical vapor deposition. The material was spin-coated with PMMA and the copper etched away in ammonium sulfate ((NH₄)₂S₂O₈) solution (Figure 5). The graphene foam was cut into a square and transferred to the p-GaN layer of a commercial blue LED nitride semiconductor epitaxial material on sapphire substrate. The assembly of graphene

foam on nitride semiconductor structure was fabricated into LED devices with plasma-etched mesas, titanium/aluminium/nickel/gold contacts with the n-GaN layer, and titanium/gold n- and p-contact pads.

Graphene foam suffers from reduced transmittance compared with bilayer graphene. At 438nm wavelength, the transmittance of foam is 71%, while that of a bilayer is 95%. However, the foam is closer to 150nm ITO's 75% transmittance at the same wavelength. The researchers point out that foam does have advantages over bilayer graphene such as low mass density, large surface area, high thermal and electrical conductivity, and good mechanical stability. The foam has a sheet resistance of

~800Ω/square, compared with 1500–3000Ω/square for 2D graphene films.

The LED chips measured 200μm x 500μm. At 100mA current injection, the forward voltage was 4.85V while without the foam the value was increased to 6.61V (Figure 6). Also, light output increased 14% at 100mA from the better current-spreading capability of the foam.

The researchers comment that the fabrication process of graphene foam needs to be optimized. For example, the foam structure partially collapsed during the photolithography processing that involves spin-coating

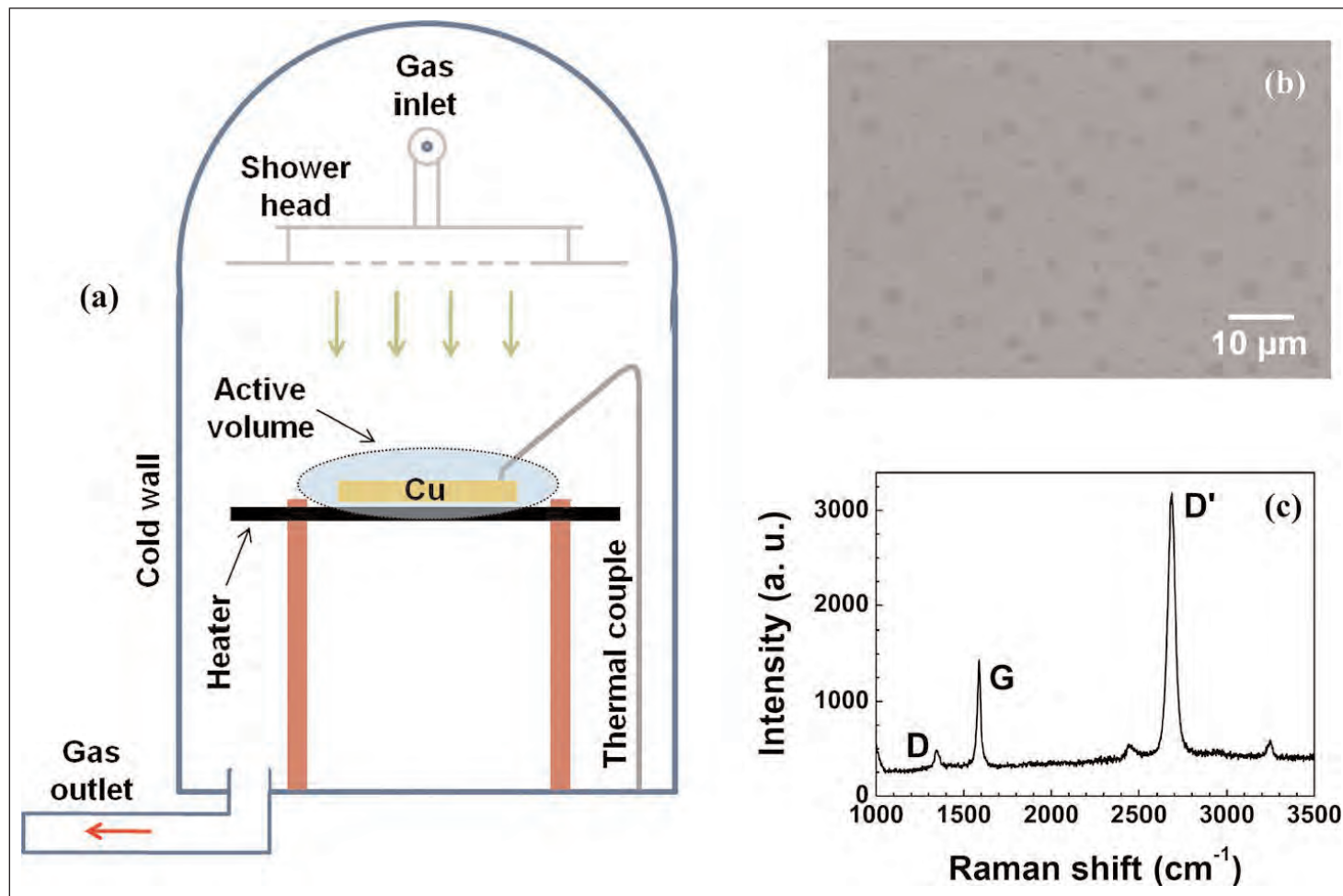


Figure 7. (a) Schematic of cold-wall CVD used by Beijing/Chalmers. Gases are injected from shower head over sample on heater. Active hot volume is very small compared with hot wall systems. (b) SEM image of high density graphene nucleation during early stage deposition on liquid Cu, captured after cooling to room temperature. (c) Typical Raman spectrum of graphene. D' peak is more than twice G peak. Small D peak indicates high quality of film.

of the photoresist, development, plasma etch, and lift-off steps. Some photolithography residue was seen in electron and optical micrograph images as structures with a spider-web appearance. Raman spectroscopy confirmed that the web-like material was not graphene.

Fast-growth graphene

Researchers based in China and Sweden have proposed fast graphene CVD as a route to more cost-effective TCLs for nitride LEDs [Xu Kun et al, Appl. Phys. Lett., vol102, p162102, 2013]. The research involved China's Key Laboratory of Optoelectronics Technology (Beijing University of Technology) and Sweden's Chalmers Tekniska Högskola AB.

While the fabrication of high-quality single-crystal graphene can take many hours, the proposed polycrystalline graphene is grown in half an hour. Despite its polycrystalline nature, the resulting graphene is found to have conductivity similar to that of normal graphene prepared by more laborious methods.

The fast graphene was grown on polycrystalline

copper foil in a cold-wall Aixtron CVD system (Figure 7). The substrate was first cleaned, then heated to 1000°C at 300°C/min and annealed for 5 minutes. The graphene source was methane (CH₄) in hydrogen/argon. The growth step was only 5 minutes. The sample was quench-cooled by shutting off the heater. The researchers see the fast growth rate as being related to the small active region with a high concentration of reactants near the deposition site enabled by the use of a cold-wall system.

The epitaxial structure for the LED (Figure 8) was a commercial product grown on c-plane sapphire. The material was fabricated into mesa-structure LEDs with different TCL structures. ITO layers were produced using electron-beam evaporation. The graphene was transferred to the ITO surface by spin coating a PMMA mechanical support layer and etching away the copper foil in ferric chloride (FeCl₃) solution.

The mesa structures were defined by photolithography and plasma etching of graphene, ITO and nitride semiconductor. The metal electrodes consisted of titanium/gold.

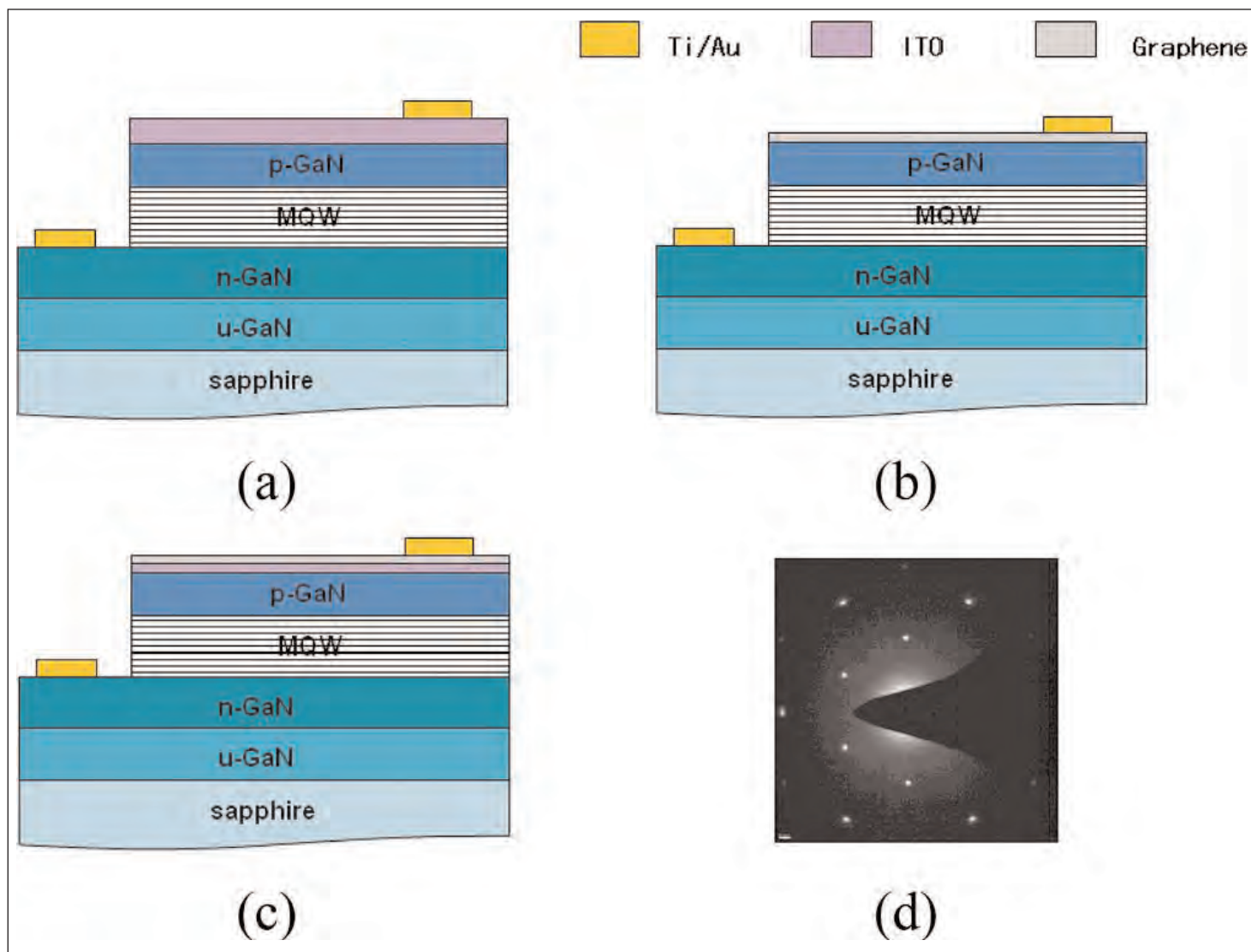


Figure 8. Beijing/Chalmers LED structures with various TCLs: (a) type I (240nm ITO), (b) type II (3-layer graphene), and (c) types III, IV, and V (3, 7, and 10 nm ITO+3-layer graphene). MQW denotes multiple quantum wells. (d) Typical selected area electron diffraction pattern of graphene. Six-fold symmetric dots with equal intensity strength indicate high quality monolayer graphene.

► Monolayer graphene as-deposited had a sheet resistance range of 800–1000Ω/square. Increasing the number of layers to three reduced the range to 300–350Ω/square. The mobility was around 2000cm²/V-s. The sheet resistance values are similar to those achieved for standard graphene.

Optical inspection of the light emission at 20mA showed that the devices with graphene emit more uniformly across the device, indicating successful current spreading. By contrast, a 10nm ITO-only TCL LED emitted more brightly closer to the p-electrode.

The work-function mismatch between graphene and p-GaN resulted in a high 6.76V forward voltage needed to drive 20mA current through a 3-layer graphene device. By inserting a thin 7nm ITO layer the forward voltage was reduced to 3.90V. An LED with 240nm ITO layer had a forward voltage at 20mA of 3.6V.

An alternative technique to bring the graphene work-function closer to that of p-GaN is doping. However,

the known techniques for this are not stable over time. Another way forward may be to grow carbon films directly on p-GaN. Adhesion of graphene is generally better to GaN than GaAs, due to a closer lattice affinity. Researchers at Chalmers recently reported a technique for direct growth on p-GaN that resulted in a carbon film with “optical transparencies comparable to that of exfoliated graphene” [Jie Sun et al, IEEE Transactions on Semiconductor Manufacturing, vol25, p494, 2012].

In terms of optical transmission, although the 10nm ITO+3-layer graphene and 240nm ITO TCLs perform comparably at long wavelengths, at ultraviolet wavelengths of 320nm the former transmits 78.6% and the latter 58.9%. ■

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

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Self-terminating recess etch produces nitride transistor with +3V threshold

An AlGaN normally-off MOSFET device has been fabricated with maximum drain current of more than 200mA/mm.

Peking and Xidian universities have jointly developed a self-terminating gate recess etch that allows them to produce aluminium gallium nitride (AlGaN) normally-off metal-oxide-semiconductor field-effect transistors (MOSFETs) with positive thresholds of up to +3.2V [Zhe Xu et al, IEEE Electron Device Letters, vol34, p855, 2013]. The maximum drain current of the device was more than 200mA/mm.

Nitride semiconductor transistors are of interest in high-frequency and high-power applications such as power switching, due to the high critical electrical field for breakdown. However, the devices tend to be normally-on, which leads to more complex circuits and increases power consumption. Also, in power applications one prefers the fail-safe operation of normally-off devices. One technique that pushes threshold voltages in a positive direction is gate recessing.

The Peking/Xidian devices used a GaN/Al_{0.3}Ga_{0.7}N/AlN/GaN (1nm/21nm/1nm/1.5µm) epiwafer produced on sapphire with metal-organic chemical vapor deposition (MOCVD). The wafer was found to have an electron sheet density of $8 \times 10^{12}/\text{cm}^2$ with mobility 1300cm²/V-s.

Device isolation was achieved using an inductively coupled plasma (ICP) mesa etch. The ohmic source-drain contacts consisted of titanium/aluminium/nickel/gold, rapid thermal annealed at 880°C for 30 seconds.

The gate recess process was enabled by a silicon dioxide mask, applied using plasma-enhanced chemical vapor deposition (PECVD). The gate region was defined by optical lithography and the mask was opened with another plasma-etch process. This open region was subjected to thermal oxidation at 615°C for 40 minutes, followed by etching with a potassium hydroxide solution at 70°C for 45 minutes.

The gate stack consisted of a 29nm atomic-layer deposited and annealed aluminium oxide (Al₂O₃) insulator, and a 3.5µm-long nickel/gold electrode. The gate width was 80µm. The source-drain, gate-source and gate-drain distances were 7.5µm, 1.5µm and 2.5µm,

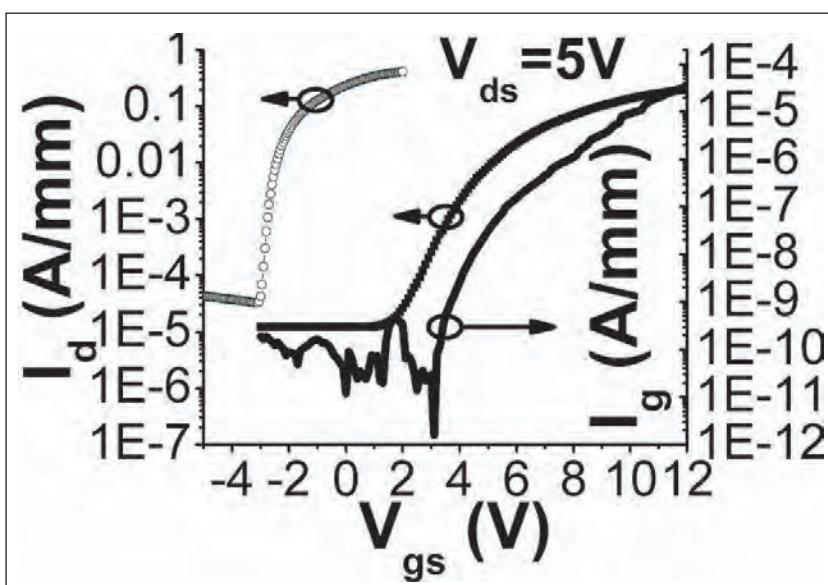


Figure 1. Log-scale transfer curve and gate leakage of fabricated device (solid lines) compared with log-scale transfer curve of conventional HEMT (dashed line).

respectively.

Atomic force microscopy of the etched gate recess showed a root-mean-square roughness of 0.3nm, similar to that of the original AlGaN surface. The depth of the recess was 22.5nm, close to that of the AlGaN barrier 21nm + GaN cap (1nm) and AlN interlayer (1nm). The researchers say that these results, and others with variations in process conditions, "show that the recess etching process could be self-terminated at the AlGaN/GaN interface".

The threshold voltage of the device was +3.2V, a high enough value to reliably operate despite switching noise. The maximum drain current density was 202mA/mm and the peak transconductance was 33mS/mm (Figure 1). The off-state drain current leakage was 10µA/mm. The gate leakage at 12V gate potential was 0.03mA/mm.

The maximum field-effect mobility was 75cm²/V-s, comparable with that of previously reported normally-off GaN-based MOSFETs, according to the team (Figure 2). The off-state (0V gate) breakdown (1mA/mm)

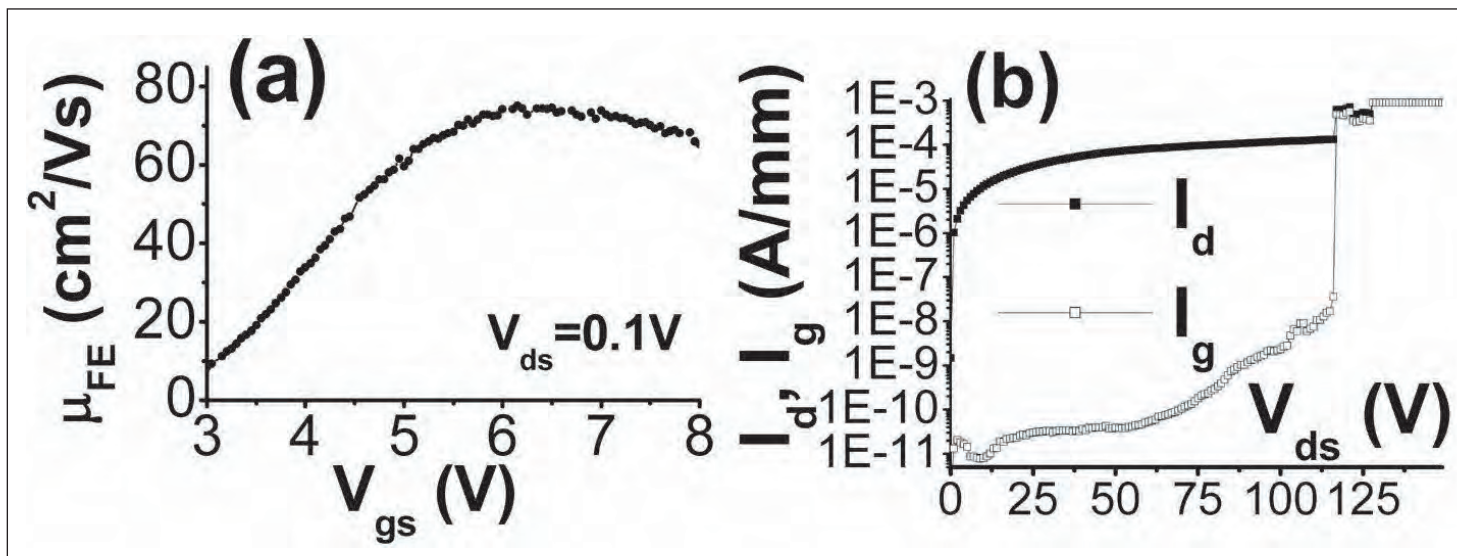


Figure 2. (a) Field-effect mobility and (b) breakdown voltage.

occurred at 125V drain bias in a device with 3.5 μm gate-drain distance. The researchers say that this is 60% higher than the value obtained for conventional HEMTs with a negative threshold voltage of -3V (75V for -5V gate off-state). The limiting factor for the

breakdown voltage was the gate dielectric, leading to increased leakage. ■

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Author: Mike Cooke

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First 40GHz results for quaternary nitride semiconductor HEMTs

Epitaxial material has demonstrated the highest ever mobility for indium-containing GaN-based high-electron-mobility transistors.

Researchers based in France and Germany report the first power characterization of 'quaternary' indium aluminium gallium nitride (InAlGaIn) high-electron-mobility transistors (HEMTs) at 40GHz [F. Lecourt et al, IEEE Electron Device Letters, published online 19 June 2013]. The participating bodies were Lille University's Institut d'Electronique, Microélectronique et Nanotechnologie (IEMN), RWTH Aachen University, and Aixtron SE.

It is hoped that quaternary devices, which can be grown with lattice-matched layers, will lead to reduced defect densities and thus improved reliability.

The epitaxial material was grown on c-plane sapphire using an Aixtron 3x3-inch CCS metal-organic chemical

vapor deposition (MOCVD) reactor. The layer structure consisted of a 500nm AlN nucleation layer, 400nm of $\text{Al}_{0.24}\text{Ga}_{0.76}\text{N}$, a $3.5\mu\text{m}$ GaN buffer layer, a 1nm AlN mobility enhancer, and a 8.3nm $\text{In}_{0.11}\text{Al}_{0.72}\text{Ga}_{0.17}\text{N}$ barrier layer.

Hall measurements on this material gave a carrier concentration of $1.2 \times 10^{13}/\text{cm}^2$ and mobility of $2200\text{cm}^2/\text{V}\cdot\text{s}$, resulting in 240Ω sheet resistance. The researchers claim the very high mobility as "the highest value ever reported on In-containing GaN-based HEMTs".

The transistors were produced with rapid thermal annealed titanium/aluminium/nickel/gold ohmic source-drain contacts and nickel/gold T-gates. Devices

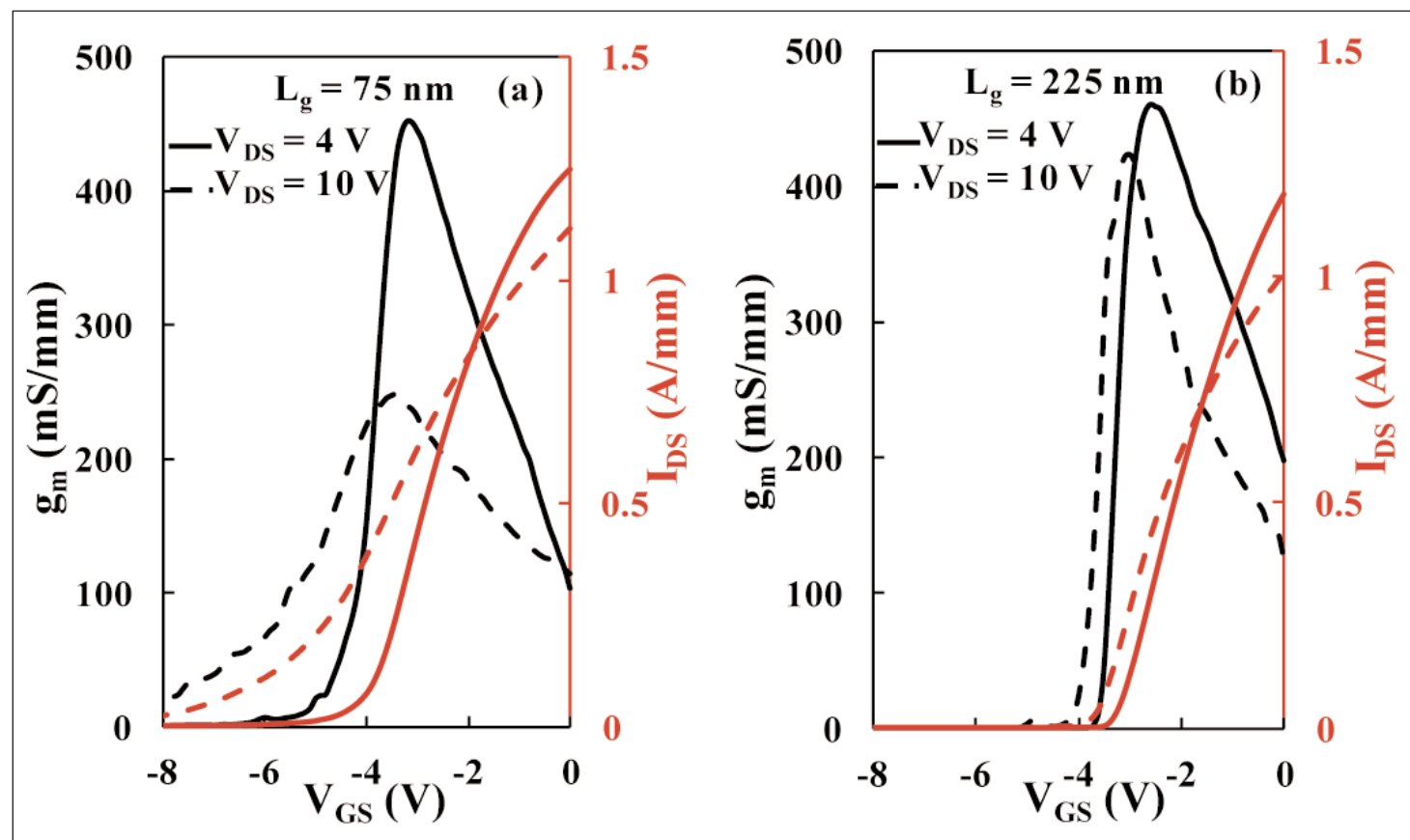


Figure 1. Transfer characteristics at 4V (solid line) and 10V (dotted line) drain biases for devices with 75nm (a) and 225nm (b) gate length.

with gate lengths of 75nm and 225nm were fabricated. The transistors were passivated with silicon nitride, applied using plasma-enhanced chemical vapor deposition (PECVD).

The maximum channel current density (Figure 1) for both gate lengths at a 4V drain voltage was 1.4A/mm at 2V gate (1.25A/mm at 0V). The channel current is reduced with the higher drain bias of 10V — it is thought that this is due to thermal effects. The peak extrinsic transconductance was 450mS/mm at 4V drain bias, but only 250mS/mm at 10V, for the shorter gate length of 75nm. The 225nm-gate HEMT has a transconductance greater than 400mS/mm at 10V.

The pinch-off gate potential of the long-gate device was -4V at both drain bias values. However, the short-gate HEMT had a pinch-off of -4.5V for 4V drain and -9V for 10V drain. "These degradations can be attributed to short-channel effects due to a lower aspect ratio between the gate length and the barrier layer thickness," the researchers comment.

The gate leakage of the devices was around 100 μ A/mm up to 10V drain bias.

Frequency performance measurements gave a cut-off (f_T) of 113GHz and power-gain cut-off (f_{max}) of 200GHz for a 75nm-gate-length device with 2x50 μ m width at the peak transconductance point for 4V drain bias. "To our knowledge, these results represent the highest performance for AlInGaN HEMT technology with T-shaped gate transistors," the researchers remark, comparing with a 220GHz/60GHz f_T/f_{max} 66nm-gate-length device reported by University of Notre Dame (USA) in 2011.

Under the same bias conditions the larger-gate IEMN device managed an f_T of 60GHz and f_{max} of 120GHz. The f_T value degraded at 10V drain, moving down from 113GHz to 76GHz for the short-gate HEMT and from 60GHz to 55GHz for the long-gate device.

The researchers traced the cause of these performance degradation effects as being due to increased drain delay in the short-gate devices. "This is physically related to the increase of the output conductance g_d for higher drain biases due to the presence of short-channel effects," they write.

Current collapse was investigated with pulsed measurements. The current drop for long-gate devices was 12% for gate lag and 27% for drain lag conditions.

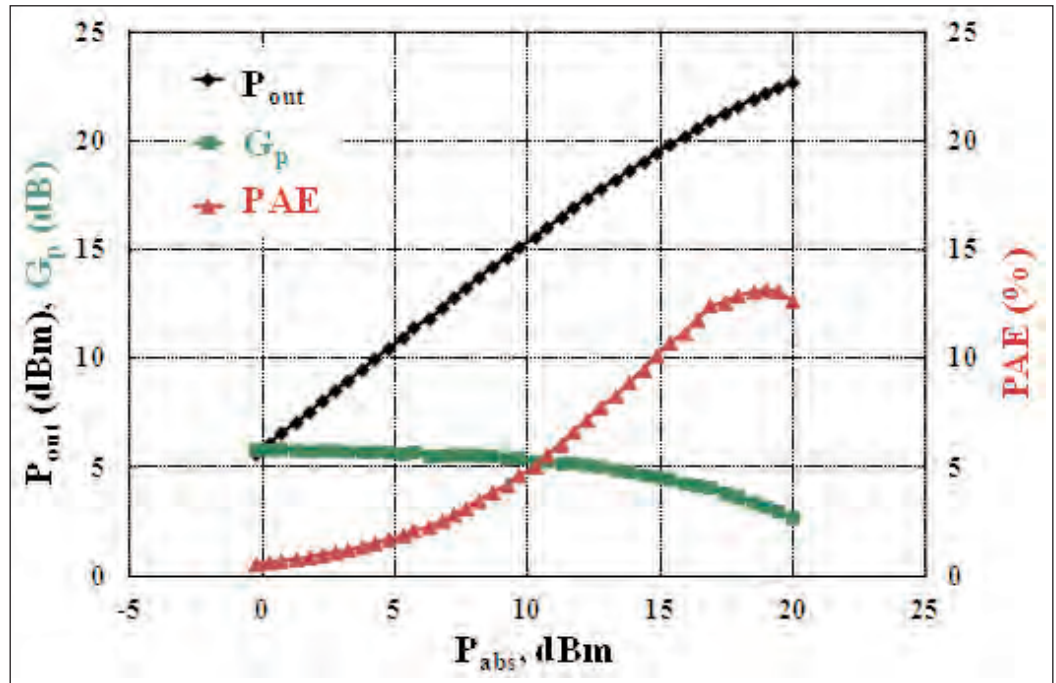


Figure 2. Microwave power characteristics at 40GHz for 2x50 μ m AlInGaN/GaN HEMT on sapphire substrate with 225nm gate length.

The respective results for the short-gate HEMT were 15% and 39%. The worse collapse here was attributed to the higher peak electric field for the shorter gate, increasing charge trapping.

The output power density for the long-gate HEMT at 40GHz was 2W/mm with 13% power-added efficiency (PAE) and 6dB linear power gain (Figure 2). A previous effort with InAlGaN-barrier HEMTs by the Fraunhofer Institute in Germany reported 10GHz power density results of 5.6W/mm (PAE 31%) with a quaternary device in 2010.

Ternary AlGaIn/GaN devices on silicon at 40GHz achieving an output power density of 3.3W/mm (20.1% PAE) were reported earlier this year by an IEMN-led team. According to the French/German paper, the record power density of 10.5W/mm (34% PAE) at 40GHz is held by a 2005 report of an AlGaIn device on expensive silicon carbide from University of California Santa Barbara.

The shorter-gate device managed a 1.25W/mm density "due to the combination of high current drop under drain lag condition and short-channel effects". The performance could be improved using a better thermal conductor as a substrate, such as silicon or silicon carbide, the researchers believe.

The researchers add: "The addition of a back barrier or an AlGaIn buffer could also lead to better performances through a better electron confinement. Additionally, further investigations should be focused on surface state passivation to reduce parasitic lag effects." ■

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Author: Mike Cooke

Straining barriers towards low-noise high-breakdown pHEMTs

New design gives 99% less gate leakage and 73% higher breakdown.

The UK's University of Manchester has used band engineering on indium phosphide (InP) to create indium gallium arsenide (InGaAs) pseudomorphic high-electron-mobility transistors (pHEMTs) with reduced gate current leakage and high breakdown voltage [F Packer, et al, J. Phys. D: Appl. Phys., vol46, p264002, 2013].

"The outstanding achievements of the new design approach are 99% less gate current leakage and a 73% increase in breakdown voltage, compared with the conventional design," the researchers write. They hope that their work will lead to "implementation of outstanding low-noise devices".

The researchers produced two epitaxial pHEMT structures (Figure 1) — one 'conventional' (XMBE171) and the other 'advanced' (XMBE210). The structures were

grown using molecular beam epitaxy (MBE) on a Riber V100 machine.

The conventional structure consists of lattice-matched layers to the InP substrate, excluding the channel.

In the advanced structure, the top barrier and spacer layers are strained in addition to the channel. Also, the advanced structure has two silicon delta-doped regions above and below the channel in place of the one region for the conventional setup.

Strain in the pseudomorphic indium gallium arsenide ($\text{In}_{0.7}\text{Ga}_{0.3}\text{As}$) channel is highly compressive compared with the lattice matched $\text{In}_{0.53}\text{Ga}_{0.47}\text{As}$. The advanced indium aluminium arsenide ($\text{In}_{0.3}\text{Al}_{0.7}\text{As}$) spacer and barrier layers are tensile strained compared with the lattice-matched $\text{In}_{0.52}\text{Al}_{0.48}\text{As}$.

Cap (50Å): Lattice matched	$\text{In}_{0.53}\text{Ga}_{0.47}\text{As}$	Cap (50Å): Lattice matched	$\text{In}_{0.53}\text{Ga}_{0.47}\text{As}$
Barrier (300Å): Lattice matched δ	$\text{In}_{0.52}\text{Al}_{0.48}\text{As}$	Barrier ₂ (190Å): Wide bandgap δ_2	$\text{In}_{0.3}\text{Al}_{0.7}\text{As}$
Spacer (50Å): Lattice matched	$\text{In}_{0.52}\text{Al}_{0.48}\text{As}$	Spacer ₂ (130Å): Wide bandgap	$\text{In}_{0.3}\text{Al}_{0.7}\text{As}$
Channel (140Å): Narrow bandgap	$\text{In}_{0.7}\text{Ga}_{0.3}\text{As}$	Channel (160Å): Narrow bandgap	$\text{In}_{0.7}\text{Ga}_{0.3}\text{As}$
Buffer (4500Å): Lattice matched	$\text{In}_{0.52}\text{Al}_{0.48}\text{As}$	Spacer ₁ (100Å): Lattice matched δ_1	$\text{In}_{0.52}\text{Al}_{0.48}\text{As}$
Substrate	InP (Fe)	Barrier ₁ (100Å): Lattice matched	$\text{In}_{0.52}\text{Al}_{0.48}\text{As}$
		Buffer (4500Å): Lattice matched	$\text{In}_{0.52}\text{Al}_{0.48}\text{As}$
		Substrate	InP (Fe)

Figure 1. Epitaxial designs for XMBE171 conventional (left) and XMBE210 advanced pHEMTs.

Transistor fabrication was performed simultaneously on the two samples to avoid inconsistent devices from being compared in testing. Mesa isolation was achieved with a wet etch down to the InAlAs buffer. The main etch was with a non-selective orthophosphoric acid ($\text{H}_3\text{PO}_4\text{:H}_2\text{O:H}_2\text{O}_2$) solution, followed by a sidewall etch with succinic acid solution to provide better isolation between the gate metal and channel during metallization.

The ohmic source-drain contacts consisted of evaporated gold-germanium and gold, alloyed at 280°C . The gate recess was achieved using a succinic acid solution selective etch through the cap layer. The gate consisted of evaporated titanium and gold. Bond pads were also evaporated, finishing the devices for probe testing.

Hall measurements gave $3.16 \times 10^{12}/\text{cm}^2$ carrier concentration and $10,653 \text{cm}^2/\text{V}\cdot\text{s}$ mobility for the conventional pHEMT structure. The respective figures for the advanced structure were $2.70 \times 10^{12}/\text{cm}^2$ and $11,008 \text{cm}^2/\text{V}\cdot\text{s}$. The reduced carrier concentration for the advanced structure is attributed to the thicker spacer (130\AA) compared with the conventional pHEMT (50\AA).

The effect of having a wider-bandgap InAlAs barrier layer in the advanced structure was expected to result in a larger Schottky barrier with the gate metal, reducing gate leakage. Such leakage occurs through thermionic tunneling in the off-state and through barrier crossing and impact ionization in the on-state. These effects are reduced by the higher Schottky barrier and thicker spacer in the advanced structure.

The double delta-doping is designed to improve confinement of the two-dimensional electron gas (2DEG) in the InGaAs quantum well. This, combined with the wide-bandgap InAlAs, should increase the Schottky breakdown voltage.

The reduced leakage current enabled the researchers to make advanced transistors with a gate width of $800\mu\text{m}$ ($4 \times 200\mu\text{m}$). The conventional devices were constrained to widths of $200\mu\text{m}$. The gate length was $1\mu\text{m}$.

The lower carrier density in the 2DEG of the advanced pHEMT was reflected in the maximum drain current density ($230 \text{mA}/\text{mm}$) and peak extrinsic transconductance ($300 \text{mS}/\text{mm}$) being less than those of the conventional device ($370 \text{mA}/\text{mm}$ and $470 \text{mS}/\text{mm}$, respectively).

The advantages of the advanced structure begin to be shown by much reduced gate leakage currents: $-9\mu\text{A}/\text{mm}$ in the -8V gate off-state, compared with $-1000\mu\text{A}/\text{mm}$ at -5V for the conventional device. The advanced pHEMT leakage is more than "two orders of magnitude better, and therefore should provide excellent noise performance," the researchers comment.

The off-state breakdown of $1 \text{mA}/\text{mm}$ gate current is extrapolated to occur at -15V in the advanced device. The conventional device, by contrast, breaks the gate current limit in the -2V to -4V range. A high break-

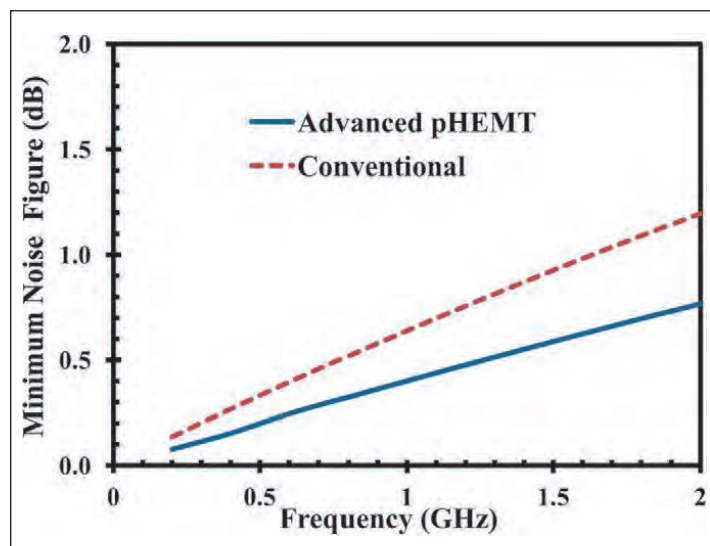


Figure 2. Comparison of minimum noise using Fukui's analysis of conventional XMBE171 and advanced XMBE210 pHEMTs, up to 2GHz.

down voltage is "excellent for designing low-noise amplifier receivers with minimal protection circuitry," the researchers comment.

In the on-state range of -3V gate, the advanced device has a gate leakage of $-0.2\mu\text{A}/\text{mm}$, independent of drain bias up to 1V . The conventional device has a current in the range between $-6 \text{mA}/\text{mm}$ and $-8 \text{mA}/\text{mm}$ at the same gate potential, depending on drain bias. Beyond 1V drain, the gate leakage of the advanced device increases, but remains less than $-16\mu\text{A}/\text{mm}$ range up to 2V bias. The comparable figure in the conventional device is $-3.3 \text{mA}/\text{mm}$.

The researchers see this factor as potentially leading to low-noise and high-power applications.

The frequency performance of the devices was measured between 40MHz and 40GHz . The cut-off frequencies (f_T) of the two devices were found to be the same at 21GHz .

"Therefore, the virtually identical f_T of the advanced device to that of conventional structures demonstrates that the advanced pHEMT epitaxial design, with its high-tensile-strained supply layer, has had no detrimental effect on the device performance," the researchers write.

The advanced device showed 'substantially' improved Fukui minimum noise figure performance (Figure 2). A $1\mu\text{m}$ gate-length pHEMT would have expected low-noise applications for the range 300MHz – 2GHz . The better noise performance is attributed to reduced current leakage. Further boosts come from the larger gate area due to reduced terminal resistance in the advanced pHEMT.

The researchers say that they are working on sub-micron gate lengths, presumably to increase frequency performance. ■

<http://iopscience.iop.org/0022-3727/46/26/264002>

Author: Mike Cooke

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4–6 September 2013

SEMICON Taiwan 2013 and LED Taiwan 2013

TWTC Nangang Exhibition Hall, Taipei, Taiwan

E-mail: ali@semi.org

www.semicontaiwan.org/en

8–12 September 2013

IEEE Photonics Society's annual Photonics Conference (IPC-2013, formerly the IEEE LEOS Annual Meeting)

Hyatt Regency Bellevue Hotel, Seattle, WA, USA

E-mail: m.hendrickx@ieee.org

www.ipc-ieee.org

18–20 September 2013

Intersolar South America 2013

Expo Center Norte, São Paulo, Brazil

E-mail: boesl@solarpromotion.com

www.intersolar.net.br

22–26 September 2013

39th European Conference on Optical Communications (ECOC 2013)

ExCeL London Exhibition Centre, London, UK

E-mail: carina.meakins@nexusmediaevents.com

www.ecoc2013.org

23–24 September 2013

CPV USA 2013 (5th Concentrated Photovoltaic Summit USA)

San Jose, CA, USA

E-mail: matt@pv-insider.com

www.pv-insider.com/cpv

23–26 September 2013

SPIE Remote Sensing 2013, co-located with SPIE Security+Defence 2013

Internationales Congress Centre Dresden, Germany

E-mail: info@spieeurope.org

<http://spie.org/remote-sensing-europe.xml>

<http://spie.org/security-defence-europe.xml>

23–26 September 2013

5th International Conference on One dimensional Nanomaterials (ICON 2013)

Annecy, France

E-mail: icon2013@grenoble.cnrs.fr

www.icon2013.fr

24–26 September 2013

3rd International LED professional Symposium + Expo (LpS 2013)

Bregenz, Austria

E-mail: symposium@led-professional.com

www.led-professional-symposium.com

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29 September– 4 October 2013

International Conference on Silicon Carbide and Related Materials (ICSCRM 2013)

Phoenix Seagaia Resort, Miyazaki, Japan

E-mail: secretary@icscrm2013.org

<http://icscrm2013.org>

30 September – 1 October 2013

Deutscher MBE Workshop 2013

Dresden, Germany

E-mail: dmb2013@namlab.com

[www.namlab.com/pages/](http://www.namlab.com/pages/en_aboutus_1_mbeworkshop.htm)

[en_aboutus_1_mbeworkshop.htm](http://www.namlab.com/pages/en_aboutus_1_mbeworkshop.htm)

30 September – 4 October 2013

28th European Photovoltaic Solar Energy Conference and Exhibition (EU PVSEC 2013)

Parc des Expositions Paris Nord Villepinte, Paris, France

E-mail: press@wip-munich.de

www.photovoltaiac-conference.com

1–3 October 2013

IEEE Photonics Society's Avionics, Fiber-Optics & Photonics Conference (AVFOP 2013)

San Diego, CA, USA

E-mail: m.figueroa@ieee.org

www.avfop-ieee.org

7–10 October 2013

SEMI CON Europa 2013

Dresden, Germany

E-mail: ktorres@semi.org

www.semiconeuropa.org

13–16 October 2013

2013 IEEE Compound Semiconductor IC Symposium

Portola Hotel and Spa, Monterey, CA, USA

E-mail: customer.service@ieee.org

www.csics.org

16–17 October 2013

SEMI Strategic Materials Conference (SMC 2013)

Santa Clara Marriott, CA, USA

E-mail: acobar@semi.org

www.semi.org/smc

27–29 October 2013

1st IEEE Workshop on Wide Bandgap Power Devices and Applications (WiPDA 2013)

Columbus, OH, USA

E-mail: program@wipda2013.org

www.wipda2013.org

27 October – 1 November 2013

224th Electrochemical Society (ECS) Meeting

San Francisco, CA

E-mail: meetings@electrochem.org

www.electrochem.org/meetings/biannual/fut_mtgs.htm

28–29 October 2013

LEDs & the SSL Ecosystem 2013: Phase 2, the Path to Profit

Omni Parker House, Boston, MA, USA

E-mail: bsantos@smithers.com

www.ledsconference.com

28–29 October 2013

SolarTech Expo Japan 2013

Tokyo, Japan

E-mail: ds@greenworldconferences.com

www.greenworldconferences.com

11–14 November 2013

Intersolar India 2013

Bombay Exhibition Centre (BEC), Mumbai, India

E-mail: steffen@intersolar.in

www.intersolar.in

12–14 November 2013

LASER World of Photonics India

Bombay Exhibition Centre (BEC), Mumbai, India

E-mail: bhupinder.singh@mmi-india.in

www.world-of-photonics.net/en/laser-india/start

9–11 December 2013

IEEE International Electron Devices Meeting (IEDM 2013)

Hilton Washington and Towers, Washington DC, USA

E-mail: iedm@his.com

www.ieee.org/conference/iedm

20–22 January 2014

14th Topical Meeting on Silicon Monolithic Integrated Circuits in RF Systems (SiRF 2014)

Newport Beach, CA, USA

www.silicon-rf.org/sirf2014

1–6 February 2014

SPIE Photonics West 2014

Moscone Center San Francisco, CA, USA

E-mail: customerservice@spie.org

<http://spie.org/photonics-west.xml>

1–6 February 2014

OPTO 2014 – Optoelectronic Materials, Devices and Applications (part of Photonics West)

Moscone Center, San Francisco, CA, USA

E-mail: customerservice@spie.org

<http://spie.org/opto.xml>

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