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COMPOUNDS & ADVANCED SILICON

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Developments in normally-off GaN HEMTs

MACOM acquiring Mindspeed • TriQuint opens Korea center
Rubicon launches PSS • Soraa adds New York fab

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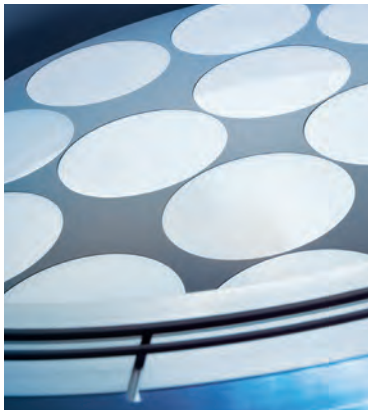

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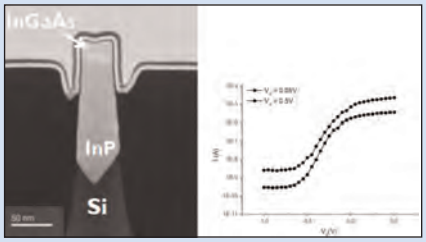
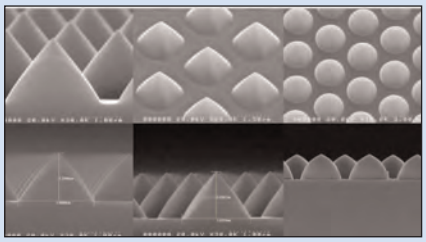


p28 SEM of structure and I–V characteristics of the first III-V FinFETs on 300mm silicon, made by Imec.



p36 SEM of various shapes and patterns on Rubicon's new large-diameter patterned sapphire substrates.

p47 Osram Opto's new Ostar Medical is claimed to be the first LED with a CRI of 95 and the capability of adjusting the temperature of the color white, suiting medical applications.

Cover: MIT spin-off Eta Devices has announced what it reckons is the most efficient power amplifier for mobile base-stations, using gallium nitride switching power amplifiers, advanced supply modulation, and digital pre-distortion algorithms. **p25**

editorial

Technical and manufacturing advances spur nitride adoption

In the feature article on pages 82–87 of this issue, we focus on developments in nitride transistors, specifically how GaN high-electron-mobility transistors (HEMTs) operating in the preferred normally-off mode are now being sampled commercially, for example by Japan's Panasonic and Fujitsu.

After a long period of development and gradual adoption in applications, commercialization of GaN-based electronics now seems to be accelerating. For example, analyst firm ABI Research expects the market for pulsed RF power semiconductors (operating up to 18GHz, e.g. for radar applications) to be driven by gallium nitride and silicon carbide competing with established silicon-based technologies as RF power semiconductor makers seek markets that are more lucrative than currently price-pressured wireless infrastructure markets (see page 6). However, given the economic pressures as well as the increasing number of firms entering these markets and technologies, consolidation is inevitable, ABI reckons.

Indeed, while on page 26 we report on US-based GaN-on-silicon HEMT maker Transphorm's involvement with Taiwanese electronics manufacturer Delta, news broke (too late for inclusion in this issue) that the University of California, Santa Barbara (UCSB) spin-off Transphorm (founded in 2007) had agreed to combine with the GaN power device business of Fujitsu, which will take a minority stake in Transphorm and form a new GaN-focused company (as a subsidiary of Transphorm) to enable high-volume manufacturing of GaN power devices as a core product at Fujitsu's existing Aizu-Wakamatsu plant, where it has already established a 6" GaN-on-Si production line. As well as enabling Transphorm's technology to be transitioned more rapidly to low-cost, high-volume manufacturing and market distribution, the merger also promises to boost Fujitsu's application of GaN power devices in both its own electronics products (RF and power supply modules) as well as those of commercial customers. Details of the merger will be reported in the next issue.

Other developments in wide-bandgap electronics reported this issue include the European Space Agency (ESA) granting funding to Poland's Ammono (which produces bulk GaN using ammonothermal technology) to develop large-size semi-insulating GaN substrates dedicated for space applications (page 27). Meanwhile, UK-based Anvil Semiconductors Ltd has secured £1m in funding to speed development and commercialization of its silicon carbide (SiC)-on-silicon technology for power devices. Also, regarding integration of compound semiconductor devices on silicon, Belgium's Imec has demonstrated what it claims are the first III-V FinFET devices integrated epitaxially on 300mm silicon wafers (see page 22).

Also this issue we report research on improving nitride lasers and LEDs for blue/white and UV light emission (on pages 70–71, 74–75 and 72–73). The latter uses patterned sapphire substrates (PSS), which are now increasingly entering commercialization, in particular on large-diameter, as evidenced by sapphire substrate maker Rubicon Technologies' launch of what it claims is the first commercial line of large-diameter patterned sapphire substrates in 4-inch through 8-inch diameters (see page 36). Such economies of scale promise to aid adoption of solid-state lighting.

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

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

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ALWAYS ONE STEP AHEAD

Pulsed RF power semiconductor device markets to exceed $250m by 2018

GaN driving growth as companies vie for non-cellular markets

Markets for pulsed RF power devices up to 18GHz are expected to show continued solid growth over the next five years — exceeding $250m by 2018 — despite the current economic turmoil and cuts in defense spending, according to the study 'Pulsed RF Power Semiconductors' (part of ABI Research's High-Power RF Active Devices Research Service).

The study forecasts the market through 2018 for devices that have greater than 5 watts of peak output power and operating frequencies up to 18GHz (examining the avionics, sub-1GHz, L-band, S-band, C-band, X-band and Ku-band radar markets). While the volatility of many global electronics markets is fueled by their association with consumer spending, markets for pulsed RF power devices are supported by quite different priorities, notes ABI.

"Many RF power semiconductor manufacturers are on a quest to find markets unrelated to mobile wireless infrastructure," notes ABI Research director Lance Wilson. "Device prices in wireless infrastructure are falling, and the total available market is shrinking."

Some markets that use pulsed RF power devices, such as transportation safety and the military, are seeing good solid growth even in the midst of today's economic downturn, says ABI Research. These devices are used in radars for military, weather and marine applications, and in the current worldwide upgrade of the air traffic control system. There is also a market segment devoted to the avionics transponder and air navigation market, which is also lifted by the air traffic control upgrade.

Intrinsically less 'optional' than many consumer markets, these segments are therefore less sensitive to economic upheavals than consumer-driven markets, although they are not totally immune to the macro-economy.

Understanding this, many semiconductor manufacturers are attempting to enter this market. However, some factors may complicate their efforts, believes ABI. Pulsed RF power device markets are becoming very competitive technologically: gallium nitride (GaN) and silicon carbide (SiC) devices are vying for market share along with the more established silicon-based technologies. There are so many companies rushing into these markets that there will probably not be sufficient market size to support them all, reckons ABI. "Undoubtedly, some consolidation will occur," says Wilson. "While not guaranteed success, those companies that have a track record working with government agencies and defense contractors are going to have an advantage over those that are new entrants," he adds.

www.abiresearch.com

GaAs device market rising at CAGR of 3.1% till 2016

Rising threat from GaN, SiGe, LDMOS and CMOS poses challenge

The gallium arsenide device market is rising at a compound annual growth rate (CAGR) of 3.1% over the period 2012–2016, according to a new report from Technavio.

A key trend contributing to growth is the increasing global adoption of smartphones, which now form the main end-user segment for GaAs devices. In particular, due to the dramatic decline in their prices in recent years. the market has seen increasing adoption of smartphones especially in emerging countries such as China and India. With the increasing adoption of smartphones, demand for GaAs devices is rising.

The market has also been witnessing an increasing number of collaborations between GaAs device makers. The key vendors dominating the market include Avago Technologies, RF Micro Devices, Skyworks Solutions, and TriQuint Semiconductor. Other vendors mentioned in the report include Apple, Advanced Wireless Semiconductor Company, Anadigics, Samsung Electronics, and WIN Semiconductors.

Through strategic alliances, collaborations, mergers and acquisitions, device vendors are expected to expand their business, improve their respective market shares, and gain access to new technologies. These collaborations also aid in offering better solutions and the latest technologies to customers. For example, in 2012 RFMD completed its acquisition of Amalfi Semiconductor Inc and Skyworks acquired Advanced Analogic Technologies Inc. Collaboration between vendors is thus expected to have a positive impact on the growth of the market during the forecast period.

However, a major challenge to the GaAs device market is the increasing availability of alternative devices. In recent years, gallium nitride (GaN), silicon germanium (SiGe), and silicon LDMOS and CMOS devices have emerged as alternatives, posing a threat to GaAs device vendors.

www.technavio.com

LED backlighting to reach 90% penetration in LCD TVs in 2013

LED suppliers focused on lighting predicted to gain market share

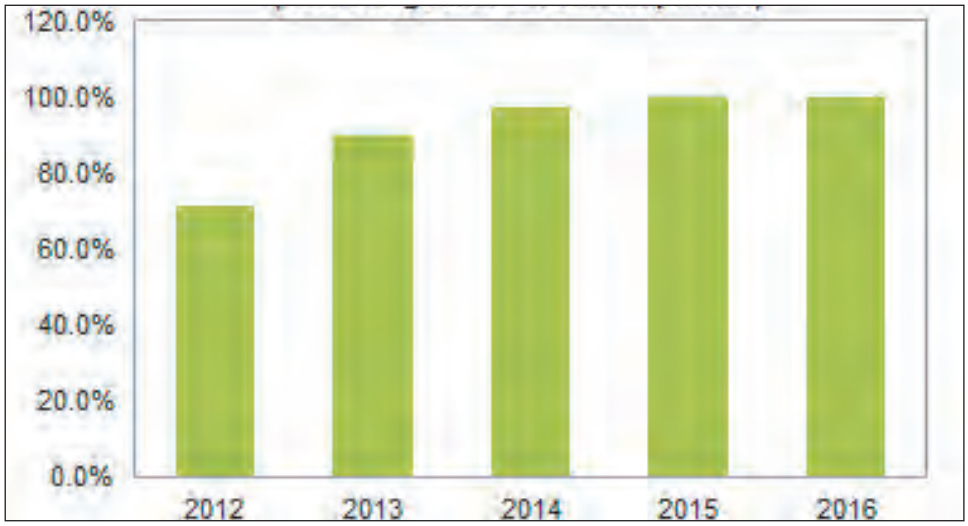
With LED backlighting technology approaching saturation point in the liquid-crystal display (LCD) television panel market this year, suppliers of light-emitting diodes are turning their attention to the new growth opportunity in the fast-expanding lighting segment, according to the report 'Q3 2013 GaN LED Supply and Demand' from IHS Inc.

The proportion of LCD TV panels that use LEDs for backlighting is set to reach 90% in 2013, forecasts the market research firm. Of a total of 231 million LCD TV panels forecast to be shipped, 207 million will use LED backlighting, with the remainder using the older cold-cathode fluorescent lamp technology.

This marks the end of a boom time that started in 2009, when LED penetration of the LCD TV panel market was just 3%, before climbing rapidly to 24% in 2010, 38% in 2011 and 71% in 2012. By 2016, LED penetration will rise to 100% of the LCD TV panel market.

In 2013, Japan's Sharp Corp is the only panel supplier that uses LED backlighting in 100% of its LCD TV panels. South Korea's Samsung and LG are not far behind, with the two firms set to reach more than 95% LED usage in their LCD TV panels by the end of this year.

Because there is little growth opportunity left in the LCD TV backlighting market, LED makers are redirecting their efforts to the lighting business. "LED suppliers that are focused on lighting are predicted to gain market share," says Jamie Fox, principal analyst for LEDs at IHS. "Some of the companies that have a large market share in LED backlighting, such as Seoul Semiconductor and Samsung, have already managed to shift much of their business to lighting and have done very well in this area, winning market share in recent years."



Penetration of LED backlighting technology in the LCD-TV panel market (percentage share of unit shipments).

LED there be light

In lighting applications, the penetration of LED products compared to alternative technologies is currently very low. Only 2.8% of all lamps shipped in 2013 are forecast to use LED technology. This amounts to 520 million LED lamps versus 18.6 billion lamps in total. However, demand for LED lighting is predicted to increase rapidly during the next five years, driving projected packaged LED revenue growth of $2.5bn within the period.

"Because the replacement rates for LED lamps are much longer than those made from competing technologies, annual demand is predicted to slow as the installed base grows for LED lamps," Fox says. "Suppliers to the LED lighting market therefore need to position themselves accordingly in order to capitalize."

Japan has the largest adoption of LED lamps in 2013. Meanwhile, the highest penetration in terms of sector breakdown can be found in retail and hospitality, at about 6% LED. This compares to about 1% for the residential market.

Backlighting moves into the background

Apart from LCD TVs, LEDs are also reaching high penetration in other backlighting applications, even if growth opportunities are slackening.

For example, while notebook, tablet and cellphone backlights are already 100% LED-backlit, desktop PC monitors this year are set to hit 86% LED penetration, similar to LCD TV panels. By the end of 2015, monitors are predicted to join the applications in reaching 100% LED usage.

However, the combined market for LED backlighting in all these applications has already gone into decline — even before 100% penetration has been reached. This is driven by a number of factors. One is the reduction in the number of LEDs needed per panel. Another reason why shipments are slowing is the increasing usage of organic light-emitting diode (OLED) displays, which do not require LED backlighting.

Meanwhile, prices are declining for LEDs, impacting revenue growth in backlighting applications, concludes IHS.

www.imsresearch.com

Chip-level optical interconnect revenue to rise to $520m by 2019 then pass $1bn in 2021

PIC-based interconnects to reach $120m in 2019 then $275m by 2021

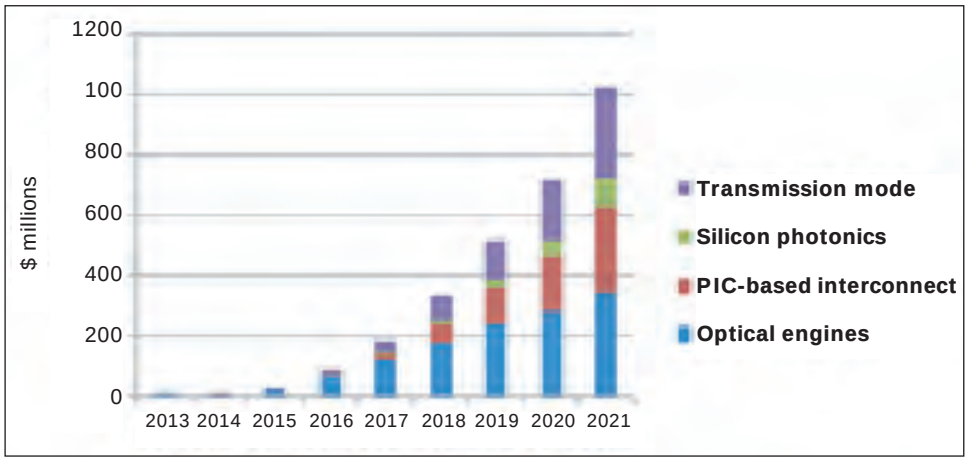
The addressable market for chip-level optical interconnects could eventually run into billions of units, as revenues rise to almost $520m by 2019 then $1.02bn by 2021, according to the report 'Revenue Opportunities for Optical Interconnects: Market and Technology Forecast — 2013 to 2020 Volume II: On-Chip and Chip-to-Chip' from industry analyst CIR, which continues the firm's coverage of this market dating back to 2009.

This follows a related report 'Revenue Opportunities for Optical Interconnects: Market and Technology Forecast — 2013–2020. Vol. I Board-to-Board and Rack-Based' issued by CIR in August.

The latest report covers four kinds of chip-level interconnect: optical engines, photonic integrated circuit (PIC)-based interconnects, silicon photonics and free-space optics. It includes nine-year (volume and value) forecasts with breakouts by active components along with fiber and waveguide transmission media. Compound semiconductor, silicon and polymer waveguides are covered, as are vertical-cavity surface-emitting lasers (VCSELs), silicon lasers and quantum dot (QD) lasers. In addition, the report contains assessments of the latest business and technology strategies in the chip-level optical interconnect space.

Companies discussed include Avago, Cisco, Corning, Dow Chemical, Dow-Corning, DuPont, Finisar, Fujitsu, Furukawa, IBM, Intel, Juniper, Kotura, Micron, Novellus, Optical Interlinks, QD Laser, Reflex Photonics, Samtec, Sumitomo, TeraXion, Tokyo Electron, ULM Photonics, and VI Systems.

The growing popularity of parallel computing, and the arrival of multicore processors and 3D chips, are leading to data traffic jams both on-chip and chip-to-chip, says CIR. However, these trends are also creating opportunities for chip-level optical interconnects, adds the report.



Chip-level optical interconnect shipments: revenue generation by product.

Avago, Finisar, IBM and Samtec have all proposed optical engines for chip-level interconnect. These miniaturized optical assemblies are currently the most mature technology available for this application and will generate revenues of $235m in 2019, CIR forecasts. But, with their attached connectors and heat sinks, optical engines may prove too large for complex optical interconnection environments, such as in the coming generation of Exascale supercomputers.

Quantum dot-enhanced VCSELs have also been proposed and these, too, may have applications in interconnection

Meanwhile, the arrival of multicore processors and 3D chips means that computer power now depends on how fast each CPU can talk to each other and to memory devices. So, reliable, low-loss, high-speed interconnects between chips are then crucial. Interconnect data rate requirements could reach hundreds of times what they are currently.

Because of the limitations of optical engines, there are emerging opportunities for compact PIC-based interconnect devices based on indium phosphide (InP) and gallium arsenide (GaAs). These opportunities will generate $120m in 2019, increasing to $275m by 2021, reckons CIR. However, bonding PIC interconnects onto a silicon processor or memory chip is both technically challenging and expensive. So far, only a few PIC and VCSEL technology companies have pursued the interconnect opportunity.

Although silicon photonics has compelling advantages, firms — especially Intel — have struggled for years to make active optical devices using silicon. A breakthrough in silicon laser technology would be the single most important development in optical interconnects, allowing the full integration of both electronic information processing and optical integration, says CIR. Faster VCSELs will also be important for the development of chip-level optical interconnect. Several firms and research institutes have announced high-speed VCSELs, operating all the way up to 55Gbps, although such lasers await extensive commercialization. Quantum dot-enhanced VCSELs have also been proposed and these, too, may have applications in interconnection, concludes CIR.

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TriQuint opens Korea design center

RF front-end component maker and foundry services provider TriQuint Semiconductor Inc of Hillsboro, OR, USA has opened a design center in Seoul, South Korea, sited strategically in the Bundang Business District (near Incheon International Airport), close to key customers (including some of the world's leading smartphone makers) as well as one of the firm's high-volume sub-contract assembly houses and other suppliers.

"Our engineers are based there to provide direct support for product development and field applications, an important advantage in the hyper-competitive, fast-paced wireless communications market," says Thomas Meier, VP of Mobile Devices Engineering. "Having our engineers nearby — in the same time zone, speaking the same language — will facilitate our collaboration on technology innovation and future product designs," he adds.

"As one of the top technology capitals in the world, Seoul is a great place to recruit and develop a strong talent base of engineers with RF and systems expertise," states Younkyu Chung, director of the TriQuint Korea Design Center.

www.triquint.com

RFMD unveils its first impedance tuners, targeting multi-band LTE and HSPA+ smartphones and tablets

RF Micro Devices Inc of Greensboro, NC, USA has expanded its portfolio of antenna control solutions by unveiling its first impedance tuner.

The programmable RF1105 functions as a tuner sub-system across all LTE frequency bands up to 2.7GHz, providing antenna feed matching over a wide frequency range. This simplifies antenna design and enables smartphone and mobile device OEMs to optimize antenna power and sensitivity while also maximizing battery life, says RFMD.

As frequency bands proliferate, cellular antennas are required to operate over wider bandwidths, greatly increasing the need for impedance tuners, adds RFMD. According to Strategy Analytics, the proliferation of multi-band LTE devices is expected to drive phenomenal growth in shipments of antenna tuning components, reaching 1.8 billion units per year by 2018.

Due to its unique topology, the RF1105 offers broad symmetric tuner gain and linear performance for optimal power transfer to the antenna, improving total system efficiency, even under the most adverse operating conditions in multi-band LTE and HSPA+ applications, claims RFMD.

The new impedance tuners provide the programmability and efficiency needed to simplify and accelerate antenna design in smartphones and tablets, says Eric Creviston, president of RFMD's Cellular Products Group. "The RF1105 is capable of matching almost any antenna impedance," he adds. "As a result, the RF1105 is already included on several leading mobile reference designs."

Like RFMD's antenna tuners, its impedance tuners improve RF system efficiency between the transceiver and the antenna element. While RFMD's antenna tuners optimize radiated efficiency by adjusting or tuning an antenna's resonant frequency, the impedance tuners optimize power transfer to the antenna. Both are part of RFMD's portfolio of antenna control solutions, which also includes high-performance routing switches that optimize antenna selection and control and boost cellular data throughput rates.

RFMD says its impedance tuners provide a dynamic matching environment and can be programmed to offer optimal performance across multiple conditions and usage cases. With the RF1105, smartphone OEMs can design antennas for optimal radiated efficiency while reducing the potential tradeoffs associated with fixed matching components, it claims.

The device is sampling now with lead customers. Volume production should begin in first-quarter 2014.

www.rfmd.com

RFMD earns Huawei Supplier of the Year Award

Telecoms equipment maker Huawei Technologies Co Ltd of Shenzhen, China has presented RFMD with its Supplier of the Year Award for 2013, accepted by RFMD president & CEO Bob Bruggeworth at a ceremony in Shenzhen. This is the second time in three years that RFMD has earned this 'Golden Core Partner' award.

RFMD is a key component supplier to handset manufacturer Huawei, providing discrete antenna switches, antenna switch modules, power amplifiers, power management ICs, and Wi-Fi low-noise amplifiers. RFMD also provides Huawei components for wireless infrastructure and point-to-point cellular backhaul.

"RFMD has been a key strategic partner for Huawei, providing outstanding technology and new product development, field applications support, proactive local customer support and excellent on-time delivery," comments Xiong Lening, VP of Huawei's Supply Chain Management Department.

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Anadigics' sales grow 7.1% in Q3 to $37m, driven by Cellular growth of 27.8%

After pause in Q4, growth to resume in 2014, driven by WiFi

For third-quarter 2013, broadband wireless and wireline communications component maker Anadigics Inc of Warren, NJ, USA has reported net sales of $37m, up 7.1% on $34.6m last quarter and 29.2% on $28.6m a year ago. The sole greater-than-10% customer was Samsung.

During the quarter, Anadigics said in August that its AWT6751 and AWT6755 dual-band ProEficient-Plus WCDMA power amplifiers (PAs) had been selected by Samsung for its new Galaxy Mega phablet, and that its AWL9581 front-end integrated circuit (FEIC) is enabling 5GHz 802.11ac WiFi connectivity in LG Electronics' new G2 smartphone. In early September, Anadigics launched its ProVantage PA product family. In early October, Anadigics said that its AWL9581 802.11ac FEIC, AWT6651 ProEficient PA, and ALT6702 HELP4 PA are enabling wireless connectivity in Samsung's new GALAXY Note 3 smartphone. In late October, Anadigics launched a DOCSIS 3.1 Edge QAM amplifier and expanded its DOCSIS 3.1 infrastructure product family with new gallium arsenide (GaAs MESFET) and gallium nitride (GaN) line amplifiers.

"In addition to delivering targeted differentiated solutions, we continue to forge new industry relationships, achieve primary positions on key reference designs, and strengthen our collaboration with existing customers," says chairman & CEO Ron Michels. "Design wins for flagship devices including the Samsung GALAXY Note 3, the LG G2 and the Samsung Note 10.1 (2014 Edition) are a direct result of the strategy and are contributing to our continued improvements and financial performance," he adds.

"I am proud of our continued ability to deliver innovative new products for high-growth market segments," says Michels. "This sharp focus, combined with our strong industry relationships, fueled customer demand during the third quarter, especially in our Cellular products group," he adds. Cellular revenue was $23m, up 9% on $21.1m a year ago but 27.8% on $18.1m just last quarter.

WiFi revenue was $10m, down 12.4% on $11.4m last quarter, but this was due to some channel inventory balancing following that quarter's 135% increase from just $4.8m in Q1. "Over the past four quarters, we have launched a completely new portfolio of front-end ICs and power amplifiers for the 802.11n and 11ac WiFi market," notes Michels. "We've been specified on nine new leading reference designs and have secured design wins for a variety of market-leading smartphones, tablets and access points. This is fueled an unprecedented 633% year-on-year WiFi sales growth [from just $1.3m a year ago]."

Infrastructure revenue was $4m, down 22.7% on $5.3m last quarter (and $6.2m a year ago) as build-out spending continued to defer.

Capacity utilization was about 70%, down from 75% last quarter despite the revenue growth. Nevertheless, gross margin was 11.9%, a 640 basis point sequential improvement, expanding on Q2's 540 basis point sequential improvement over Q1 (and compared with breakeven a year ago). "We are pleased with the outstanding leverage our manufacturing investment is providing," comments VP & chief financial officer Terry Gallagher. "The 640 basis point sequential margin improvement was accomplished in spite of the sales mix cross wins where we faced decreases in WiFi and Infrastructure which were offset by Cellular's revenue growth," he adds. "Margin expansion was driven principally by operational improvement as we benefitted from higher manufacturing throughput and other efficiencies as we optimize our ILD [inter-layer dielectric] technology, improve yields, move newer products into larger volumes, and improve on production costs," says Gallagher.

For the fourth quarter, we are seeing an uptick in Infrastructure and WiFi orders offset by market softness in Cellular

R&D expenses increased modestly by 2.5% sequentially from $8.6m to $8.9m, reflecting incremental project spend to help drive new products for 2014. Selling & administrative expenses fell slightly by 5.5% from $5.3m to $5m. Overall operating expenses of $13.9m were lower by $100,000 as the firm maintained tight control over costs.

On a non-GAAP basis, net loss has been cut further, $15.3m a year ago and $12m last quarter to $9.5m. Compared with just $0.25m a year ago, capital investment was $1.7m, supporting the more efficient ILD capacity. During the quarter, cash, cash equivalents and short- and long-term marketable securities hence fell further, from $41m to $32m.

"I am pleased with this quarter's impressive revenue growth, more efficient production and outstanding leverage on our largely fixed expense base," comments Gallagher.

"We're ramping the fourth quarter as customers demand for WiFi world-class solutions increases," says Michels. "Specifically we're gaining traction on our 802.11n and ac FEICs with both module and OEM chip-on-board opportunities. We believe that this growth is being driven by the exceptional combination of linearity, efficiency and thermal characteristics that they provide," he adds.

"For the fourth quarter, we are seeing an uptick in Infrastructure

and WiFi orders offset by market softness in Cellular," says Gallagher. "Overall, we expect revenues in the fourth quarter to be flat to down 5% sequentially [with capacity utilization below 70%], while the revised mix supports an improvement in gross margin," he adds. "The increasing mix of ILD and realizing further production efficiencies leaves adequate available capacity beyond our expected 2014 growth." Michels adds: "We have incremental increases with capacity that we can kick in when we decide to depreciate certain pieces of equipment. So at the moment we can comfortably get up into $55–60m, and we can go beyond that if we chose to late into next year or after that."

"Through continued close collaboration with leading chipset providers and tremendous design-win activity, we anticipate that WiFi products will continue to fuel company growth moving forward," says Michels.

The new ProVantage 3G/4G power amplifier family combines high power-added efficiency with space-saving integration and lower overall systems costs. "They are also ideally positioned to support the transition of 2G to 3G in emerging markets with compatibility across multiple low-cost WCDMA chipset suppliers," believes Michels. "Customer response has been extremely positive and we now have design wins at several OEMs ramping into production," he adds. "The significant traction we are achieving in WCDMA phones for emerging markets with our ProVantage power amplifiers is expected to fuel Cellular growth in 2014."

"Our expanded Cellular portfolio now includes ProEfficient, ProEfficient plus, ProVantage and Penta-band power amplifiers. By segmenting the market we are now able to offer solutions optimized for a wider variety of applications," says Michels. "While we are seeing some market softness in the start of the fourth quarter as key OEMs manage inventory and portfolio transitions, we believe that Anadigics is well positioned to resume profitable sales growth over the longer term with our Cellular products."

"Moving to our Infrastructure products, we are positioned for growth with the launch of several new DOCSIS 3.1 solutions," says Michels. "We will continue launching new products to address DOCSIS 3.1 as MSOs prepare the transition of networks to the new standard over the next couple of years." The new standard extends frequencies above 1.2GHz (with a high split return path to enable ultra-high data speeds as well as additional HDTV content in IP voice capabilities). But "We also have new design wins with our 1GHz power doubler at key OEMs. We are helping a number of our customers expand the use of our existing infrastructure amplifiers into new applications," says Michels.

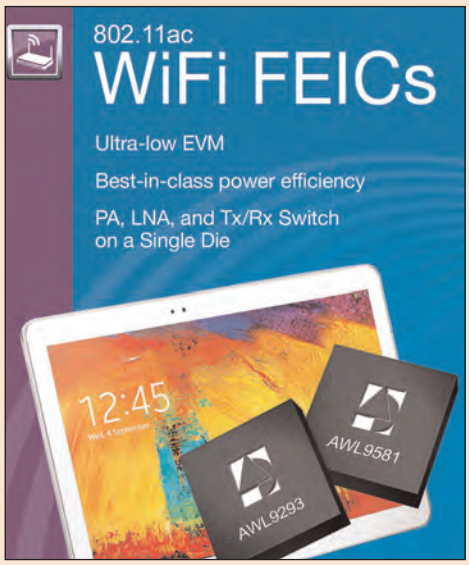
"In addition to CATV solutions, our Infrastructure group continues to work closely with leading small-cell OEMs and chipset developers. We believe that these relationships, coupled with our high-performance products, will enable us to capture a leadership position as the small-cell industry expands," he adds. "Additionally, we are developing opportunities in new markets with targeted R&D taking place within this group. We expect results from these efforts to meaningfully contribute to revenue growth in the second half of 2014."

"Moving forward, we remain dedicated to operational excellence and cost-efficiency improvements that we believe will further expand our gross margins," says Michels. "We anticipate that these efforts, in addition to continued enhancements in product mix, position Anadigics for long-term profitability."

Anadigics' 802.11ac front-end ICs enabling WiFi connectivity in Samsung's GALAXY Note 10.1 tablet

Anadigics says that its AWL9293 and AWL9581 802.11ac front-end integrated circuits (FEICs) are enabling WiFi connectivity in Samsung Electronics' new GALAXY Note 10.1 (2014 Edition) tablet.

The AWL9293 2.4GHz and AWL9581 5GHz FEICs leverage Anadigics' patented InGaP-Plus technology and unique design architectures to combine a high-performance power amplifier (PA), low-noise amplifier (LNA) with bypass option, and RF Tx/Rx switch on a single die (in a compact 2.5mm x 2.5mm x 0.4mm QFN package) to improve manufacturability and reliability. Also incorporating a high-accuracy integrated power detector and RF ports internally matched to 50Ω, this level of integration also reduces PCB space requirements and simplifies RF front-end design for faster time-to-market, says Anadigics.



Anadigics' complete family of 802.11ac FEICs provides what is claimed to be outstanding noise figure performance and error vector magnitude (EVM) in the toughest 802.11ac modulation formats, enabling ultra-high data throughput.

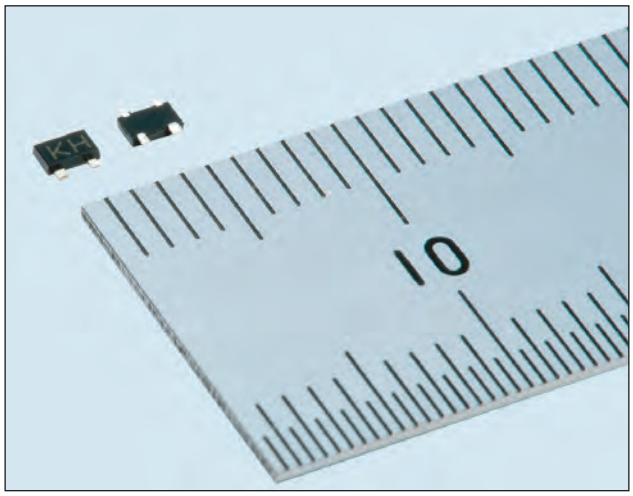
www.anadigics.com

Mitsubishi Electric launches Ku-band low-noise GaAs HEMT for DBS receiver modules

Tokyo-based Mitsubishi Electric Corp has launched the MGF4937AM gallium arsenide (GaAs) high-electron-mobility transistor (HEMT), as a low-noise amplifier (LNA) for receiver modules in direct broadband satellites (DBS) and very small aperture terminals (VSAT).

Offering what is claimed to be the lowest noise-figure performance among fully molded package products, the new GaAs HEMT is targeted at simplifying the manufacturing and improving the performance of receiver module systems. Shipments will begin on 20 December at an initial production volume of 4 million units per month. Mitsubishi Electric will exhibit the MGF4937AM GaAs HEMT at the 2013 Microwave Workshops& Exhibition (MWE 2013) in Pacifico Yokohama, Japan (27–29 November).

The market for wireless communication systems using satellites is growing rapidly, mainly in developing countries because they can be deployed at lower costs than wired systems using optical fiber networks, says Mitsubishi Electric. Demand is hence rising for DBS and VSAT receiver modules that offer both improved noise performance and simplified manufacturing. Conventionally, hollow-type packaged transistors are generally used in first-stage LNAs due to their strong noise performance, but this complicates assembly.



Mitsubishi Electric's MGF4937AM Ku-band low-noise GaAs HEMT.

Mitsubishi Electric says that, in contrast, its MGF4937AM GaAs HEMT improves the transistor structure and optimizes packaging while achieving noise performance that is unsurpassed for a fully molded package and almost the equal of hollow-type packages, it is claimed. Specifically, the minimum noise figure (NF) of 0.37dB (at f=12GHz, typical) is 0.08dB less than conventional fully molded package products, contributing to higher performance in receiver modules. The recommended bias conditions are V_{DS}=2V and I_D=10mA, and the associated gain (G_s) is 13.0dB (f=12GHz, typical).

The firm says that, as well as having a simple structure (as a standard 4-pin fully molded package), replacing hollow-type package transistors simplifies the customer's production line, enabling greater efficiency.

www.MitsubishiElectric.com

Hittite launches 2W PA and analog VGA covering 27.5–31GHz for VSAT, PtP and radar

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 launched a gallium arsenide (GaAs) pHEMT monolithic microwave integrated circuit (MMIC) power amplifier and an analog variable gain amplifier (VGA) suitable for Ka-band VSAT, high-capacity microwave radio and radar systems in the 27.5–31GHz frequency range.

The HMC7441 is a three-stage GaAs pHEMT power amplifier that operates between 27.5 and 31GHz. The PA provides 23dB of gain and +34dBm of saturated output power at 25% power-added efficiency (PAE) from a 6V supply. With an output IP3 of +38dBm, the it is suitable for linear applications demanding +34dBm of efficient saturated output power. The RF I/Os are DC blocked and matched to 50Ω for ease of integration into multi-chip modules (MCMs).

The HMC6187LP4E is a GaAs MMIC pHEMT analog VGA and/or driver amplifier that operates between 27 and 31.5GHz and delivers what is claimed to be excellent gain flatness. The amplifier provides up to 19dB of gain, +24dBm output P1dB, and +31dBm of output IP3 at maximum gain, while requiring 230mA of current from a +5V supply. A gain control voltage (V_{ctrl}) is provided to allow variable gain control up to 13dB. The HMC6187LP4E is housed in a RoHS-compliant 4mm x 4mm plastic QFN leadless package and is compatible with high-volume surface-mount manufacturing.

Both products complement Hittite's line of microwave power amplifiers and analog VGAs, which provide continuous frequency coverage from 0.01 to 86GHz. Samples are available from stock.

www.hittite.com

AmpliTech enters into talks for product marketing and promotion in Europe

AmpliTech Group Inc of Bohemia, NY, USA, which designs and makes RF/microwave, microelectronic, monolithic microwave integrated circuit (MMIC), and low-noise amplifiers spanning the 50kHz to 40GHz frequency range for critical and high-reliability wireless and commercial applications, says it has entered into discussions with telecoms systems company AO Technologies-UK Ltd to market and promote its amplifier products in their satellite communications (SATCOM) and telecom systems in Europe.

"This joint marketing program will be finalized in the near future and will enhance AmpliTech's position in the rapidly growing SATCOM and telecom markets," believes AmpliTech's president & CEO Fawad Maqbool.

"We are already a leading provider of high-performance low-noise amplifiers in the US and global markets," he adds. "This joint marketing effort will allow us to provide complete amplifier systems and new products for SATCOM and telecom applications as well as increase awareness of our other products in Europe."

AmpliTech currently has international customers and sales representatives in more than 16 countries worldwide.

www.amplitechinc.com

Customers announce defense program extensions up to 2034

AmpliTech says that it's largest defense customers have reported that their defense program orders have been extended out to 2034. AmpliTech's custom amplifiers are designed into these programs and are not available to the general marketplace.

"This expands AmpliTech's role in these key programs and increases our opportunity to participate in these programs well into the future," says CEO Fawad Maqbool. The firm reported previously that its booked orders have grown to new highs. The latest developments ensure that growth will continue well past this year, the firm says.

At the International Microwave Symposium in Seattle, AmpliTech announced that during second-quarter 2013 it had received over $500,000 of orders for its amplifier solutions from three large defense and commercial contractors. "These were awarded contracts from some of the largest defense contractors in the microwave space," notes Fawad Maqbool. "We are pleased to be experiencing a continued strength in the follow up order flow. We expect this to have a positive impact on our third- and fourth-quarter financial statements for this year," he adds.

UMS at European Microwave Week

At the European Microwave Week (EuMW 2013) conference in Nürnberg, Germany (6–11 October), UMS presented the following product and research developments:

- 'mm-Wave Circuits' session (EuMiC09-2): 'E-band Medium Power Amplifiers with Gain Control and Output Power Detector' by A. Couturier, E. Byk, C. Auvinet, S. Tranchant, P. Auxemery, M. Camiade, C. Teyssandier, M. Hosch, H. Stieglauer;
- 'EuMIC/EuMC' session (Poster 01-16): 'Nonlinear Transistor Modeling for Industrial 0.25-µm AlGaN-GaN HEMTs', by C. Chang, V. Di Giacomo-Brunel, D. Floriot, J. Grünenpütt, M. Hosch, H. Blanck; and
- 'Innovative Design Approaches for GaN Power Amplifiers' session (EuMC/EuMIC 05-5): 'Wideband High Efficiency High Power GaN Amplifiers Using MIC and Quasi-MMIC Technologies' by UMS, Villebon/Yvette, France (C. Berrached, D. Bouw, M. Camiade) - XLIM-UMR 6172- Université de Limoges/CNRS, Limoges (C. Berrached, D. Barataud).

Papers in collaboration

- Session Semiconductor Devices and Characterization - (EuMIC14-3): 'Investigation of Gate and Drain Leakage Currents of AlGaN/GaN HEMTs at Sub-threshold Regime for Temperature Range 300K–400K', A Collaboration between IMS laboratory, Talence, France (M. Rzin , A. Curutchet, N. Labat, N. Malbert , L. Brunel) and UMS, France (L. Brunel, B. Lambert).
- Session Semiconductor Devices and Characterization - (EuMIC14-4): 'Analysis of Barrier Inhomogeneities in AlGaN/GaN HEMTs' Schottky Diodes by I-V-T measurements' A collaboration between LAAS - CNRS - University of Toulouse, Toulouse, France (S. Karboyan, J. Tartarin) and UMS, France (B. Lambert);
- EuMIC/EuMC Session Poster 01-15: 'A Robust Ku-Band Low Noise Amplifier using an Industrial 0.25-µm AlGaN/GaN on SiC Process', A collaboration between MEC srl, Bologna, Italy (D. Resca1, F scappaviva), University of Bologna, Italy (C. Florian), TAS France, Toulouse, France (J. Muraro), UMS, France (V. Di Giacomo-Brunel, C. Chang, D. Baglieri).

www.ums-gaas.com

Skyworks' quarterly revenue grows more-than-expected 9.4% to $477m

December-quarter revenue to grow to $500m

For its fiscal fourth-quarter 2013 (to 27 September), Skyworks Solutions Inc of Woburn, MA, USA (which manufactures analog and mixed-signal semiconductors) has reported revenue of $477m, up 9.4% on $436.1m last quarter and 13.3% on $421.1m a year ago (and slightly above the forecast of $475m).

Revenue was split 40% for high-performance analog (HPA) and 60% for handsets.

For fiscal full-year 2013, revenue was a record $1792m, up 14% on fiscal 2012's $1568.6m.

"Skyworks continues to outperform as we expand our diversified market footprint, gain content with customized analog solutions and capitalize on global demand for the Internet of Things," says president & CEO David J. Aldrich.

Gross margin has risen from 42.9% a year ago and 44% last quarter to 44.4% (ahead of the midpoint of the 44–44.5% guidance range).

Operating expenses were $81.5m. On a non-GAAP basis, operating income has risen from $103.6m (operating margin of 24.6% of revenue) a year ago and $111.9m (operating margin of 25.7%) last quarter to $130.3m (operating margin of 27.3%).

Net income has risen from $103.5m ($0.53 of diluted earnings per share) a year ago and $103.8m ($0.54 per share) last quarter to $121.2m ($0.64 per share, $0.02 better than guidance). For full-year 2013, net income was $423.5m ($2.20 per share), up from fiscal 2012's $365.6m ($1.90 per share).

For fiscal Q4, cash flow generated from operations was $166m (up from $65m last quarter), contributing to full-year fiscal 2013 operating cash flow of $508m and free cash flow of $384m. Quarterly capital expenditure was $38m and depreciation was $19m. During the quarter, cash reserves hence rose from $400m to $511m. Skyworks also repurchased over 8 million shares of common stock at an average price of $22.75 per share (totalling $173m).

"Our ongoing diversification coupled with analog content gains in connectivity are enabling us to deliver better-than-seasonal revenue and year-over-year EPS growth of 20%," notes VP & chief financial officer Donald W. Palette.

During the quarter, Skyworks: enabled WNC's remote lighting, in-home monitoring and security/automation platforms with power management and ZigBee front-end devices; launched highly efficient isolators at Ericsson for LTE wireless base-stations; partnered with Silicon Labs to develop low-power, smart energy solutions supporting communication hubs, meters and in-home displays; and captured analog control IC sockets for Johnson Controls' Homelink system. The firm also developed low-noise amplifiers targeting Shure's broadcast microphones; delivered optical solutions for Varian Medical radiation oncology applications; began volume shipments of DC/DC converters and LED backlight drivers for automotive displays at LG; supported global satellite navigation standards with high-linearity modules; and won hi-reliability designs at Cobham, EADS and Teledyne for aerospace and defense applications

Over the course of fiscal 2014, we expect continued margin enhancement, driven by growth of our diversified analog business and by capturing new customized content across the world's leading connectivity platforms... putting us on a clear path to achieving our mid-term business model of 30% operating margins at a quarterly revenue level of $550m

"Based on our product innovation, proprietary solutions and track record of operational execution, we've created a differentiated business model," says Aldrich. "As a result, we are well positioned for sustainable above-market growth."

For fiscal first-quarter 2014, Skyworks expects revenue to grow by 4.8% to $500m (the firm's first quarter at a $2bn annualized revenue run rate). Gross margin should rise slightly to 44.5%. Operating expenses are expected to grow slightly to $82.5m, yet operating margin should still rise to 28% (up from 25.3% a year ago). Diluted earnings per share are forecast to grow to $0.66.

"Over the course of fiscal 2014, we expect continued margin enhancement, driven by growth of our diversified analog business and by capturing new customized content across the world's leading connectivity platforms," says Palette. "Many of the drivers for a strong 2014 are in place today, giving us a high level of confidence in our growth trajectory over the course of the year and putting us on a clear path to achieving our mid-term business model of 30% operating margins at a quarterly revenue level of $550m," he adds. "This would produce around $3 in annualized earnings per share [versus $2.20 for fiscal 2013]."

www.skyworksinc.com

HTC and Samsung opts for Skyworks' SkyOne front-end

Analog semiconductor maker Skyworks Solutions Inc of Woburn, MA, USA says that HTC and Samsung are ramping SkyOne, a highly customizable fully optimized front-end solution, in several of their recent smartphone launches. The SkyOne platform integrates all RF and analog content between the transceiver and antenna, reduces complexity, size and time-to-market for demanding architectures in advanced mobile applications.

Utilizing Skyworks' full technology portfolio and multichip module capabilities (including proprietary shielding and packaging), SkyOne is the first semiconductor device to condense multi-band power amplifiers and high-throw switches along with all associated filtering, duplexing and control functionality into a single, ultra-compact package — all in less than half the area of the industry's most advanced approach — while at the same time providing the world's best linearity and power-added efficiency for smart RF integration, claims the firm.

"SkyOne offers smartphone, tablet and ultrabook OEMs improved size, flexibility, and time to market — all in an easy-to-implement and scalable platform that addresses the dramatic increase in bands worldwide," says Brad Byk, senior VP, worldwide sales at Skyworks.

HTC's Desire 601 offers consumers 4G LTE speeds for extremely fast music and video streaming with HD clarity. It leverages HTC's Boom-Sound with dual frontal stereo speakers for more immersive volume and richer audio, and Blink-Feed, a feature that automatically refreshes the home screen every time you turn it on. The advanced camera in the Desire 601 features a photo clustering function that unstills pictures for moving images.

The SkyOne platform integrates all RF and analog content between the transceiver and antenna

The Galaxy Express 2 is powered by Android 4.2, with a 1.7GHz dual core processor and 4.5 inch display. The new handset features a number of Samsung's smart functions such as Smart Stay — using advanced facial recognition to detect when the phone is in use, and Group Play — allowing users to share music, documents and photos with compatible Samsung devices. In addition, the device features S Travel, Story Album and S Translator.

SkyOne is a fully tuned, complete system solution that integrates all the RF and analog content between the transceiver and antenna. The highly integrated platform delivers best-in-class performance, addresses co-existence issues, and provides the greatest design flexibility to address the increasing number of frequency modes and bands across the world — all in the industry's smallest form factor.

www.skyworksinc.com

IN BRIEF

Peregrine UltraCMOS antenna tuning switch chosen for Pantech's LTE-A phablet

Peregrine Semiconductor Corp of San Diego, CA, USA, a fabless provider of radio-frequency integrated circuits (RFICs) based on silicon-on-sapphire (SOS) and silicon-on-insulator (SOI), says that it is supplying the UltraCMOS main-antenna tuning switch for the Vega Secret Note LTE-A phablet of South Korean mobile phone manufacturer Pantech.

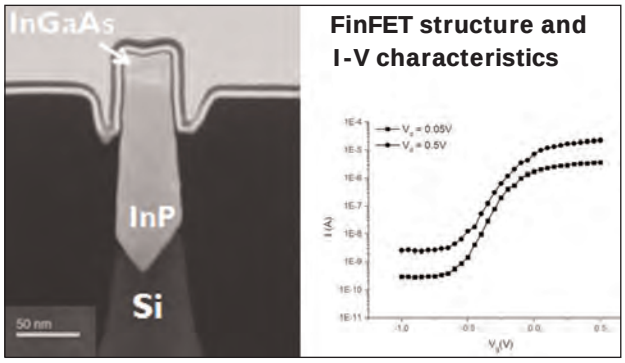
Peregrine says that the PE613010, which is also being used for Pantech's Vega LTE-A smartphone, provides RF performance enhancements that help the phablet increase battery life, boost data throughput and improve connection quality for fewer dropped calls — even when roaming. Optimized for LTE-A networks, Peregrine's high-linearity switch also enables carrier aggregation and gives consumers access to more networks globally.

"Pantech first started working with Peregrine for this year's Vega LTE-A smartphone design because the performance was superior to everything else we evaluated," comments Mr Song, senior engineer at Pantech.

Peregrine's high-linearity UltraCMOS antenna-tuning switch enables carrier aggregation and is optimized for the LTE-Advanced standard, which is offered on SK Telecom's network in Korea. The switch delivers what is claimed to be the industry's lowest on-resistance (R_{on}) of 1.2Ω from 700–2700MHz, enabling a 1dB improvement at the antenna (which translates to a 25% performance gain).

www.psemi.com

Imec demos first III-V FinFET devices monolithically integrated on 300mm Si



By using a unique silicon fin replacement process, Imec of Leuven, Belgium has demonstrated what it claims are the first III-V compound semiconductor FinFET devices integrated epitaxially on 300mm silicon wafers.

The nanoelectronics research center says that the achievement illustrates progress toward high-volume manufacturing on 300mm and future 450mm wafers of advanced heterogeneous CMOS devices, monolithically integrating high-density compound semiconductors on silicon. The development not only enables continual CMOS scaling down to 7nm and below, but also enables new heterogeneous system opportunities in hybrid CMOS-RF and CMOS-optoelectronics, imec adds.

"To our knowledge, this is the world's first functioning CMOS-compatible III-V FinFET device processed on 300mm wafers," says An Steegen, senior VP core CMOS at imec, "demonstrating the technology as a viable next-generation alternative for the current state-of-the-art Si-based FinFET technology in high volume production."

The proliferation of smart mobile devices and the ever growing user expectations for bandwidth and connectivity will drive the continual need for software and hardware advances extending from networks to data servers and mobile gadgets, says imec. At the core of the hardware will be new process technologies that allow more power-efficient CMOS transistors and increased integration, enabling a higher level of functionality. This prompts process technologies that enable heterogeneous devices spanning operating ranges for targeted circuits, maximizing system performance.

"During the last decade, transistor scaling has been marked by several leaps in process technologies to provide performance and power improvements," notes imec's director of the logic R&D Aaron Thean. "The replacement of poly-silicon gate by high-k metal-gate in 45nm CMOS technology in 2007 represented a major inflection in new material integration for the transistor. The ability to combine scaled non-silicon and silicon devices might be the next dramatic transistor face-lift, breaking almost 50 years of all-silicon reign over digital CMOS," he adds. "This work represents an important enabling step towards this new paradigm."

At the finest grain, co-integration of high-density heterogeneous transistors has been challenged by the ability to combine disparate materials and structures while maintaining low enough complexity and defectivity. Imec's new process selectively replaces silicon fins with indium gallium arsenide (InGaAs) and indium phosphide (InP), accommodating nearly 8% of atomic lattice mismatch. The new technique is based on aspect-ratio trapping of crystal defects, trench structure, and epitaxial process innovations. The resulting FinFET device integrating III-Vs on silicon shows what is claimed to be excellent performance.

Imec's research into next-generation FinFETs is performed as part of its core CMOS program, in cooperation with key partners including Intel, Samsung, TSMC, Globalfoundries, Micron, SK Hynix, Toshiba, Panasonic, Sony, Qualcomm, Altera, Fujitsu, nVidia, and Xilinx.

www.imec.be

Peregrine ships 2 billionth UltraCMOS RF chip

Peregrine Semiconductor Corp of San Diego, CA, USA, a fabless provider of radio-frequency integrated circuits (RFICs) based on silicon-on-sapphire (SOS) and silicon-on-insulator (SOI), has shipped its 2 billionth UltraCMOS chip (to Murata Manufacturing Company, a supplier of RF front-end modules for mobile wireless applications). Peregrine shipped its 1 billionth chip only 2011,

UltraCMOS technology comprises ultra-thin silicon (UTSi) circuitry processed on silicon-on-insulator (SOI) technology on a silicon-on-sapphire (SOS) or silicon-on-insulator (SOI) substrate. It combines the monolithic integration of RF, mixed-signal and digital capabilities of a CMOS silicon process while tolerating the high power required for high-performance wireless applications.

Also, in an event at the Estancia Hotel in La Jolla, CA, Peregrine was held a 25th anniversary celebration of its founding, bringing together individuals and organizations — such as the Space and Naval Warfare Systems Center (SPAWAR) — who have been instrumental in the firm's growth. "I am pleased to recognize the success of Peregrine Semiconductor and the Space and Naval Warfare Systems Center Pacific's (SSC Pacific) role in successfully transitioning technology, originally developed for our warfighters, to commercial applications," says Stephen D. Russell Ph.D, SPAWAR chief technology officer and director of Science & Technology. "This highlights the need to make investments in basic and applied research, in this case engineering materials at the atomic level, which enables significant new capabilities offered by UltraCMOS technology," he adds. "This is just one example of the importance and impact of research that is performed at SSC Pacific, which has been fielding new capabilities to the Fleet for more than 70 years."

I am pleased to recognize the success of Peregrine Semiconductor and the Space and Naval Warfare Systems Center Pacific's role in successfully transitioning technology

With roots in government R&D, Peregrine supplies high-performance integrated RF solutions. Products provide critical communication pathways for devices used worldwide and beyond – from the most advanced smartphones to the Mars Rover (Peregrine's chips have also been to seven planets, Pluto and the Itokawa asteroid). "Peregrine is the shining example of a successful transition of government technology into the commercial sector," reckons CEO Jim Cable.

www.psemi.com

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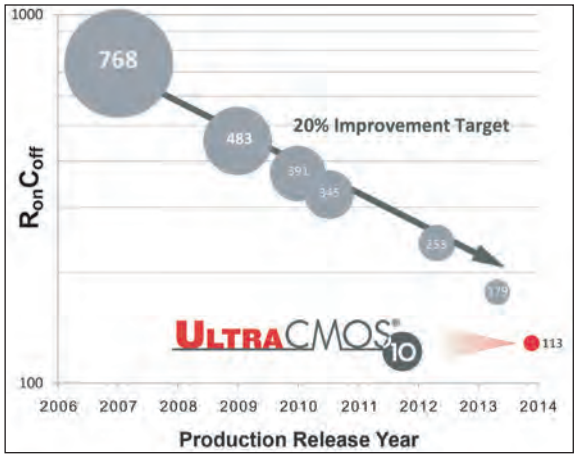
Peregrine launches UltraCMOS 10 technology for RF SOI

Peregrine Semiconductor Corp of San Diego, CA, USA has announced UltraCMOS 10, the latest development of its UltraCMOS technology. The firm says that UltraCMOS 10 RF SOI (silicon-on-insulator) delivers both flexibility and performance for addressing the ever-increasing challenges of RF front-end design. It offers the performance of UltraCMOS technology with the economies of SOI, and it delivers a more than 50% performance improvement over comparable solutions, it is reckoned.

Peregrine's 130nm UltraCMOS 10 technology delivers the support needed for the latest generation of LTE-Advanced smartphones and, for the first time, will allow it to deliver cost-competitive products for 3G smartphones.

Peregrine is enhancing a long-term relationship and leveraging a new one for the launch of UltraCMOS 10 — the SOI semiconductor materials of Soitec of Bernin, France coupled with the custom fabrication flow of tier-one fab GLOBALFOUNDRIES Inc of Milpitas, CA, USA.

"Together, we co-developed a custom flow to help make Peregrine's new UltraCMOS 10 generation a truly cutting-edge advance in RF SOI," says GLOBALFOUNDRIES' CEO Ajit Manocha.



UltraCMOS 10's $R_{on}C_{off}$ metric of 113fs, a five-fold improvement over the first generation.

Smartphone makers face tough design challenges, says Peregrine, including balancing performance requirements with cost and maintaining consumers' signal quality and data-rate speeds despite the increasing number of frequency bands and volume of data. "The iPhone 5S has more than double the frequency bands than the iPhone 5, and this is just one example of how dramatically the requirements for smartphone components are increasing," comments Joe Madden, principal analyst of Radio Access and RF Semiconductors at Mobile Experts. LTE units are expected to grow at a compound annual growth rate (CAGR) of 42% from 150 million in 2012 to 1.2 billion in 2018. "Peregrine's UltraCMOS 10 technology will outpace these increasing performance needs so consumers will continue to see improved connectivity," he adds.

The UltraCMOS 10 130nm generation delivers what is claimed to be the industry's best R_{ON} C_{OFF} performance and enables improved performance and scaling. The R_{ON} C_{OFF} figure of merit is a ratio of how much loss occurs when a radio signal goes through a switch in its ON state (R_{ON}, on-resistance) and how much the radio signal leaks through the capacitor in its OFF state (C_{OFF}, off capacitance). RON C_{OFF} for UltraCMOS 10 technology is 113fs, a five-fold improvement over the first generation released by Peregrine 10 years ago (i.e. lowering insertion loss without sacrificing isolation performance). The UltraCMOS 10 platform also leverages Peregrine's patented design technology, which delivers linearity of more than 75dBm at 900MHz and equates to higher data rates and improved co-existence for consumers.

www.psemi.com

GLOBALFOUNDRIES samples RF switches using UltraCMOS 10

Peregrine and GLOBALFOUNDRIES of Milpitas, CA, USA are sampling the first RF switches fabricated using Peregrine's new UltraCMOS 10 RF SOI process. In a joint development effort, GLOBALFOUNDRIES and Peregrine created a unique fabrication flow for the 130nm UltraCMOS 10 technology platform. The new technology is claimed to deliver a performance improvement of more than 50% over comparable solutions. Peregrine says that UltraCMOS 10 offers smartphone makers flexibility and value without compromising quality for devices ranging from 3G through LTE networks.

The partnership with GLOBALFOUNDRIES "enables us to have a comprehensive technology roadmap with access to future-generation technologies," says Peregrine's CEO Jim Cable. "This joint-development partnership offers our customers new levels of product performance, reliability and scalability, and it enables us to push the envelope of integrated RF front-end innovation," he adds.

"Peregrine Semiconductor's leadership in RF SOI solutions makes the company an ideal partner as we expand our expertise and capabilities as part of our Singapore Vision 2015 initiative [announced in November 2012, to expand Singapore-based 300mm manufacturing capabilities to mixed-signal technologies]," comments GLOBALFOUNDRIES' CEO Ajit Manocha. "The joint development of a unique fabrication flow, coupled with Peregrine's RF expertise, allows us to produce the highest-performing RF SOI solution on the market," he claims.

www.globalfoundries.com

MACOM to acquire Mindspeed for $272m

M/A-COM Technology Solutions Inc of Lowell, MA, USA, which makes semiconductors, components and subassemblies for RF, microwave and millimeter-wave applications, has agreed to acquire Mindspeed Technologies Inc of Newport Beach, CA, USA (which designs network infrastructure semiconductors for communications applications).

Mindspeed is also in advanced discussions with a potential strategic buyer for its wireless business, which it intends to sell prior to closing the MACOM transaction.

"This acquisition will position MACOM as a leading global provider of 100G optical solutions, which underscores our growth strategy in commercial communications markets," says president & CEO John Croteau. "Our interest in Mindspeed is the company's high-growth, high-margin High-Performance Analog (HPA) business as well as its cash-generating VoIP [Voice over Internet Protocol] business," he adds. "The addition of the HPA portfolio, which consists of the world's fastest crosspoint switches, ultra-low-power signal conditioners and industry-leading optical PMDs [physical media devices], aligns well with MACOM's business model - offering non-GAAP gross margins approaching 70%, long product life-cycles, and sticky customer relationships."

Mindspeed also has a communications processor business, which does not align with MACOM's long-term strategic focus, so additional options will be explored while continuing to support its customers. Separately, in the event that Mindspeed's wireless business is not sold, it will be restructured and wound down while continuing to support its customers.

"Mindspeed's leadership in silicon germanium (SiGe)-based products, along with its long-held position in enterprise video and metro markets, complements our strong position in long-haul modulator drivers based on indium phosphide (InP) and gallium arsenide (GaAs) technology," says Croteau. "This will position MACOM as a clear leader across all 100G segments, all physical-layer products, and all requisite technologies enabling us to capitalize on the expected decade-long build-out of the 100G optical market," he adds.

"This acquisition will diversify our served markets to include enterprise applications, while also enabling MACOM to strengthen our core RF and microwave position with SiGe technology," continues Croteau. "The transaction will also broaden our customer footprint and reach, by leveraging Mindspeed's strong sales channel in Asia, which complements our strength in North America and other regions."

The two companies' combined trailing twelve months (TTM) revenue is about $451m, with non-GAAP gross margin of about 50% (excluding Mindspeed's wireless business).

MACOM intends to commence a tender offer to purchase each outstanding common share of Mindspeed for $5.05 in cash (without interest), and MACOM will assume certain equity awards held by Mindspeed employees. The cash transaction is valued at $272m for Mindspeed's $132m in TTM revenue (excluding wireless business and non-recurring revenue from sales of intellectual property), or $246m net of Mindspeed's cash position of $26m as of 27 September. MACOM expects to finance the acquisition through a combination of cash on hand and its existing undrawn revolving credit facility.

MACOM estimates that the acquisition will result in substantial synergies from corporate overhead, corporate R&D overhead, SG&A (selling, general & administrative), and exiting underperforming businesses. The firm also expects the acquisition to be immediately accretive to non-GAAP earnings per share, by $0.15–0.20 in fiscal 2014 and $0.25–0.30 in fiscal 2015.

The boards of both firms have approved the transaction (which is subject to customary closing conditions and regulatory approvals). MACOM expects the transaction to close by the end of 2013.

www.mindspeed.com
www.macomtech.com

MACOM launches 5V broadband LNA for CPE universal front-ends

M/A-COM Tech has launched 5V RF low-noise amplifier suited for 50–2700MHz cable, terrestrial and satellite applications.

The MAAM-011117 is targeted at users needing a broadband, high-performance solution for CPE (customer premises equipment) applications. Operating over a 50–2700MHz frequency bandwidth, it incorporates a power-down function in order to minimize power consumption during stand-by.

The device is packaged in an 8-lead 2mm x 2mm plastic package that incorporates a number of off-chip components, resulting in a highly integrated solution for space-constrained front-ends. The LNA delivers high gain of 16dB, low noise of 2.7dB and what is claimed to be very low distortion performance, providing a universal amplifier solution targeting easy and efficient front-end implementation.

"The MAAM-011117 has been designed specifically for customers requiring a highly linear, low-noise amplifier solution that covers DVT-T,-C and-S bands," says Graham Board, product manager, Networks.

Production quantities and samples of the MAAM-011117 are available from stock.

www.macomtech.com

GeneSiC launches SiC bare die up to 8000V ratings for high-voltage circuits and assemblies

Silicon carbide (SiC) power semiconductor supplier GeneSiC Semiconductor Inc of Dulles, VA, USA has announced the immediate availability of 8000V SiC PiN rectifiers; 8000V SiC Schottky rectifiers, 3300V SiC Schottky rectifiers and 6500V SiC thyristors in bare die format. The products are the highest-voltage SiC devices on the market, GeneSiC claims, and are targeted specifically at oil and gas instrumentation, voltage multiplier circuits and high-voltage assemblies.

Contemporary ultra-high-voltage circuits suffer from low circuit efficiencies and large sizes because the reverse recovery currents from silicon rectifiers discharge the parallel connected capacitors, notes GeneSiC. At higher rectifier junction temperatures, this situation worsens further, since the reverse recovery current in silicon rectifiers increases with temperature. With thermally constrained high-voltage assemblies, junction temperatures rise quite easily even when modest currents are passed.

In contrast, high-voltage SiC rectifiers offer characteristics that could revolutionize high-voltage assemblies, reckons GeneSiC. The firm's 8000V and 3300V Schottky rectifiers feature zero reverse recovery current that does not change with temperature. This relatively high voltage in a single device allows a reduction in voltage multiplication stages required in typical high-voltage generator circuits, through the use of higher AC input voltages. The near-ideal switching characteristics allow the elimination or dramatic reduction of voltage balancing networks and snubber circuits, says GeneSiC. The 8000V PiN rectifiers offer higher current levels and higher operating temperatures. The 6500V SiC thyristor chips are also available to accelerate R&D of new systems, adds the firm.

"The 8000V rating goes beyond what silicon devices can offer at rated temperatures," says president Dr Ranbir Singh. "GeneSiC's low-V_F, low-capacitance SiC rectifiers and thyristors will enable system-level benefits not possible before."

www.genesicsemi.com

Anvil gains £1m funding to commercialize low-cost SiC-in-silicon power devices

Anvil Semiconductors Ltd of Coventry, UK has secured £1m in funding to help it speed the development and commercialization of its silicon carbide (SiC)-on-silicon technology for power devices.

The benefit of SiC-based devices is their increased efficiency compared with those based on conventional silicon, resulting in much reduced carbon emissions and running costs. However, the high costs of producing devices in SiC has discouraged their widespread adoption, particularly in cost-competitive consumer applications, says Anvil. The use of SiC devices has hence been largely restricted to niche markets where system benefits justify the cost premium. Anvil's long-term objective is to enable the production of SiC materials and devices at a cost that rivals conventional forms of silicon, while offering substantial energy-saving benefits.

Anvil was spun off in August 2010 from the University of Warwick's School of Engineering by its technology commercialization subsidiary Warwick Ventures Ltd in order to exploit patented developments in SiC power semiconductor technology. Led by co-founder Dr Peter Ward, Anvil has developed unique technology for the production of epitaxial 3C-SiC layers on silicon substrates that promises a step reduction in the cost of manufacturing power switches in this material, it is reckoned. Anvil's objective is to enable production of SiC materials and devices at costs close to those for conventional silicon, opening up high-volume SiC device markets.

The latest funding round was led by the Low Carbon Innovation Fund (LCIF) and involved Ntensive angel investor group, Cambridge Capital Group, and several angel investors, as well as existing investors Midven and Minerva Business Angels. LCIF is a venture capital fund managed by Turquoise International on behalf of the Low Carbon Group at the University of East Anglia and supported by the East of England Competitiveness Program of the European Regional Development Fund (ERDF, a seven-year investment program part-financed by the European Union). "Anvil has invented a highly disruptive technology applicable to a large and growing market," comments Noel Forrest, manager at specialist energy and environment merchant bank Turquoise International (which oversees the LCIF fund). "The management team has both technical and commercial strengths," he adds.

"This investment will enable us to further develop our innovative technology and demonstrate its cost and efficiency benefits to the market," says CEO Jill Shaw. "With the demand for power electronics and electricity growing continuously, the development of low-cost SiC technology provides a low-carbon and energy-efficient alternative to current power electronics."

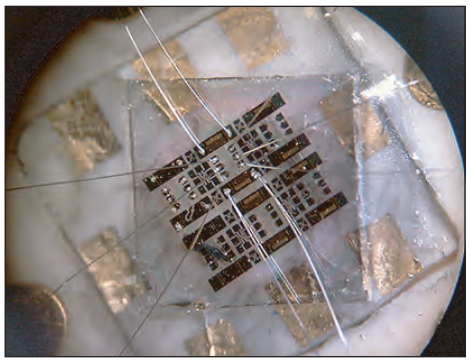
http://anvil-semi.co.uk

Graphene on SiC yields quantum resistance standard

Measurement now possible at lower magnetic field on industrially produced material

Graphene on silicon carbide (SiC) has been shown to give an accurate resistance standard outperforming the presently used GaAs devices. Now, researchers at the Centre for Metrology and Accreditation of MIKES (Mittatekniikan keskus) in Espoo, Finland have shown that the measurements can be performed at lower magnetic fields and on industrially produced material ('Precision quantum Hall resistance measurement on epitaxial graphene device in low magnetic field' by Satrapinski et al, Applied Physics Letters vol 103 issue 17; DOI: 10.1063/1.4826641).

The quantum resistance standard is an ultimate test of materials. This resistance, based on the quantum Hall effect in two-dimensional (2D) structures, allows very accurate realization of resistance in terms of two fundamental constants of nature: elementary charge (e) and Planck constant (h). It is hence independent of other factors and may therefore be used as a universal standard for resistance.



Graphene-based quantum Hall standard of resistance.

Quantum resistance measurements require a high applied magnetic field and a low cryogenic temperature. Earlier precision measurements on graphene have been performed in a magnetic field of about 10 Tesla or more, and at temperatures of about 0.3K or below. But now the researchers at MIKES have demonstrated that highly accurate measurements can be obtained at lower magnetic fields (ranging from 8 Tesla down to 3 Tesla) even when the measurement temperature was not less than 1.5K.

Using MIKES's self-developed precision resistance bridge based on a cryogenic current comparator (CCC), the correctness of the quantum Hall resistance of the graphene device could be verified with accuracy much better than 1 part per million.

The measurements were performed on industrially produced material supplied by Graphensic AB of Linköping, Sweden (Europe's first commercial supplier of graphene on silicon carbide), which applies a high-growth-temperature method to produce the graphene. Photolithographic patterning and electrical contacts were made by Aalto University in Espoo.

"It is very interesting to see how the material and its growth can be pushed to maintain the exceptional properties of graphene," comments Alexandre Satrapinski, who is in charge of graphene research at MIKES.

http://ieeexplore.ieee.org/xpl/login.jsp?tp=&arnumber=6646155
www.mikes.fi
www.graphensic.com

Cree's SiC MOSFETs used in Shinry's HEV/EV power converters, achieving 96% efficiency

Cree Inc of Durham, NC, USA says that Shinry Technologies Co Ltd of Shenzhen, China, which focuses on energy-efficient applications in transportation and lighting, has employed its 1200V C2M family of silicon carbide (SiC) MOSFETs in its new, high-efficiency, hybrid electric and electric vehicle (HEV/EV) power converters for passenger cars and buses to achieve what is claimed to be industry-leading efficiency of 96%. According to Shinry, Cree's C2M SiC MOSFETS also enabled a 25% reduction in product size and over 60% reduction in peak power losses compared to the traditional silicon versions. "Our customers care a great deal about efficiency, compact size and system weight and cost," comments Shinry's CEO Dr Wu Ren Hua.

Shinry specializes in creating HEV/EV DC–DC converters, on-board chargers and rapid chargers for a market that demands high reliability, efficiency and compact size. By implementing Cree's second-generation SiC MOSFETs in its latest 3–10kW DC–DC converters designed for use in electric buses, Shinry says it has achieved considerable efficiency improvement and significant size and weight reduction.

Launchd in March, the C2M family of SiC MOSFETs has been demonstrated to achieve over three times the power density of typical silicon technology in standard power supply designs, says Cree. The MOSFETs have been actively employed in solar inverters, industrial power supplies, battery chargers, uninterruptible power supply (UPS) systems and several other applications. The new 1200V and 1700V MOSFETs enable significant improvements in efficiency, reliability and/or power density, the latter of which can also lead to reductions in the size, weight, volume and, in some cases, even the total cost of power systems, claims Cree.

www.cree.com/power

ITAC honours GaN Systems' chief technology officer with Lifetime Contribution Award

John Roberts, co-founder & chief technical officer of 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 won the Information Technology Association of Canada (ITAC)'s 2013 Lifetime Contribution Award for "outstanding service to Canada's microelectronics industry". The ITAC is the voice of Canada's ICT industry and represents Canada's 33,000 high-tech firms, which together contribute $67.2bn to Canada's economy.

Roberts was given the award at ITAC's 19th National Executive Forum and CMC's 2013 Annual Microsystems Symposium in October by Steve Kovacic, director, technology at Skyworks Solutions Inc. Roberts' list of achievements includes founding two Ottawa-based semiconductor firms: Calmos (later Tundra) Semiconductor and SiGe Semiconductor. He also founded the Strategic Microelectronic Consortium (an alliance of 25 industry companies including Nortel, PMC Sierra, IBM, Gennum Corp, c-MAC MicroTechnology and other hybrid and semiconductor manufacturers.

Roberts' co-founded GaN Systems with CEO Girvan Patterson. The firm is introducing gallium nitride high-power transistors based on its proprietary Island Technology, which is claimed to offer significant advantages over traditional silicon devices and can yield smaller, lighter and more efficient power electronics. GaN devices are projected to secure a significant portion of the silicon-based semiconductor market within the next 3–5 years, says GaN Systems.

www.gansystems.com

GaN Systems showcasing power semiconductors at iPower 2013

GaN Systems exhibited and gave a paper at the iPower 2013 'Building A Smart Power Future' event at Warwick University, UK (27–28 November).

Organized by IMAPS-UK (the UK chapter of the International Microelectronics And Packaging Society) and NMI (the UK trade association for electronic systems, microelectronics and semiconductors) in conjunction with Warwick University's Electronics, Power and Microsystems Research Group, the second day was devoted to packaging and opportunities presented by higher-power, faster semiconductors for power conversion products. VP of business development Geoff Haynes presented 'Breaking the Bonds', highlighting performance gains in switching speed and potential junction operating temperature that GaN switches can bring.

He explored and discussed overcoming the challenges these new devices present and how to harness them to greatest effect, achieving savings through intelligent use of increased power during peak production.

At the exhibition, GaN Systems showcased its high-power transistors for clean power conversion applications based on its proprietary Island Technology. The new devices have low on-resistance and negligible charge storage, so switching efficiency performance is superior to existing silicon semiconductors, it is claimed.

http://uk.imapseurope.org

EPC demonstration board featuring eGaN FETs delivers high-quality audio in space-saving design

Efficient Power Conversion Corp of El Segundo, CA, USA, which makes enhancement-mode gallium nitride on silicon (eGaN) power field-effect transistors (FETs) for power management applications, has launched the EPC9106, a reference design for a 150W, 8Ω Class D audio amplifier. The demonstration board uses a bridge-tied-load (BTL) design, composed of four ground-referenced half-bridge output stages, allowing scalability and expandability of the design. All elements that can impact the sonic performance of Class D Audio systems are minimized or eliminated in an eGaN FET-based system, says EPC.

The EPC9106 features the EPC2016 eGaN FET in conjunction with the LM5113 100V half-bridge gate driver from Texas Instruments. The firm says the board demonstrates that high-quality sound can be achieved in a small size due to the performance capabilities of high-frequency-switching eGaN FETs when coupled with this dedicated eGaN driver. With this high efficiency, the EPC9106 design allows for the complete removal of any heat-sink requirement, which also reduces the potential contribution to radiated EMI/EMC emissions.

The power block of the EPC9106 — including eGaN FETs, driver, inductor and input/output caps — is a compact 2.1mm x 1.6mm layout. Despite this, the EPC9106 achieves 96% efficiency at 150W, 8Ω, and 92% efficiency at 250W, 4Ω.

http://epc-co.com

TriQuint adds GaN transistors with Modelithics design support to speed production while boosting performance

RF front-end component maker and foundry services provider TriQuint Semiconductor Inc of Hillsboro, OR, USA has announced five new second-generation gallium nitride (GaN) transistors with companion non-linear RF models from Modelithics Inc of Tampa, FL, USA, which provides active and passive simulation models for electronic design automation (EDA) using RF, microwave and millimeter-wave devices. The new devices and companion models enable quicker, more accurate performance testing, speeding production readiness and manufacturing for commercial and defense RF applications, says TriQuint.

The firm's new GaN field-effect transistors (FETs), with output power up to 90W, offer enhanced power-added efficiency (70% PAE or greater) and wideband frequency coverage (DC–18GHz). Enhanced efficiency and greater power density can reduce the number of transistors in amplifier designs while improving overall performance through reduced combining loses, says TriQuint. Semiconductor

The new GaN FETs include TGF2023-2-01, TGF2023-2-02, TGF2023-2-05, TGF2023-2-10 and TGF2023-2-20. The new non-linear modeling library was created by Modelithics. The two firms aim to expand the TriQuint GaN library in the coming months.

TriQuint's new models are available for download from Modelithics and are compatible with the industry's most popular design software including Agilent ADS and National Instruments/AWR applications.

Advanced features include scaling of operating voltage, ambient temperature and self-heating effects, as well as intrinsic voltage/current node access for waveform optimization.

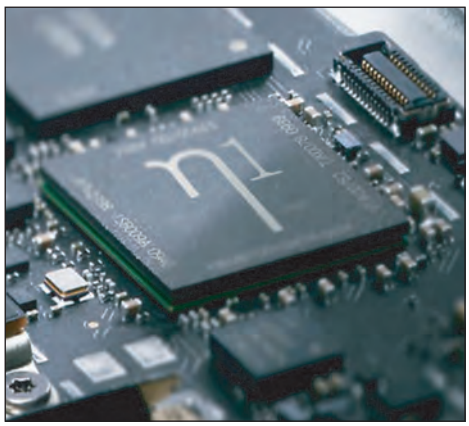
www.triquint.com
www.modelithics.com

Eta Devices launches GaN power amplifier to double mobile base-station efficiency

Fabless semiconductor firm Eta Devices Inc of Cambridge, MA, USA has announced availability of what it reckons is the most efficient power amplifier for mobile base stations, using new patented technology that exploits the performance capabilities of gallim nitride (GaN) switching power amplifiers (PAs), advanced supply modulation, and digital predistortion algorithms.

"Our power amplifier architecture brings real sustainability to the world's mobile operators," claims co-founder & CEO Mattias Åström. "We deliver 70% drain efficiency for 4G LTE — an industry first," he adds. "By deploying our solution, base-station efficiency is doubled compared to current state-of-the-art technology, which saves a tremendous amount of power."

Eta, which was spun off from Massachusetts Institute of Technology (MIT) but has an R&D office in Stockholm, Sweden, first demonstrated its new power amplifier technology at the 2013 Mobile World Congress in Barcelona in February.



Eta Devices' power amplifier for mobile base stations.

"Until today, mobile operators have not been able to build genuinely sustainable mobile networks," says MIT professor Joel Dawson, Eta's co-founder & chief technology officer. "They have had no choice other than to focus on relatively minor sustainability initiatives such as changing the vehicle fleet to improve fuel economy, office recycling and substituting some flights with video conferences. While commendable, these initiatives have not touched on the operators' core business of running mobile networks and as a result the impact has been relatively minor," he adds. "Operators can now double the efficiency of their mobile networks and realize substantial reductions in power usage, resulting in a major reduction in greenhouse-gas emissions, and at the same time huge cost savings from using less power."

On a global level, mobile networks consume about 120TWh of electricity per year. "If Eta Devices' solution is deployed on a worldwide basis by mobile operators, it would result in a reduction of greenhouse-gas emissions equivalent to taking more than 7 million cars off the road," says Åström. "It would also save mobile operators $18bn per year in utility costs, thereby paying for the replacement many times over."

Dawson gave the presentation 'Beyond Token Gestures — Delivering Sustainable Mobile Networks' at the Telco Energy & Infrastructure Conference in London, UK (13 November).

www.etadevices.com

Shibaura Institute of Technology chooses Silvaco's TCAD for simulation of GaN power devices

Yokohama-based Silvaco Japan Co Ltd — a branch of Silvaco Inc of Santa Clara, CA, USA, a provider of technology computer-aided design (TCAD), circuit simulation and electronic design automation (EDA) software tools — says that the Department of Electronic Engineering's Semiconductor Electronics Laboratory in the Shibaura Institute of Technology (SIT) has adopted Silvaco's Atlas device simulator for its research on gallium nitride (GaN).

SIT provides applied research on GaN compound semiconductors for power electronics (an area that is expected to grow considerably in the near future). Associate professor Kan Akatsu, director of theCenter for Power Electronics, decided to adopt the Atlas device simulator for its proven performance in compound semiconductor analysis, says Silvaco.

Atlas includes many models for electrical, thermal and frequency analysis that provide the high accuracy needed for compound semiconductor device simulation. It also includes a unique solver for compound semiconductor materials with wide bandgaps, resulting in high convergence of the simulation. Silvaco says that Atlas has been widely used in many companies, universities and R&D facilities for research and development of semiconductor devices created with new materials including compound semiconductors.

"For current R&D of GaN compound materials, a reliable device simulator is indispensable for optimizing the design incorporating the properties of each material," says Hiroyasu Ishikawa, associate professor of SIT in charge of the creation of wide-bandgap devices. "Silvaco's Atlas is the appropriate tool to satisfy our laboratory's needs, and I hope that Atlas will accelerateour research and development," he adds.

Silvaco's extensive experience in developing and providing device simulation solutions for semiconductor devices, especially compound devices, places it in a unique position position as a vendor for the simulation of power devices, reckons Silvaco's CEO David Halliday.

www.silvaco.com
http://global.shibaura-it.ac.jp/en/academics/college_of_engineering/electronic-engineering

Delta adopts Transphorm's 600V GaN power conversion

Transphorm Inc of Goleta, near Santa Barbara, CA, USA (which designs and delivers power conversion devices and modules) was invited to present at the exclusive Power Design Engineering event in Shanghai (22 November) of Taiwan-based manufacturer Delta Electronics Inc.

Transphorm presented its JEDEC-qualified gallium nitride on silicon (GaN-on-Si) high-electron-mobility transistor (HEMT) products and applications based on its proprietary EZ-GaN technology. Transphorm reckons that its participation as the only invited external supplier at the internal event, where Delta shared technology insights across a variety of areas at its Hangzhou Design Center (HDC) and Shanghai Design Center (SDC), will allow Delta's engineering force to proliferate the adoption of 600V GaN products in applications ranging from power supplies to various other inverters/converters, expects Transphorm.

With its TPH3006PS GaN HEMT, Transphorm has established what is claimed to be the industry's first qualified 600V GaN device platform. The GaN transistor combines low switching and conduction losses, offering reduced energy loss of 50% compared to conventional silicon-based power conversion designs, it is reckoned. The TO-220-packaged device features $R_{DS(on)}$ of 150mΩ, Qrr of 56nC, and high-frequency switching capability that enables compact lower-cost systems.

We have long recognized GaN as providing unprecedented power conversion efficiency as well as reduced-form-factor in systems. We look forward to realizing the benefits of GaN being implemented into real power products in the marketplace

"We have long recognized gallium nitride as providing unprecedented power conversion efficiency as well as reduced-form-factor in systems," says Dr Alpha Zhang, director of Delta SDC/HDC and vice chairman of the China Power Supply Society. "With the proof that high-voltage GaN-on-Si is qualified and available for production, we look forward to realizing the benefits of GaN being implemented into real power products in the marketplace."

Transphorm says that its efficient, compact and easy-to-embed modules simplify the design and manufacturing of a wide variety of electrical systems and devices, including power supplies and adapters, motor drives, and inverters for solar panels and electric vehicles. It claims that its proprietary EZ-GaN platform can reduce power system size, increase energy density and deliver high efficiencies across the grid.

www.transphormusa.com
www.deltaww.com

Ammono granted ESA funding to develop large-size semi-insulating GaN substrates

Ammono S.A. of Warsaw, Poland, which produces bulk gallium nitride (GaN) using ammonothermal technology, has been granted a contract by the European Space Agency (ESA) with the aim of developing large-size semi-insulating gallium nitride (GaN) substrates dedicated for space applications.

GaN is a key material for boosting the performance of space-related electronics, says Ammono. One of its main advantages is a strong robustness against ionizing radiation effects, which can degrade the performance of electronics in space and reduce their operating life-time. In addition, the higher power density and higher efficiency offered by GaN allows miniaturization of electronic payloads, leading to reduced mass and volume of electronics systems launched in space. Last but not least, compared with the existing generation of space electronics based on gallium arsenide (GaAs), GaN enables operation of devices at higher frequencies and higher power (essential for long-distance space communications), notes Ammono.

The main electronics application areas are in transistors for RF communication and DC–DC power conversion applications. However, a promising new application is also in the area of GaN-based solar cells, since they allow the possibility of generating more energy per square centimeter than offered by existing solutions, says the firm.

The main electronics application areas are in transistors for RF communication and DC–DC power conversion applications. However, a promising new application is also in the area of GaN-based solar cells

For space applications the material quality is of key importance. AMMONO-GaN substrates, which the firm claims have the best quality available on the open market, have extremely low dislocation density. This characteristic can potentially improve the reliability of devices, which is important for space application, says the company. AMMONO-GaN therefore fits with the high-performance requirements of space applications, and is the first step towards the design of a novel generation of space electronics, reckons Ammono.

www.ammono.com

Veeco Q3 revenue flat sequentially, down 25% year-on-year

Profits hit by low demand and pricing pressure for MOCVD

For third-quarter 2013, epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA has reported revenue of $99.3m, down 25% on $132.7m a year ago but up just 2% on Q2's $97m (albeit a significant improvement from Q1's $62m).

Data Storage revenue was $24.3m (24% of sales), down 28% on $33.8m a year ago but up 13% sequentially. LED & Solar revenues were $75m (76% of sales), down 24% on $98.9m a year ago. Of this, metal-organic chemical vapor deposition (MOCVD) contributed $68m (flat sequentially) and molecular beam epitaxy (MBE) $7m.

End-Market Trends Still Muted

MOCVD/LED:
- Top customers' utilization rates stable and high (80-90%+)
- Some pick-up in LED customer financial results and business confidence
- BUT… customers remain cautious on capacity expansion

MBE:
- Deal funnel is improving for R&D; starting to increase our win rate
- Wireless market still digesting capacity – unclear when demand returns; orders remain depressed

Data Storage:
- Strong data center growth and some reports that PC units may have "bottomed"
- Slow absorption of capacity - **no capacity buys in Q3 '13**
- Customers making strategic investments to enable areal density growth (HAMR and other next-gen technology)

"Third-quarter 2013 results were impacted by persistent overcapacity and weak business conditions in our MOCVD and Data Storage businesses," says chairman & CEO John R. Peeler. In addition to low volumes, gross margin remains under pressure from intense pricing pressure in MOCVD (falling further, from 37% in Q1 and 36% in Q2 to 31% in Q3). "While we continue to take manufacturing costs out of MOCVD and other products, it is too difficult to swim against the tide of dramatically lower prices coming from the competition," comments Peeler. "Due to our MOCVD systems' market leadership and cost of ownership advantage, we do generally command a premium pricing in the market. Nonetheless, our selling prices for both single-chamber and cluster systems are much lower than historic levels."

Operating expenses (OpEx) has been flat all year ($42m in Q1, $41m in Q2, $40m in Q3), but that has included the cost of the firm's accounting review (about $3–4m per quarter — about $15m in total through Q3/2013).

On a non-GAAP basis, adjusted EBITA (earnings before interest, taxes and amortization) has deteriorated further, from +$14.2m a year ago and –$2.2m last quarter to –$5.1m, with LED & Solar making a loss of $1.7m (compared with profits of $3.1m last quarter and $9.5m a year ago), due mainly to the low volumes and weaker MOCVD selling prices. Net loss has grown to $3m, compared with $1.3m last quarter and net income of $11.7m a year ago. Nevertheless, Veeco's cash balance (cash and short-term investments) has fallen by just $6m from year-end 2012 to $573m at the end of Q3, as losses have been offset by strong working capital management.

Order bookings rose to $91.5m, up 7.6% on $85m last quarter and 9.3% on $83.7m a year ago. LED & Solar orders were $73.5m, up 8.4% on $67.8m a year ago and 27% on $58m last quarter.

Of this, MOCVD bookings rose 28% from $52m last quarter to $67m (80% of total bookings), up on $63m a year ago but still at 'trough' levels. However, "this continues to represent incremental capacity adds from just a handful of customers," says Peeler. "LED fab utilization rates appear to be relatively stable and high at all of our key accounts [80–90%+]. Many of our top customers are reporting improved profitability and are optimistic about the future of the LED market. But overall, they are cautious about expanding capacity," he adds. "In Q3, we won key MOCVD deals from a top Taiwanese customer for one of their Chinese factories and from the global GaN-on-silicon leader in Japan… We are winning the most important deals, but we have not yet seen a recovery in MOCVD demand," says Peeler.

"Production orders for MBE and Data Storage systems also remain elusive," Peeler adds. MBE bookings were $7m (up just 12% on $6m last quarter and up on $5m a year ago). "Production orders remained low due to manufacturing overcapacity, but we're doing well in the R&D applications." Data Storage bookings were $18m, up on $15.9m a year ago but down by a third on $27m last quarter (and falling to 20% of total bookings).

For Q4/2013, Veeco expects revenue to fall to $65-75m due to the low level of system shipments in both MOCVD and Data Storage. "Bookings are currently expected to be weak," notes chief financial officer

& executive VP David D. Glass. "In MOCVD, there are a couple of factors that are contributing to the weak quarter. About 35–40% of backlog is coming from service contracts, which often take longer to turn into revenue than tool shipments. There are a couple of China deals in our backlog that are converting to revenue slowly," he adds. "We continue to focus on winning the key strategic deals, which we have done very successfully so far."

Given the low revenue expectation and continuing pressure on selling prices, margins should be weaker. OpEx will rise, as Veeco sees some continuing tail costs related to the accounting review completed in Q3, while beginning to bring on new costs related to the acquisition of Synos Technology Inc — now Veeco ALD Inc, which makes Fast Array Scanning Atomic Layer Deposition (FAST-ALD) systems for the production of flexible organic light-emitting diode (OLED) displays for mobile devices — at the beginning of October. "Unfortunately, we do expect to see losses for the next few quarters," cautions Glass.

"While business conditions have remained challenging throughout 2013, we remain positive about long-term trends in LED lighting and our new opportunity in flexible OLED encapsulation for mobile phones," says Peeler. "Success will come from top-line revenue growth. We are willing to run Veeco at a loss for a few quarters to seize on the market opportunities.

"Chinese customers like Sanan Optoelectronics and HC SemiTek, who were formerly relegated to the low-power LED world, have become established players in the mid-power space. Top Korean and Taiwanese customers are also improving their brightness and cost efficiency and are making significant inroads into the high-power market," he adds. "Many of Veeco's top customers are reporting strong demand for mid-power LEDs for indoor replacement bulbs and for high-power LEDs for outdoor lighting. All this movement up the LED food chain will have a disruptive effect on supply and demand dynamics, and it will drive down residential light bulb prices and will ultimately drive the tipping point for lighting," Peeler forecasts.

Chinese customers, who were formerly relegated to the low-power LED world, have become established players in the mid-power space

"We also think GaN power electronics has great potential for energy efficiency, electric vehicles and other applications," says Peeler. "We recently created a new core R&D group and staffed it with some of our best talent. This group will work with our business unit R&D teams to explore and execute on initiatives that penetrate adjacent markets such as new ALD applications," he adds.

"Our strong R&D capability, technology leadership position, world-class sales & support organization, flexible manufacturing approach and solid balance sheet provide a strong foundation for the future," believes Peeler. "We will continue to look for businesses and technology acquisitions to accelerate our growth."

Redsolar buys multiple Veeco K475 MOCVD systems

China-based concentrated photovoltaic (CPV) solar cell maker Guangdong Redsolar Photovoltaic Tech Co Ltd has purchased multiple Veeco TurboDisc K475 As/P metal-organic chemical vapor deposition (MOCVD) systems (fully integrated deposition tools that create compound semiconductor layers for CPV devices). Redsolar is already operates several TurboDisc K475 MOCVD systems that were purchased in 2012.

"China's appetite for highly efficient green energy sources remains strong," says Redsolar's general manager Dr Ji. "Veeco's proven, best-in-class MOCVD systems reduce the production costs of CPV solar cells and allow us to easily ramp production in a modular way with supreme reliability at the lowest cost of ownership," he adds.

Veeco's TurboDisc K475 As/P MOCVD system.

"The K475 is the perfect choice for concentrated solar cells because our critical integrated reactor design produces excellent uniformity and repeatability with the highest uptime between maintenance," reckons Jim Jenson, senior VP & general manager of Veeco's MOCVD System Operations. "All those features lead to unmatched product yield and throughput."

The TurboDisc K475 is equipped to maximize uptime and throughput by leveraging Veeco's technology (as the leader in the GaN LED market) and integration of critical reactor design elements. Elements include a tunable FlowFlange, advanced RealTemp 200 temperature control and ultimate TurboDisc high-velocity laminar flow, along with an integrated system load-lock that remains under constant vacuum to minimize downtime between runs.

www.veeco.com/mocvd

LayTec's EpiCurve TT improves HVPE GaN growth at Ulm

LayTec AG of Berlin, Germany, which makes in-situ metrology systems for thin-film processes, focusing on compound semiconductor and photovoltaic applications, says that researchers at Germany's Ulm University have used LayTec's EpiCurve TT in-situ system in their work on growing think (1mm and more) gallium nitride (GaN) layers using hydride vapor phase epitaxy (HVPE).

A major challenge to growing thick GaN layers by HVPE is the bowing of the free-standing GaN after its self separation from the sapphire substrate. Martin Klein and his colleagues at Ulm University have proved that the initial strain of the MOVPE template has a great impact on the final bowing of HVPE samples and on the remaining curvature of separated GaN wafers. See: M. Klein in Annual Report 2012, University of Ulm, pp. 83–90 — www.uni-ulm.de/in/opto/forschung/jahresberichte.html

To optimize the template conditions, the researchers used in their MOVPE process a combination of an oxygen doped AlN nucleation layer, GaN buffer and a sub-monolayer of SiNx mask. With LayTec's EpiCurve TT, they monitored the related curvature changes during growth (Figure: 1). By variations of the growth conditions of the AlN nucleation and the subsequent GaN buffer layer, the curvature of the templates could be varied between tensile and compressive strain. Under optimized conditions, a fairly flat template could be produced (Case C), thereby being optimized for the subsequent HVPE growth.

Applying their newly acquired understanding of the MOCVD / HVPE strain effects, researchers in Ulm plan to use pre-curved sapphire wafers as templates to produce GaN wafers with zero bow

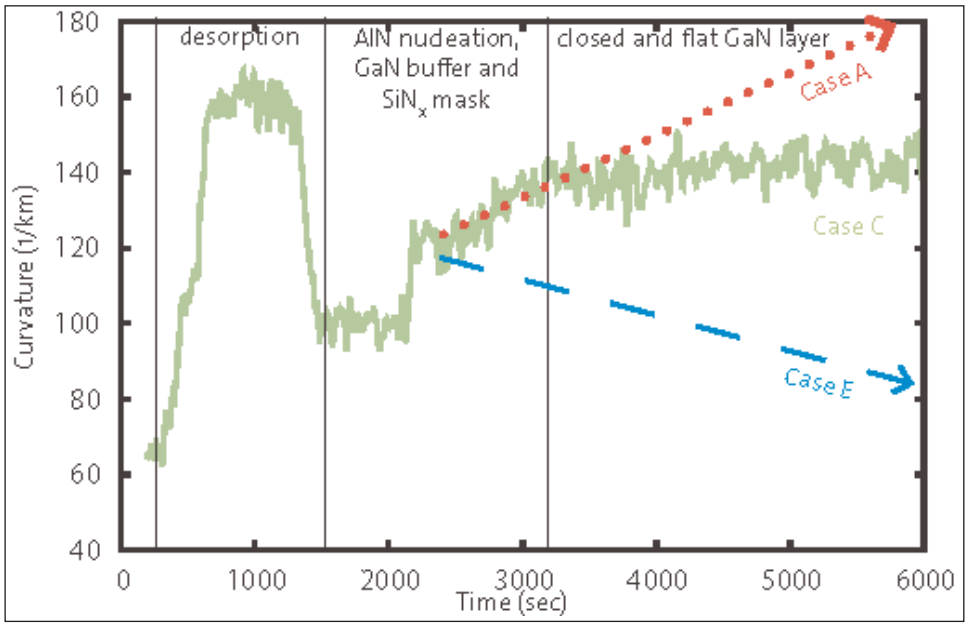


Figure 1: In-situ curvature measurements during MOVPE template growth on sapphire. A, C, E correlate to Figure 2.

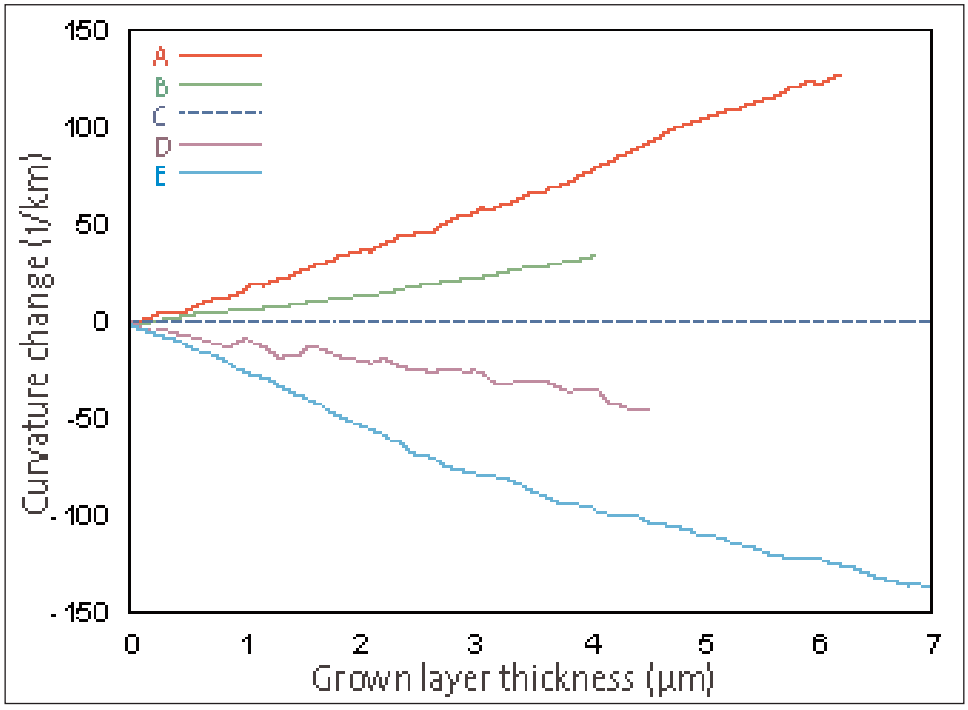


Figure 2: In-situ curvature data during overgrowth in HVPE. Lines A–E: identical growth runs on different templates.

Figure 2 shows EpiCurve TT measurements during the subsequent HVPE growth. Lines A, C, E refer to the related template procedures in Figure 1. B and D relate to intermediate AlN buffer thickness. All samples showed the same HVPE curvature evolution as their MOCVD templates. In the end, the final separated GaN layers grown on optimized C-type templates had low curvature values (100–200km^{-1}) regardless of their thickness.

As the next step, applying their newly acquired understanding of the MOCVD/HVPE strain effects, researchers in Ulm plan to use pre-curved sapphire wafers as templates to produce GaN wafers with zero bow.

www.laytec.de

Aixtron hosts MOCVD seminar at China SSL 2013

Deposition equipment maker Aixtron SE of Aachen, Germany says that, at its MOCVD Seminar at the 10th China International Forum on Solid State Lighting (China SSL 2013) in Beijing (10–12 November) — organized by the China Solid State Lighting Alliance (CSA) — LED makers presented practice-oriented production results based on Aixtron's current system generations. The potential of organic light-emitting diodes (OLED) was also the subject of much discussion at the conference.

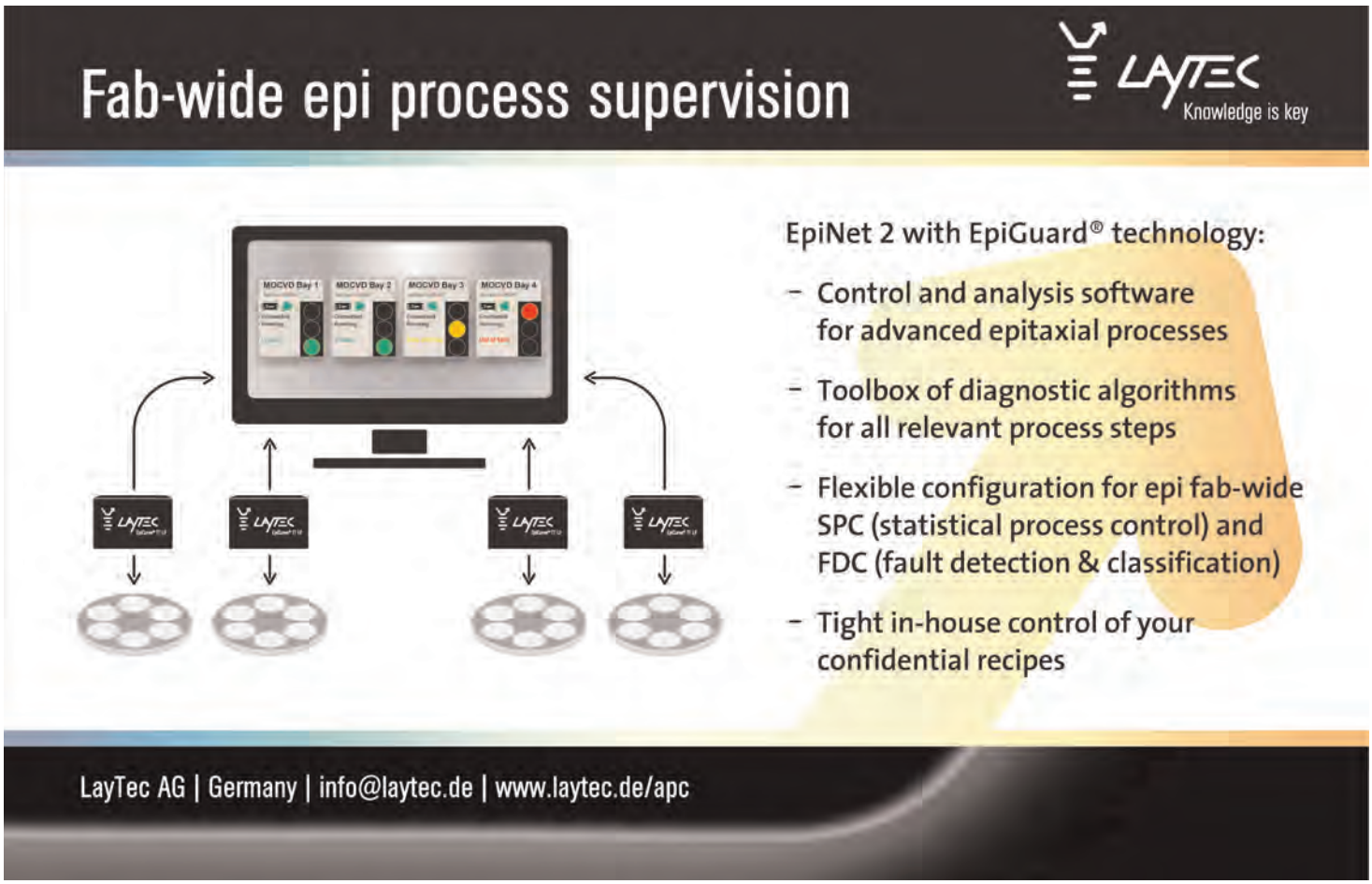
"I am delighted to have some of our key customers, such as Nantong Tongfang Semiconductor, Nanojoin Photonics and Changelight, hold presentations on actual production data achieved on our systems," said Tim Wang, general manager of Aixtron China Ltd, to 180 guests. "They covered our main products which are widely used in China including AIX G5 HT, CRIUS II-XL and AIX 2800G4 systems," he added.

Martin Goetzeler and Tim Twang.

"The adoption of LEDs within the general lighting market is progressing rapidly. To support our customers in enhancing their competitiveness, we have intensified our technical customer service and our efforts to increase productivity," stressed CEO Martin Goetzeler in his speech. "This is being positively received in China, one of our most important markets for LED manufacturing equipment." Aixtron was the first foreign guest member to be admitted to the China Solid State Lighting Alliance.

"Alongside LED production-related topics, such as yield improvement, low production costs and increasing throughput, Aixtron is working closely on new cost-effective production technologies for use in organic electronics," stated chief technology officer Andreas Tönnis. In first-quarter 2014, Aixtron's organic cluster system (with multiple process modules for the deposition of organic materials on 200mm x 200mm substrates) will be put into operation. The new cluster will allow the demonstration of deposition processes for organic thin films at the device level and in a production-like environment. Aixtron claims that its OVPD technology enables the production of OLED devices with very high deposition rates at attractive manufacturing costs compared with conventional vacuum deposition processes.

www.aixtron.com
www.sslchina.org



IN BRIEF

ALD and ion beam workshop at UCSB

Hosted by University of California Santa Barbara, on 12 November Oxford Instruments Plasma Technology held a technical workshop addressing the latest developments in atomic layer deposition and ion beam etch and deposition.

Experts from Oxford Instruments and UCSB presented the following:

- An introduction to plasma and thermal ALD techniques;
- ALD hardware developments;
- An introduction to ion beam technology;
- Ion beam etch – a users perspective;
- Ion beam developments;
- ALD process (metal & nitride);
- ALD – a user's results; and
- Ask the experts, Q & A and ion beam & ALD process posters.

www.oxford-instruments.com

OIPT's plasma systems installed at University of Science and Technology of China's Nanotechnology Center

UK-based etch, deposition and growth system maker Oxford Instruments Plasma Technology (OIPT) is currently installing several PlasmaPro plasma etch and deposition tools at the University of Science and Technology of China (USTC)'s Nanotechnology Center to facilitate its fundamental research on micro- and nano-scale technology. Based in Hefei, An'hui province, east China, USTC's nanofabrication facility aims to drive collaborative, interdisciplinary and fundamental research in the micro- and nano-scale.

The Nanotechnology Center recently ordered a PlasmaPro100 ICP380 system for silicon etching, a PlasmaPro80 RIE advanced etching tool for SiO_2 and SiN_x etching, and a PlasmaPro100 PECVD system for SiO_2 and SiN_x deposition. "These systems will be used to replicate and form various nanostructures on wafers, which is highly critical in several nanoscale science fields including quantum physics, quantum information, nano-materials and nano-chemistry," says Dr Zhu Xuelin. "We chose Oxford Instruments tools as they could provide the multiple leading-edge technologies, excellent process flexibility and capabilities, backed by the effective customer support offering that USTC expects," he comments.

"At USTC, researchers are pushing the limits in nanoscience, nano-engineering, and nanotechnology to create novel materials, structures, and devices," comments Dr David Haynes, sales & marketing director at Oxford Instruments.

www.oxford-instruments.com

Picosun launches 150–200mm wafer batch atomic layer deposition tool

Atomic layer deposition (ALD) equipment maker Picosun Oy of Espoo, Finland has launched the P-200 batch ALD system, specifically optimized for fast and efficient manufacturing of MEMS (micro-electro-mechanical systems, e.g. sensors and actuators), LEDs, and power electronics components.

The P-200 ALD tool is designed for 150mm- or 200mm-diameter wafers in batches of 25. Picosun says that the cornerstones of its ALD system design — unmatched versatility, modularity and flexibility — are manifested in the variety of automation options available for the P-200: the system can be equipped with a linear inline loader, operated with an industrial robot, connected to a vacuum robot, or integrated with a vacuum load lock, glove box or mini clean environment. Quick, fully automated batch processing enables high production throughput with proven process quality and low cost-of-ownership, claims the firm.

The P-200 ALD system has already been accepted by two production customers for MEMS and selected by two prominent LED makers, says Picosun. With the P-300 and P-1000 ALD systems launched previously, Picosun now offers a full range of industrial batch production tools to suit every size of wafer and production volume.

"The compact, small-footprint design of the tool, combined with extremely fast batch processing and excellent film quality, give us an unrivaled competitive edge," reckons managing director Juhana Kostamo.

www.picosun.com

IN BRIEF

Liquid flow sensor for 0–120ml/min

Digital microsensor and system maker Sensirion AG of Staefa, Switzerland says its SLQ-QT500 liquid flow sensor can be used to monitor coating processes with a variety of liquids.

"The sensor is suitable for measuring hydrocarbon-based solvents such as photoresists, as well as water-based liquids such as TARC and H_2O_2," says Dr Andres Laib, director of sales Liquid Flow Products. "Liquids with virtually any viscosity [100,000cP and more] as well as liquids which contain particles can be measured.". Based on patented CMOSens technology, flow rates span 0–120ml/min.

www.sensirion.com/slq-qt500

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IN BRIEF

Integra approved by USA's Defense Logistics Agency for MIL-STD-750 processing

Semiconductor test and services firm Integra Technologies says that its facility in Wichita, KS, USA has been approved by the US Defense Logistics Agency (DLA) Land and Maritime to support screening to MIL-PRF-19500P and MIL-STD-750. The approval covers 76 individual test methods.

Additionally, Integra claims to be the only test lab to have MIL-STD-750 suitability for the following test methods:

- 1036 — Intermittent Operation Life;
- 3261 — Extrapolated unity-gain frequency;
- 3475 — Forward transconductance of power MOSFETS or IGBT;
- 3501 — Breakdown voltage, drain-to-source;
- 3505 — Maximum available gain of a GaAs FET;
- 3510 — 1dB compression point of a GaAs FET;
- 3570 — GaAs FET forward gain (Mag S21);
- 3575 — Forward transconductance.
- 4101 — Conversion loss.

"When this capability is added to our existing extensive MIL-STD 883 capability, and combined with our recent purchase of Analytical Solutions Inc [which provides semiconductor device evaluation services through destructive physical analysis, construction analysis, failure analysis, non-destructive testing and counterfeit device investigation], we now have one of the industry's broadest semiconductor test and evaluation service offerings," reckons president Becky Craft.

www.integra-tech.com

EVG launches non-contact lithography system for cost-efficient volume production of photonic components

EV Group (EVG) of St Florian, Austria, a supplier of wafer bonding and lithography equipment for MEMS (microelectromechanical systems), nanotechnology and semiconductor applications, has introduced the EVG PHABLE exposure system, which is designed specifically for manufacturing photonic components.

The system incorporates what is claimed to be a unique contactless lithography mask-based approach that enables full-field, high-resolution and cost-efficient micro- and nano-patterning of passive and active photonic components, such as patterned structures on light-emitting diode (LED) wafers, in high-throughput production environments.

The EVG PHABLE exposure system is the first fully automated production equipment to feature PHABLE (photonics enabler) technology from Eulitha AG (a spin-off of the Paul Scherrer Institute in Villigen, Switzerland that develops lithographic technologies for optoelectronics, photonics, biotechnology and data storage applications). Integrating Eulitha's full-field exposure technology with EVG's established nanolithography production platform provides a unique solution for the automated fabrication of photonic nanostructures, the firms say.

The new system combines the low cost-of-ownership, ease-of-use and non-contact capabilities of proximity lithography with the sub-micron resolution of lithography steppers to provide low-cost automated fabrication of photonic patterns over large areas. This makes it suitable for patterned sapphire substrates (PSS) or to enhance the light extraction (and thus the efficiency) of LED devices, says EVG. The system includes a unique Displacement Talbot Lithography approach that enables it to produce features ranging from 3 microns down to 200nm with effectively no depth-of-focus limitation or stitching effects that can arise from using steppers on substrates with rather poor total thickness variation. It can hence be used to pattern substrates up to 6-inches in diameter in a single exposure step. This approach also enables the system to maintain consistently high patterning throughput (independent of the size of the processed wafer) as well as very large exposure gaps (up to several hundreds of microns) between the mask and wafer, thereby avoiding process-related mask contamination.

"We are excited to enter the commercialization phase of our collaboration with Eulitha," says Hermann Waltl, executive sales & customer support director at EVG. "The EVG PHABLE system broadens EVG's micro- and nanopatterning process portfolio, providing a unique, very cost-efficient solution to our customers in the LED, optics and photonics markets," he adds. "The novel equipment clearly demonstrates the synergies of our respective technologies."

The EVG PHABLE system can produce both one-dimensional patterns (such as lines and spaces) as well as two-dimensional patterns (such as hexagonal or square lattices). Thus, it supports a variety of approaches to enhance light extraction from LEDs. These include LED surface structuring, PSS, photonic crystal applications, nano-wire LEDs and optical gratings.

EVG says that the system can also be configured for photovoltaic, optics or biomedical manufacturing applications.

www.eulitha.com
www.EVGroup.com

OEM Group opens expanded facility in Japan

Semiconductor capital equipment provider OEM Group of Phoenix, AZ, USA has opened its new Sales and Service Center in Yokohama, Japan.

Operating from this strategic central location, OEM Group Japan G.K. has doubled its staffing in the last four years. The new location is 2.5 times larger than the previous office opened in 2010. From this facility, OEM provides parts distribution throughout Japan for all of its customers, along with field service, a technical call center and sales support. Additional space also allows for repairables services for critical equipment subassemblies and capital equipment refurbishment and reconfiguration. With increasing demand for its LEGENDS product portfolio in Japan, the larger facility provides the infrastructure for meeting customers' needs, says the firm.

Attending the opening ceremony were executives from OEM's largest customers, executives from Applied Materials Japan (with whom OEM partners to service the Varian Semiconductor ion implant market throughout Japan), and OEM Group board member Graham Stone.

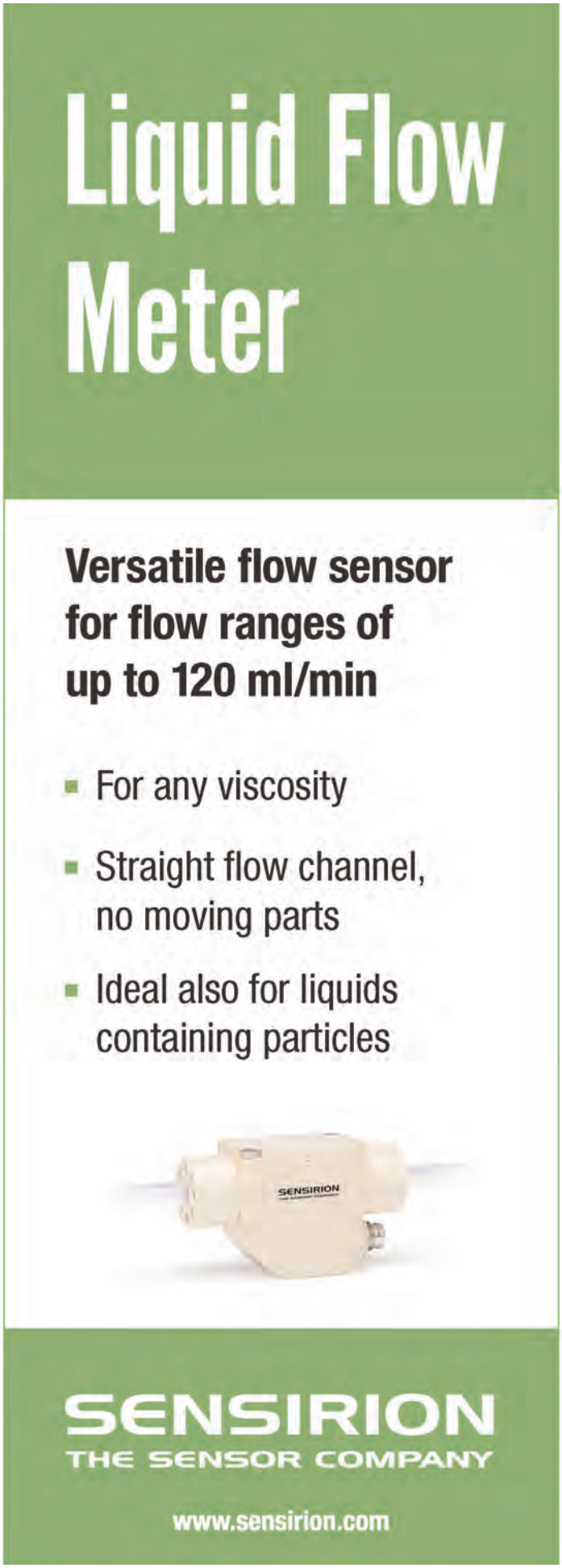
"Our semiconductor equipment product offering has expanded from an initial single product line to the current range of 15 different lines," said OEM Group Japan's president Takao Inagawa. The LEGENDS technology portfolio is based on exclusive intellectual property acquired from semiconductor brands, including: P5000, Tegal Etch, Sputtered Films Endeavor, AMS, MRC Eclipse, AGHeatpulse, Varian Sunset, Lam AutoEtch and Applied Materials–Semitool surface preparation equipment.

"In addition to the Japan head office, we have established a service office in Osaka, and a support base in Kumamoto in southern Japan," Inagawa added. "We have now achieved the scale to respond to a wide variety of customer needs."

OEM Group says that the facilities in Japan — and the openings of a Sales and Service Center and separate Manufacturing Center in Taiwan in October — demonstrate its commitment to customer service throughout the Asia-Pacific region, and accelerate the firm's momentum in introducing product lines to emerging markets.

"OEM Group is the industry's leader in supporting legacy capital equipment product lines," claims CEO Wayne Jeveli. "Through strategic acquisitions and licensing agreements, we now exclusively own and operate 15 'best-in-class' product lines globally. That includes owning and enhancing the intellectual property of each product line; and supporting customers with a dependable continuous supply of certified spare parts, qualified and experienced field service, engineering support, upgrade kits, and new and remanufactured equipment," he adds. "Our install base of over 33,000 systems has become a critical component of the industry's shift to Asia-Pacific," Jeveli reckons. "As our markets evolve, OEM Group will also evolve, by establishing world-class infrastructure."

www.oemgroupinc.com

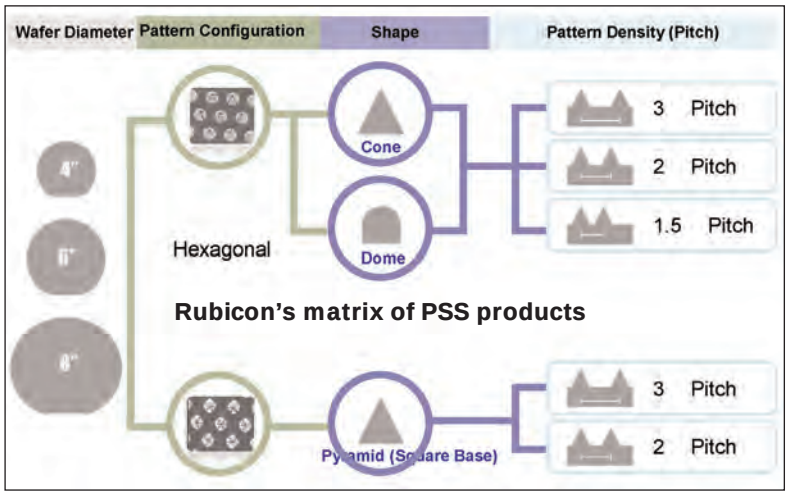


Rubicon launches first commercial large-diameter patterned sapphire substrates for LEDs

Highly customizable PSS improves light extraction

Rubicon Technology has launched what it claims is the first commercial line of large-diameter patterned sapphire substrates (PSS) in 4-inch through 8-inch diameters. The new products provide LED chip makers with a ready-made source of large-diameter PSS to serve the needs of the rapidly growing LED general lighting industry, says the firm.

The LED general lighting market is expected to grow from nearly 300 million lamps shipped in 2012 to 3 billion by 2020, according to market analyst firm IMS Research. Technology innovation is helping the LED supply chain prepare for this dramatic growth. Most high-brightness LED makers etch a pattern into the sapphire wafers in order to both improve epitaxial growth and extract more light from each chip. Patterned sapphire substrates have been available for purchase in smaller diameters, but Rubicon claims to be the first to offer highly customizable 6" and 8" PSS, increasing chipmakers' throughput and efficiency.



Rubicon's matrix of PSS products

"As LED-based general lighting gains worldwide adoption, large-diameter patterned sapphire substrates will become necessary to meet the demands of the rapidly growing lighting market," says president & CEO Raja M. Parvez. "Rubicon has developed an unmatched technology platform that is vertically integrated from raw material through crystal growth, large-diameter polished wafers, and now custom PSS in 4", 6" and 8" diameters," he adds. "Our vertical integration enables Rubicon to produce progressively larger sapphire products while providing customers with exceptional quality, cost control, reliability and consistency."

Rubicon offers fully customizable sub-micron patterning capability with tight dimensional tolerances (within ±0.1μm). The firm adds that, with an edge exclusion zone as small as 1mm, it offers more usable area to maximize the number of chips per wafer. Patterning is available in a range of shapes including cone, dome and pyramid, and in a range of orientations. Further customization of geometry, pattern and orientation is available upon request.

Rubicon appoints senior VP of sales & marketing

Rubicon Technology Inc of Bensenville, IL, USA (which makes monocrystalline sapphire substrates and products for the LED, RFIC, semiconductor and optical industries) says that Warren S. Stewart III has joined the firm as senior VP of sales & marketing, providing leadership to the global sales and marketing team and reporting to president & CEO Raja M. Parvez.

Stewart was VP, sales, at LED chip, lamp and lighting fixture maker Cree Inc in Durham, NC from 2005 to 2013, and was employed by Cree since 1997 in increasingly responsible sales management roles. Previously, following his service as an officer in the US Navy, he gained international experience in advanced materials with Superior Graphite Co. He earned an M.B.A. degree from the International University of Japan in Niigata-ken, and a B.S. degree from the United States Naval Academy in Annapolis, Maryland.

"Warren Stewart's experience forging strong relationships with leading manufacturers in the LED industry and driving sales growth make him an excellent addition to Rubicon at this pivotal stage," believes Parvez. "With the recent launch of our line of large-diameter patterned sapphire substrates (PSS), we are bringing an all-new value proposition to the world's most sophisticated LED chip-makers. Warren's depth of industry experience and his proven leadership skills will provide an advantage in the further development of our global customer relationships," he adds.

"Rubicon's reputation in the sapphire industry for product quality, innovation, and reliability has created an excellent platform for the next stage in the company's development," comments Stewart. "Rubicon is facilitating even greater efficiency for its LED customers with large-diameter polished wafers and PSS and, at the same time, is enhancing its capabilities for premium-quality optical sapphire."

www.rubicontechnology.com

BluGlass commissions former production MOCVD system to grow MQW base structures

BluGlass Ltd of Silverwater, Australia has increased its operational capacity by commissioning a former production Thomas Swan metal-organic chemical vapour deposition (MOCVD) system capable of producing 19x2" (or 5x4" or up to a single 8") LED wafer/s in a single growth run. The system has been commissioned and qualified to grow the multi-quantum well (MQW) base structures required for the demonstration of the Brighter LEDs milestone. This involves demonstrating LED performance improvement by growing low-temperature remote-plasma chemical vapor deposition (RPCVD) p-GaN on top of MOCVD grown multi-quantum wells (see Figure 1).

InGaN quantum wells are prone to degradation at elevated temperatures in the subsequent MOCVD grown p-GaN process steps, resulting in a loss of LED brightness. Growing the p-GaN layer at lower temperatures with RPCVD instead of MOCVD should reduce the MQW degradation, hence resulting in a brighter LED, says the firm.

"This system will give BluGlass control of the whole LED structure required for the company to demonstrate an LED performance lift with RPCVD grown p-GaN on MOCVD grown wafers," says chief technology officer Dr Ian Mann. "The key focus of having both MOCVD and RPCVD capability under one roof will be to demonstrate a successful integration of RPCVD and MOCVD to obtain better light output. In addition, it will assist in the performance comparison of the two technologies."

BluGlass recently took delivery of a second MOCVD system, which will be installed and reconfigured as an RPCVD system. According to BluGlass, this second system will further accelerate the firm's RPCVD development and will assist in demonstrating the scalability of RPCVD technology from its current 7x2" deposition capability to a 19x2" (or up to a single 8") wafer deposition capability.

This new MOCVD resource will enable us to simplify this development process by giving the technology team full flexibility of MOCVD run cycles, but also by eliminating the lead-time required to obtain templates from overseas suppliers

The commissioning of the new tools will now enable multiple programs (including GaN on silicon) to proceed simultaneously at the Silverwater facility. BluGlass will also target revenue generation by producing wafer templates as an early market entry point to boost acceptance of RPCVD technology by building credibility in the market place.

"Having multiple programs in place simultaneously will significantly expedite our technology progress," says CEO Giles Bourne. "Our primary goal remains now to demonstrate that low-temperature RPCVD has the ability to produce brighter LEDs," he adds. "This new MOCVD resource will enable us to simplify this development process by giving the technology team full flexibility of MOCVD run cycles, but also by eliminating the lead-time required to obtain templates from overseas suppliers."

www.bluglass.com.au

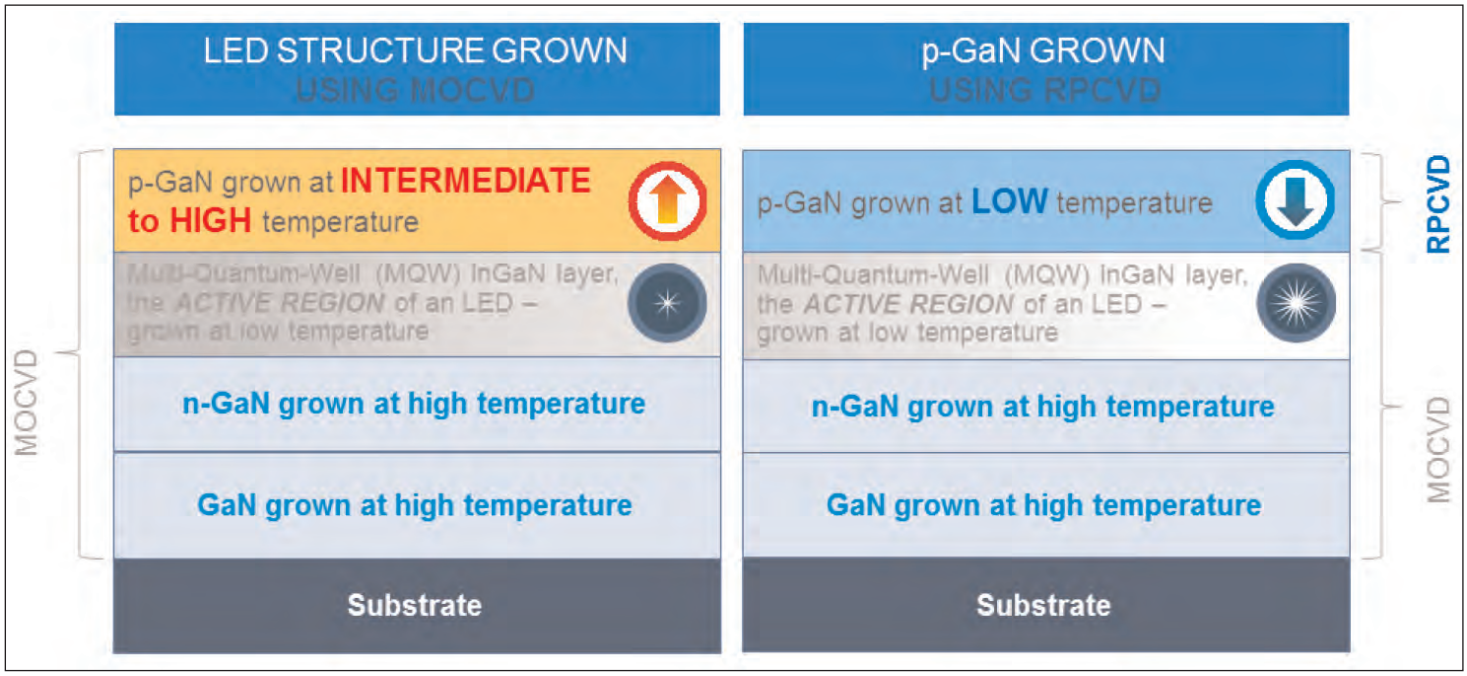


Figure 1: Using low temperature p-GaN to achieve brighter LEDs.

Soraa expanding with new LED fab in New York State

Partnership with SUNY College of Nanoscale Science and Engineering aids control of product quality and IP

Soraa Inc of Fremont, CA, USA, which develops solid-state lighting technology built on 'GaN-on-GaN' (gallium nitride on gallium nitride) substrates, is to open a new semiconductor fabrication plant in Buffalo, NY. In partnership with the State of New York, the firm will construct a new GaN-on-GaN LED fab that is projected to be operational in 2015 and will employ hundreds of workers. Soraa currently operates an LED fab in Fremont.

"We chose Buffalo as the best location for our new fabrication facility based on several factors, including the innovative high-tech vision and strategy of Governor Cuomo; the ability to attract some of the best and brightest scientists and engineers in the world; and the capacity to tightly control the product quality and intellectual property around our LEDs through our partnership with the SUNY College of Nanoscale Science and Engineering (CNSE)," explains president & chief operating officer Dr Tom Caulfield. "With the new facility, our LED lighting capabilities will be refined and expanded, product innovation will accelerate, and light quality and efficiency will continue to improve," he expects.

"Under the largest investment in our Buffalo Billion initiative, we are building a state-of-the-art campus to house high-tech and advanced manufacturing companies that will create hundreds of jobs and leverage over a billion dollars in private investment for Western New York," Governor Cuomo says. "This [Soraa] project marks a giant step forward in our Buffalo Billion strategy, transforming a once vacant property into a development-ready site that will create good-paying permanent jobs, make Buffalo an international hub for innovation, and attract more businesses from around the world," he adds.

We chose Buffalo as the best location for our new fabrication facility based on several factors, including... the capacity to tightly control the product quality and intellectual property around our LEDs through our partnership with the SUNY CNSE

Soraa was founded in 2007 by University of California Santa Barbara (UCSB) professors Shuji Nakamura (developer of the blue laser and LED), Steven DenBaars (founder of Nitres) and James Speck (of UCSB's College of Engineering) on the basis that GaN-on-GaN LEDs would produce more light per area of LED and be more cost-effective than technology based on established foreign substrates such as sapphire or silicon carbide (SiC). Now, Soraa's LEDs emit more light per LED material than any other LED; handle more electric current per area than any other LED; and the firm's crystals are up to 1000 times more precise than any other LED crystal, it is claimed.

"Our proprietary GaN-on-GaN LED technology has allowed the company to make ordinary lighting extraordinarily vibrant, brilliant and efficient," claims Caulfield. "Whites look whiter, colors are natural and more saturated, and shadows are crisp and clean. This has fueled sales growth over the past year and created the opportunity to open a new fabrication facility," he adds.

www.soraa.com

Excelitas acquires UV system maker Lumen Dynamics

Excelitas Technologies of Waltham, MA, USA, which provides customized optoelectronics to OEMs, has acquired Lumen Dynamics of Ontario, Canada, a privately held volume manufacturer of lamp- and LED-based UV curing and fluorescence illumination systems.

"Lumen Dynamics' technology and innovative product portfolio complement Excelitas' existing suite of specialty lighting products," says Excelitas' CEO David Nislick. "With the addition of Lumen Dynamics' expertise in UV curing, Excelitas is now poised to expand our penetration of the high-growth UV curing markets and address an even wider range of demanding medical and industrial applications." Excelitas reckons that the acquisition strengthens its UV and LED capabilities and broadens its portfolio of offerings to the fluorescence illumination and microscopy markets.

Founded in 1984, Lumen Dynamics offers a comprehensive suite of products under the OmniCure and X-Cite brands. The combined firms will offer an expanded range of customized fiber-optic UV and LED solutions and specialty lighting products for OEMs in electronics/optoelectronics, digital printing, medical device, and life-science applications.

Lumen Dynamics is Excelitas' fourth acquisition since its formation in late 2010. In October 2013, Excelitas completed the acquisition of Qioptiq, diversifying its range of optoelectronic products to OEMs and increasing its global footprint. In 2012, Excelitas acquired high-voltage power supplier Kaiser Systems and lamp-manufacturer Carsan Engineering.

www.ldgi.com

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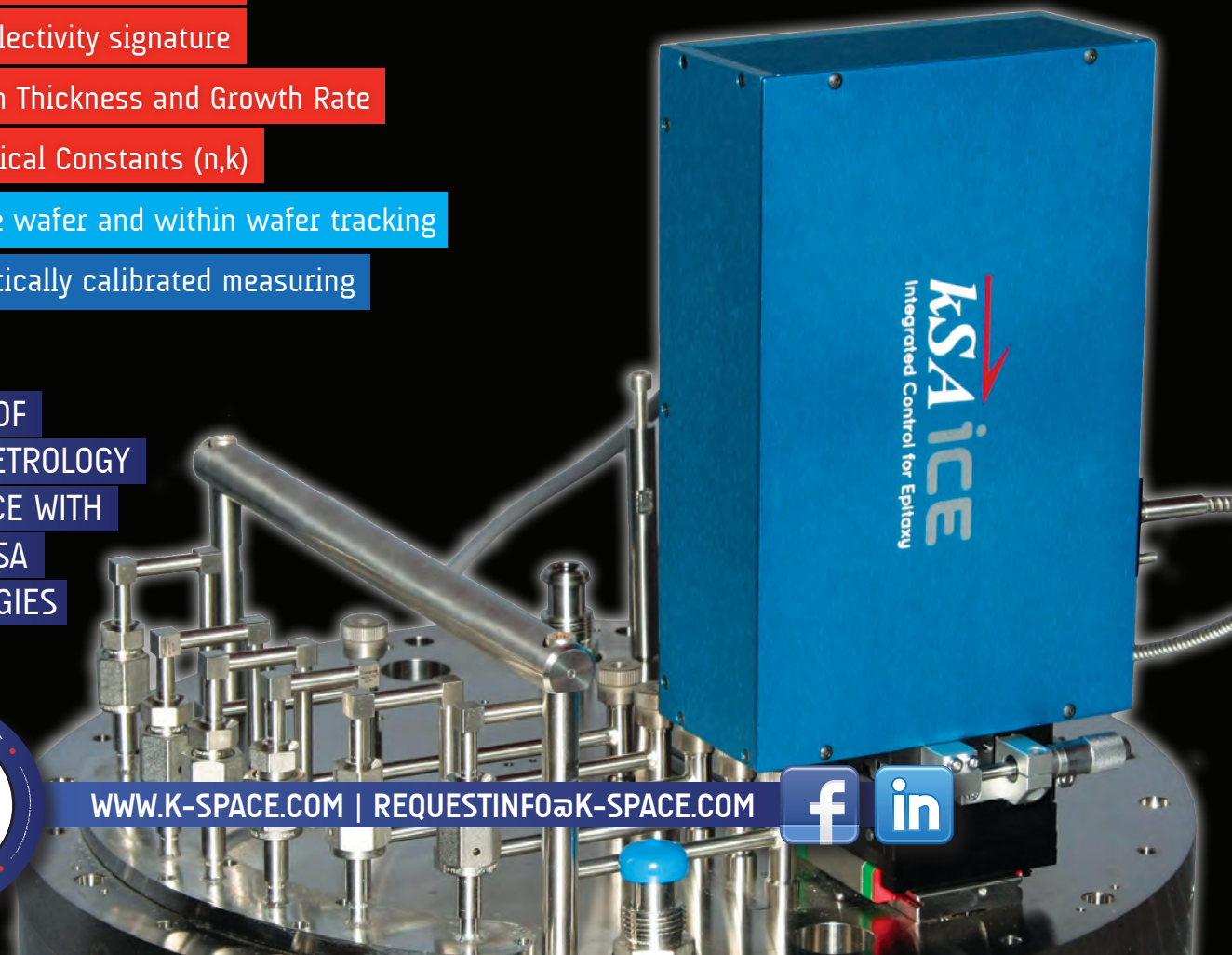

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Intematix and Lumileds announce remote phosphor LED lighting module delivering 203lm/W

Intematix Corp of Fremont, CA, USA, which makes customizable, patented phosphors and remote phosphor components for LED lighting, and LED maker Philips Lumileds of San Jose, CA, USA have announced a remote-phosphor-based LED lighting module with luminous efficacy of 203 lumens per watt, which is reckoned to be the highest among LED-based light sources commercially available for production on the market.

"This result is a significant step along our innovation roadmap for phosphor solutions," says Intematix's chief technology officer Yi-Qun Li. "Remote phosphor architectures lower cost, increase efficacy and improve light quality in many of the consumer, commercial, industrial and outdoor area lighting applications commonly deploying LED technology today."

The LED lighting module uses a commercially available 26mm-

diameter dome-shaped remote phosphor developed by Intematix that converts blue light to on-the-black-body-line 6000K daylight spectrum and 70CRI (color rendering index) with conversion efficacy of 267 lumens per radiant watt. The design is applicable for round and linear module configurations and is offered in color temperatures ranging from 2700K to 6000K with CRI values from 70 up to 98.

The lighting module uses Lumileds' LUXEON T/TX family of royal blue LEDs, achieving wall-plug efficiencies of 76%.

The efficacy of 203lm/W was achieved using Lumileds' latest commercially available LED technology and Intematix's remote phosphor, notes Jy Bhardwaj, senior VP of R&D at Philips Lumileds. "This marquee performance simplifies a wide variety of thermally constrained applications such as 100W A19 bulbs and high-lumen candle lamps, and enables downlights with the highest efficacy in the industry."

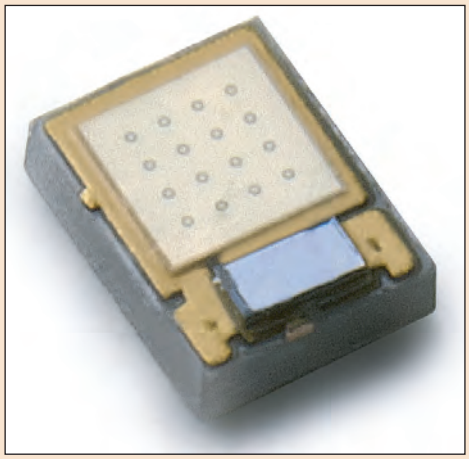
Remote phosphor solutions are notable for delivering high-quality, uniform light and omni-directional light distribution to applications such as replacement lamps, high-bay industrial illumination and linear applications like commercial lighting. By increasing efficacy, remote phosphor reduces material and operating costs, says Intematix.

www.philipslumileds.com
www.intematix.com

LUXEON UV LEDs launched as smallest high-power UV emitters

Philips Lumileds of San Jose, CA, USA has launched the LUXEON UV family of LEDs, delivering what are claimed to be the highest system flux densities in the industry. Available with emission wavelengths of 380–430nm, the emitters are specifically designed for applications including ultraviolet curing, counterfeit detection, medical, industrial and specialty lighting.

"The UV LED market has been hampered by limited flux density and a lack of design flexibility," says senior product line manager Kurosh Hashemi. "Philips Lumileds addressed these limitations by introducing a compact, high-power emitter that can be tightly spaced to deliver the highest flux density to the desired medium," he adds. "For example, for curing applications, 395nm emitters enable arrays of up to 38W/cm^2 when



Lumileds' new LUXEON UV LED.

driven at 1A." With a micro-footprint of only 2.2mm^2 [one-fifth the size of other high-power emitters, it is reckoned], each LED is provided in undomed form for precise optical control.

Since the product's inception, Lumileds has optimized LUXEON UV LEDs for high reliability: using surface-mount assembly instead of wire bonding; designing for high-power operation (up to 1A drive currents) with what are claimed to be best-in-class droop and forward voltage; and offering multiple binning options. The LUXEON UV is modeled after the firm's LUXEON Z family. "We combined the proven advantages of high-flux density and optical control of the LUXEON Z design with a high-performing UV chip," says Hashemi.

The LUXEON UV is designed for superior thermal management. The package uses flip-chip assembly, where the chip is in direct contact with the thermally conductive AlN substrate. Customers have shown interest in using air cooling units rather than more costly water cooling, notes Hashemi.

www.philipslumileds.com

Seoul Semiconductor launches Z5-M1 Series of improved efficacy high-power LEDs

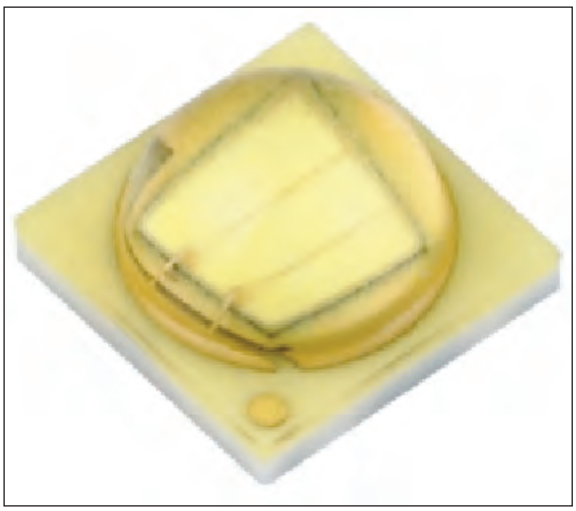
South Korean LED maker Seoul Semiconductor says that its new Z5-M1 series LED has been optimized to deliver maximum efficacy and luminous flux with an industry-standard 3535 surface-mount package.

The Z5-M1 combines high light output, reliability and color uniformity to deliver luminous efficacy of up to 132 lumens per watt at a drive current of 350mA (at 85°C junction temperature, 80 CRI minimum) in warm white (3000K). In cool white (6000K), it delivers up to 150 lumens per watt at 350mA (85°C junction temperature, 70 CRI minimum). The Z5-M1 series is available in the full correlated color temperature (CCT) range of 2600-7000K and two CRI options to provide lamp and luminaire manufacturers with maximum flexibility.

Seoul Semiconductor says that advances made in chip architecture and phosphor technology are the key ingredients to the performance enhancement of the new Z5-M1 series. The improved efficacy helps lighting manufacturers to use fewer LEDs in their system designs, translating to lower system costs. Also, the Z5-M1 can be operated at a drive current ranging from 150mA to 1.5A, making them suitable for a wide range of general illumination applications (from street and area lighting to replacement lamps to high output flashlights).

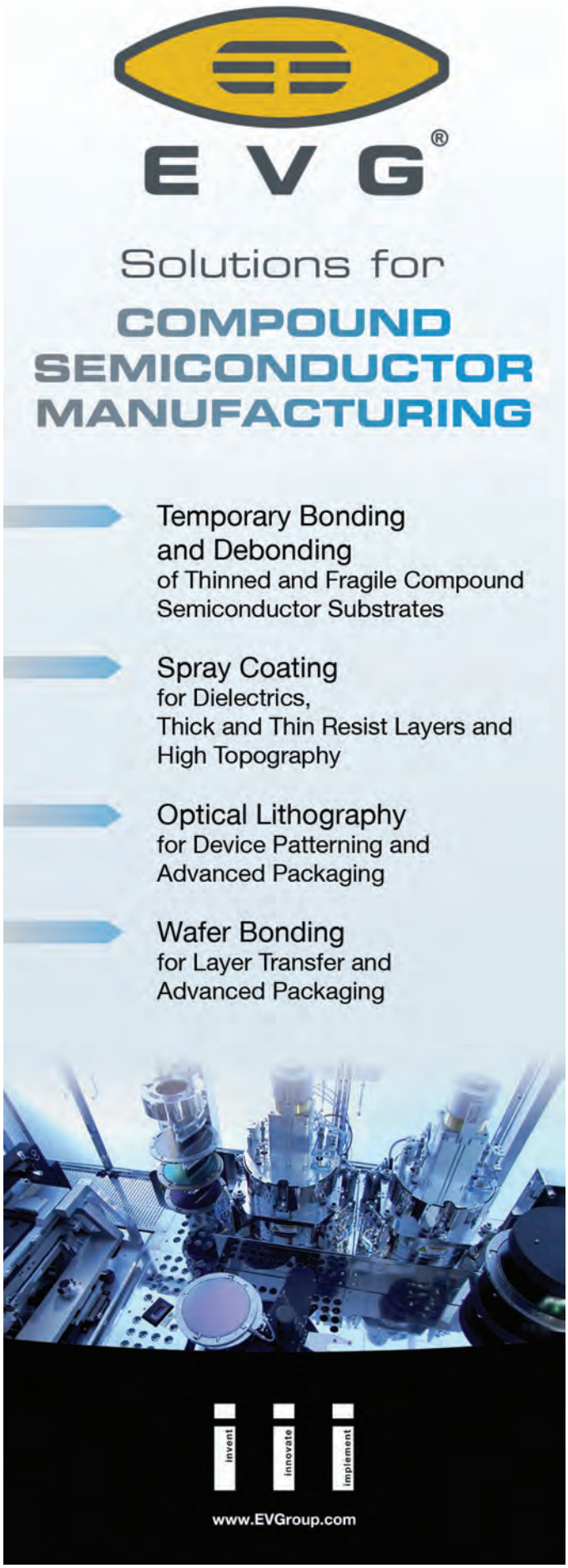
The new product also features what is claimed to be excellent color uniformity over angle, based on new phosphor coating technology that enables high-quality directional light sources.

"The efficacy enhancements in the new Z5-M1 series not only ensure a reduction in luminaire development costs incurred by our customers, but also enable the best possible color over angle homogeneity with the new phosphor coating technology," comments J.B Choi, president of Seoul Semiconductor's Lighting Division.



Seoul Semiconductor's new Z5-M1 series LED.

www.seoulsemicon.com



SemiLEDs' revenue falls 29% from last quarter

For fiscal fourth-quarter 2013 (to end-August), LED chip and component maker SemiLEDs Corp of Hsinchu, Taiwan has reported revenue of $3.4m, down 29% on $4.8m last quarter and down 38% on $5.5m a year ago. Revenue for full-year fiscal 2013 was $18m, down 39% on $29.3m for fiscal 2012.

Revenue from LED chips fell 7% sequentially and 30% for the full-year (comprising 27% of total revenue in Q4 and 30% for the full-year). Revenue from LED components fell 25% sequentially and 53% for the full-year (comprising 34% of revenue in Q4 and 39% for the full-year). Revenue from lighting products rose 13% sequentially but fell 5% for the full-year (comprising 29% of revenue in Q4 and 23% for the full-year).

Compared with –55% a year ago, gross margin has recovered slightly from –129% last quarter to –103%.

R&D expenses have been cut from $1.5m a year ago, but rose slightly from $1.15m last quarter to $1.19m. Selling, general & administrative expenses are down from $4.1m a year ago but up from $2.2m last quarter to $2.9m due to the write-off of certain property, plant and equipment and an increase in bad debt expense. Total operating expenses have fallen from $5.6m a year ago and $m last quarter to $4.1m.

Operating margin has worsened to –523%, compared with –278% last quarter and –296% a year ago. However, in addition to the reduction in revenues and an excess capacity charge for LED chips, margins for fiscal Q4/2013 were also impacted by a $10.1m charge for impairment of long-lived assets, triggered mainly by significant under-utilization of the firm's LED epiwafer and chip manufacturing facilities for a sustained period of time.

On a non-GAAP basis (excluding stock-based compensation expense of $0.5m and the $10.1m impairment charge), net loss was $7.3m, cut from $16.6m a year ago but up from $6.6m last quarter. Net loss for full-year fiscal 2013 (excluding stock-based compensation expense of $2m and impairment charges on long-lived assets, goodwill and investments of $13.9m) was $27.8m, cut from $37.8m for fiscal 2012.

Cash used in operating activities was $4.7m, doubling from $2.3m last quarter. However, capital expenditure has been cut from $1.2m a year ago to just $83,000. Hence, total cash burn (operating cash flow) has been reduced from $6.5m a year ago to $4.7m. Consequently, during the quarter, cash and cash equivalents have fallen from $41.4m to $36.3m.

"We continue to pursue our strategy of lowering our dependency on general lighting chip sales, where supply is exceeding demand, while at the same time broadening our component and UV product lines, where pricing pressure is reduced," says chairman, president & CEO Trung Doan. "Our goal is to improve gross margin and operating cash flow."

For fiscal Q1/2014, SemiLEDs expects revenue to grow slightly to $3.5m, but gross margin to continue to be negative as the firm will not fully utilize its production capacity.

"As our product mix evolves, we will continue to invest in our component manufacturing assets," says Doan. "We recently acquired an additional LED component production line and added an array of new LED component products and related technology to our existing products and technology portfolios. Our current LED chip technology, together with this new LED component technology, will provide an advantage in the niche markets we target."

www.semileds.com

SemiLEDs launches 10W red-green-blue-white LED

SemiLEDs has launched the 10-Watt M63 RGBW integrated 6363 LED, a 4-channel LED delivering more than 410 total lumens of combined red, green, blue and white light output.

The compact 6.3mm x 6.3mm size enables it to fit in a wide range of color-changing applications, e.g. entertainment (stage lights, backdrops and spotlighting), large-scale displays and color-adjustable luminaires for building facade, wall washing or specialized interior luminaires.

"By combining three colors, plus an independent phosphor-coated white emitter, onto a single LED package, our customers will be able to better optimize the optical and thermal properties of their design, while minimizing the manufacturing complexities of their luminaires or large-scale displays," says Dr Ilkan Cokgor, executive VP of sales & marketing. "This integrated approach is enabled by our well-validated and robust metal vertical LED product portfolio, which can be reliably driven harder to deliver higher-than-average lumen density."

The integrated package is the first to bring together SemiLEDs vertical, white chip, and ceramic packaging technologies. The multi-color LED enables arrays with cumulative lumen-densities over 6000 lumens per square inch. The square footprint also simplifies color mixing and integration with secondary optics, including narrow-beam spotlights, which benefit from the symmetry and depend on minimized source sizes. Adding discrete white to the color-changing LED enables a broader spectrum and more natural white palette to be projected, claims the firm. The white source delivers luminous efficacy of 100lm/W at a correlated color temperature (CCT) of 6300–8000K. By its nature, an RGBW LED should include a cool-white source to complement the additive nature of the colors in the integrated device, adds the firm.

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IN BRIEF

Cree's Xlamp XP-G2 LEDs chosen by QuantumLED for new commercial lamp brand

LED lighting product manufacturer CRS Electronics Inc of Welland, Ontario, Canada says it has selected Xlamp XP-G2 LEDs from Cree Inc of Durham, NC, USA for its new QuantumLED commercial lamp brand.

"We do all of our product development in-house," says CRS Electronics' chief technology officer Scott Riesebosch. "As a customer that uses the XP package, we're excited to be able to extend our product portfolio with the newest XP-G2 LED."

Cree's XLamp XP-G2 LED has been employed throughout the QuantumLED directional lamp product portfolio. The initial product offering includes PAR lamps, as well as MR16 lamps in three distinct lumen packages. A family of R and BR reflectorized lamps will also be offered. Directional lamps will be available in multiple beam angles, and all will offer what is claimed to be the highest lumen output, efficacies, and color temperature ranges on the market. QuantumLED will also feature the hard-to-find 2200K color temperature option throughout its entire product line.

"The XP-G2 LED allows CRS to seamlessly leverage the higher-performance Cree LEDs without making any additional investment," notes Paul Thieken, Cree's director of marketing, LED Components.

CRS Electronics says that its QuantumLED lamps will be sold through commercial electrical distributors throughout North America.

www.crselectronics.com
www.cree.com

Cree wins three awards at CHINASSL

At the 10th China International Exhibition and Forum on Solid State Lighting (CHINASSL2013) in Beijing, LED chip, lamp and lighting fixture maker Cree Inc of Durham, NC, USA won three LED lighting industry awards. The China SSL Alliance presented Cree with the award for 'Most Influential Company in Decades', while the International SSL Alliance awarded Cree the '2012-2013 Global SSL Industry Annual Event' (for the introduction of the 200lm/W XLamp MK-R LED) and the '2013 Global SSL Industry Showcase Top 100' (for its collaboration with Shanghai Yaming on the Shanghai Yuexing Global Harbor).

"It is an affirmation of the significance of our achievements from the previous years and will encourage us to expand our leadership in LED technology through relentless innovation and joint efforts with our Chinese industry allies," said Dr Jiaping Shao, sales general manager and technology director, Cree China.

This year marks the 10th anniversaries of both China's National SSL Program and CHINASSL. Each year a series of award ceremonies is held during CHINASSL to recognize the companies that make remarkable contributions to the development of the global SSL industry.

www.sslchina.org

Cree LEDs light NASA's headquarters

Cree says that the 600,000ft^2 headquarters of the National Aeronautics and Space Administration (NASA) has been fitted with energy-saving Cree CR Series LED troffers.

More than 1,300 Cree CR22 architectural LED troffers have been installed, and Piedmont Office Realty Trust, owners of the NASA headquarters building, expects the new fixtures to deliver energy savings of 52% over the previously installed T8 fluorescent fixtures. An additional 5,200 Cree CR22 troffers are planned to complete the lighting upgrade, says the firm.

"We originally considered replacing the existing T8 fluorescent tubes with T5 fluorescents, but after testing Cree's CR22 LED troffer, we knew it was the best solution for this installation," said Tony Roberts, senior chief engineer supporting Piedmont Office Realty Trust. "No other manufacturer offered the combination of performance, pricing and efficacy we desired. We continue to be impressed by the improved lighting quality and significant savings the CR22 troffers provide."

Featuring Cree's TrueWhite Technology, Cree linear luminaires enabled Piedmont Office Realty Trust to reduce the fixture count by 10%, adding to the overall savings. Designed to last for more than 50,000 hours, twice the lifetime of comparable linear fluorescents, the new fixtures are designed to reduce maintenance and operational costs for the headquarters.

The CR22 troffers feature integrated Lutron EcoSystem dimming technology, and the system is controlled by a Lutron Quantum lighting control system, offering the ability to fine-tune light levels individually in each fixture.

"The CR Series is a no-compromise alternative to fluorescent lighting and demonstrates our commitment to driving the broad adoption of LED lighting," said Mike Bauer, VP of lighting sales, Cree. "The successful integration of CR troffers with digital controls and dimming allows Cree to further the obsolescence of antiquated fluorescent lighting. Optimal lighting is essential to workplace environments like NASA's headquarters. Cree linear luminaires deliver unrivaled performance, making the decision to choose LED lighting over fluorescent options an obvious choice."

www.Cree.com/Lighting

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Osram's new wafer fabrication building in Penang certified as a Green Building

Osram Opto Semiconductors GmbH of Regensburg, Germany says that its new Pen32 wafer fabrication plant in Penang, Malaysia, has been certified as a Green Building, conforming to requirements on design and construction under the Green Building Index (GBI). The new building aligns with Osram's standards for fabrication sites and is said to be one of the first industrial buildings in Malaysia to have been awarded the certification, following close scrutiny on design and construction.

GBI looks at the efficient use of resources (such as energy, water, and materials) and the reduction of building impact on human health and environment during a building's lifecycle. It is challenging for an industrial building to meet these criteria, notes Osram Opto.

"Right from the beginning when we planned to build a new wafer facility here, we wanted it to have minimal impact on its surroundings," says Dr Roland Mueller, managing director of Osram Opto Semiconductors (M) Sdn Bhd. "Not only can we achieve savings in our operations, but also we can show that we are committed for a better future for the people and environment around us."

Starting with the construction phase, amenities have been made available and accessible to the project workers. Care was taken not to be the source of pollution during and after construction, says the firm. All construction materials are acquired locally (in line with GBI requirement), while refrigerants and cleaning agents are of non-ozone-depleting types. Waste is removed properly on a daily basis and stations are set up to collect materials that can be recycled.

Pen32, Osram Opto's new wafer production building.

Penang has an equatorial climate. So, to cool the building and to lower the overall building thermal transfer value to within GBI-acceptable levels, several measures are taken. The use of thermal-efficient bricks and low-emissivity glass, together with adequate insulation, significantly reduces the overall thermal transfer. Energy usage is optimized through the use of lighting zoning, relevant energy monitoring sub-meters, and medium-temperature chillers. Pumping systems are fitted with variable-speed drives to cater for different usage, further reducing energy needs.

Indoor environment quality also forms part of the GBI. To keep indoor air quality fresh, air handling systems are installed with CO_2 monitoring sensors to modulate fresh-air intakes. Also, to reduce smells and fumes, low-VOC (volatile organic compounds) paints, adhesives and carpets are used. Adequate external views are made accessible from anywhere within the building to mitigate claustrophobic feelings and to create a more relaxed environment. Architectural and mechanical design efforts are made to provide comfortable lighting as well as to lower glare effect and noise levels for people working in the building.

In operation, most of the plant's process waste water is reused as cooling tower recycling water. Water-efficient fittings are used to minimize water wastage in wash rooms. Heat pumps and a chilled water degassing system are innovative features adopted to achieve the GBI certification, says the firm.

"Pen32 is to last for years and, according to the GBI rating scheme, it has to be re-assessed every three years in order to maintain its status as a Green Building," notes Mueller. "We will make every effort to ensure that the building will continue to have minimal impact on its surroundings and to provide a quality working place for our employees throughout its lifecycle."

www.osram-os.com

Osram and Dominant settle opto component patent dispute

Lighting manufacturer Osram GmbH of Munich, Germany and Malaysia-based LED maker Dominant have settled their dispute concerning patents in the field of optoelectronic components. Additionally, Osram has licensed certain patents to Dominant. The parties have agreed to keep the details of the settlement confidential.

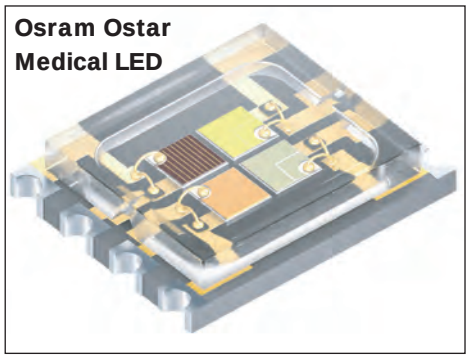
Osram says that it has already entered into patent license agreements with big players in the optoelectronic component market. The firm adds that such agreements assure legal security for both Osram and its licensing partners while entering future lighting markets.

www.dominant-semi.com
www.osram.com

Osram's Ostar Medical LED provides tunable white light with color rendering index of 95

Osram Opto Semiconductors GmbH of Regensburg, Germany claims that its new Osram Ostar Medical is the first LED component with a high color-rendering index (CRI) of 95 and the capability of adjusting the temperature of the color white. This makes it suitable for medical applications such as operating rooms, where a precisely controlled chromaticity coordinate and high natural color rendering are crucial.

The Osram Ostar Medical consists of four different LED chips in the colors warm white, ultra white, green and amber, allowing users to set the shade of white emitted by the LED according to their individual requirements within a color temperature range of 3700-5000K. This combination of precise chromaticity coordinate control and high CRI is particularly important for lighting in the medical sector, says the firm. When optimized for the red spectrum (Ra9), the CRI remains at around 95 so that red shades are particularly true-to-life – suiting lighting systems in operating rooms.



Osram Ostar Medical LED

With a footprint of just 5.9mm x 4.8mm (about 0.23 inches x 0.19 inches) and a housing height of only 1.2mm (about 0.5 inches), the compact Osram Ostar Medical is only about one-quarter the height of the components that are ordinarily used. The new LED owes its compact design to the flat, antireflection-coated glass cover with which the LED is equipped instead of the usual lens.

"Compact luminaires prevail in the modern medical lighting sector, and the low height of the new Osram Ostar Medical makes it the ideal lighting solution," reckons Michael Godwin, director of Visible LED Products at Osram Opto. "The component is standardized, which means that customers can use the commonly available lenses." As with other members of the Osram Ostar LED family, the Osram Ostar Medical is simple to install with standard soldering processes.

www.osram-os.com

Atech Korea's Glasses Free 3D LED Display enabled by Multi Chipled

Osram Opto Semiconductors says that, due to its technology, a recent 'Glasses Free 3D Display' introduced by Atech Korea Co Ltd measures up to 500-inches. The video display walls are intended to be used in indoor public areas, such as shopping malls and exhibition halls. With a contrast ratio of 4000:1 and screen brightness at 4500cd/m^2, viewing distance can be up to 30m.

Glasses Free 3D Displays were introduced more than a year ago, but the adoption rate in large-size applications was unsatisfactory, says Osram Opto. The existing displays are LCD displays with backlit LEDs or edge-lit LEDs, and display size is constrained by the size of LCD panels. But, due to recent work by Atech using Osram's Multi Chipled to produce a truly 3D LED display, this size barrier has been overcome. The LEDs emit light directly and operate as individual pixels with Atech's 'Lenticular Lens' to create high-definition (HD) 3D images.

"We have chosen Osram's Multi Chipled LEDs because the RGB chips in these LEDs can be driven individually to mix any color required, thereby producing extremely accurate pixel colors for vivid images, and also the product has a black surface with diffused resin to provide the highest contrast possible in our screens," says Atech Korea's president Seokhwa Kim. "They also come in a tiny 1.6mm x 1.6mm x 0.9mm package, making it possible to have a pixel spacing of only 2mm. In effect, millions of pixels can be accommodated in an area of less than 10m^2, sufficient to display pictures in resolution of 1980 x 1080 HDTV with brilliant colors and excellent contrast," he adds.

"Our Multi Chipled series come in an ultra-black package that hardly reflects any ambient light at all, and the high image quality is maintained even in very bright environment," says Kai-Chong Cheng, Osram Opto's senior marketing director APAC. "Moreover, the color impression remains constant across the entire viewing angle of 100˚. That is why Multi Chipled LEDs are ideal for display applications in public space such as shopping malls, exhibition halls and being a true LED TV," he claims.

Nobody in a public space will be willing to pick up eyewear just to watch public video displays that are mostly of an infotainment nature, reckons Osram Opto. It is therefore believed that the potential of 3D will be unlocked by eliminating the need for glasses. Atech has developed a 'Lenticular Lens' to deliver 3D images without the use of glasses, but this is also capable of converting 3D images to 2D, depending on the display requirements. With the use of Osram's Multi Chipled, these displays have high-resolution, good picture quality and high brightness, says Osram Opto.

www.atechcorea.com

IN BRIEF

SETi launches UV LED disinfection cases for mobile devices in hospitals

At the Medica expo in Dusseldorf, Germany (20–23 November), ultraviolet light-emitting diode maker Sensor Electronic Technology Inc (SETi) of Columbia, SC, USA is introducing a new line of disinfection cases for phones, tablet computers and other mobile devices. Using SETi's UV LEDs, the disinfection cases are reckoned to be the world's first fully portable disinfection units and are designed to be carried with the mobile device as a protective case as well as a disinfection system.

The units can be used by anyone, however SETi is targeting healthcare workers initially, in a bid to reduce hospital acquired infections (HAIs).

HAIs affect more than a million people a year in the USA alone and are linked to nearly 100,000 US deaths according to the Centers for Disease Control and Prevention (CDC). More than 50% of healthcare workers admit to using mobile devices during direct physical contact with patents, yet only 8% say that they actually clean them. According to Hospital and Health Networks, 65% of doctors believe that increased use of mobile devices in the healthcare environment is leading to the spread of disease.

SETi says that the new disinfection cases are easy to use: the device can simply put back in its protective case and the disinfection process starts automatically, removing more than 99.9% of germs it is reckoned. Powered by a rechargeable battery, the portable cases can be taken anywhere that a mobile device is normally taken. Recharging is via a mini-USB.

www.s-et.com

Gallium oxide/silicon carbide heterojunction yields fast, high-sensitivity detection of UVC light

Photodiode shows promise for space-based communication & monitoring ozone depletion

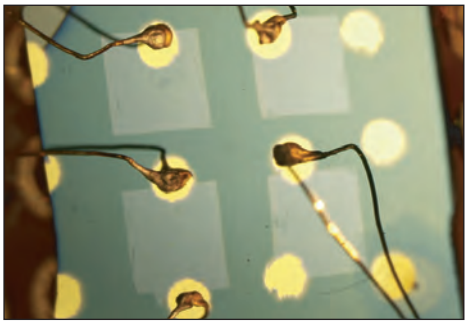
Researchers at Japan's Ishinomaki Senshu University have developed a new photodiode that can detect in just milliseconds high-energy deep-ultraviolet (UVC) light, which is powerful enough to break the bonds of DNA and harm living creatures ('Deep ultraviolet photodiodes based on β-Ga_2O_3/SiC Heterojunction', Shinji Nakagomi, Toshihiro Momo, Syuhei Takahashi and Yoshihiro Kokubun, Applied Physics Letters vol103, 072105 (2013)).

Although this radiation does not normally reach the Earth's surface, it can leak through to just below the hole in the ozone layer. Monitoring this radiation is a way of tracking the hole in the ozone layer, and photodiodes that measure UVC are also used as flame sensors and for communication in space.

Now, Shinji Nakagomi and colleagues have built a new kind of photodiode that can detect the whole range of UVC light while remaining insensitive to visible light from the sun — two features that have eluded designers of current devices. By being 'solar blind', photodiodes are more sensitive to the UVC range and are thus more useful.

Some photodetectors consisting of vacuum tubes on sale, but they have short lifetimes and are relatively large and unwieldy. Currently, many photodetectors are instead based on a p-n junction photodiode.

Other photodiodes made from materials like aluminum nitride and diamond are sensitive only to a limited range of UVC light. But recently, gallium oxide has shown promise because it is sensitive to the entire UVC range and is solar blind. The problem, however, is that it is difficult to make p-type gallium oxide.



The Ga_2O_3/SiC DUV photodiode.

Instead of a photodiode based on a conventional p-n junction, the researchers fabricated one based on a heterojunction, incorporating two different semiconductor materials: β-Ga_2O_3 gallium oxide (with an energy bandgap of 4.9eV) and 6H-SiC silicon carbide (with an energy bandgap of 3.02eV). Specifically, A thin (200nm) layer of β-Ga_2O_3 was prepared on a p-type 6H-SiC substrate through gallium evaporation in oxygen plasma.

The heterojunction device showed good rectifying properties. Under reverse bias, the current increased linearly with increasing deep-UV light intensity. The responsivity of the photodiode was highest to deep-UV light below a wavelength of 260nm.

The team also found that the device responds quickly to UV light — within milliseconds — and has little dark current (the intrinsic electrical current flowing through the device even in the absence of light), which is key for photodiode sensitivity.

"The most important aspect about our device is that it is based on a heterojunction between gallium oxide and silicon carbide," says Nakagomi. "This gallium oxide and silicon carbide photodiode is promising for the detection of UV light," he concludes.

http://apl.aip.org/resource/1/applab/v103/i7/p072105_s1

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www.semiconsingapore.org

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www.semiconrussia.org

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www.semiconwest.org

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www.semicontaiwan.org

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www.semiconeuropa.org

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www.plastic-electronics.org

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Fraunhofer Heinrich Hertz Institute enables visible light communication by LED at 3Gb/s

New components presented at ITU Telecom World

The Fraunhofer Heinrich Hertz Institute HHI of Berlin, Germany (a research center for communication systems, digital media and services) claims to have set a further milestone in visible light communication on the way to high-speed Internet from the ceiling lamp. The development of novel components for data transmission by LEDs means that significantly higher bandwidth can now be used in real-time, with data throughput rates of up to 3Gb/s. The new components were presented at the ITU Telecom World 2013 event in Bangkok, Thailand (19–22 November).

The technology developed by HHI makes it possible to use standard off-the-shelf LED room lights for data transmission. Data rates of up to 800Mb/s have been reached using this optical WLAN under laboratory conditions, while a complete real-time system exhibited at trade fairs reached data throughput of 500Mb/s. The newly developed patent-protected components have now achieved a transmission rate of over 1Gb/s per single light frequency. As off-the-shelf LEDs mainly use three light colors, speeds of up to 3Gb/s are feasible, says HHI.

Up to now, LEDs could only be used with a bandwidth of around 30MHz, yet the new components enable a much higher bandwidth of up to 180MHz to be exploited. As the higher frequency bands are also used for transmission, this significantly boosts the data throughput rate.

Development of the components as modules makes them suitable for customized integration in technology developments such as Car-to-X communication.

However, visible light communication also has a broad array of other possible applications, ranging from areas like aeroplanes (where safety is at a premium) to places like trade shows and factory halls (where radio communication is problematic).

HHI reckons that this new development represents a major step towards optical high-speed wireless local-area networks (WLANs).

www.hhi.fraunhofer.de/vlc
http://world2013.itu.int

Firecomms' RedLink optical transceivers for industrial applications enter full production

Firecomms Ltd of Cork, Ireland and Tongxiang, China, which manufactures fiber-optic solutions and optical transceivers, has announced full production and shipping of its new RedLink line of fiber-optic transmitters and receivers for the industrial command, control and communications markets.

Specifically designed to be compatible with Versatile Link connectors from Avago Technologies, the RedLink family of products includes transmitters and receivers that operate from DC–1Mb, DC–5Mb, DC–10Mb and DC–50Mb.

Firecomms says it puts its RedLink devices through thousands of hours of testing to guarantee extended lifetimes at high temperatures. Due to the firm's unique resonant-cavity LED technology (which keeps the transmitters burning brightly after several decades) and the monolithic architecture of Firecomms' fully integrated receivers, users can design for the toughest of applications, says Firecomms.

"Products operate in the harshest of environments and are regularly exposed to extremes of temperature, climate and electromagnetic interference," notes CEO Hsin Chia. "Not only must our devices operate within these harsh environments, they must operate effectively for many, many years." The milestone is "a reflection of the thousands of hours our team has invested in meeting our customers' launch plans," he adds.

"Our new RedLink devices have been ordered by some of the world's largest industrial conglomerates for use in applications such as electric trains, high-voltage grid stations, wind and solar energy converters, mining, oil and gas exploration, and motor drives," says Hugh Hennessy, VP of worldwide sales & marketing. "We are pleased with the positive response we received to bring a reliable source to market and plan to build on these successful deployments with continued innovation and expansion of our RedLink portfolio."

Firecomms uses in-house photonics, and transmitter and receiver chips together with an internal production facility to guarantee the quality of its supply chain. The firm says that its vertical integration around the core technologies used in fiber-optic transceivers enables it to respond flexibly to customer demands while maintaining tight control of major cost drivers.

In addition to the RedLink family of products, Firecomms produces a range of integrated 100Mbps to 500Mbps transceivers in its OptoLock and compact LC connector systems for higher-speed communications links in the medical, industrial and consumer home networking markets.

www.firecomms.com

II-VI Laser Enterprise ships 200 millionth VCSEL and samples high-power VCSEL for volume applications

Semiconductor laser manufacturer II-VI Laser Enterprise GmbH has shipped from its Zurich, Switzerland headquarters its 200 millionth vertical-cavity surface-emitting laser (VCSEL) since 2008, consolidating its position as the leading volume supplier of VCSELs for consumer electronics applications such as optical finger navigation, laser computer mouse, and active optical cables (AOCs).

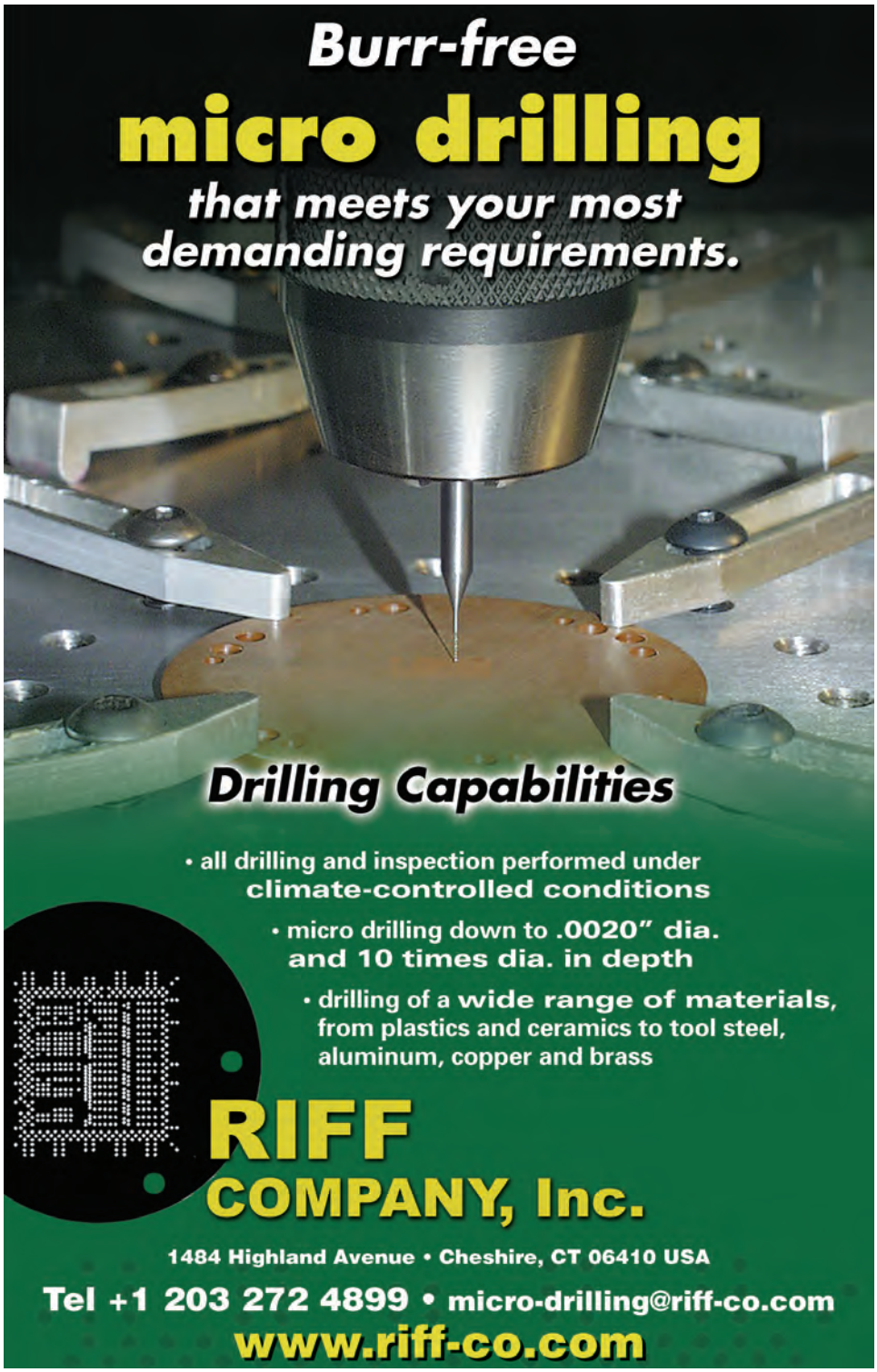
II-VI Laser Enterprise is a subsidiary in the active optical products segment of engineering materials and optoelectronic components provider II-VI Inc of Saxonburg, PA, USA that was acquired in September from optical communications component maker Oclaro Inc of San Jose, CA, USA for $115m.

The optical characteristics of VCSELs such as low beam divergence, small wavelength shift over temperature, narrow spectral linewidth and high-speed modulation properties make them the ideal light sources for advanced sensing, communication and illumination applications in mobile devices, says II-VI Inc. Also, VCSELs can be produced cost-competitively by using high-throughput wafer-scale manufacturing and testing processes.

II-VI Laser Enterprise says that it unites design expertise (at design centers in Tucson, AZ, USA and Paignton, UK) with a long-standing and field-proven, reliability track record and the manufacturing control to provide the required combination of performance, reliability and cost advantages to demanding high-volume markets. As well as VCSEL solutions, the firm provides 980nm single-mode pumps and high power laser diode, for applications including pumping, medical, printing, telecoms and consumer electronics.

II-VI Laser Enterprise has also announced the addition of high-power VCSELs to complement its product portfolio geared at high-volume consumer electronics markets. The firm is now sampling high-power VCSELs for sensing and illumination applications. The single-die lasers emit more than 10mW at 850nm. Furthermore, replication of the same die in a two-dimensional (2D) array enables optical power to reach 2W at 850nm for illumination of larger volumes that can be required in sensing applications such as in time-of-flight.

www.ii-vi.com



Brolis gains €1.6m more EU funding for R&D facilities expansion in 2014

GaSb-based mid-IR laser maker to add cleanroom space and focus on reliability and yield optimization

Brolis Semiconductors Ltd of Vilnius, Lithuania says that the Lithuanian Ministry of Economy has approved European Union (EU) structural funds support for the expansion of its R&D facility in 2014. The EU is to cover 46% of the total project cost (estimated at €1.6m).

Established by brothers Augustinas Vizbaras, Kristijonas Vizbaras and Dominykas Vizbaras in 2011, the firm specializes in mid-infrared type-I gallium antimonide (GaSb) lasers and molecular beam epitaxy, manufacturing epitaxial wafers for antimonide and arsenide materials for thermal imaging focal plane arrays, CPV and custom devices.

The expansion of R&D facility will include additional cleanroom space and will focus on the development of Brolis' long-wavelength laser diodes, with particular emphasis on reliability and yield optimization.

"We have managed to start-up the fab in less than 9 months from scratch, which we started operating early this year and we already have pilot devices with state-of-the-art performance, including 25% wall-plug efficiency and high-brightness Watt-level CW laser diodes with extremely low input powers," says chief technology officer Kristijonas Vizbaras. "Our goal is to continue innovation, and do everything possible to bring these to market as soon as possible," he adds.

www.brolis-semicon.com

Molex launches HD AOC delivering 12Gbps up to 100m

High-speed fiber-optic interconnect firm Molex Inc of Lisle, IL, USA has expanded its iPass Connector and Cable Assembly Solution with the introduction of its High-Density (HD) Active Optical Cables (AOCs), capable of delivering 48Gbps data rates over four lanes of 12Gbps with reaches of up to 100m. The iPass HD AOCs complement the existing copper iPass+ HD connector and cable offerings and provide large-scale enterprise and data center storage system customers with a complete end-to-end solution. Molex showcased its HD AOCs at Supercomputing 2013 (SC13) in Denver, CO (18–21 November).

"Storage systems are becoming larger and more distributed due to the pervasive growth of new technologies that provide on-demand entertainment and information, in-depth data analytics and increased information retention," says product manager Brent Hatfield. "As a result, longer-length cables are required that enable systems designers to build next-generation SAS 3.0, 12Gbps storage equipment," he adds. "The newest addition to our iPass family provides nearly double the density of the current QSFP+ AOCs, making the HD AOCs ideal for larger-scale multi-rack designs."

The HD AOCs has a small 3mm cable outer diameter, decreasing cable management and routing challenges by reducing bulk cable size and increasing flexibility. The smaller size also provides extra board space for system designers to implement more I/O ports. The iPass+ HD system enables four 4x ports on low-profile PCIe cards, doubling port density while providing easier routing through the cable management system, says Molex.

The HD AOCs also offer low power consumption of 0.9W per cable for improved overall data-center power consumption and thermal efficiency.

The cables are compliant with SAS-3 (12Gbps) systems with optical-mode capability, InfiniBand (10Gbps) and Ethernet (10Gbps), and are backward compatible with 6Gbps SAS-2.1 optical-mode-capable systems.

www.molex.com

POET Technologies grants incentive stock options

POET Technologies Inc of Toronto, Canada — which, through subsidiary 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 wafer — has granted additional incentive stock options (under its stock option plan) to certain officers and staff of the company, to purchase up to a total of 1,480,000 common shares (1.12% of its outstanding shares).

Of these options, 42.6% were granted to key employees (technical staff related to the POET effort) and 57.4% to company officers. No options were granted to directors.

The stock options are exercisable at a price of CA$0.44 per share, expiring 14 November 2018. Pursuant to the policies of the TSX Venture Exchange, the exercise price was fixed by the closing market price of 13 November. The options will vest and be exercisable on the basis of 25% on the date of grant and 25% every six months thereafter.

www.poet-technologies.com

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IN BRIEF

GigOptix ranked on Deloitte's 2013 Technology Fast 500

GigOptix Inc of San Jose, CA, USA (a fabless supplier of analog semiconductor and optical components for Cloud connectivity, data centers and high-speed optical and wireless communications networks) has been listed 305th on Deloitte's Technology Fast 500, a ranking (conducted by Deloitte & Touche LLP) of the 500 fastest-growing technology, media, telecoms, life sciences and clean-tech firms in North America. Firms are selected based on percentage fiscal year revenue growth in 2008–2012. GigOptix grew 280% in that time.

"We recently announced our third quarter revenue grew 7% sequentially and have guided to an additional 5% revenue growth, along with improved bottom-line performance, in Q4," notes senior VP & chief financial officer Curt Sacks. "With a strong order backlog and new products scheduled for introduction over the next few quarters, we have a solid platform to build on as we continue look to grow our business in 2014," he adds.

"The 2013 Deloitte Technology Fast 500 companies are exemplary cases of those spurring growth in a tough market through innovation," comments Eric Openshaw, vice chairman, Deloitte LLP.

"The fastest-growing companies in the US are drivers of constant innovation and operate with the agility to stay ahead of a quickly evolving marketplace," says James Atwell, national managing partner of the Emerging Growth Company practice, Deloitte Services LP. "Companies excelling in these sectors have a startup mentality that allows them to be nimble and adapt quickly, which is why they consistently lead the list of fast-growing companies."

www.gigoptix.com

Infinera's co-founder & president awarded by IET

Infinera Corp of Sunnyvale, CA, USA, a vertically integrated manufacturer of digital optical network systems incorporating its own indium phosphide-based photonic integrated circuits (PICs), says that co-founder, president & board member Dr David Welch has received the JJ Thomson Medal for Electronics from the Institution of Engineering and Technology for his role as a "pioneer in the field of optical devices and optical networks".

Welch's technical contributions and leadership first made it possible to commercially deploy reliable high-power semiconductor lasers including 980nm laser pumps, which are crucial for low-noise optical amplifiers in dense-wavelength division multiplexing (DWDM) systems. Welch later achieved the first commercial optoelectronics integrated circuit, several years ahead of any competing research or developments in the laboratory, Infinera says. PICs are now essential for addressing the bandwidth and energy challenges faced by global telecoms networks.

"What I am most proud of is how these innovations have now been incorporated in highly successful commercial systems by the team at Infinera and are making a difference in how networks are built," comments Welch.

"The Institution of Engineering and Technology Achievement Awards recognise individuals who have made a truly outstanding contribution to engineering," says IET's CEO Nigel Fine.

www.theiet.org
www.infinera.com

DTN-X delivers Terabit capacity for SC13

Zayo Group LLC of Boulder, CO, USA, an international provider of fiber-based bandwidth infrastructure services and carrier-neutral colocation and interconnection services, used Infinera's DTN-X platform to deliver 1Tb/s super-channel transmission capacity in support of the SCinet network for the Super Computing 2013 (SC13) conference at the Colorado Convention Center in Denver, CO (18–21 November).

This is the first time that 1Tb/s of super-channel transmission capacity was deployed on SCinet's network. Zayo will also demonstrate the rapid provisioning of 100 Gigabit Ethernet (GbE) services from the show floor in Denver to Chicago. Zayo offers 100GbE services to high-bandwidth customers including research and education institutions, Internet content providers, and government agencies. Infinera is a supplier of multi-terabit transport capacity for Zayo's 100GbE services.

SCinet is a specialized network created each year to support the Super Computing event. Brought together by academia, government and industry groups, the high-capacity network supports applications and experiments conducted throughout the conference. It serves as the platform linking the Colorado Convention Center to research and commercial networks worldwide. The demonstration marks the first delivery of terabit capacity and the fastest 100GbE provisioning in SCinet history.

"The delivery of terabit service on SCinet demonstrates how fast Zayo can deploy capacity for our customers," says David Dunn, VP of wavelength product at Zayo. "Through our collaboration with Infinera on this deployment, we are demonstrating our ability to expand our 100GbE services to accommodate the bandwidth-driven needs of our customers."

www.sc13.supercomputing.org
www.zayo.com

Emcore appoints Dr LC Chiu as general manager of Fiber Optics unit

Emcore Corp of Albuquerque, NM, USA, which makes compound semiconductor-based components and subsystems for the fiber-optic and solar power markets, has announced a broad realignment of operational responsibility in its Fiber Optics business segment and the appointment of Dr Liew-Chuang (LC) Chiu as the new general manager for its Fiber Optics business, reporting to president & CEO Dr Hong Q. Hou.

Prior to joining Emcore, Chiu served as chief operating officer for Contour Energy Systems Inc, a developer of advanced primary and next-generation rechargeable battery systems and as CEO for Superprotonic Inc, a start-up developing fuel cell technology. As a veteran in the fiber-optics industry, he has more than 20 years of experience in engineering design, manufacturing, quality and business processes. Chiu has worked in management and executive level positions for PCO, HP, E2O Communications, JDSU, and Optical Communication Products over recent years. He received his BS in Physics, and MS and Ph.D in Applied Physics from California Institute of Technology.

"LC brings us a wealth of knowledge and expertise in the fiber-optics industry," comments Hou. "With his deep technical and operations background, we believe he can drive further improvements in our business for new product introduction, cost reduction, and operational efficiency."

www.emcore.com

Emcore introduces 1x2, 1x4 and 1x8 3GHz RF redundancy switching for Optiva platform

Emcore has introduced the OTS-RSU 3GHz RF redundancy switch units (RSU) for the Optiva platform.

The Optiva platform includes a wide range of fiber-optic transport products for satellite and microwave communications from 1MHz to 40GHz. The OTS-RSU series supports satellite signal transport link redundancy applications for 1x2, 1x4 and 1x8 redundant switch configurations when integrated with Optiva RF fiber-optic transmitters and receivers.

Emcore says that Optiva OTS 3GHz RSUs are suited to minimizing the amount of spare equipment required by broadcast and cable operators while still maintaining link redundancy and back-up for multiple channels. They feature 50 and 75Ω BNC or 50Ω SMA connector options, dedicated Comm-Link for rapid switching response, and automatic and manual redundancy modes. Additional features include manual position/enable select button, channel status and switch position LED, and LNB power pass-through.

"The launch of the Optiva OTS-RSU 3GHz Redundancy Switch Units expands the Optiva platform's fiber-optic switching capabilities and supplements the existing 2.3GHz and 18GHz 1x1 OTS-RSU-1 switch models," says Frank Weiss, VP of Advanced Systems. "This makes the OTS-RSU series a complete optical switching platform."

All Optiva redundancy switch units provide SNMP monitoring and control. They can be housed in the same chassis and monitored by the same Network Management System (NMS) as Optiva HD video, audio, serial data, and USB extension and distribution cards to support the transport of multiple signal formats and frequency bands in a single flexible platform. The OTS-RSU series is CE & CSA certified and RoHS compliant.

www.emcore.com/optiva-ots-rsu-3-ghz

IN BRIEF

Supercomputing interconnects

At Supercomputing 2013 (SC13) in Denver (18–21 November), Finisar of Sunnyvale, CA, USA introduced a broadened portfolio of products for supercomputing interconnects using 10G, 14G and 25G building blocks common across the portfolio and leveraging high-performance optics.

The 25G-enabled products include enhancements to the established Quadwire and C.wire active optical cables (AOCs), board-mounted optical assemblies (BOA) and QSFP28 transceivers. These support the latest InfiniBand EDR and 100G Ethernet protocols, enabling the fastest applications in HPC. The 10G/14G-enabled products include SFPwire, Quadwire, and C.wire AOCs as well as SFP+, QSFP+ and CXP transceivers, designed for InfiniBand QDR/FDR, Ethernet, Fibre Channel, SAS, and PCIe protocols.

The products use Finisar's core technology components including VCSELs, photodiodes, and ICs. Leveraging a common set of building blocks shortens development times and improves manufacturing efficiency. Finisar adds that its AOC offer a lightweight, more compact solution than traditional copper cables.

At SC13, Finisar demonstrated its suite of 25G building blocks in an optical engine form factor, providing low power and what is claimed to be the highest-density optical interface for supercomputing interconnects. The demo showed a 25G BOA connected to a second 25G BOA with integrated CDRs on both transmit and receive channels. The BOA features what is claimed to be the world's fastest VCSEL (previously shown to work at up to 56Gbps). It is now sampling, and should be in full production in early 2014.

www.finisar.com

NeoPhotonics' quarterly revenue grows 16.1% year-on-year to record $76.8m

For third-quarter 2013, NeoPhotonics Corp of San Jose, CA, a vertically integrated designer and manufacturer of both indium phosphide (InP) and silica-on-silicon photonic integrated circuit (PIC)-based modules and subsystems for high-speed communications networks, has reported record revenue of $76.8m. This is up 2.4% on $75m last quarter and up 16.1% on $66.2m a year ago (and toward the higher end of the projected range of $72–78m). There were three customers that comprised over 10% of revenue: Alcatel-Lucent (18%), Ciena (13%) and Huawei Technologies (23%).

During the quarter, total cash, cash equivalents and short-term investments fell from $74.7m to $70.9m. Bank debt has risen from $26.3m to $34.2m.

The record revenue is a direct result of continuing adoption of the firm's PIC technology in the rapidly growing 100G market, says chairman, president & CEO Tim Jenks. "I particularly want to highlight the contribution of NeoPhotonics Semiconductor [formerly the Optical Component Unit of LAPIS Semiconductor, acquired in March], which significantly enhances our 100G product suite." Revenue from NeoPhotonics Semiconductor was about $14m (toward the high-end of the projected range for the business). Revenue from high-speed products was $28.4m (37% of total company revenue), up 31% on a year ago. "We continued to accelerate our 100Gb/s product suite," says Jenks. "We continue to achieve sequential growth, both organically and in the acquired NeoPhotonics Semiconductor business."

Interim chief financial officer Cal Hoagland attributes the growth primarily to: (a) continued strength in 100G products, including those used in coherent networks; (b) increased revenue from NeoPhotonics Semiconductor; and (c) an increase in revenue for Access products.

Revenue from the Access product group (point-to-point networks, certain wireless backhauling applications, and PON passive optical networks) was 23% of total revenue, up $2.7m on last quarter.

Revenue from Speed and Agility products was 69% of total revenue (consistent with last quarter). Of this, revenue from 40G and 100G products was about 37% of total company revenue, up $7m (31%) on a year ago although down slightly by $0.9m on Q2/2013, which had been up 33% on Q1 (resulting in slight excess inventory at key customers, which has now been consumed). Specifically, 100G products (with six different product families, all in production) now constitute 54% of Speed and Agility product group revenue, encompassing all of the firm's top-tier customers.

"This product group [40G and 100G] has been on an accelerated growth path over the last two years and, with Metro deployments beginning in 2014, we expect this trend to continue," notes Jenks. "Essentially all of our 100G product families are early in their life cycles, and we expect to leverage these product families for years to come. We are building on our proprietary PIC technology platform to introduce new and enhanced products and gain new customer design wins," he adds.

We expect to see modest increases in carrier capital expenditure, such as was recently announced by Verizon, and new program awards for 100G transport and metro deployments

"Our PON products have been declining slowly over the last two years," continues Jenks. "Due to plateaued growth in PON and continued pricing pressure in the market, we do not expect to see a growth trend in PON over the foreseeable future. As a result we have trimmed our spending in this area in order to enhance our 100G focus. PON products are relatively low margin, such that a slow decline in these products as they mature will not be adverse to overall margin or profitability. We anticipate that this segment will decline as a percent of our total revenue overtime."

For Q4/2013, NeoPhotonics expects revenue of $70–76m and non-GAAP gross margin of 24–28% (impacted by annual pricing negotiations in November and December).

"The China market in the first three quarter of the year was slower than previously expected, and we anticipate this to continue into the fourth quarter as large tenders announced by two of China's largest carriers have taken longer to be awarded than originally estimated by our analysts and our customers," says Jenks. "Recently, we have seen some large tenders being awarded for LTE deployments, and we anticipate that wireline deployments will start to pick up as well within 2014."

"We expect an increase in the economic growth in China could be accompanied by stronger demand from China carriers and their network equipment suppliers. In turn this would be beneficial to our top-line and create more leverage in our operating model," continues Jenks. "We believe that tender awards in China for 100G network deployments will strengthen our product mix and our market position as we participate in those network upgrades," he adds.

"In the industry going forward, we expect to see modest increases in carrier capital expenditure (CapEx), such as was recently announced by ►

Verizon, and new program awards for 100G transport and metro deployments, which we would expect to result in increasing demand conditions over time," says Jenks.

NeoPhotonics has added considerable manufacturing capacity that is just now beginning to be utilized as intended. "We have the necessary capacity for increasing volumes and at competitive cost," he concludes.

www.neophotonics.com

SEC filing delayed; Deloitte & Touche named as independent auditor

NeoPhotonics' quarterly report on Form 10-Q was due to be filed with the US Securities and Exchange Commission (SEC) by 12 November and would be deemed to be timely filed if the firm filed a Form 12b-25 and then filed the Form 10-Q by 18 November. However, the firm was unable to file by that date for the following reasons.

NeoPhotonics' financial statements for first-quarter 2013 (previously filed with the SEC in its quarterly report on Form 10-Q/A) included a real-estate registration tax of about $0.5m as a component of property, plant and equipment acquired in Japan as part of the purchase of NeoPhotonics Semiconductor. Upon further examination as to the nature and party legally responsible for the payment of the real-estate registration tax, NeoPhotonics has concluded that the tax amount should have been expensed as an acquisition cost. It will hence need to restate its financial statements for Q1 and Q2/2013 to reflect a decrease in cash flows from operating activities of about $0.5m, an increase of cash flows from investing activities of about $0.5m, and an increase in loss before income taxes of $0.5m in Q1 and the six months to end-June.

NeoPhotonics has determined that there is not enough time to complete the necessary close of its accounting records, perform procedures to adjust its financial statements for the item discussed above and reviews by an independent public accounting firm, and amend its quarterly reports on Forms 10-Q/As for Q1 and Q2, as well as file its quarterly report on Form 10-Q for Q3, prior to the required filing date. The firm intends to complete its review of the purchase transaction and the work related to the close of its accounting records as of end-September, and to amend and file its quarterly reports on Form 10-Q/As and 10-Q and file its Form 10-Q for Q3 after the completion of the appropriate work and quarterly reviews by an independent public accounting firm.

NeoPhotonics has further said that Deloitte & Touche LLP (which has experience in serving as independent registered public accounting firm to leading technology companies) has been appointed as its independent auditor, as of 15 November.

● Bandy Wu (previously controller at Micrel) has joined NeoPhotonics as VP & corporate controller, reporting to Hoagland. "Her professional experience and depth of knowledge in public company controls and reporting procedures will be an important and valuable addition," comments Hoagland.

Advanced Photonix receives 100G commitment

Picometrix LLC, a subsidiary of 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 completed its annual negotiations to supply high-speed optical receivers to a leading OEM telecom systems customer, leading to estimated 2014 annual revenue of $4.6-6m from the negotiations.

The 2014 commitment includes the full suite of Picometrix's 100G products, including the new CR-100D with integrated variable optical attenuator (VOA), designed for 100G long-haul communications in dense wavelength division multiplexing (DWDM) systems that use DP-QPSK and DP-BPSK modulation formats. The CR-100D receiver is designed to increase dynamic range, as well as improve optical signal-to-noise ratio (OSNR) performance. The receiver spans the entire extended C- and L-band wavelength range and can be used in 'colorless' coherent networks that enable service providers to better manage network capacity. Colorless capabilities allow communication equipment to use any wavelength for any port at the add/drop site, says the firm, allowing faster data throughput and lower costs per bit transport.

"We highly value our strong relationship and close collaboration with this strategic customer and their commitment to work with us this past year as our advanced procurement and engineering teams solved difficult supply chain disruptions in our 100G product offerings in the first half of 2013," says Rob Risser, chief operating officer of API and general manager of Picometrix. "The demand for 100G coherent equipment is in its early growth stage as bandwidth-intensive applications like full motion video and social media place demands on the networks infrastructure," he adds. "Virtually every carrier is deploying, or plans to deploy, 100G systems into the long-haul and metro markets over the next several years, and we plan to participate in this growth with our current and future 100G product offerings."

www.picometrix.com

OIF members approve Implementation Agreements for 100G applications, plus medium-reach CEI-28G

Optical Internetworking Forum (OIF) members recently approved three Implementation Agreements (IAs) addressing the needs for smaller modules for 100G deployments. The IAs focus on long-haul DWDM transmission modules, integrated polarization multiplexed quadrature modulated transmitters, and intradyne coherent receivers. A fourth IA defines medium-reach Common Electrical I/O (CEI)-28G-MR, for an electrical channel operating at peak speeds. All four agreements build on the already extensive list of IAs that the OIF has generated to help enable the interoperable 100Gb/s ecosystem.

"100G DWDM represents a significant development expense for component and system suppliers," says Nathan Tracy of TE Connectivity and OIF technical committee chair. "The original implementation agreements for 100G have been refreshed to support second-generation smaller-form-factor modules and the expectation for future pluggable modules," he adds. "Smaller-form-factor modules enable higher-density, lower-power equipment."

The 100G Long-Haul DWDM Transmission Module IA specifies key electromechanical aspects of Generation 2.0 of a 100G long-haul DWDM transmission module, for optical line interface and specifically 100G PM-QPSK long-haul DWDM transmission applications. The module size has been decreased by 40% to 4" x 5" to accommodate technological advances made since the first module was introduced and to reflect lower power consumption.

The Integrated Polarization Multiplexed Quadrature Modulated Transmitters IA specifies key aspects of optical transmitters operating at rates up to 32GBd per channel for applications such as 100G PM-QPSK DWDM transmission. The agreement reduces the size of the transmitter to fit into the Gen 2 LH DWDM transmission module.

The Intradyne Coherent Receivers IA also targets 100G PM-QPSK applications with nominal rates up to 32GBd. This IA reduces the size of the receiver to fit within the smaller 4" x 5" module and also will now fit into future CFP modules.

The CEI-28G-MR IA expands on the OIF's CEI work that defines the characteristics required to communicate between a CEI-28G-MR transmitter and a CEI-28G-MR receiver. This clause details the requirements for the CEI-28G-MR medium-reach high-speed electrical interface between nominal baud rates of 19.90Gsym/s and 28.1Gsym/s using NRZ coding. Medium reach is defined as capable of driving up to 500mm of PCB and up to 1 connector.

www.oiforum.com

OIF members continue focus on 100G and 400G applications

Optical Internetworking Forum (OIF) members convened in Hong Kong in late October for the Q4 Technical Committee meeting and OIF Day at Huawei. Three new projects were launched, including plans to define 400G characteristics through a Framework Document. Projects to define Integrated Polarization Multiplexed Quadrature Modulated Transmitters for 100G Metro Applications and an update on the Multi-Link Gear box protocol also kicked-off during the meeting. After the main meeting, 65 attendees took part in a live, interactive educational workshop featuring OIF and Huawei subject-matter experts to discuss both the OIF's projects and Huawei's current and future needs for electrical/optical and networking technologies.

400G Framework Document

The Physical and Link Layer (PLL) and Carrier Working Groups joined forces to begin developing a 400G Framework Document. The paper will analyze and discuss trade-offs between high-order modulation formats, high data rates per channel and a number of subcarriersleading to the definition of application scenarios and limits for 400G operation. The framework document will also consider single optical carrier versus multi-carrier solutions for long-haul and metro applications.

"Recently, several approaches to achieving 400G data transmission have been proposed with reported transmit fiber distances from short-haul to long-haul applications," says Nathan Tracy, TE Connectivity and the OIF's Technical Committee chair. "To develop this white paper, the OIF intends to bring the industry together to discuss the options and where the gaps exist for initial 400G long-haul implementations."

Integrated Polarization Multiplexed Quadrature Modulated Transmitters for 100G Metro

There is a great need for 100G coherent optical modulator modules for lower-cost, higher-density coherent metro. The project will incorporate the use of new modulator technologies enabling smaller and more cost-effective components needed for these metro applications.

Multi-Link Gearbox (MLG) 3.0

This project will define a protocol to support in-band and remote Monitoring & Control and define IEEE 802.3bj RS-FEC compatibility. In some applications the transport of 10GBASE-R signals over Nx20G links requires definition, including 2x20G and 1x40G links. The project will define in-band coding that preserves 10GBASE-R physical lane-to-lane ordering and in-lane bit ordering to support synchronous and asynchronous 10G lanes.

JDSU's revenue rises 1.8% in Q3 to $429m

Growth driven by network capacity build-out; Telecom bookings up 60%

For fiscal first-quarter 2014 (to 28 September 2013), JDSU of Milpitas, CA, USA has reported revenue of $429m, up 1.8% on $421.3m last quarter and 1.9% on $420.9m a year ago (and at the high end of the $410–430m guidance range).

Of total revenue, 46.4% ($199.2m) came from the Americas, 24.3% ($104m) came from EMEA (Europe, Middle-East and Africa), and 29.3% ($125.8m) came from Asia-Pacific. This compares with 48% ($204.5m), 21% ($86.8m) and 31% ($130m) respectively last quarter, i.e. EMEA was up significantly, while the Americas was down slightly due to lower North America demand and Asia Pacific was also down slightly.

By sector, 47.7% of revenue came from Communications and Commercial Optical Products (CCOP), 40.1% from Communications Test & Measurement (now termed Network and Service Enablement or NSE) and 12.2% from Optical Security and Performance (OSP). This compares with 43.3%, 45% and 11.7% last quarter, i.e. a swing from NSE (due to weak order intake in North America, including US government) to CCOP.

CCOP revenue was $204.6m, up 5% on $194.9m a year ago and 12.2% on last quarter's $182.3m, driven by renewed telecom product strength and continued growth in the datacom portfolio. Within CCOP, Optical Communications revenue was $176.2m, up 14.3% on $154.1m last quarter and 8.1% on $163m a year ago (with telecoms, datacoms and gesture recognition all recording double-digit percentage growth); Commercial Lasers revenue was $28.4m, down 11% on $31.9% a year ago but up 0.7% on $28.2m last quarter (as demand for lasers and semiconductor applications offset softness in other microfabrication applications and a flat quarter for fiber lasers).

"Results for the quarter were driven by strong growth in products that help our customers build out network capacity [including 100G solutions] and this, coupled with robust customer adoption of our new products, positions JDSU well in the markets we serve," says president & CEO Tom Waechter. Network-related revenue from new products less than two years old (such as the TrueFlex ROADMs) was 64%, marking the 10th consecutive quarter of new product revenue ahead of the firm's 50% target.

"The increase we are seeing in telecom demand is usually an indicator of future demand for transmission products that support Metro and Access networks, including our tunable XFP and tunable SFP+," says chief financial officer Rex Jackson. "Our TrueFlex ROADMs grew as expected, tripling off a small revenue base from Q4, as we completed qualifications and started to ramp into live network deployments," he adds. "Cloud networking is driving growth in our Datacom business. We have a strong profit pipeline for this market and excellent customer engagement for our 10G, 40G and 100G solutions."

On a non-GAAP basis, CCOP gross margin rose from 30.9% last quarter to 32% (including Optical Communications improving from 28.2% to 29.5%, due to increased revenue and continued operational improvements; Commercial Lasers gross margin rose from 45.4% to 47.5%). Overall gross margin has risen from 45.8% a year ago and 46.1% last quarter to 46.3%.

Operating expenses were $163.1m, down slightly from last quarter but up from $154m a year ago, due mainly to fiscal 2013 acquisitions and continuing investments in R&D. This yielded operating margin of 8.3%, down on 9.2% a year ago but up on 7.2% last quarter (and above the midpoint of guidance). In particular, CCOP margin was 13.3%, above the guidance of 10–12% due to the significant increase in revenue, good control of operating expenses, and continued improvement in product cost reduction.

Net income was $30.2m, down slightly from $30.4m last quarter and $35m a year ago. Although down from $57.1m last quarter, operating cash flow was still $29.5m, "our 28th consecutive quarter of positive operating cash flow, further strengthening our balance sheet and ability to fuel JDSU's strong innovation pipeline," says Waechter.

During the quarter, total cash and investments rose from $515.9m to $1087.3m, due largely to JDSU's senior convertible debt offering of $650m in August. The firm used $100m of the $636m net proceeds to repurchase 7.4 million shares of outstanding common stock. "We intend to use the balance of the proceeds for general corporate purposes, including potential strategic transactions," says Waechter.

Telecom bookings rose by 60% on last quarter. "It's a pretty good indicator that we're back in the beginning of a pretty strong telecom buildout," comments executive VP & CCOP president Alan Lowe. In contrast, NSE bookings fell.

For fiscal Q2/2014 (to 28 December 2013), JDSU expects revenue to be flat at $420–440m. In particular, NSE revenue should be flat to up 5% and OSP revenue should rise 2–5%. CCOP revenue should be flat. However, this is due to a drop in Gesture Recognition (due to seasonality) as well as lower Commercial Lasers revenue (due to slower demand for lasers used in micromachining) offsetting the higher Optical Communications revenue in Telecoms and Datacoms. Specifically in Optical Communications, following the strong telecom bookings in Q1, JDSU expects growth in both tunable modules (SFP+, XFP) and ROADMs (for which JDSU is adding capacity to meet the rapidly rising demand for TrueFlex products). Operating expenses should rise by 2–3%, yielding operating margin up to 8.5–10.5% (including CCOP margin remaining steady at 12–14%).

www.jdsu.com

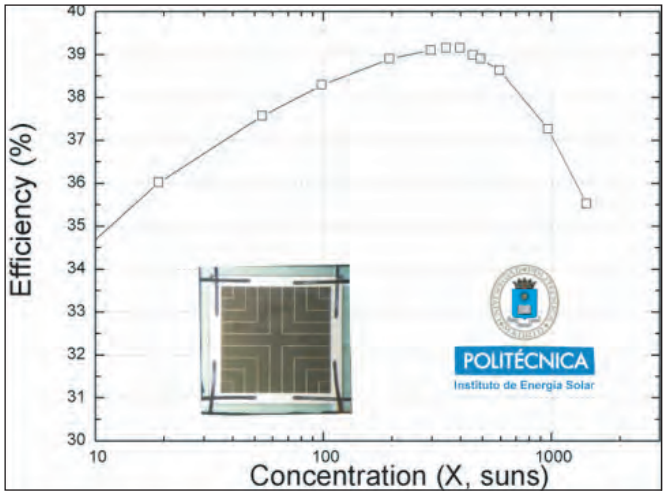
Spain's IES-UPM reaches 39.2% efficiency with triple-junction CPV solar cell

Future optimization targets 42% at 1000-sun concentration

The Group of III-V Semiconductors of the Instituto de Energía Solar at Universidad Politécnica de Madrid (IES-UPM) in Spain has reported a triple-junction concentrator photovoltaic (CPV) solar cell with an efficiency of 39.2%, as confirmed by the Fraunhofer Institute for Solar Energy Systems in Freiburg, Germany.

After in November 2008 reporting record dual-junction solar cell efficiency of 32.6% at 1026 suns, the research group has since focused on fabricating lattice-matched triple-junction solar cells for ultra-high concentration (1000 suns and above). The devices have an active area of 1 mm2 and consist of a gallium indium phosphide (GaInP)-based top cell (TC) with a bandgap energy of ~1.9eV, a gallium indium arsenide (GaInAs)-based middle cell (MC) with a bandgap energy of ~1.4 eV, and a germanium (Ge) bottom cell (BC) of with a bandgap energy ~0.6 eV, grown on a Ge substrate.

The measured cell shows a peak efficiency of 39.2% at a concentration of 398 suns, while the efficiency is still higher than 37% at 1000 suns.



Concentration performance of the cell.

The cell was manufactured using metal-organic vapour phase epitaxy (MOVPE) at IES-UPM's facilities, and the semiconductor structure includes a high-bandgap GaInP/AlGaAs tunnel junction between the TC and the MC that is able to operate at concentrations higher than 15000 suns. Besides, the TC consists of disordered GaInP, induced by using antimony (Sb) during the epitaxial growth of the TC.

The whole cell is now being optimized using proprietary software. So, in the near future, efficiencies higher than 42% are expected to be achieved at concentrations of 1000 suns.

Operation at irradiance of 1000 suns or greater has traditionally been a goal for the IES-UPM research group in order to achieve competitive electricity prices (well below those of 500-sun operation). Besides, good performance of the cells at concentrations greater than 1000 suns is recommended in order to prevent detrimental effects due to the unavoidable non-uniformity of light impinging on the solar cell in optical concentrators.

www.ies.upm.es

Germany's Fraunhofer ISE becomes research partner in US SunShot Initiative

The Fraunhofer Institute for Solar Energy Systems ISE in Freiburg, Germany has been awarded project funds within the framework of the US SunShot Initiative, becoming one of only three research partners in the program not from the USA.

Started in 2011 by the US Department of Energy (DOE) as a collaborative national effort supporting private companies, universities, and national laboratories, the SunShot Initiative's aim is to reduce the electricity generation costs for solar electricity in the USA to $0.06 per kilowatt hour, making solar energy fully cost-competitive with conventional fossil-fuel energy sources before the end of the decade. For over 30 years, Fraunhofer ISE has been working on increasing the energy efficiency of solar cells.

"We are delighted to be a European research partner in the second round of the SunShot Foundational Program to Advance Cell Efficiency (F-PACE)," says Dr Stefan Glunz, division director of Development and Characterization at Fraunhofer ISE. Together with the US National Renewable Energy Laboratory (NREL) and project leader Georgia Institute of Technology, the Fraunhofer researchers will work on further improving the efficiency of high-efficiency silicon solar cells. "The research focus will be on passivation strategies for solar cell contacts, emitter optimization as well as improved light trapping in the solar cell," says Glunz.

"Photovoltaics is a key player in the inevitable global energy transition to renewable energy sources and still holds potential for efficiency gains, which can be realized through international joint research efforts," says professor Eicke R. Weber, Fraunhofer ISE director since 2006 and former professor at the University of California, Berkeley.

www.energy.gov/sunshot
www.ise.fraunhofer.de

Spectrolab raises efficiency record for ground-based non-concentrator solar cells to 38.8%

New bonding technology boosts record from 37.8% set in April

Boeing subsidiary Spectrolab Inc of Sylmar, CA, USA has raised its world record for energy conversion efficiency in a ground-based solar cell without solar concentration from 37.8% (set in April) to 38.8%, as verified by the US Department of Energy's National Renewable Energy Laboratory in Golden, CO.

Spectrolab manufactured the high-efficiency multi-junction solar cell, which was developed from new Boeing semiconductor bonding technology. This solar cell technology could be used to power high-power spacecraft and unmanned aerial vehicles.

Spectrolab (part of Boeing Defense, Space & Security) claims to be the world's leading merchant supplier of high-efficiency multi-junction solar cells and panels for concentrated photovoltaic (CPV) and spacecraft power systems, in addition to being the world's leading provider of airborne searchlights.

"We will continue to innovate new ways to achieve even better results," says Spectrolab's president Troy Dawson.

www.spectrolab.com

China Development Bank loan for Focusic and Soitec to construct 20MW CPV project in Xinjiang

First utility-scale project to be granted CDB loan for CPV

Concentrating photovoltaic (CPV) system maker Soitec of Bernin, France says that renewable-energy power plant developer Focusic New Energy Holding Co Ltd of Zhengzhou, China has secured a loan for 200m Yuan (about $32.7m) from the China Development Bank (CDB) to finance a 20MW CPV project in Hami, a city on the edge of the Gobi desert in China's Xinjiang province. The project (of which the initial 3MW pilot plant was announced by Focusic and Soitec in 2011) is the first utility-scale project to be granted a CDB loan for CPV technology. This also marks the first large CPV power plant in China to secure financing.

Focusic is building the 20MW power plant in partnership with Soitec, which supplied the full dual-axis CPV systems for the first 3MW and will supply its new generation of high-efficiency modules for the entire project. Focusic has so far ordered 8.5MWp of modules from Soitec out of the 20MWp for which Focusic has secured the financing. The power plant is expected to begin contributing about 3MW to the local power grid by the end of this year and then ramp up its output as the plant is built out with another phase completed in 2014.

"The demo plant with Soitec technology has proven to be perfectly suited for the northwestern part of our country; we now look forward to getting connected to the power grid and beginning to generate electricity," says Focusic's managing director Ma Wenxing.

"This represents a very important milestone in our development strategy," comments Gaetan Borgers, executive VP of Soitec's Solar Energy Division. "As we continue our work with Focusic, we look forward to developing a pipeline of projects in China."

Soitec says that, with its power-generating efficiency of more than 30% and low installation and maintenance costs, CPV technology is the most cost-efficient solution for high-volume power generation in regions with high direct normal irradiance (DNI). China contains an estimated 500,000 square miles of territory with high-DNI ratings and has an enormous and growing demand for energy.

www.focusic.hk/English
www.soitec.com

First Solar to invest $100m to develop power plants in Japan

First Solar Japan established; local partners sought

Cadmium telluride (CdTe) thin-film photovoltaic module maker First Solar Inc of Tempe, AZ, USA says that it will invest about $100m in Japan to develop solar power plants. The firm aims to partner with Japanese companies to develop, construct, and operate solar power plants, mitigating Japan's dependence on nuclear and natural gas fuel imports.

"We invest in markets where solar power addresses a fundamental need on a sustainable basis," says CEO James Hughes. "Japan is adopting a progressive approach by incorporating clean, safe, renewable sources of power in its plans to address the gap created by idle nuclear power," he adds.

"First Solar has proven solutions to support Japan's vision of energy security and economic growth, and we will continue to invest here as part of our strategy to develop sustainable solar markets," Hughes continues.

Japan is expected to become one of the key solar markets due to its significant energy demand, with a government-set target to install 28GW by 2020. PV plants can be built quickly and safely, says First Solar, providing robust solutions to idled nuclear power.

"First Solar is the world's largest developer of solar power plants," says chief commercial officer Joseph Kishkill. "We plan to invest in Japan by developing solar power plants both with our own team and through local partners. We believe this strategy will accelerate the adoption of clean and safe solar power in Japan," he adds. "We welcome partnerships with Japanese companies who seek project investments and complete solar solutions."

With its expertise in development, engineering, procurement and construction of solar power plants, First Solar has established the Japan operating subsidiary First Solar Japan GK and opened an office in Tokyo, investing in Japanese resources and expertise, in order to effectively pursue growth opportunities.

www.firstsolar.com

First Solar starts construction of PV project in Japan

First Solar has started construction of a solar project in Kitakyushu-shi, Japan. Generation capacity will be 1.4MW_{DC}, and operation will start in first-quarter 2014. The project is described as providing clean and safe solar power to Japan, mitigating idle nuclear energy.

"This project illustrates First Solar's capability to develop and build solar power plants in Japan," says chief commercial officer Joseph Kishkill, adding that it marks the beginning of the firm's long-term strategic investment in Japan.

First Solar notes that more than 100 million of its modules (which integrate Japanese technology) have been installed worldwide. Tokyo-based Nippon Sheet Glass Co Ltd (NSG Group) supplies the glass with a proprietary electrical film tuned to First Solar's CdTe thin-film modules.

First Solar holds 100% equity in the project. Global construction contractors Obayashi Corp (based in Tokyo) and Yaskawa Electric Corp (based in Kitakyushu) will construct the project.

www.firstsolar.com

JX Nippon to distribute First Solar's PV modules in Japan

JX Nippon Oil & Energy Corp (Japan's leading distributor of oil and other energy solutions) has signed an agreement for the distribution of First Solar's modules in Japan through April 2015. As part of the agreement, First Solar will develop and manufacture the new technology obtained through the acquisition of TetraSun of San Jose, CA, USA (announced in April). JX Nippon is the market leader in Japan in refining and marketing oil through its ENEOS brand, and is also engaged in new energy business, aiming to become an integrated energy firm.

Developed with a unique and revolutionary PV cell architecture, and an innovative manufacturing process combining the consistency of conventional crystalline silicon technology with the high performance of high-end monocrystalline technologies, the First Solar's TetraSun offering allows Japanese consumers' access to technology that is high on efficiency, performance and quality, the company claims.

"JX's far-reaching distribution and our technology expertise will combine to deliver high-quality solar power solutions to Japan," reckons First Solar's CEO James Hughes. "This agreement reinforces First Solar's commitment to deliver safe, clean, and sustainable solutions to meet Japan's unique energy needs and energy security goals."

www.noe.jx-group.co.jp/english
http://tetrasun.com

First Solar sells 250MW Silver State South Solar Project to NextEra Energy Resources

Cadmium telluride (CdTe) thin-film photovoltaic module maker First Solar Inc of Tempe, AZ, USA has agreed to sell the 250MW$_{AC}$ Silver State South Solar Project to a subsidiary of NextEra Energy Resources LLC (a subsidiary of NextEra Energy Inc of Juno Beach, FL). The deal is expected to close early in 2014.

Silver State South is located on about 3000 acres of public land in Clark County, NV. The project is adjacent to the 50MWAC Silver State North project, which was developed and built by First Solar and commissioned in 2012 (acquired by energy distributor Enbridge Inc of Calgary, Canada).

First Solar will continue to develop and permit Silver State South, and provide engineering, procurement & construction (EPC) services for the project. Construction is expected to begin once final regulatory and permitting approvals have been received, and be completed in late 2016. At peak activity, the project will create up to 300 full-time construction jobs.

Silver State South will use First Solar's PV modules, installed on its single-axis tracker mounting system. All the power from Silver State South will be sold to Southern California Edison under a long-term power purchase agreement (signed in February 2011).

"First Solar is committed to bringing Silver State South to life as part of our growing Nevada solar power portfolio," says Tim Rebhorn, First Solar's senior VP of business development for the Americas.

"The acquisition of Silver State South is another important milestone as we continue to build our solar business," says NextEra Energy Resources' senior VP of development Mike O'Sullivan.

In mid-October, NextEra Energy Resources named First Solar as the EPC contractor for its 250MWAC McCoy Solar Energy Project in Riverside County, CA.

www.NextEraEnergyResources.com
www.firstsolar.com

IXL Group contracted to supply framing system for AGL Energy's New South Wales projects

Cadmium telluride (CdTe) thin-film photovoltaic modules First Solar Inc of Tempe, AZ, USA has awarded a contract to the IXL Group of companies based in Geelong, Australia to manufacture and deliver the framing system for the 155MW$_{AC}$ utility-scale solar photovoltaic (PV) projects at Nyngan and Broken Hill in New South Wales (NSW). Sydney-based AGL Energy Ltd (Australia's largest private owner and operator of renewable energy assets) engaged First Solar to construct the solar projects, which are expected to produce about 360,000 megawatt hours of electricity each year (enough to meet the needs of over 50,000 average homes in NSW).

In 2012, IXL manufactured and delivered the framing system for the 10MW Greenough River Solar Farm (GRSF) in Western Australia, which was also constructed by First Solar. Until now, GRSF was the largest solar project completed in Australia. IXL has benefited from the experience with that first project to provide First Solar an Australian-manufactured framing capability with a relatively short supply chain. The framing system for the Nyngan and Broken Hill projects will require about 6000 tonnes of Australian-made steel.

"Our continued selection of local supply chain providers validates the economic viability of producing solar components in Australia and will continue to help support Australian industry and job creation," says Jack Curtis, First Solar's VP of business development for Asia Pacific. "Partnering with IXL will further enable First Solar to reduce the cost of delivering solar power to the Australia market through the efficiencies that come from working on multiple projects."

Various companies in the IXL Group will contribute to the project, which at its peak will create about 40 additional jobs within IXL. Backwell IXL in Geelong will be responsible for a range of components to be used in the framing system, as well as building much of the manufacturing infrastructure. These activities will also have a positive impact on ancillary companies in Geelong and Victoria more generally, as tooling and a roll forming line for the project will be sourced from suppliers in Victoria.

IXL Solar will assemble the framing systems in Adelaide, and ship the completed frames to site using road trains. Generally, framing system suppliers need to assemble product in locations that are relatively close to installation sites. The Adelaide assembly location helps First Solar to substantially reduce its project freight costs. Assembly locations for other future projects will be based on the requirements of those projects.

"This is a very important step in the development of our solar business," comments IXL Solar's general manager Claude Dagescy. "We look forward to working with First Solar on the Nyngan and Broken Hill projects and beyond, and believe that Australian-made framing systems can be more than competitive with imports."

www.ixl.com.au

ZSW raises thin-film PV efficiency record from 20.3% to 20.8%

CIGS efficiency surpasses peak performance of 20.4% for polycrystalline silicon cells

ZSW (Zentrum für Sonnenenergie- und Wasserstoff-Forschung — or Center for Solar Energy and Hydrogen Research — Baden-Württemberg) in Stuttgart, Germany has raised its energy conversion efficiency record for thin-film solar cells from 20.3% to 20.8%, as confirmed by the Fraunhofer Institute for Solar Energy Systems ISE in Freiburg. This is also the first time that a CIGS PV cell has exceeded the laboratory efficiency levels of existing widely used polycrystalline solar cells (which have held an advantage for nearly 30 years), overcoming the remaining disadvantage of using cost-efficient thin-film PV technology, it is reckoned.

Covering an area of 0.5cm^2 (normal for experimental cells), the record copper indium gallium diselenide (CIGS) cell was manufactured in a laboratory coating system using the co-evaporation method which is capable of being transferred into industrial production processes, and which was developed further and patented jointly by ZSW and industrial partner Manz AG of Reutlingen, Germany (a supplier of integrated production lines for crystalline silicon solar cells and thin-film solar modules). The latest record is the result of joint research by ZSW and Manz.

The goal of the partnership is to cut the cost of solar power more rapidly. With the latest efficiency record, the two firms reckons they have moved a large step closer to this goal.

Manz holds the exclusive rights to use the record technology, and will now transition it from laboratory-scale cells into mass-production modules.

"With a record module efficiency of 14.6% we have already caught up with polycrystalline technology last year," notes Manz's founder & CEO Dieter Manz. "The research result of the world record cell will help us speed up the increase in efficiency on production-size modules," he adds. Manz has its CIGS innovation line in Schwäbisch-Hall, where it produces modules on a large scale and transfers knowledge gained in the lab to mass production. "Customers of our CIGSfab — the fully integrated, turnkey production line for CIGS thin-film solar panels [which uses ZSW technology] — will see the greatest benefit from this achievement," says Manz.

Dieter Manz (right) with Dr Kay Orgassa, head of CIGS development, next to a CIGS thin-film solar panel.

"We are going to offer them exclusive access to the world's leading world-record technology."

CIGS production costs are already considerably more favourable, reckons Manz. "On top of that, the technology has the greatest potential for further efficiency increases," he adds. "Production lines can be scaled as desired and, thanks to the comparatively low initial investment, they are perfect for manufacturing panels locally in the large growth markets of PV with local content requirements. These markets are characterized by an energy demand that is constantly increasing, which cannot be covered by fossil fuels. Due to the high level of integration compared to crystalline production, the CIGS PV production process is much simpler, more affordable and can thus be realized much faster, Manz claims. In addition, most of the materials needed can be sourced locally, strengthening the local economy.

Existing market-standard CIGS PV modules have efficiencies of 14–15%. Manz has a roadmap for its solar business that plans to offer CIGSfab customers solar panel efficiency increases of up to 16% and more within the next four years. Professor Michael Powalla, board member and head of the photovoltaics division at ZSW, believes that 16–18% in commercial modules is possible over the next few years.

It is reckoned that the latest efficiency record will help technologies 'made in Baden-Württemberg' to compete against Asian rivals.

ZSW's research has been supported for many years by both the German Federal Environment Ministry and the state of Baden-Württemberg.

www.zsw-bw.de
www.manz.com

ZSW achieves 10.3% European CZTS efficiency record

Simpler, printed process yields less costly, less complex CZTS cell

In its search for more advantageous materials and processes for manufacturing efficient thin-film solar cells, ZSW (Zentrum für Sonnenenergie- und Wasserstoff-Forschung — or Center for Solar Energy and Hydrogen Research — Baden-Württemberg) has developed a simplified production process for kesterite (copper-zinc-tin-chalcogenide) thin-film solar cells, where the absorber layer contains tin and zinc (two readily available and inexpensive materials). ZSW's highest-performing copper zinc tin selenide (CZTS) cell reaches an efficiency of 10.3% — a new European record — as confirmed by Germany's Fraunhofer Institute for Solar Energy Systems ISE.

The research institute in Stuttgart, Germany broke through the 10% efficiency threshold for kesterite solar cells in October. The new value is close to the world record of 11.1% for CZTS solar cells set by IBM Research in August 2012. However, that cell was manufactured in a more complicated process. At 0.5 square centimetres, the ZSW solar cell has the standard experimental cell size.

"The new compound is similar to CIGS [copper indium gallium diselenide], however instead of indium and gallium it contains the abundantly available elements tin and zinc," notes professor Michael Powalla, ZSW board member and head of its Photovoltaics Division. Due to the new material, the production method (which involves a simple printing process) is less expensive and less complex. "During the kesterite solar cell manufacturing process, substrate glass is coated with a non-toxic ink solution containing the preferred elements – without requiring any complex vacuum technology," adds Powalla. The resulting precursor layer is subsequently selenized in a heating process. The remaining production process involves the same methods as the related CIGS technology. However, according to ZSW, kesterite cells are not yet ready for commercial application.

The kesterite solar cells were developed at ZSW in collaboration with researchers at the Karlsruhe Institute for Technology (KIT). The Karlsruhe School of Optics & Photonics (KSOP, a graduate school at KIT) is also supporting the work through a PhD scholarship (with PhD student Thomas Schnabel winning this year's KSOP Publication Award in the solar energy research area). ZSW has collaborated for several years with both the KSOP and KIT's Center for Functional Nanostructures (CFN).

ZSW says that the results again confirm the importance of basic research for the application-oriented development of new solar cells. "These fundamental findings are absolutely essential for any technological progress in terms of sustainability, more efficient manufacturing processes and a reduction in costs," says Powalla.

www.zsw-bw.de

Honda to discontinue operations of subsidiary Honda Soltec in spring 2014

Japan's Honda Motor Co Ltd plans to discontinue the operations of its copper indium gallium diselenide (CIGS) thin-film photovoltaic module manufacturing subsidiary Honda Soltec Co Ltd in spring 2014 and withdraw from the production and sale of photovoltaic products.

Honda Soltec was established in December 2006 and began operation in October 2007 on the campus of Honda Motor's Kumamoto Factory in Kumamoto Prefecture. Capital investment was ¥4bn. With 11,080m^2 of floor space on a 25,000m^2 site, Honda Soltec's annual production capacity is 30MW. Spanning R&D, production, and sales & service of photovoltaic modules, generators and other electrical and precision equipment (with sales offices in Wako in Saitama prefecture, Osaka in Osaka prefecture and Kikuch in Kumamoto prefecture), staffing comprised 91 associates (as of end-September).

The firm says that Honda Soltec strove to maintain and improve the competitiveness of its products amidst considerable changes in the competitive environment of the PV industry, including a decline in the price of silicon-based solar panels due to falling silicon prices. Despite such efforts, Honda reckons that the prospects are not good for Honda Soltec to attain its original business plan (for example, its CIGS PV panels' maximum solar energy conversion efficiency is 13%, which is several points lower than that of crystalline silicon PV panels). So, the firm has concluded that it is difficult to continue in the PV business.

Honda Soltec will be dissolved as a firm in spring 2014. In the Japan market, it will take new orders until mid-February, and after-sales service for Honda PV systems sold up to that date will be continued through the affiliated company Honda Kaihatsu Co Ltd.

Honda says that it will continue its electricity generation and sales business, which targets the widespread use of renewable energy, as well as R&D on the Honda Smart Home System through which Honda aims to foster recycling-oriented energy management based on home energy generation and consumption.

www.honda.co.jp/soltec

Solexant rebrands as Siva Power, refocusing on Gigawatt-scale CIGS PV production

New direction targets sub-$0.40 per Watt production cost; firm forms Technical Advisory Board

Solexant Corp of San Jose, CA, USA has announced a new corporate identity as Siva Power, the culmination of a two-year transition to a platform that aims to create a profitable path to sub-$0.40 per watt solar power, along with what it claims is unprecedented production scale. The firm has also announced a Technical Advisory Board.

"Unlike silicon photovoltaics (PV), our new approach provides a pathway to building the solar industry's 'factory of the future' with gigawatt production capacity, and the world's lowest cost in solar," says CEO Brad Mattson. "Two years of data-driven research and analysis has led us to pursue a co-evaporated CIGS [copper indium gallium selenide] via monolithic integration on glass technology."

Drawing upon Mattson's past success in scaling new semiconductor technologies through process, equipment and materials innovation, the firm cancelled its expansion plan to build a 100MW CdTe production line in Oregon, and instead tripled its R&D budget with a goal of investigating new technologies that offered much lower-cost production. After investigating several promising solar technologies including gallium arsenide (GaAs), indium phosphide (InP), copper zinc tin sulfide (CZTS), cadmium telluride (CdTe) and CIGS, Siva determined that CIGS was the only viable path to less than $0.40/watt.

Siva Power has completed its R&D phase and is raising money to build its first production line. At 300MW, the facility is threefold larger than any other full production line and tenfold larger than typical silicon lines, it is reckoned.

In the USA, in 2011 the Department of Energy created the PV Manufacturing Consortium (PVMC) dedicated to accelerating CIGS transition from R&D to manufacturing. Meanwhile, solar manufacturers in China have shown increased confidence in the technology, recently acquiring three CIGS firms. Solar Frontier in Japan has also become the world leader in CIGS and second only to CdTe PV module maker First Solar in thin-film production.

To capitalize on the growing consolidation around CIGS, earlier this year Siva Power hired CIGS technologist Dr. Markus E. Beck as chief technology officer. Building on that foundation, Siva Power has formed a Technical Advisory Board and added two new advisory board members:

- Dr Rommel Noufi is a pioneer in thin-film solar cells (particularly CIGS), spending over 33 years at the National Renewable Energy Laboratory (NREL) dedicated to the advancement of PV and CIGS technology. His work in co-evaporation techniques led to a deep understanding of the basic technology and several world-record CIGS devices.
- Dr John Benner, a 33-year veteran of NREL (focused on PV technology), is now executive director of the Bay Area Photovoltaic Consortium (BAPVC), the west coast counterpart to PVMC. Working out of Stanford University and University of California, Berkeley, the BAPVC is investigating advanced techniques in CIGS along with other PV technologies.

"It has been frustrating to see CIGS technology breaking efficiency records for many years, but not see that technical success translate into success in the commercial arena," comments Noufi. "In Siva Power I see the technology, the team, and the technical and business leadership to bring CIGS to the scale it deserves."

www.sivapower.com

Ascent Solar raising $10m in financing with Ironridge

Proceeds to fund expansion of retail channels and launch of extra EnerPlex products

Ascent Solar Technologies Inc of Thornton, CO, USA, which makes lightweight, flexible copper indium gallium diselenide (CIGS) thin-film photovoltaic modules that it integrates into its EnerPlex series of consumer products, has signed an agreement to raise $10m through a registered direct offering with institutional investor Ironridge Technology Co, a division of Ironridge Global IV Ltd. Ascent will issue up to $10m of Series B convertible preferred stock in two tranches.

The initial $5m tranche of preferred stock will be convertible into shares of common stock at a fixed conversion price of $1.15 per common share.

The second tranche of $5m is expected to close in late 2013 or early 2014, and to be convertible into shares of common stock at a fixed conversion price of either $1.15 or $1.50 per common share.

Ascent intends to use the proceeds of the offering to fund the continued operations and expansion of its retail channels for its EnerPlex products in the USA, Europe and Asia, brand building, and the launch of additional EnerPlex products.

www.ascentsolar.com

LayTec's PearL qualified for CIGS monitoring in high-volume PV production

LayTec AG of Berlin, Germany, which makes in-situ metrology systems for thin-film processes (focusing on compound semiconductor and photovoltaic applications), says that its PearL spectroscopic photoluminescence (PL) system has been evaluated by German solar equipment and module manufacturer Manz CIGS Technology GmbH.

To improve the production process of $Cu(In,Ga)Se_2$ thin film modules, it is important to ensure the quality of the absorber, says the firm. Measurements on over 2000 production and test modules showed that PearL has numerous advantages under production conditions:

- PearL provides reliable CIGS characterization across the full module length at different points;
- PearL provides spatially resolved information about band gap, material composition and quality of the CIGS absorber material;
- PearL analyzes the absorber directly after its deposition and, therefore, feeds back important absorber parameters without interference of other layers;
- PearL identifies faulty substrates before cost-intensive back-end processing;
- compared to x-ray fluorescence (XRF), which needs about 90s for one measurement point, the measurement time of PearL is only 0.1s, which makes the tool more appropriate for high-volume production.

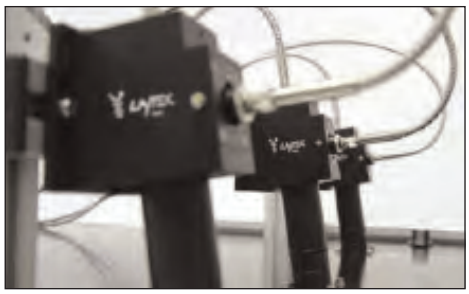


Figure 1: Three measurement heads of PearL installed over a module.

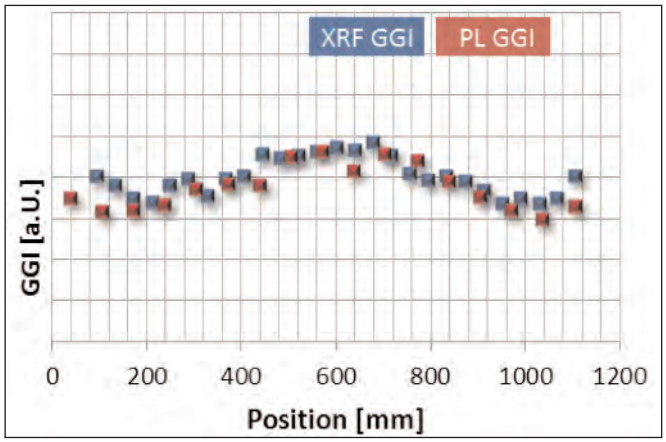


Figure 2: Direct comparison of GGI results measured by XRF (blue) and PearL (red) across substrate.

To monitor the CIGS coating process and to optimize the module performance, an exact identification of Ga/(Ga+In) ratio (GGI) is extremely important. Since the GGI is directly correlated to the bandgap of the absorber, this parameter has an influence on the open-circuit voltage (V_{oc}) and external quantum efficiency (EQE) of the device.

A line scan across the length of a CIGS coated substrate was performed by both PearL and XRF. With the XRF method, the element composition of the absorber is determined and the GGI can be computed. The agreement of both measurement methods to determine the Ga/In ratio is very good (see Figure 2), which proves that the spectrally resolved PL is a reliable and fast method to obtain in-line GGI line scans.

These results were presented by Manz and LayTec at the 28th European Photovoltaic Solar Energy Conference and Exhibition (EU PVSEC 2013).

www.laytec.de/pearl

Hanergy Solar increases shareholding by 8 million shares

Beijing-based Hanergy Holding Group Ltd — which is claimed to be the world's biggest thin-film photovoltaic (PV) firm — says that, through its subsidiary Hanergy Investment Ltd, it has further acquired from the market a total of 8 million shares of Hanergy Solar Group Ltd.

Hanergy says that it has confidence in the future prospects of China and global solar energy industry and believes that there will be considerable growth and development in the solar energy industry in foreseeable future.

Earlier this year, Hanergy Solar acquired the intellectual property rights of two copper indium gallium diselenide (CIGS) thin-film photovoltaic technologies, namely of MiaSolé of Santa Clara, CA, USA and Solibro GmbH (the latter from Q.CELLS SE of Bitterfeld-Wolfen, Germany).

On 24 September, Hanergy Solar launched 120MW large-scale solar power plant projects in Qinghai and Xinjiang. On 30 October, Hanergy Solar acquired the entire equity interests of Columbia Solar Energy LLC, which is in the course of developing a 19MWAC solar facility in Pittsburg, CA, USA.

Hanergy Solar says that it continues proactive investment in the downstream solar business. Also, adds the company, CIGS thin-film solar modules are becoming more widely used in building-integrated photovoltaic (BIPV) and building-applied photovoltaic (BAPV) projects due to its superior conversion efficiency performance, as well as the competitive cost structure.

www.hanergy.com

Thinning gallium nitride barriers for more efficient photovoltaic conversion

Structures with up to 50 InGaN quantum wells produced on sapphire and bulk GaN.

University of California Santa Barbara (UCSB) and Fuji Electric Corp of America have been developing indium gallium nitride (InGaN) solar cell structures in efforts to extend the conversion efficiency of multi-junction photovoltaic (PV) devices to shorter photon wavelengths [N. G. Young et al, Appl. Phys. Lett., vol103, p173903, 2013].

Existing three- and four-junction PV devices are limited to converting photons with energies less than 2eV (620nm, red-orange). According to theoretical analyses, a further semiconductor junction with an absorbing material having a bandgap around 2.6eV (480nm, blue) is needed to utilize higher-energy photons.

Indium gallium nitride is a material system capable of creating such bandgaps. However, InGaN with indium fractions above 20% is tricky to grow with sufficient thickness and quality to convert these high-energy photons. The material is generally grown on gallium nitride and can only be applied in thin nanometer-scale layers before the crystal quality degrades. Hence, InGaN for light emission is usually grown in a series of thin layers separated by GaN barriers, creating multiple quantum wells (MQWs). In light-emitting diodes the wells are often less than 5nm thick, while barriers are more than 10nm.

Unfortunately, the barriers impede carrier extraction and also create other electrical problems, so it is desired to reduce the barrier thickness as much as possible. UCSB reported last year a technique for growing InGaN MQWs with thinner GaN barriers, and have now applied the method to create PV structures with up to 50 wells.

The UCSB/Fuji researchers grew the InGaN multiple quantum wells for the solar cells (Figure 1) on co-loaded sapphire and bulk GaN substrates using metal-organic chemical vapor deposition (MOCVD). The sapphire substrate was half of a 50mm-diameter wafer that included a 2µm n-GaN template layer. The 5mm x 5mm bulk GaN was supplied by Furukawa Denshi Co Ltd from a hydride vapor phase epitaxy (HVPE) process.

Heavily-doped contact	p^+-GaN ($1x10^{20}/cm^3$ [Mg])	10nm
Moderately-doped contact	p-GaN ($2x10^{19}/cm^3$ [Mg])	20nm
Heavily-doped contact	p^+-GaN ($5x10^{19}/cm^3$ [Mg])	25nm
MQW	$In_{0.2}Ga_{0.8}N$/GaN	10-50 periods
Highly-doped contact	n^+-GaN ($2x10^{19}/cm^3$ [Si])	10nm
Template/contact	n-GaN ($6x10^{18}/cm^3$ [Si])	2µm
Substrate		

Figure 1. MQW structure of InGaN solar cells.

The bulk GaN had a threading dislocation density (TDD) of $3x10^6/cm^2$, while the n-GaN template on the sapphire substrate had a TDD value at least two orders of magnitude greater.

The active region consisted of 10-to-50-period MQWs consisting of 2.3nm wells on sapphire and 3.0nm wells on bulk GaN. The researchers do not fully understand the different well thicknesses given the same process conditions. High-angle annular dark-field imaging with a scanning transmission electron microscope (HAADF-STEM) showed 'severe' well thickness fluctuations on sapphire substrates.

The GaN barrier layers were 4.0nm on both substrates. The thinness of the barriers was achieved by using a low temperature to deposit a 2nm GaN cap on the InGaN and then adding the remaining 2nm at high temperature in hydrogen "to improve surface adatom mobility and effectively fill in the V-defects". (V-defects tend to nucleate on pre-existing threading dislocations, creating losses through recombination centers and current leakage.) This process had previously been developed and optimized at UCSB to achieve thinner barriers than previously achieved. HAADF-STEM analysis of the bulk GaN structure showed slight variation in barrier thickness.

The solar cells were fabricated by standard techniques: 1mm x 1mm mesa isolation plasma etch, evaporation of

palladium/gold p-electrodes in a grid pattern, and deposition of aluminium/gold n-electrodes onto the n-GaN contact material at the base of the mesa.

The 50x MQW devices showed increased external quantum efficiency (EQE) and absorption over the thinner MQW devices. The spectral response extended down to 460nm. The peak EQE was 60% on bulk GaN. For the sapphire-based devices the improvements with more MQWs fell off significantly beyond the cell with 20x MQW.

Current-voltage measurements in dark and illuminated conditions gave open-circuit voltages up to 2.28V and fill factors up to 80% (Figure 2). The researchers consider the best device to be one with a 30x MQW active region grown on bulk GaN. For this cell the peak EQE was 51.2%, the open-circuit voltage 2.26V, the fill factor 70.4%, the short-circuit current density 2.10mA/cm^2, and the maximum power density 3.33mW/cm^2 (33.3W/m^2). The conversion efficiency came out at 2.5% on the basis of the input integrated power density of 1336.1W/m^2 under the AM0 standard. (AM0 represents the radiation intensity from the sun as seen in the vacuum of outer space, as needed for artificial satellite/space applications.)

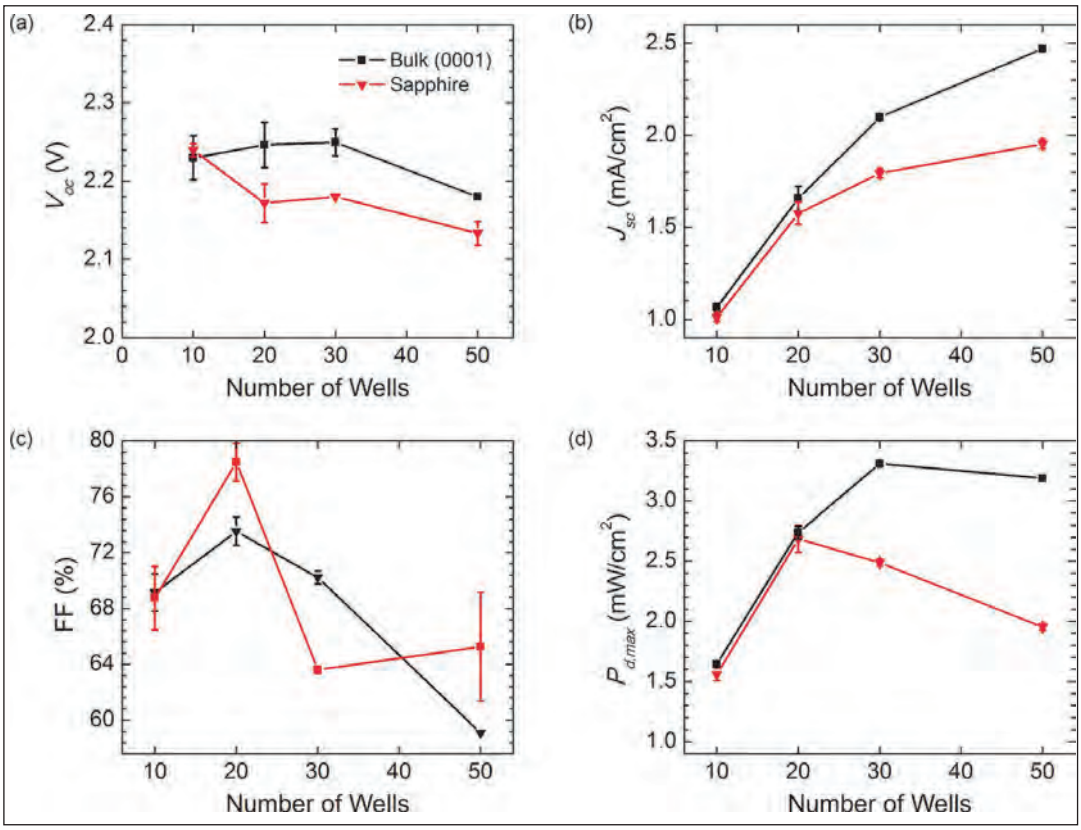


Figure 2. Dependence of (a) open-circuit voltage, (b) short-circuit current density, (c) fill factor, and (d) maximum power density on number of QWs for samples grown on co-loaded bulk (0001) GaN and sapphire substrates.

The bulk GaN substrate devices showed generally improved performance over the sapphire cells, except for the fill factor (maximum power as a fraction of the product of open-circuit voltage and short-circuit current). This is partly a result of reduced numbers of V-defects that tend to emanate from the threading dislocations and then propagate through the MQW region.

Above 20 wells, sapphire-based cells showed pits on the surface, indicating V-defects in atomic force microscopy (AFM) analysis. By contrast, the bulk GaN cells were smooth and pit-free up to 50 wells. However, beyond 30 wells the bulk GaN cells did show a decline in performance.

Some of the improved cell performance from material grown on bulk GaN can be attributed to the thicker wells compared with the material grown on sapphire. HAADF-STEM study also showed some defects arising in the quantum well structure itself rather than being propagated from the underlying material. The researchers suggest this would lead to a drop in performance for the thicker MQW structures on bulk GaN beyond 30 periods.

The 30-period MQW on bulk GaN solar cell is still some way off from the theoretically ideal performance for an InGaN structure (Table 1). The main deficit in performance is related to the short-circuit current. The researchers say the limiting factor for the current density is the thickness of InGaN that can be grown before the onset of structural instabilities due to mismatch stresses. Such stresses degrade the absorbing material quality and hence solar cell performance.

The team comments: "One possible solution for preventing strain-related degradation is a strain-balanced InGaN/AlGaN MQW active region, though any solution will involve significant materials growth challenges." ■

http://dx.doi.org/10.1063/1.4826483

Author: Mike Cooke

Table 1. Comparison of device parameters between values measured for 30 QW InGaN/GaN solar cell on bulk (0001) GaN and for an ideal InGaN-based solar cell with the same bandgap.

Parameter	Measured	Theoretical	% of ideal
Short-circuit current	2.10mA/cm^2	6.23mA/cm^2	33.7%
Open-circuit voltage	2.26V	2.343V	96.5%
Fill factor	70.4%	89.5%	78.7%
Maximum output power	3.33mW/cm^2	13.06mW/cm^2	25.5%

White light from near-UV and blue laser diodes and phosphors

Researchers at UCSB seek ways to avoid efficiency droop in high-brightness devices.

University of California Santa Barbara has been exploring the use of laser diodes (LDs) in combination with phosphors as a means to produce white light [Kristin A. Denault et al, AIP Advances, vol3, p072107, 2013].

Commercial 'white' light-emitting diodes (LEDs) generally use a blue or near-ultraviolet (near-UV) III-nitride LED to excite a phosphor target that converts the relatively narrow spectrum of the LED into something that approaches a white light spectrum of varying quality.

UCSB believes that using laser diodes instead of LEDs could have a number of advantages such as avoiding the 'efficiency droop' problem of nitride semiconductor LEDs at high current injection. Further, the use of laser diodes could allow better thermal management, with the exciting laser diode being separated from the phosphor target material, due to the higher directionality of laser light. In LEDs, self-heating effects cause shifts in wavelengths that alter the color-rendering quality, along with reducing the efficiency.

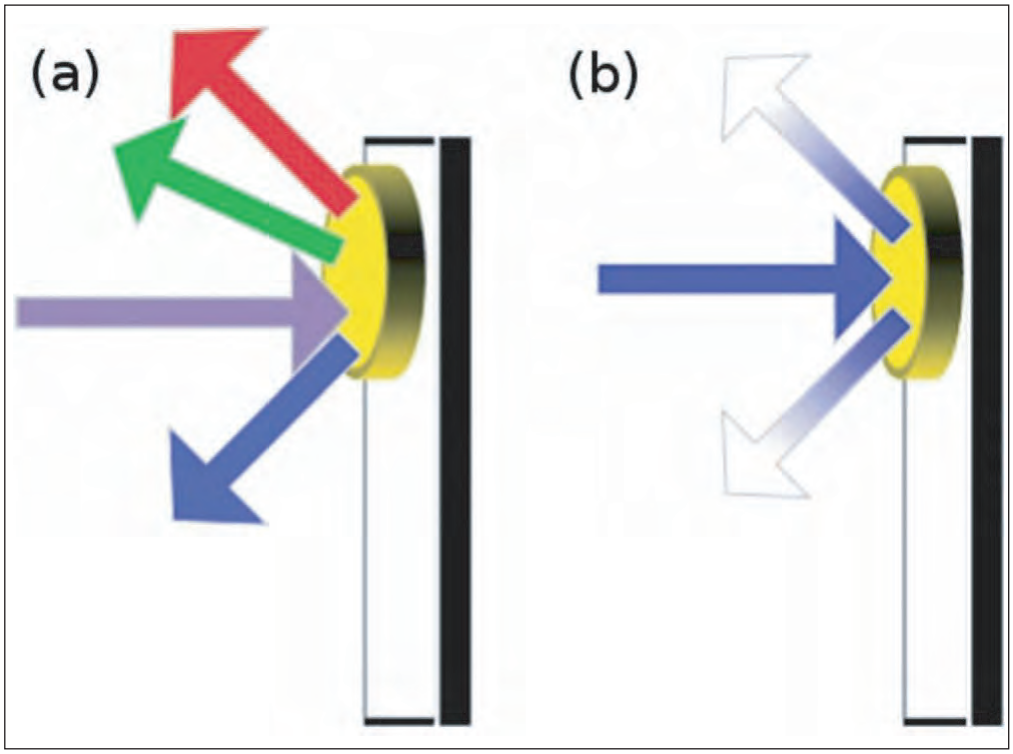


Figure 1. Experimental schematic for laser-excited phosphor samples in an integrating sphere for (a) near-UV-excited RGB phosphors and (b) blue-excited YAG:Ce.

Table 1. Parameters of commercial LDs used.

	Peak wavelength	Full-width at half-maximum	Threshold current	Wall-plug efficiency
Near-UV	402nm	2.6nm	30mA	20%
Blue	442nm	2.7nm	150mA	30%

Commercial near-ultraviolet (UV) and blue LDs (Table 1) were used to excite phosphors in disk form (Figure 1). The UV LD was used in combination with two types of red-green-blue phosphor mixed in silicone resin with respective weight ratios of 1.65:1:3.45 (RGB_1) and 3.3:1:2.3 (RGB_2). The phosphors that were used were a proprietary formulation developed by Mitsubishi Chemical Corp.

The blue LD was used on standard yellow-emitting cerium-doped yttrium aluminium garnet phosphor, as used for low-cost white LEDs ($Y_3Al_5O_{12}$:Ce_3+/YAG:Ce = $Y_{2.94}Ce_{0.06}Al_5O_{12}$). The powdered YAG:Ce was formed into pellets and heated at 1500°C for 5 hours to make the phosphor target.

The measurements were taken with the phosphor mounted in an integrating sphere. The laser light came in through a side port, hitting the phosphor disk at a

slight angle to avoid reflection back out of the side port. The measurements (Table 2) included values for correlated color temperature (CCT), color rendering (R_a), luminous flux (ϕ_v) and luminous efficacy (η_v) of the resulting 'white' light.

The near-UV LD was operated at peak efficiency with an injection current of 450mA. The near-UV results are described as showing excellent color temperature and color-rendering capabilities. "The luminous flux produced is comparable to current commercially available bright white LEDs of similar color temperatures," the researchers write. The use of near-UV allows a range of color temperatures to be achieved with high color rendering.

However, the LDs have relatively low wall-plug efficiency (WPE), impacting luminous efficacy. The researchers hope that future development in laser technology may lead to efficacies exceeding those of commercial LEDs.

White-light emitting devices using near-UV LD excitement would presumably contain filters that would remove the unconverted laser light, avoiding concerns about eye safety.

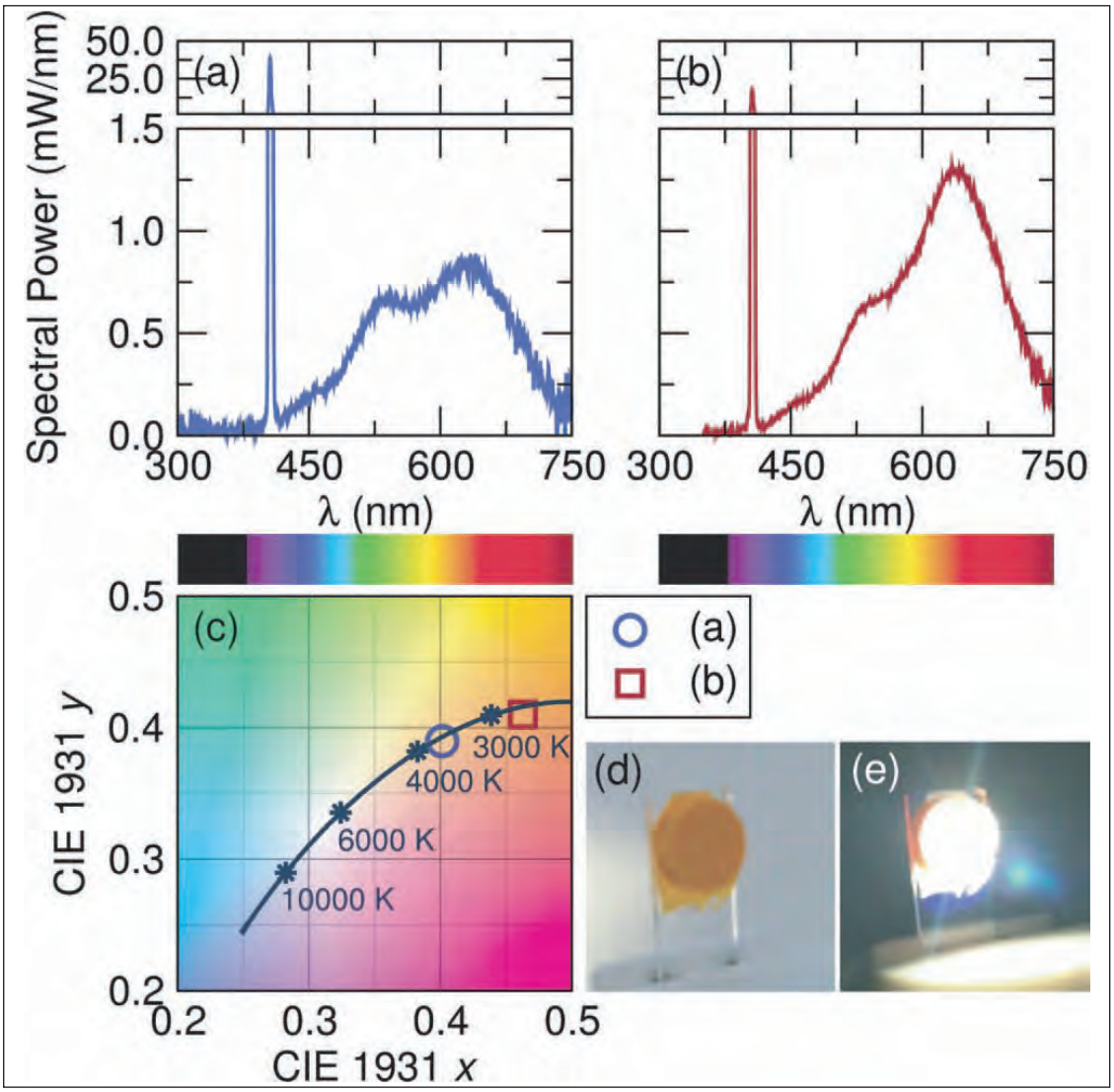


Figure 2. Spectral power distribution for phosphor samples (a) RGB_1 and (b) RGB_2 excited using a near-UV LD and (c) corresponding CIE (Commission Internationale de l'Éclairage) chromaticity coordinates. Photographs of RGB_2 phosphor sample (d) without and (e) with laser excitation.

Table 2. Measured correlated color temperature (CCT), color rendering (R_a), luminous flux (ϕ_v) and luminous efficacy (η_v).

Sample	CCT (K)	R_a	ϕ_v (lm)	η_v (lm/W)
RGB_1	3600	91	47	16
RGB_2	2700	95	53	19
YAG:Ce	4400	57	252	76

The blue-LD setup with a peak efficiency injection current of 750mA had much better efficacy, but the cost was a cool color temperature and poor color rendering due to the absence of a strong red component. LEDs that only use YAG:Ce phosphors suffer from a similar problem. A further problem for blue laser excitation is that the blue component covers a smaller range of wavelength due to narrower width of the laser spectral line compared with that resulting from spontaneous emissions from an LED.

The researchers performed calculations to gauge the possible improvements in efficacy for a blue-LD on YAG:Ce phosphor setup if the WPE could be increased from 30% to 75%. At 30% WPE, the calculations gave an efficacy of 78lm/W for a device of CCT of 4555K and R_a of 58. The efficacy at 75% WPE was almost 200lm/W. The calculated performance with 30% WPE is close to the experimental measurements achieved with the blue LD. ■

http://dx.doi.org/10.1063/1.4813837

Author: Mike Cooke

Extending effectiveness of transparent conductive oxide into ultraviolet

Light output power from a 380nm UV LED has been increased by 166% at drive current of 20mA.

Taiwan's National Tsing Hua University has developed a method to improve the performance of zinc oxide (ZnO) transparent conductive oxide (TCO) as an electrode for short-wavelength nitride semiconductor light-emitting diodes (LEDs) [Chung-Yen Lee et al, IEEE Electron Device Letters, published online 11 September 2013]. In particular, the method enhances the light output power of an LED emitting 380nm ultraviolet (UV) at 20mA by 166%.

The method uses the technique of rapid thermal diffusion to drive zinc and magnesium (Mg) into gallium-doped ZnO (GZO). The MgZnO material system has a range of optical bandgaps from 3.3eV (ZnO) to 7.8eV (MgO), so adding Mg can be expected to increase the transmittance of the material at shorter wavelength.

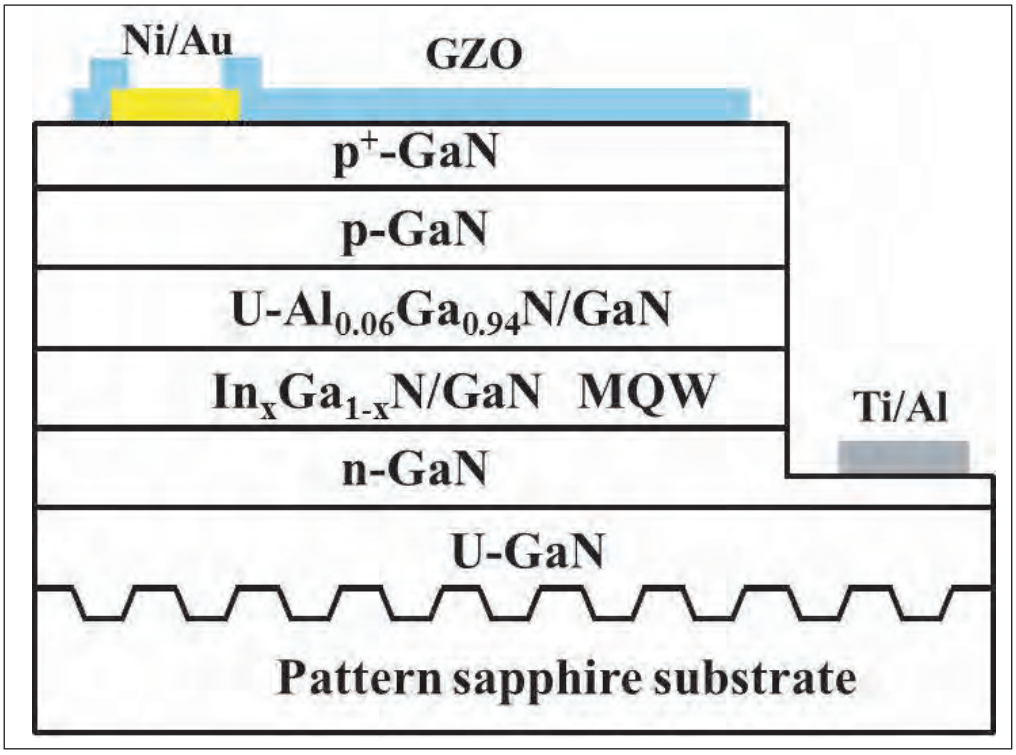


Figure 1. LED structure for violet and UV LEDs.

The extra zinc tackles a problem with ZnO films where the zinc tends to dissociate from the crystal structure at raised temperature, leaving an oxygen-rich residue that reduces the effectiveness of the n-type Ga-doping. In particular, the Ga donor configuration where the dopant substitutes for Zn can be converted to the Ga_2O_3 dielectric form, degrading the conductance.

Test LED structures (Figure 1) were grown on patterned sapphire using metal-organic chemical vapor deposition (MOCVD). The undoped GaN buffer was 3µm, the n-GaN contact was 2µm, the multiple quantum well (MQW) active region comprised 9 pairs of 16nm InGaN/GaN layers, and the electron-blocking layer was 6nm of undoped AlGaN. The p-contact/cap consisted of 200nm of GaN (with a hole concentration of about $10^{17}/cm^3$) and 10nm of GaN (with a higher hole density of $5x10^{17}/cm^3$). Violet and ultraviolet emissions were achieved by using InGaN wells with 5% and 6% In fraction, respectively.

The LED fabrication consisted of mesa etch and deposition of electrodes. After the structure was annealed at 500°C for 10 minutes, 250nm of GZO was applied as TCO using atomic layer deposition (ALD). The precursors consisted of diethylzinc (DEZn), triethylgallium (TEGa), and water vapor (H_2O). The film had a sheet resistance of 15.6Ω/square.

Then rapid thermal diffusion process was used to drive in Mg and Zn into the GZO. The dopant sources were ZnSiOx and MgSiOx spun onto a sapphire wafer that was applied to the top of the LED wafer while thermal diffusion at 400°C was carried out for 5 minutes. The final LEDs were processed by patterning and etching away the excess TCO with hydrochloric acid.

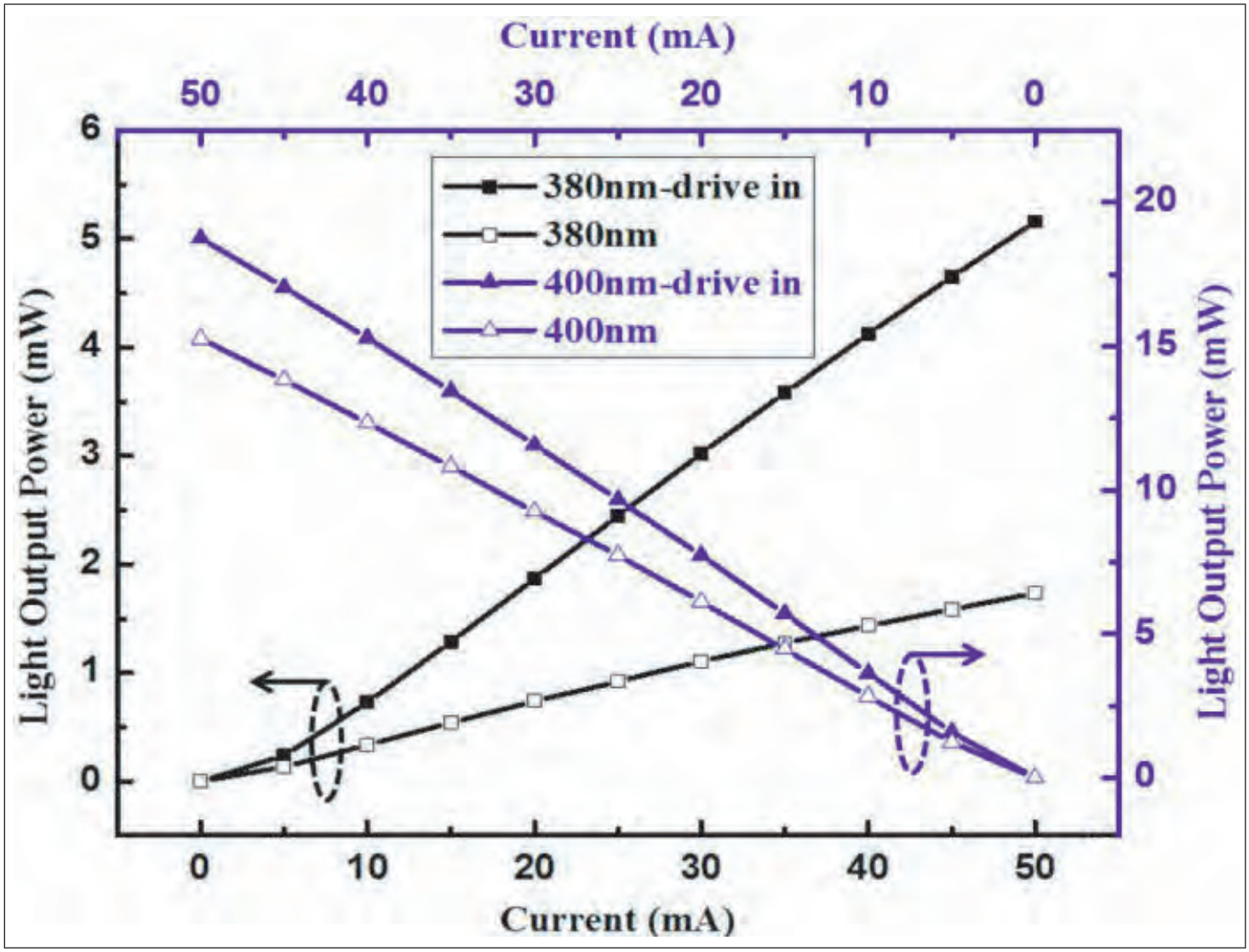


Figure 2. Light output power versus current measured at room temperature for 400nm violet and 380nm UV LEDs with and without Zn and Mg driven-in GZO films. Note: the scale increases from left to right for the 380nm LED and from right to left for the 400nm LED.

The effect of driving Zn and Mg into the GZO was to increase the transmittance from 83% to 93% at 400nm wavelength. For the even shorter wavelength of 380nm, the GZO as-grown had a transmittance of 80%. Driving in of Zn/Mg improved this to 91%. The enhancement was a reflection of an increase in optical bandgap from 3.64eV as-grown and 3.70eV annealed-only, up to 3.78eV for GZO with driven-in Zn/Mg.

The extra zinc tackles a problem with ZnO films where the zinc tends to dissociate from the crystal structure at raised temperature, leaving an oxygen-rich residue that reduces the effectiveness of the n-type Ga-doping. In particular, the Ga donor configuration where the dopant substitutes for Zn can be converted to the Ga_2O_3 dielectric form, degrading conductance

The effect of Zn/Mg treatment on electroluminescence was to give about 1.4x and 2.5x greater emission at 20mA for 400nm and 380nm LEDs, respectively. The forward voltages at 20mA were, respectively, 3.7V and 4.5V with treatment and 3.9V and 4.2V without.

Light output power measurements (Figure 2) were carried out on LEDs bonded with aluminium wire and packaged in TO-46S metal cans. The 20mA output powers were 7.7mW (400nm) and 1.9mW (380nm) for the LEDs with Zn/Mg treatment. The respective values for the devices without treatment were 6.1mW and 0.7mW. The enhancements for the Zn/Mg treatment come out at 27% at 400nm and 166% at 380nm.

In addition to the effect from the improved optical transparency, the researchers suggest that there is a boost in light extraction from changes in refractive index. ■

http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=6595557

Author: Mike Cooke

Lateral current thinking improves light and voltage in nitride LEDs

Superlattices introduced on n-side of LED increase output power by 13.7% and reduce input power by 6.7%.

LG Electronics Materials and Components Laboratory in South Korea has used aluminium gallium nitride (AlGaN) superlattice structures (SLs) to improve lateral current spreading from the n-side of nitride semiconductor light-emitting diodes (LEDs) [Hooyoung Song et al, Appl. Phys. Lett., vol103, p141102, 2013].

Lateral current spreading is important in nitride semiconductor LEDs for several reasons. For example, these devices are mostly produced with the n-contact to one side of the LED because vertical flow is not possible through insulating substrates such as sapphire. Also, nitride semiconductor LEDs suffer from efficiency droop effects at high current density so that non-uniform flow through the devices leads to avoidable power losses.

Superlattice structures have previously been used to improve current flow properties of nitride LEDs from the p-side because hole generation and flow are often seen as stumbling blocks on the path to more efficient LEDs. "However," the LG researchers say, "n-type conductivity is also an important factor in devices such as LEDs where current spreading still remains as an issue." They thus set out to investigate "methods to enhance transport properties of n-type AlGaN/GaN SLs layers and demonstrate improved LED performance from n-type AlGaN/GaN SLs embedded LED structures".

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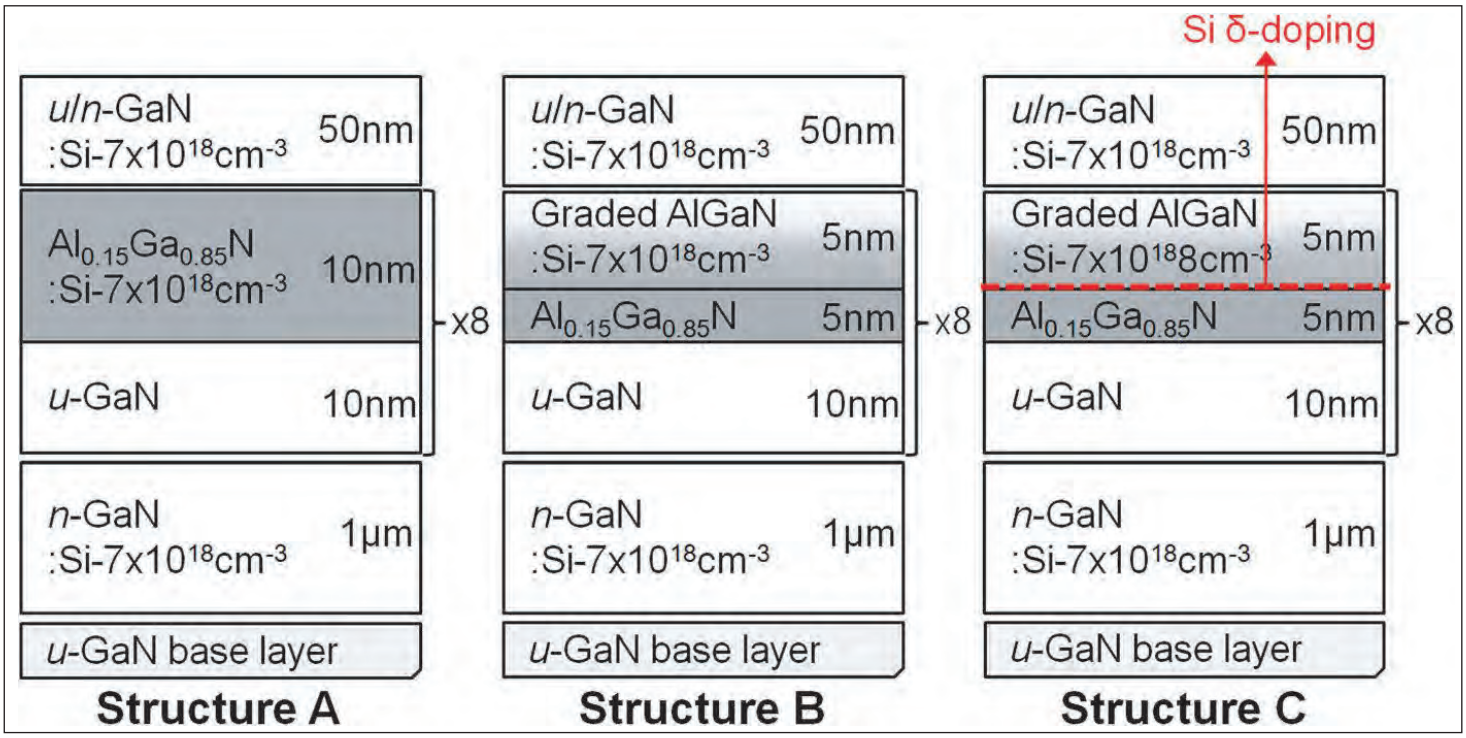

Figure 1. Schematics of structures A, B and C used to explore current-spreading effects of superlattices.

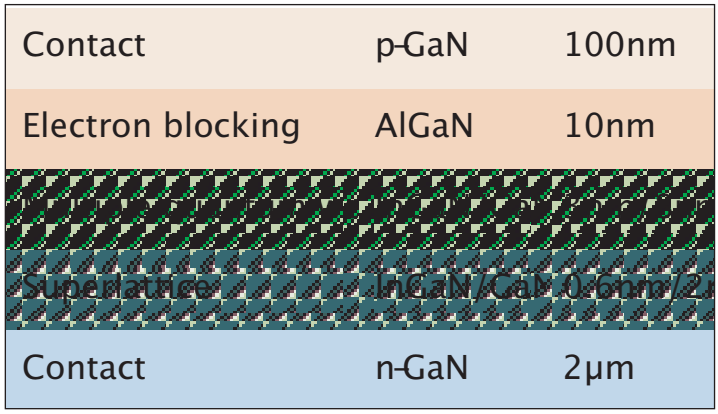

Figure 2. Schematic of LED layers. Where there was an AlGaN/GaN superlattice (structures A–C), this was 1µm below the InGaN/GaN superlattice.

The nitride structures were grown using metal-organic chemical vapor deposition (MOCVD). Various current-spreading AlGaN/GaN superlattices were produced based on simulations (Figure 1). These structures were tested using Hall-effect measurements and by incorporation into LEDs (Figure 2). Standard lateral LEDs were fabricated with mesa etch, and the application of indium tin oxide (ITO) transparent conductor on the p-GaN top layer and chromium/nickel/gold n- and p-electrodes.

The Hall-effect measurements (Table 1) showed improved conductivity for the superlattices over a 1.2µm n-GaN layer with target doping concentration of $7x10^{18}/cm^3$ ('structure D'). The higher mobility of the superlattice structures 'B' and 'C' was attributed to "reduced ionized impurity scattering as a result of undoped AlGaN layer that separates 2DEG channel and Si-doped graded AlGaN layer".

In addition to lateral conductivity, superlattices for use with LED structures need to have good vertical conductivity. Tests of the vertical conductivity of the superlattices were in line with simulations with high conductivity correlated with low barrier height. Thus, structure C had a similar vertical conductivity to the reference structure D. By contrast, structures A and B had reduced current for a given voltage, with the lowest vertical current being that through structure A that had the highest barriers in simulation.

The performance of the LEDs (Figure 3) confirmed the superiority of structure C for giving improved current spreading without impacting the vertical flow. The peak wavelength at $60A/cm^2$ current density was 635nm for all devices. At the same current, the output powers were 73.1mW, 75.3mW, 79.9mW, and 70.1mW for structure A-D, respectively.

The devices with current-spreading superlattices showed increased output power. However, structure A with high barriers to vertical current flow also showed the highest forward voltage, indicating series resistance.

The structure C LED had 13.7% better light output power and 6.7% reduced forward voltage at $60A/cm^2$, compared with the reference LED (structure D). ■

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Author: Mike Cooke

Table 1. Hall-effect measurements for structure A, B, C, and D.

Sample	Sheet concentration ($x10^{13}/cm^2$)	Mobility (cm^2/V-s)	Conductivity (/Ω-cm)
Structure A	6.61	649	289
Structure B	6.25	960	340
Structure C	1.02	1075	569
Structure D	N/A	237	197

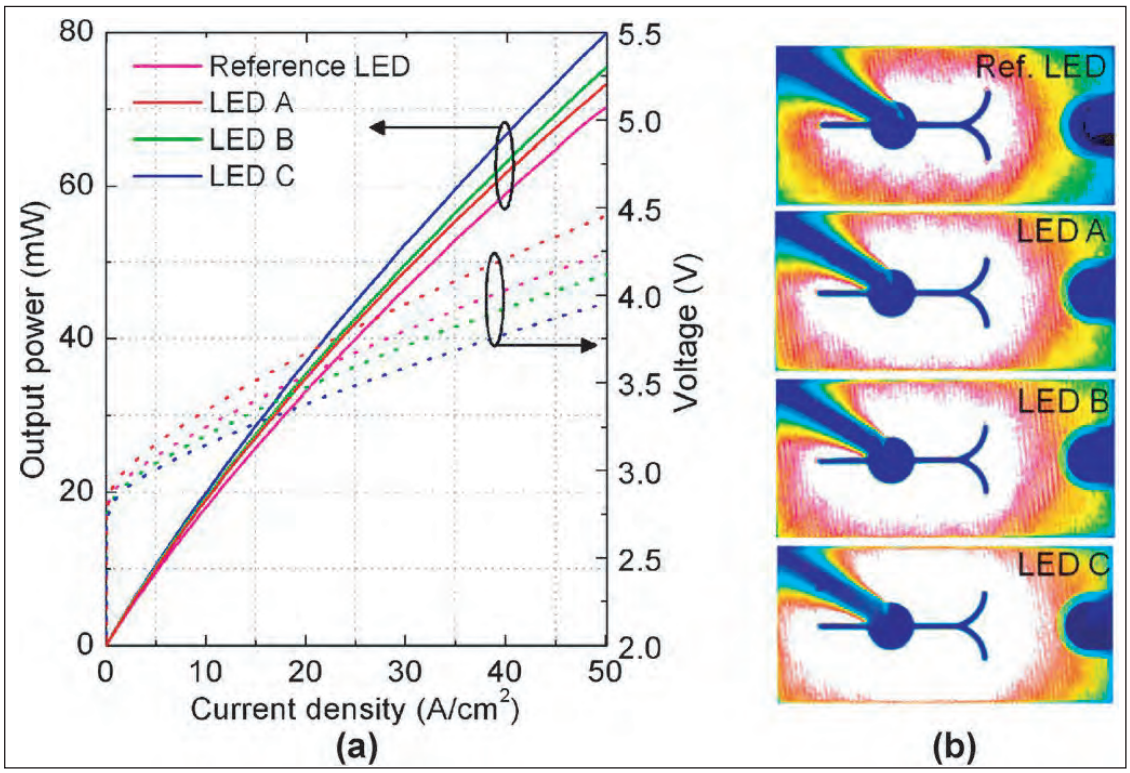


Figure 3. (a) Output power-current-voltage (L-I-V) relations and (b) current-spreading images of LED A, B, C, and reference.

Emergence of low-price LEDs pushing adoption for general lighting

...but cost reduction is changing industry structure and pushing M&A.

While growth in the LED industry came initially from small-display applications and has been driven by LCD display applications, in 2012 general lighting surpassed all other applications, representing nearly 39% of total packaged LED revenue, notes market research firm Yole Développement in its latest 'Status of the LED Industry' report. Indeed, the LED TV crisis of 2011 (following an overestimation of the market) had the benefit of decreasing LED prices and intensifying the competitive environment. In fact, LED-based lighting product prices have fallen more rapidly than expected, increasing the penetration rate of the technology.

Yole estimates that the packaged LED market will reach $13.9bn in 2013 and peak at $16bn in 2018. Growth will be driven mainly by general lighting applications (45-65% of total revenue during this period), complemented by display applications.

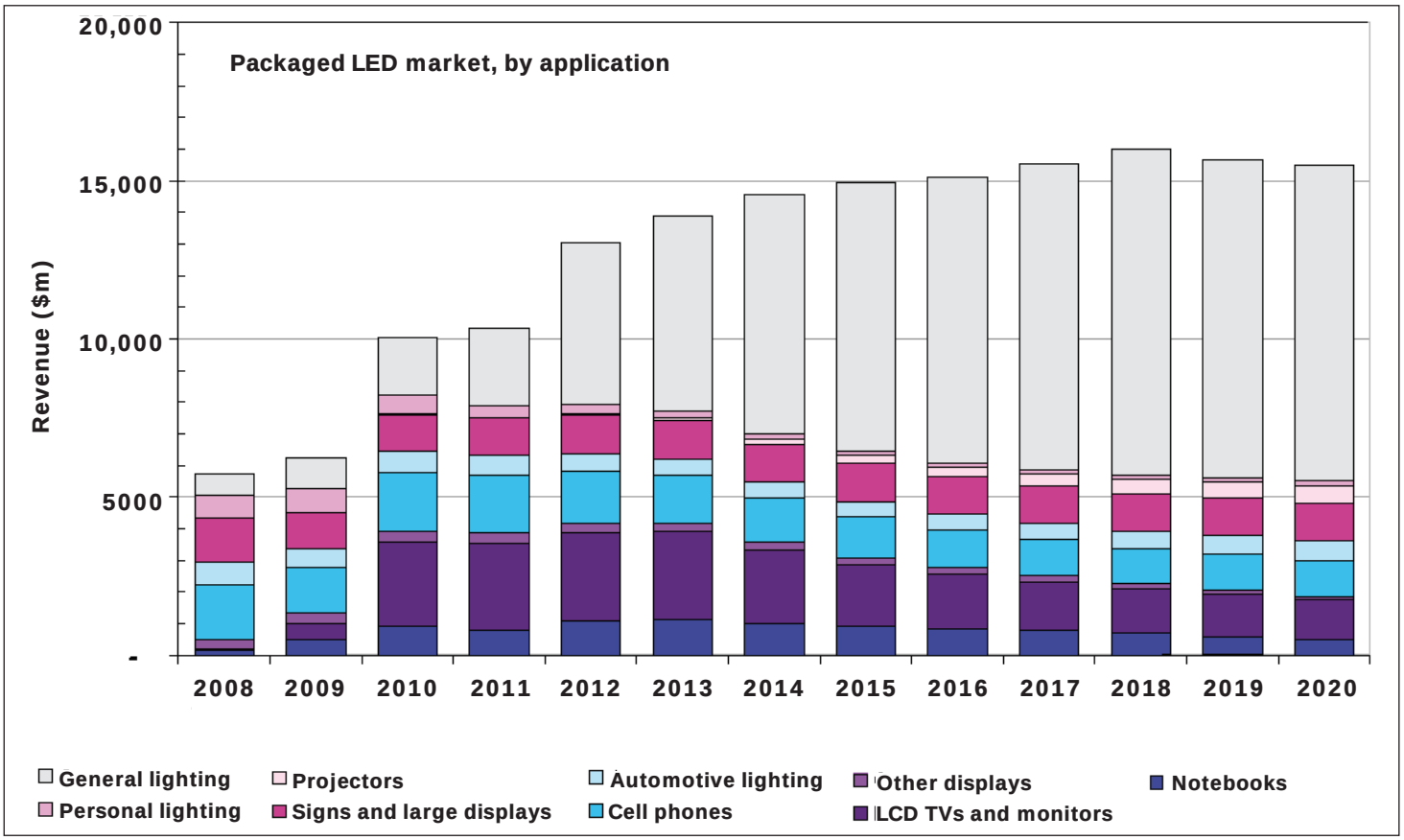
Other applications still in play

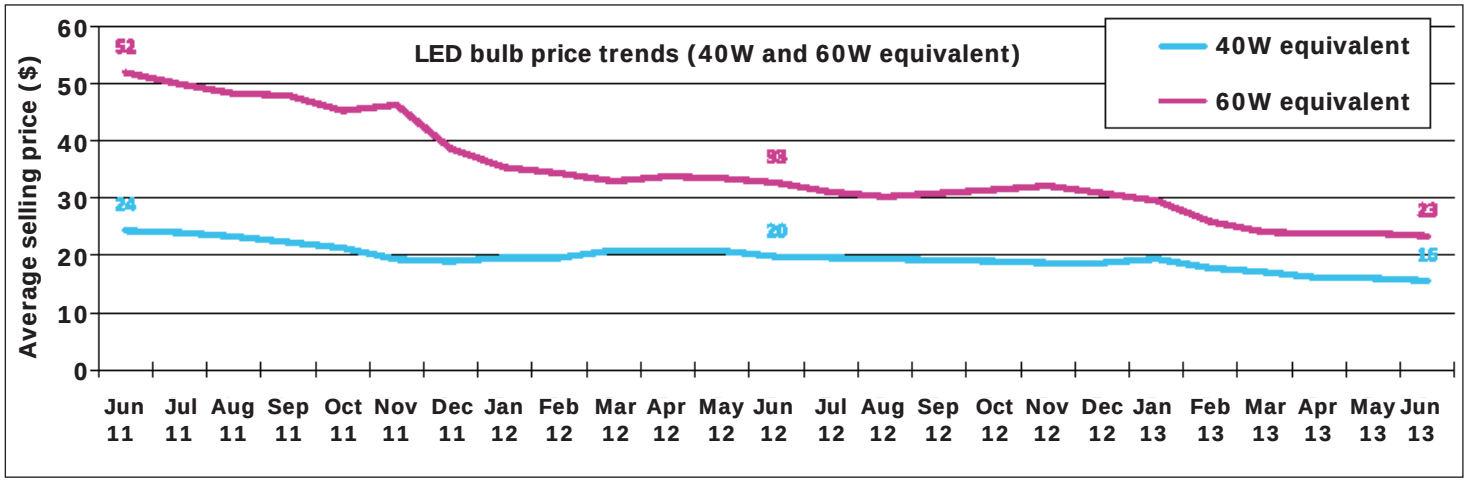
Regarding displays and other applications, most products now on the market integrate LED technology. But saturation mixed with strong pricing pressure and competition from organic LEDs will lead to most of these markets declining, starting in 2013/2014. In contrast to general lighting, overcapacity (inducing pricing pressure) has yielded a faster- than-expected decline in market size.

To maintain momentum, LED-based lighting product costs still need to be cut

"Cost represents the main barrier LEDs must overcome to fully compete with incumbent technologies," explains Pars Mukish, market and technology analyst, LED at Yole. "Since 2010, the price of packaged LEDs has sharply decreased, which has had the consequence of decreasing the price of LED-based lighting products."

However, to maintain the growth trajectory, more effort is needed in terms of price. LEDs still have some





potential for cost reduction, but widespread adoption will also require manufacturers to work on all components of the system (drivers, heat sink, PCB etc).

Merger of LED and lighting industries has begun

Over 2010–2012, the number of mergers and acquisitions (M&A) has continued to grow, reflecting increased consolidation in the LED industry. Yole counts about 60 significant M&A deals during this period. Also, 17 further deals have been identified during first-half 2013.

The main objectives of these deals are:

1. ***Vertical integration*** — A consistent trend in the LED space, reinforced by the promising boom in general lighting applications. Such deals are motivated by the need for firms to access new technologies, to close gaps in expertise in the LED supply chain, secure supply etc.
2. ***Strategic acquisition*** — The LED lighting market remains highly fragmented in all regions of the world (e.g. local features of fixtures). In this environment, strategic acquisitions are motivated mainly by economies of scale and the desire for improved market share, access to a wider customer portfolio, an increased sales force etc.
3. ***Geographical acquisition*** — Mergers and acquisitions, rather than organic growth, have proven to be the main market-entry strategy by overseas acquirers. Such deals have been driven primarily by firms seeking access to new markets and local distribution networks.

The number of M&As is likely to continue to grow, as LED technology has created a solid-state lighting (SSL) chasm, modifying all traditional aspects of the lighting industry (light source, system design, test) and forcing players in the supply chain to acquire new competencies.

Emerging substrates could change rules in sapphire-dominated industry

Sapphire — and silicon carbide (SiC)—- remain the most widely used substrates for the epitaxial growth of gallium nitride (GaN), but many research teams are working on finding better alternatives in terms of performance and total cost of ownership. In that context, silicon (Si) and GaN are the main new substrates being developed in the LED industry:

- The benefits of GaN-on-Si LEDs rely on reducing manufacturing cost by using cheaper silicon substrates but mainly by switching to an 8” substrate and using fully depreciated and highly automated CMOS fabs.
- The benefits of GaN-on-GaN LEDs stem from the lower defect density in the epitaxial layers, allowing the device to be driven at higher current levels and hence the use of a lower number of LED devices per system.

However, several barriers need to be overcome:

- GaN-on-Si LEDs are getting closer to GaN-on-sapphire LED performance, but greater manufacturing yields and full compatibility with CMOS fab still need to be achieved.
- GaN-on-GaN LEDs suffer from GaN substrate availability and its cost.

While GaN-on-GaN LEDs have some potential for specific high-end niches, Yole considers GaN-on-Si LEDs to be the more serious contender as a potential alternative to the widespread use of sapphire. However, the success of GaN-on-Si LEDs will depend on advances in LED performance and developments in manufacturing techniques, concludes Yole. ■

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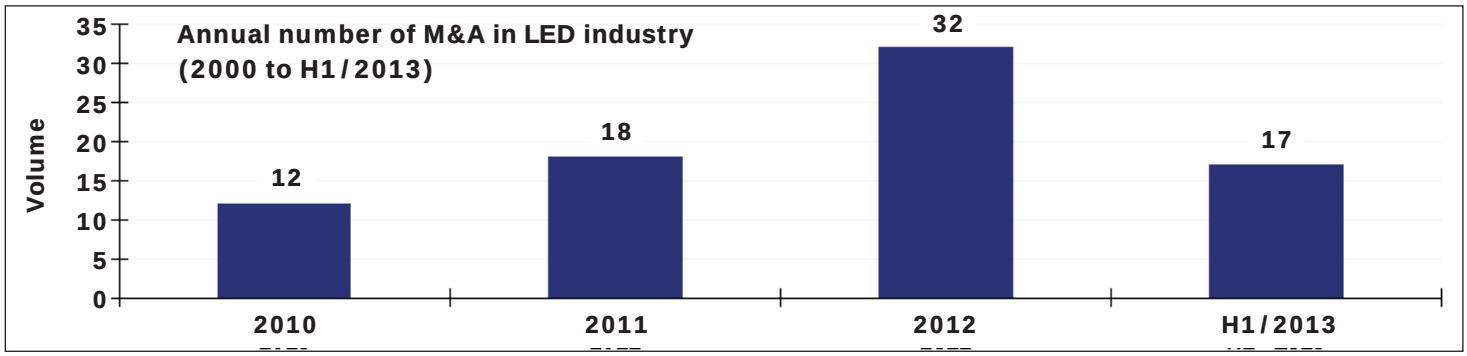


LED applications to be key drivers for bulk GaN market

No bulk GaN substrate to penetrate power device market unless price of $1500 per 4" wafer can be reached, forecasts Yole.

In either a cautious or a more aggressive scenario, LED applications will be the key drivers for the bulk gallium nitride (GaN) market, reckons market research firm Yole Développement in its report 'Free-Standing & Bulk GaN Substrates for Laser Diode, LED and Power Electronics'.

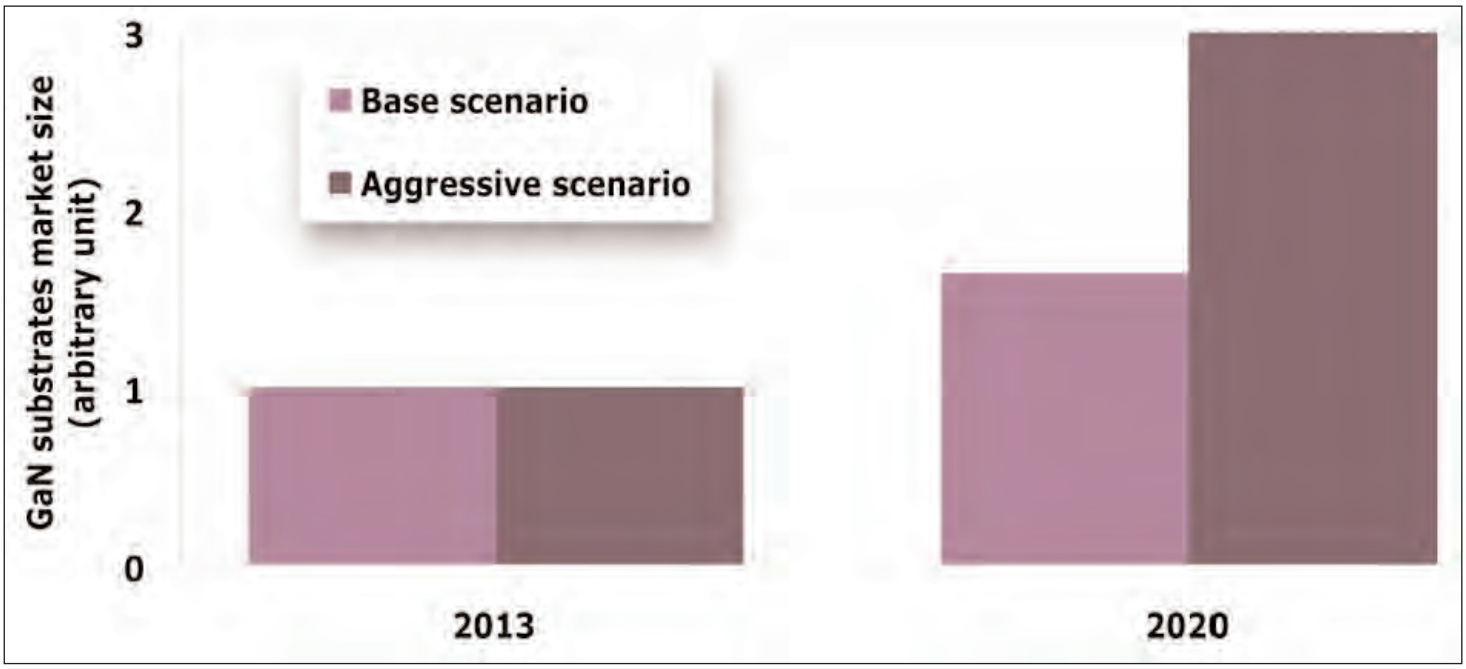
According to Yole, there is no doubt that LED technology will take market share over the traditional lamp and tube business. Recent announcements from LED makers (e.g. of LEDs with luminous efficacy of >150lm/W entering production) prove that the performance roadmap is in line with expectations: LEDs perform as well and even better than traditional bulbs and tubes.

Native bulk GaN is emerging as an alternative to sapphire or silicon, allowing further improvement in LED performance. Despite potential performance benefits for ultra-high-brightness (UHB)-LEDs, massive adoption of GaN wafers remains hypothetical, says Yole. Taking into account the historical price reduction of bulk GaN substrates, a base scenario outlines where GaN-on-GaN LEDs will be limited only to niche markets. "If the GaN industry succeeds in replying to the cost pressure from LED makers and the price of 4" GaN wafers falls below the breakeven price, a more significant adoption could be forecast," says Dr Hong Lin, market & technology analyst, Compound Semiconductors, at Yole. "We see an about three times difference in terms of market volume for LED manufacturing between the two scenarios," he adds.

Demand for GaN substrates for LDs will probably fall below the 20,000 two-inch-equivalent (TIE) per year threshold in the coming years

Blu-ray applications currently represent the largest market for blue laser diodes (LDs). This market will increase in the short term with the arrival of the new generation of game stations. However, Yole believes that this growth will not persist, as more and more people will play games and watch movies online instead.

Despite the recent rapid development of blue and green laser diodes, Yole sees two scenarios for the adoption of GaN-based laser diodes for the emerging projector market. Their price is the essential factor to consider.



Overall GaN substrate market size (2013/2020): comparison of scenarios.

	Japan	China	US	Europe
Players	Sumitomo Hitachi Metals Mitsubishi Chemical NGK Insulators Furukawa AETech	Sino Nitride Semiconductor Nanowin PAM Xiamen	UCSB Soraa Kyma SixPoint Materials Goldneye	Ammono SaintGobain / Lumilog Unipress Freiberger

Worldwide players in GaN substrates.

Combining all applications, demand for 2" GaN substrates will be more than twice as much in the aggressive scenario than in the base scenario, says Yole. In the best case, demand would remain relatively stable until 2020.

In R&D, non-polar and semi-polar substrates have been proposed for LD manufacturing. In principle, the semi-polar approach seems to be the most promising in terms of device performance. However, in practice, c-plane-based devices still have better performance.

Over 85% of commercial GaN wafers are produced by HVPE, dominated by Japanese firms

Currently, essentially all commercial GaN wafers are produced by hydride vapour phase epitaxy (HVPE), but the details of the growth process and separation techniques vary from company to company (e.g. ammonothermal growth at Mitsubishi Chemical, and the new acidic ammonothermal method at Soraa). Na-flux LPE growth seems promising, but Yole's analysts have not yet seen many GaN devices based on these substrates. It will take some time to convince the device producers, reckons the firm.

Non-polar and semi-polar substrates have attracted significant attention. However, the substrate size is still very small and unsuitable for mass production.

As of today, the GaN substrate market is heavily concentrated, with an 87% share held by Japanese firms. Non-Japanese players are currently in small-volume production or in the R&D stage, and it is too early for them to challenge the market leaders. Without exception, Japan will continue to dominate the bulk/free-standing (FS) GaN market in the coming years, reckons Yole.

Bulk GaN substrates for power electronics applications, a very challenging mission

The GaN power device industry probably generated less than $2.5m in revenues in 2012, says Yole. However, overall GaN activity has generated extra revenue, as R&D contracts, qualification tests and sampling for qualified customers have been extremely buoyant. Out of 20 established power electronics companies, 16 either are involved or will be involved in the GaN power device industry, reckons Yole.

Among the many substrates proposed for GaN power devices, bulk GaN is definitely beneficial to device performance. However, Yole remains quite pessimistic that bulk GaN can broadly penetrate the power electronics segment unless the cost of 4" bulk GaN wafers can be reduced to the $1500 range by 2020.

The main reason is that GaN power devices are positioned as a cost-effective solution, between incumbent silicon technology and the silicon carbide (SiC) technology that is ramping up. If the $1500 cost cannot be reached, then Yole assumes that no bulk GaN substrate will penetrate this market. ■

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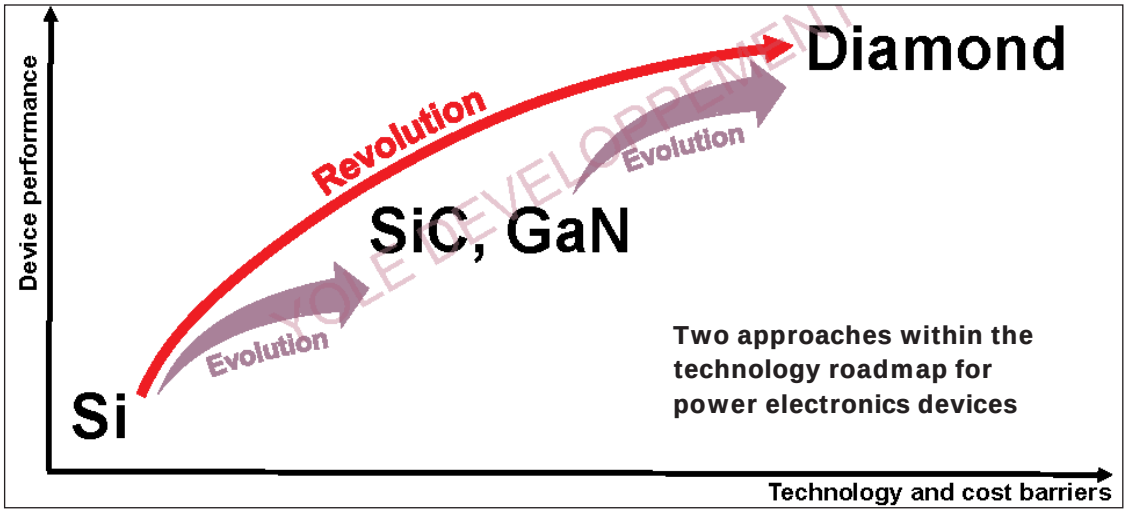
Diamond materials for semiconductors to grow to $43m market in 2020, driven by passive devices

Access to high-quality material key for device development, says Yole.

Driven mainly by heat spreaders for high-power device thermal management, the diamond materials market for semiconductor devices will rise at a compound annual growth rate (CAGR) of 14% to over $43m in 2020, according to the base scenario in a report 'Diamond materials for semiconductor applications' from market research firm Yole Développement that considers both passive (heat spreaders) and active (diodes, transistors) diamond solutions.



Diamond materials have been in development for more than 50 years. Besides the traditional tooling applications (drilling, cutting etc), interest in diamond continues to grow for optical and thermal applications, and for new applications in semiconductor devices such as high-power devices and high-frequency devices able to work at elevated temperatures.

In fact, diamond's unique physical and electrical properties — which include the highest known thermal conductivity, a wide bandgap energy, excellent electrical insulator properties, very high breakdown voltage, and very high carrier mobility — make diamond an great candidate for electronic devices with ultimate performance.

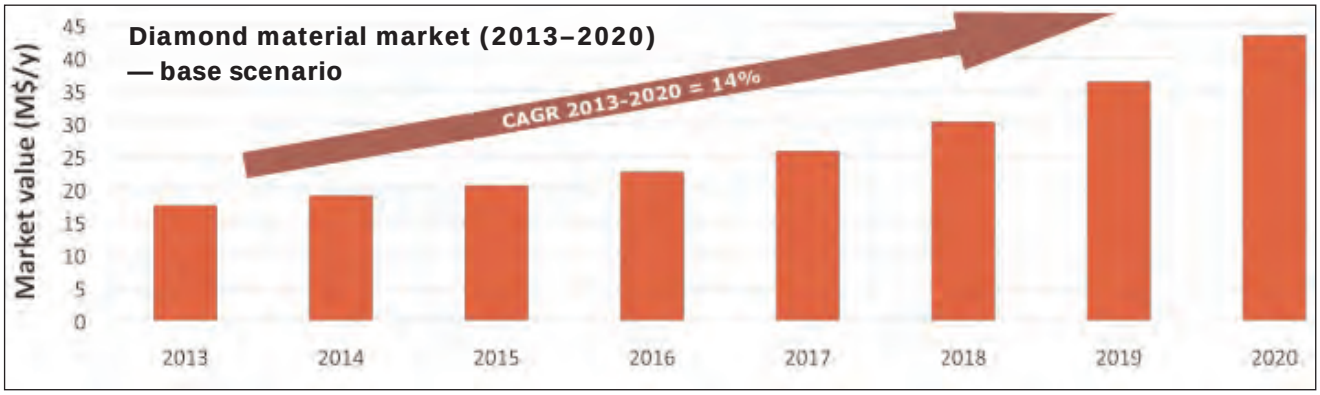
Applications in electronic devices include high-voltage power electronics, high-frequency high-power devices, and high-power optoelectronic devices (laser diodes, LEDs). Despite the high costs of high-quality materials, a large number of players are involved in the 2013 diamond materials market and its largest segment (R&D activities), reckons Yole.

However, the costs of diamond — as well as the remaining technology barriers — limit the diamond material market to just a few applications and some high-end devices.

Access to high-quality diamond material is key for device development

Electronic applications (such as Schottky diodes, transistors etc) require high-quality single-crystalline diamond grown by chemical vapour deposition (CVD), which has superior characteristics such as high carrier mobility, long carrier lifetimes, high breakdown fields and high thermal conductivity.

High-quality low-defect diamond wafers produced from diamond crystal made by the high-pressure high-temperature (HPHT) method are only a few millimeters in size. In comparison, the competing semiconductor materials such as silicon carbide (SiC) are already available in wafer sizes up to 150mmin diameter. For future diamond-based active devices, it is crucial to increase wafer size above 2", with defect density of 100cm^{-2} or less. Different approaches



to obtaining free-standing wafers from thick diamond films are under development. A mosaic-type method is currently approaching 2" wafer size, but the defect density needs to be reduced. According to Yole's technology roadmap for single-crystal diamond wafers, low-defect 2" wafers could be commercially available in 2016–2017.

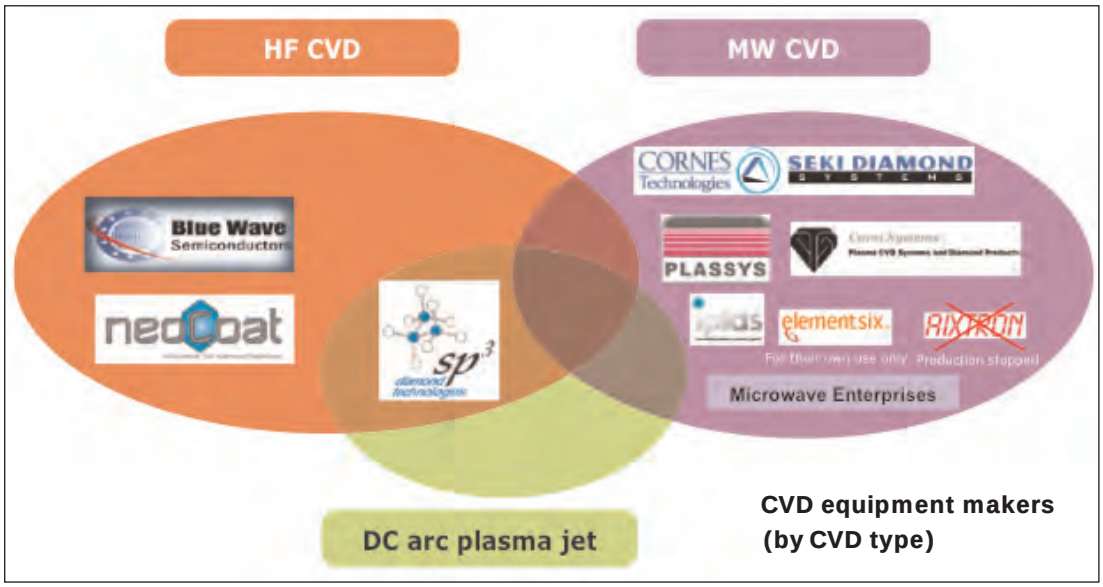
Alternatively, the microwave-enhanced chemical vapor deposition (MWCVD) approach for crystal growth is more promising than HPHT, due to its potential for scaling. MWCVD is also the most promising technique for thin-film growth, details the report. High-quality thick diamond films can be grown by homoepitaxy on single-crystal diamond wafers.

The heteroepitaxy of diamond on iridium enables diamond films of up to 4-inch in size, but further development is needed to obtain a well-controlled and reproducible manufacturing process.

Apart from the technology challenges related to single-wafer material manufacturing, electronic applications of diamond are severely hampered by the fact that n-type doping is still relatively difficult to obtain due to the lack of an efficient charge donor. As p-type doping of normally insulating diamond can now be reliably achieved using boron, much activity has been focused on the fabrication of unipolar devices. The first expected active diamond power devices will be Schottky diodes.

Although polycrystalline films have inferior electric and thermal properties compared with single crystal material, they are available in larger dimensions and at lower costs. As shown in the report, they are used mainly as heat spreaders (plus many non-electronic applications, such as optical windows, etc).

Future cost reduction and performance improvement of diamond films relies strongly on the CVD equipment that is used. Much effort from equipment makers such as Cornes Technologies (Seki Diamond), Element Six, Plassys-Bestek, sp3 Diamond Technologies etc is hence being focused on the development of CVD reactors with a larger deposition area, higher growth rate, lower electricity consumption and better film quality. The 'integration' of diamond film directly into a wafer (used for the fabrication of electronic and opto devices, as done for instance in Group4 Labs' GaN-on-diamond approach) has great potential to reduce the cost of heat management solutions for high-power and high-frequency applications, says Yole.



CVD equipment makers (by CVD type)

Earlier market entry to secure better position in future market

Differentiation between diamond material suppliers is mainly through technology. Although many players are currently able to supply diamond material, only a few can supply high-quality material, providing greater differentiation compared to lower-performance but less costly non-diamond alternatives. In fact, fewer than three companies per material type can consistently deliver high-quality products. Many players have significant R&D activity underway to develop new products and access dedicated R&D funding, as well as to maintain any technological advantages that they have over the competition.

The recent acquisition of Group4 Labs by Element Six (a member of De Beers Group) indicates the trend to maintain key technologies within a select group of players, providing them with a well-established position in the diamond material market. History tells is that the development and optimization of diamond technologies is complex and takes many years. During this period, the historical diamond players will acquire a significant technological and IP advantage, which may be hard for new players to overcome and makes it nearly impossible to enter the market in the future, reckons Yole.

The developers/manufacturers of high-performance devices (such as high-power and high-frequency devices and high-power optoelectronics) rely on the reproducible supply of high-quality materials. Leading European and Japanese companies — especially those involved in the power electronic business — are still quite conservative with regard to using diamond-based devices. This provides an opportunity for other companies to take a lead in this market segment and to progressively develop their market share in power electronics by avoiding the direct competition within the established technologies, concludes Yole. ■

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Developing market for normally-off nitride power electronics

With Japanese companies sampling normally-off gallium nitride transistors, Mike Cooke looks at some recent research towards improved performance.

High-electron-mobility transistors (HEMT) and similar structures based on layers of gallium nitride (GaN) and aluminium gallium nitride (AlGaN) have recently been developed with a view to high-voltage and high-power switching applications. The attractions of these materials include high critical fields and higher switching speeds that allow smaller, more efficient devices to be created. Potential applications cover home appliances, communications and automobiles.

Table 1. Some specifications for transistors sampling from Fujitsu and Panasonic.

	Fujitsu			Panasonic
Parameters	**30V**	**150V**	**600V**	**600V ('tentative')**
Drain current [A]	12	20	20	15
Threshold voltage [V]	1.8	1.8	1.8	1.2
On resistance [mΩ]	12.5	13	92	65
Gate charge [nC]	4	16	12	11
Package (sample)	WLCSP	WLCSP	TO247	TO220

Unfortunately, simple AlGaN/GaN-based HEMTs have a negative threshold voltage, giving a normally-on 'enhancement-mode' operation at 0V gate potential. For safe operation at high voltage or high power densities, transistors with normally-off characteristics are preferred. Further advantages include lower power consumption and simpler drive circuits.

A number of techniques such as fluorine implantation and gate recessing can shift the threshold in a positive direction. However, these methods suffer from thermal stability or process damage problems that impact HEMT performance. Using a metal-insulator-semiconductor (MIS) gate structure can also push HEMT structures into positive threshold voltages.

The Japanese companies Panasonic and Fujitsu even have products for sale (Table 1). These involve processes that grow GaN-based HEMTs on silicon substrates to reduce costs and hence increase market attractiveness.

In March, Panasonic's Industrial Devices Company announced sampling of a GaN-based normally-off power transistor with a blocking voltage of 600V. A few months later in July, Fujitsu released a GaN power device (MB51T008A) with a drain-source breakdown voltage of 150V and normally-off operation — also for sampling — with volume production due in 2014. Other Fujitsu devices with 600V and 30V breakdown characteristics are under development and/or entering sampling aimed at a range of product applications.

Fujitsu sees its 150V-breakdown device as being suitable for high- and low-side switches in DC–DC converters, as deployed in power supplies for data communications equipment, industrial products, and automobiles. The gate structure used to achieve normally-off behavior is described as being 'proprietary'. Company researchers did report in 2010 a MIS-HEMT structure with maximum drain current and threshold voltage of 800mA/mm and +3V, respectively [M Kanamura et al, IEEE Electron Device Letters, vol31, p189, 2010]. The gate was also recessed.

Panasonic's 600V device is produced on 6-inch silicon and uses a p-type gate-injection of holes to achieve normally-off performance. The company claimed that the device was the first to achieve 'failure-free' operation and stable performance in terms of being free from the current collapse effects that are often seen with AlGaN/GaN HEMTs in pulsed operation.

Target applications for Panasonic's device include deployment in power supplies for data-centers/base transceiver stations, and in hybrid electric vehicles (HEV/EV/PHEV).

Despite these 'commercial' products, researchers have not finished work on improving normally-off nitride semiconductor performance. In Europe, the

Framework Programme 7 (FP7) EU project for 'GaN-based normally-off high power switching transistor for efficient power converters' (HIPOSWITCH, www.hiposwitch.eu) involves companies and academic institutes from Austria, Germany, Slovenia, Italy, and Belgium: Aixtron SE, Artesyn Austria GmbH & Co KG, EpiGaN, Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik (FBH), Infineon Technologies Austria AG, Slovak Academy of Sciences, Institute of Electrical Engineering, University of Padua, and Vienna University of Technology. The project was set up in 2011 and is due to finish 2014.

The aim is to produce high-voltage normally-off GaN power devices on silicon substrates with a vertical architecture for technology transfer to a European industrial environment. Since GaN-based devices can theoretically perform reliably at elevated junction temperatures, the team also wants to develop equipment that can handle operation environments up to 225°C.

Thin high-Al content barriers

China's Xidian University has produced 'normally-off' GaN HEMTs with a thin high-Al content AlGaN barrier layer [Kai Zhang et al, Jpn. J. Appl. Phys., vol52, p111001, 2013]. The Xidian approach is similar to gate recessing in that the distance between the gate and channel is reduced. However, gate recessing involves a plasma etch that damages the device structure, leading to higher gate leakage current in operation.

Xidian's nitride semiconductor structure (Figure 1) was grown on c-plane sapphire using metal-organic chemical vapor deposition (MOCVD). A 1.5nm GaN cap layer was applied to the top of the AlGaN barrier. The difference in polarization between the GaN cap and AlGaN barrier created a negative polarization charge at the heterointerface that shifted the threshold voltage in a positive direction. The charge was also expected to enhance the Schottky barrier height of the gate, reducing leakage current.

The ohmic source and drain contacts consisted of annealed titanium/aluminium/nickel/gold. Devices were isolated by plasma etching to a depth of 120nm. Passivation was achieved by plasma-enhanced chemical vapor deposition (PECVD) of silicon nitride (SiN). The passivation reduced the sheet resistance of the two-dimensional electron gas (2DEG) channel by 11% due to a 16% increase in carrier density.

The mobility was slightly reduced by the passivation. It is thought that such passivation mitigates the effects of surface states and defects that can deplete the 2DEG. Possible reasons for reduced mobility include increased electron-electron scattering and/or increased carrier scattering from GaN/AlGaN interface roughness due to the higher carrier density.

The 0.5μm-long gate was formed by creating an opening in the SiN passivation with a plasma etch and

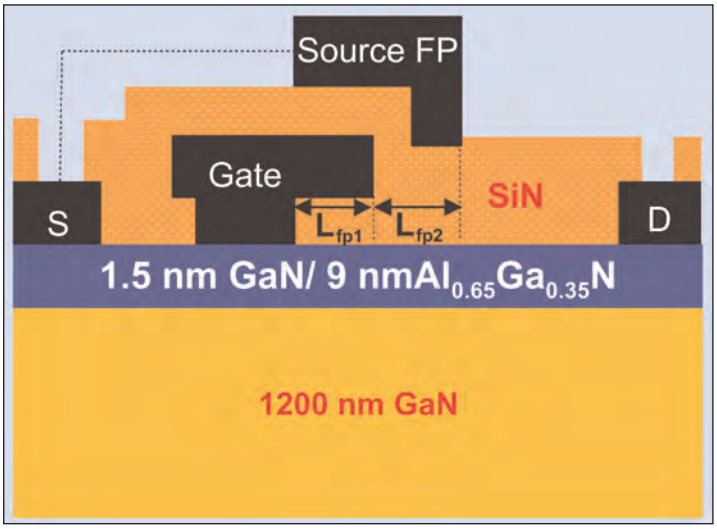

Figure 1. Schematic of fabricated normally-off HEMT with dual field plates. Growth was initiated on the sapphire substrate using a 200nm AlN nucleation layer.

depositing nickel/gold/nickel as the gate electrode. Gate and source field plates (FPs) were included in the design to combat current collapse and to push breakdown to higher voltages. The gate FP overhang was 0.3μm (L_{fp1}) and the source FP extension was 0.4μm (L_{fp2}). The gate width was 50μm. The gate–source and gate–drain distances were 0.7μm and 2.6μm, respectively.

The saturation drain current of the device at 5V drain bias (V_{DS}) and 3V gate potential (V_{GS}) was 441mA/mm. The extrinsic maximum transconductance with the same drain bias was 204mS/mm. The threshold was estimated at +0.3V.

The gate leakage at negative gate potentials was 10^{-7}mA/mm at –5V and 10^{-4}mA/mm at –20V. These low values are attributed to the higher estimated Schottky barrier of 0.91eV compared with barriers in the range 0.5–0.7eV for lower Al-fraction AlGaN (15–35%).

The off-state (–2V gate rather than 0V) breakdown voltage for 1mA/mm leakage was 111V. The gate leakage was significantly lower than the drain leakage. The researchers believe this "suggests enhanced breakdown characteristics can be achieved with further optimization in buffer design, such as lowering the defect density, using compensation iron doping or growing back-barrier layers or double heterojunctions."

The drain-induced barrier lowering (DIBL) was 3.28mV/V over the drain bias range 1–20V. The researchers say that this is "greatly superior" to reported values for AlGaN HEMTs with 25nm barrier and 0.6μm gate length. The improved DIBL is attributed to the high quality of the AlGaN and the use of an insulating buffer layer.

Current-collapse effects were investigated under pulsed operation (Figure 2). An off-state test was used to evaluate gate lag. The researchers comment: "The result indicates that the presented Al-rich AlGaN/GaN

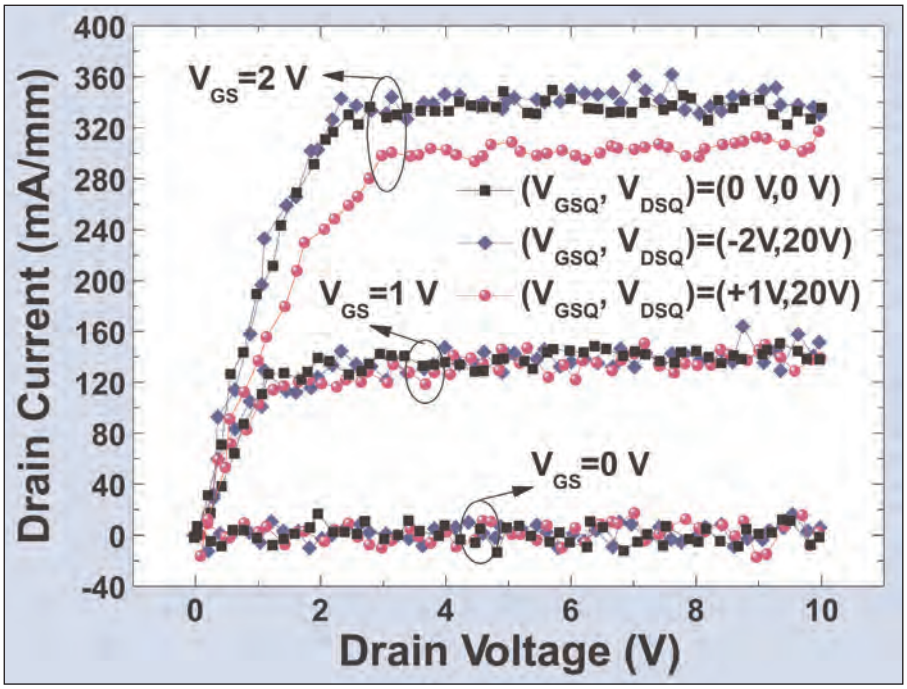

Figure 2. Comparison of pulsed current–voltage characteristics at three quiescent bias points of (V_{GSQ}, V_{DSQ}) = (0V, 0V), (–2V, 20V), and (+1V, 20V), and at V_{GS} = 0, 1, and 2V.

HEMTs do not suffer from gate lag effects induced by surface-related defects at moderate drain bias, originating from the excellent AlGaN quality, Si_3N_4 surface passivation as well as the incorporation of a dual-field-plate design."

The researchers warn that their results were carried out with a relatively low quiescent drain bias of 20V. For power switching applications this should be increased to more than 100V to show the impact of trap charging on dynamic on-resistance.

Current collapse of 12% at 2V gate was seen in the on-state stress testing. "The apparent drain lag effect can be explained as being due to hot-carrier injection into the buffer followed by trapping in deep levels," the researchers write. The team says that more advanced buffer design is needed to tackle this source of current collapse.

The researchers also looked at thermal stability by performing post-gate annealing in the temperature range 200–450°C in steps of 50°C for 10 minutes each. The tests were carried out in nitrogen atmosphere. During the test the threshold voltage was determined. The threshold shifted only 0.045V in the positive direction. The threshold is thus much more stable

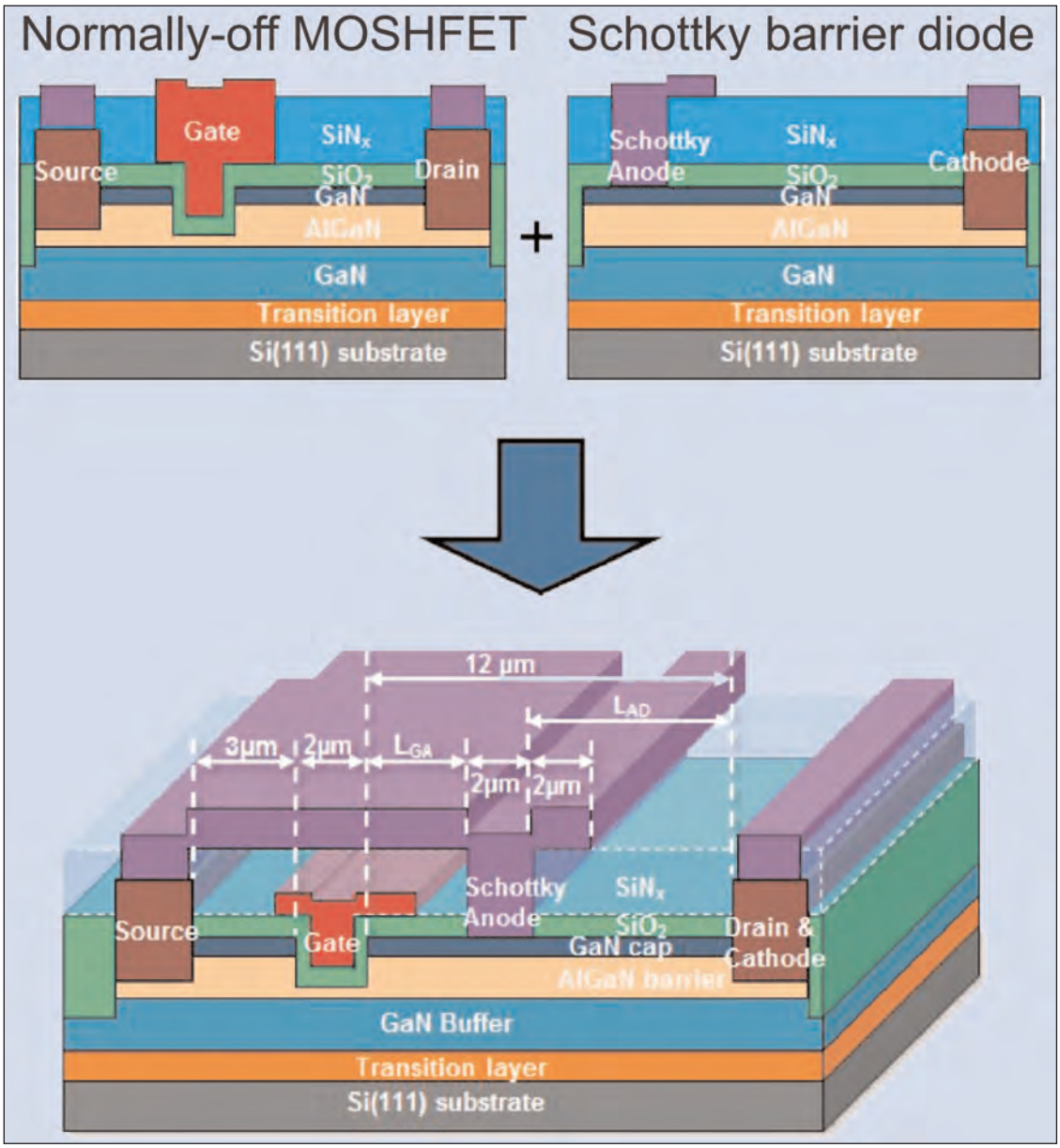

Figure 3. Cross-sectional schematic of SBD embedded AlGaN/GaN-on-Si switching transistor.

compared with fluorine treatments used to give positive-threshold HEMTs, indicating higher reliability for the Xidian devices.

Embedding diodes

A Korea/USA team of engineering researchers has developed a GaN metal-oxide-semiconductor high-electron-mobility transistor (MOSHEMT) with embedded Schottky barrier diode (SBD) [Bong-Ryeol Park et al, Semicond. Sci. Technol., vol28, p125003, 2013]. The researchers were based at Hongik and Cornell universities.

In power switching applications such as for conversion from direct current to alternating current (inverters), circuits often need a Schottky diode, allowing negative current flow during the off-state. If external diodes are used for this, parasitic inductances lead to problems such as ringing, voltage spikes and switching losses.

Some researchers have adopted gate-injection transistor structures (such as those of Panasonic) to avoid the need for external SBDs. These 'GIT' devices have the disadvantage that the rectification and transistor properties are tied together, reducing design flexibility.

Hongik/Cornell adopted a simple method to integrate transistor and diode. The epitaxial undoped AlGaN semiconductor material for the transistor/diode device (Figure 3) consisted of a 4nm GaN cap, 20nm $Al_{0.23}Ga_{0.77}N$ barrier, 1nm AlN spacer, 1.7μm GaN buffer, and AlN/AlGaN/GaN transition layer, grown on n-type (111) silicon.

Mesa isolation was performed with an inductively coupled plasma reactive-ion etch (ICP-RIE). This was followed by gate recess patterning and further ICP-RIE. The recess into the AlGaN barrier had a target AlGaN thickness between the gate foot and GaN buffer of 3nm. The recessing has to be this thin in order for the channel to be completely depleted under the gate, giving the desired normally-off behavior.

Next, a 35nm layer of silicon dioxide was applied using ICP chemical vapor deposition. This layer was then patterned and openings were made for the ohmic contacts with ICP-RIE. The ohmic metals consisted of silicon/titanium/aluminium/molybdenum/gold annealed at 820°C in nitrogen for 30 seconds. The gate electrode consisted of nickel/gold.

The Schottky barrier diode was created with ICP-CVD of silicon nitride insulation and ICP-RIE/wet buffered oxide etch (BOE) of the anode contact region. The remaining metallization was nickel/gold. The main variable in the devices was the anode-drain distance (L_{AD}) with the related gate-anode distance (L_{GA}) being 10μm — L_{AD}.

The Hongik/Cornell device acts as a normally-off transistor with forward drain bias (Figure 4). The diode blocks current flow. However, with negative drain bias sufficient to turn on the Schottky diode (–1.2V),

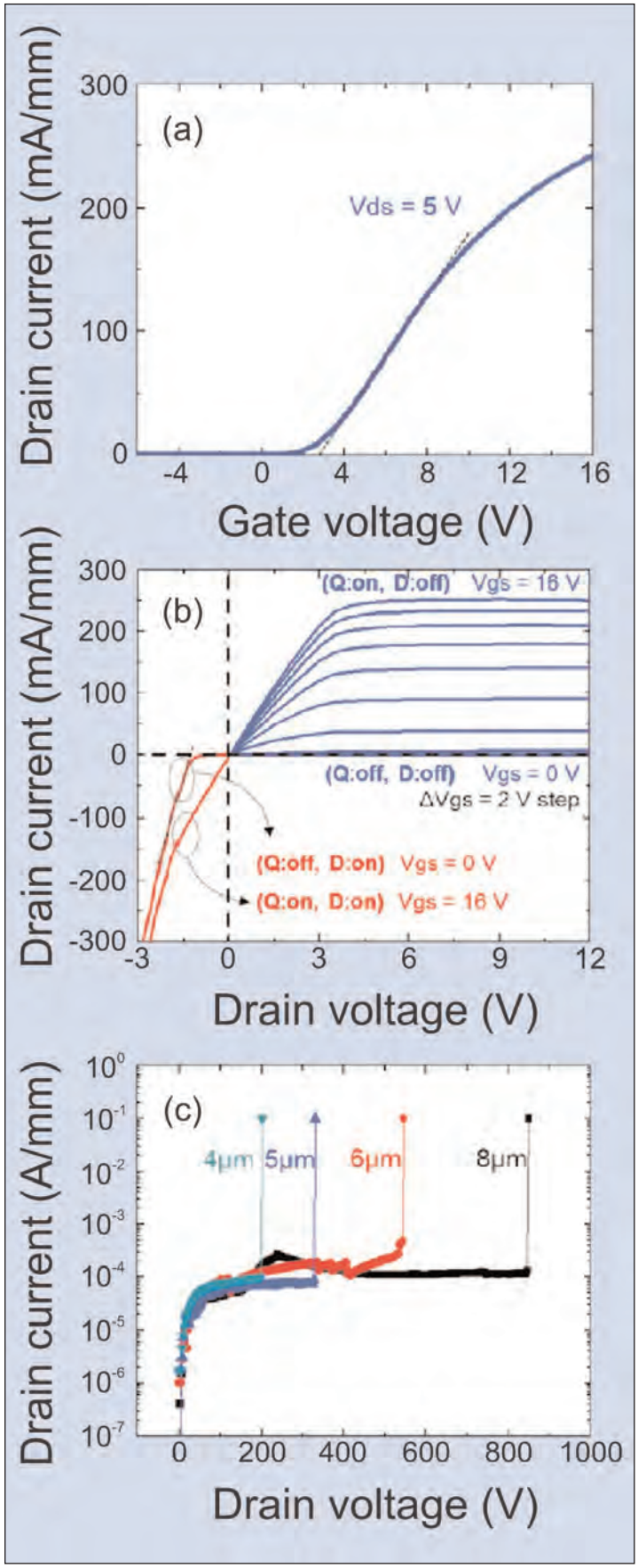

Figure 4. (a) Transfer and (b) drain current–voltage characteristics of the anode-to-drain distance of 8μm and (c) breakdown characteristics of fabricated devices as a function of anode-to-drain distance (L_{AD}).

current flows even when the transistor is off (0V gate) through the anode contact and over through a field-plate structure attached to the source terminal. With the transistor on with a negative drain bias, current flows both through the transistor and the diode structure.

The maximum forward current was 252mA/mm at 16V gate potential. The on-resistance was 2.66Ω-cm^2. The transistor threshold was estimated at +2.8V.

The researchers point out that a significant difference from GIT-type devices is that the Schottky diode turn-on voltage is not affected by the gate potential. This gives an extra degree of freedom for device design. Variations in fabrication such as recess depth and gate dielectric could change the threshold, while the Schottky turn-on could be altered by removing the GaN cap under the anode and/or by changing the metals used.

Off-state breakdown was found for 0V gate as a function of the anode–drain distance. With an L_{AD} of 8\micron, breakdown set in at 849V drain bias. The researchers say that breakdown is governed by the SBD, not the HEMT. Hence, shorter L_{AD} values give lower breakdown voltages.

The researchers speculate that the high leakage current level of ~100μA/mm (0.1mA/mm) in the off state was due to buffer leakage, which could be improved by optimization of buffer quality and better mesa isolation.

The impact of high temperature (up to 300ºC) on device performance was also investigated on devices with L_{AD} of 4μm. The transistor threshold showed no noticeable change. However, the on-currents in both the transistor and diode tend to degrade at elevated temperature. Enhanced thermionic emission also means that the diode turn-on voltage 'decreases' slightly — i.e. it turns on sooner with negative drain bias of the device.

Improving gate swing, avoiding current collapse

Hong Kong University of Science and Technology (HKUST) has developed a 600V GaN-on-silicon (GaN/Si) normally-off metal-insulator-semiconductor high-electron-mobility transistor (MIS-HEMT) with large gate swing and low current collapse [Zhikai Tang et al, IEEE Electron Device Letters, published online 17 September 2013]. The HKUST team raised the threshold voltage of their devices by using fluorine plasma implantation and silicon nitride gate insulator. The MIS-HEMTs also featured a passivation layer that combined aluminium nitride (AlN) and silicon nitride (SiN) to avoid current-collapse effects from charge trapping.

The epitaxial aluminium gallium nitride (AlGaN) structure was grown on 4-inch p-type (111) silicon. The buffer/transition GaN layer was 4μm, on which was added a 1nm AlN spacer, 18nm $Al_{0.25}Ga_{0.75}N$ barrier, and 2nm GaN cap.

Transistor fabrication began with the deposition of ohmic source-drain contacts of thermally annealed titanium/aluminium/nickel/gold. Passivation layers of 4nm AlN then 50nm SiN were added by plasma-enhanced atomic layer deposition (PE-ALD) then PECVD, respectively. Device isolation was achieved using fluorine ion implantation.

Gate formation consisted of making an opening in the passivation layers using a low-power dry etch, treating the gate region with carbon tetrafluoride plasma implantation to shift the threshold voltage to enhancement-mode, the removal of photoresist, ex-situ plasma cleaning in a PE-ALD system to remove surface gallium-oxygen bonds, applying another 17nm of PECVD SiN as gate insulator, and the formation of the nickel/gold gate electrode with 1μm footprint and 0.5μm overhang.

Further dimensions of the tested devices were 1μm gate–source spacing, 10μm gate width and 15μm gate-drain spacing. The resulting MIS-HEMTs were found to have a threshold voltage of +3.6V for normally-off behavior. Comparison HEMT devices with a Schottky gate had a lower threshold of +1.2V. The difference is primarily attributed to "reduced gate-to-channel capacitance by the insertion of the SiN_x gate dielectric" in the MIS-HEMT.

The on/off current ratio was 4x10^9 with a maximum drain current of 430mA/mm. The suppression of gate leakage current enabled by the SiN insulation allowed the device to demonstrate a 14V gate swing. Traditional Schottky-gate GaN HEMTs tend to have the gate swing restricted to less than 3V. The on-resistance for the MIS-HEMT was a 'low' 9.8Ω-mm. The specific on-resistance was estimated at 2.1mΩ-cm^2.

Simple AlGaN/GaN-based high-electron-mobility transistors have a negative threshold voltage, giving a normally-on 'enhancement-mode' operation at 0V gate potential. For safe operation at high voltage or high power densities, transistors with normally-off characteristics are preferred. Further advantages include lower power consumption and simpler drive circuits

Off-state breakdown with a drain current of 1μA/mm occurred at a drain bias of 604V with the gate, source and substrate grounded (0V). Up to 450V, the main leakage comes from the source. At higher biases, gate and vertical substrate leakage increase and become comparable with the source current at 600V. The researchers compared their device with other pub-

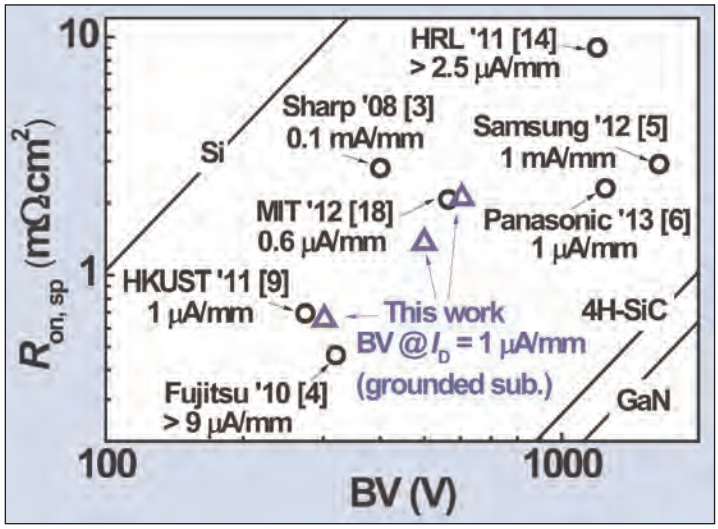

Figure 5. Specific on-resistance (R_{ON}) versus breakdown voltage (BV) of some state-of-the-art GaN-based normally-OFF power devices. OFF-state leakage criteria in defining the OFF-state breakdown voltage in different reports are highlighted.

lished results (Figure 5).

The researchers stress the need for a low off-state current of less than 1μA/mm "to ensure low power dissipation when the device is operated in the high-voltage OFF-state".

The current-collapse effect seen in HEMTs with pulsed bias was assessed using MIS-HEMTs with 1μm gate–source spacing, 2x50μm gate width, 1μm gate length, and 10μm gate-drain spacing. The devices showed "little difference between the dc and pulsed drain current in the linear region" (Figure 6a). Under pulsed operation, self-heating effects are smaller. The researchers suggest this is the reason for the higher drain current in pulsed-mode compared with dc at larger drain bias.

High drain bias stress testing was also carried out (Figure 6b). Below 200V stress, the on-to-off switching time was 0.1 seconds. This increased to 2.7 seconds for higher biases. ■

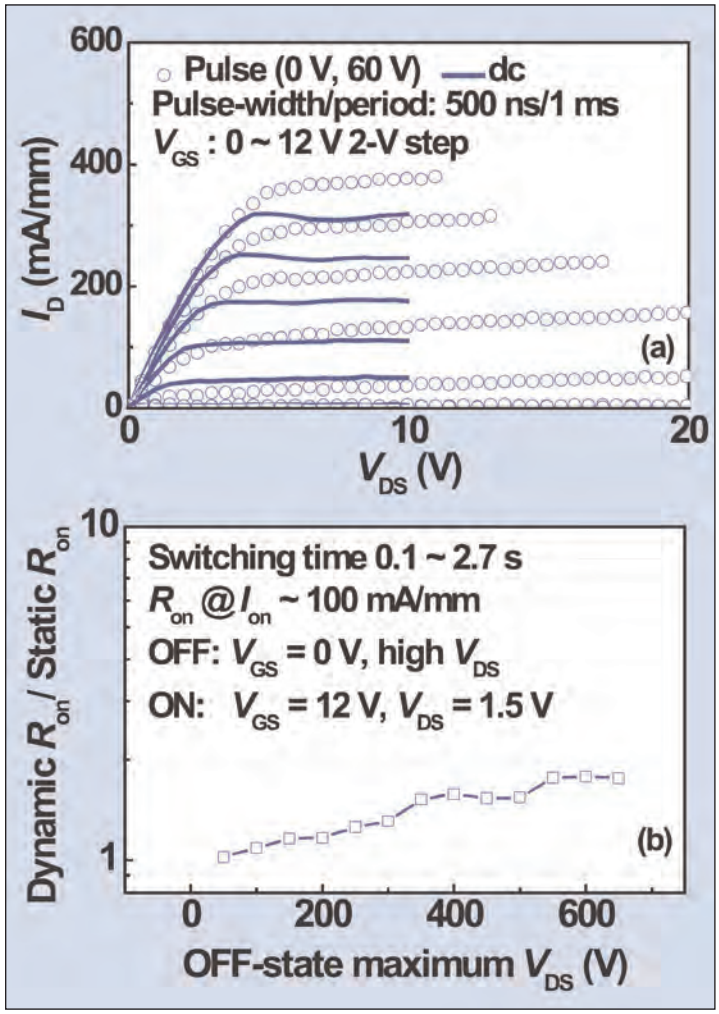

Figure 6. (a) Pulsed drain current versus bias (I_D — V_{DS}) characteristics of E-mode MIS-HEMT with L_{GS} = 1μm, $(W/L)_G$ = 2x50μm/1μm, and L_{GD} = 10μm. (b) Ratio of dynamic and dc static on-resistance (R_{ON}) obtained by low-speed high-voltage switching measurement on device with L_{GS} = 15μm, $(W/L)_G$ = 10μm/1μm, and L_{GD} = 15μm.

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Palladium oxide interlayer cuts gate leakage in nitride HEMTs

On/off current ratio increased three orders of magnitude, subthreshold swing halved.

Researchers in Taiwan have used a palladium oxide (PdO) gate interlayer to improve nitride semiconductor high-electron-mobility transistor (HEMT) performance [Ray-Ming Lin et al, Jpn. J. Appl. Phys., vol52, p111002, 2013]. In particular, the on/off current ratio was increased by three orders of magnitude and the subthreshold swing was halved over devices using pure palladium in the gate. The researchers were based at Chang Gung University and National Taiwan University.

The HEMT structures (Figure 1) were grown on high-resistivity p-silicon wafers of 6-inch diameter using metal-organic chemical vapor deposition (MOCVD). The devices were isolated by etching down to the GaN buffer to create a mesa. The ohmic source–drain contacts were thermally annealed titanium/aluminium/nickel/gold.

The gate stack was formed by patterning, evaporation of palladium in oxygen to create a 10nm PdO layer, and then deposition of more palladium (70nm) and 140nm of gold. Devices without the PdO layer were also produced.

Further processing for device interconnection and probe pads and passivation consisted of titanium/gold evaporation and silicon dioxide deposition.

Averaged over ten randomly selected devices, the maximum drain current at 2V gate potential was 430mA/mm for the HEMT with a PdO layer in the gate stack and 402mA/mm without. The slightly higher drain current with PdO layer is attributed to a passivating effect increasing the carrier density in the two-dimensional electron gas (2DEG) near the AlGaN/GaN interface that acts as the conductive channel between the source and drain.

The researchers believe that the improved on-resistance can be attributed to the higher work function of up to 7.9eV for PdO. The high work function also creates a higher Schottky barrier of

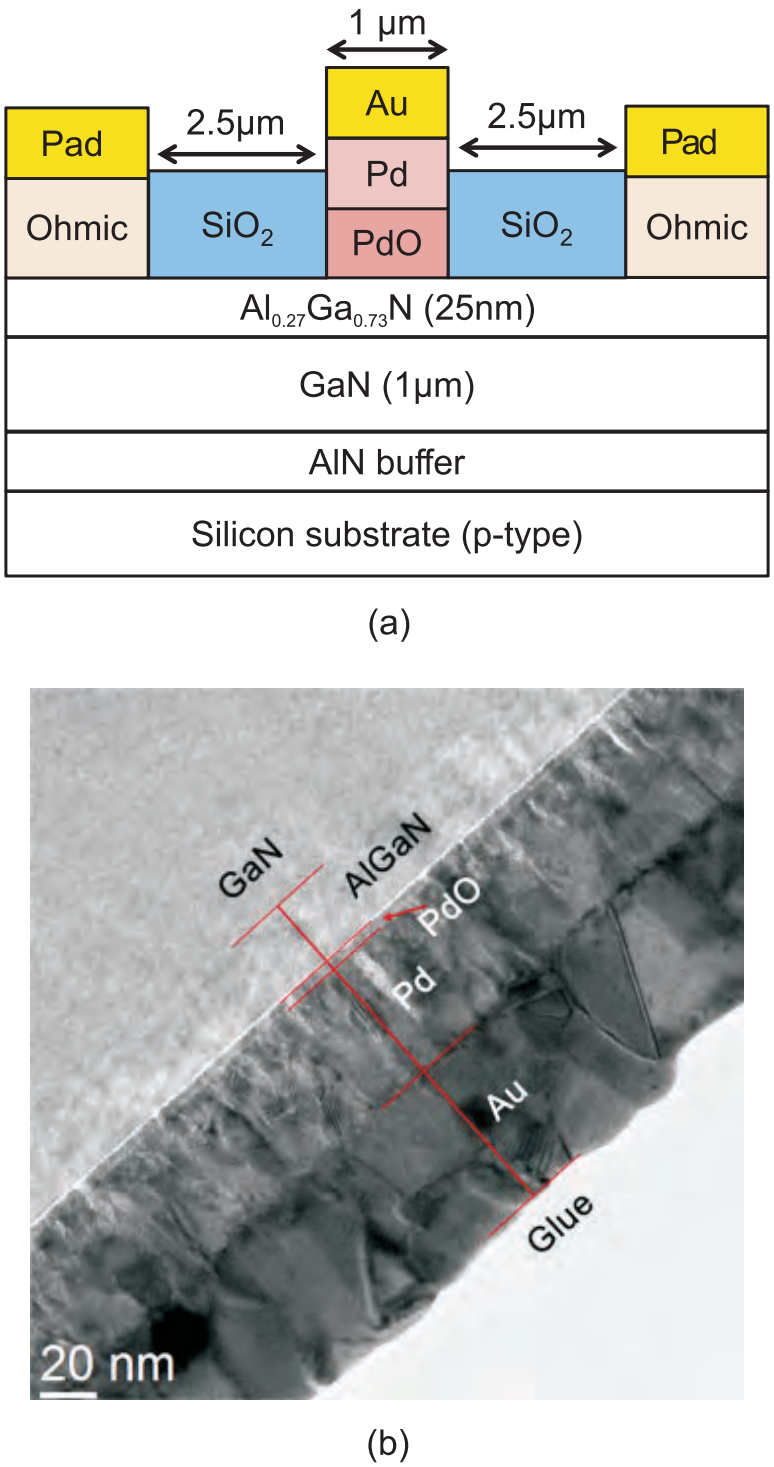

Figure 1 (a) Schematic cross-sectional image of GaN/AlGaN/PdO/Pd–Au HEMTs. (b) TEM image of GaN/AlGaN/PdO/Pd–Au structure.

0.884eV between the gate stack and AlGaN barrier layer, compared with 0.716eV for the HEMT without PdO.

Pinch-off occured at –3.6V for both types of HEMT. The PdO layer improved the on/off current ratio and subthreshold swing. The on/off ratio at 8V source-drain bias was increased by three orders of magnitude from 9.5×10^5 for the device without PdO to 1.2×10^9 with PdO. The off current leakage was 7.1×10^{-4}mA/mm for the device without PdO and 4.3×10^{-8}mA/mm with PdO.

Subthreshold swing was halved to 66mV/decade from 122mV/decade. Both these features suggest "excellent gate control of the 2DEG channel" with a PdO layer in the gate stack. Using the subthreshold swing, the researchers estimate that the effective trap state density in the PdO-HEMT was reduced to 2.04×10^{11}/eV-cm^2 from 2.08×10^{12}/eV-cm^2 in the device without PdO.

Low-frequency noise measurements (Figure 2) were carried out with the help of Taiwan's National Nano Device Labs (NDL). The low gate leakage of the PdO gate stack also reduced flicker (1/f) noise in the low-frequency range 1Hz–100kHz. The Hooge coefficient that normalizes flicker noise current spectral density, taking account of device structure and material, was 4.04×10^{-2} without PdO in the gate stack. This was reduced to 3.08×10^{-3} with the PdO layer. The researchers also expect the introduction of PdO to reduce shot noise that affects high-frequency performance. ■

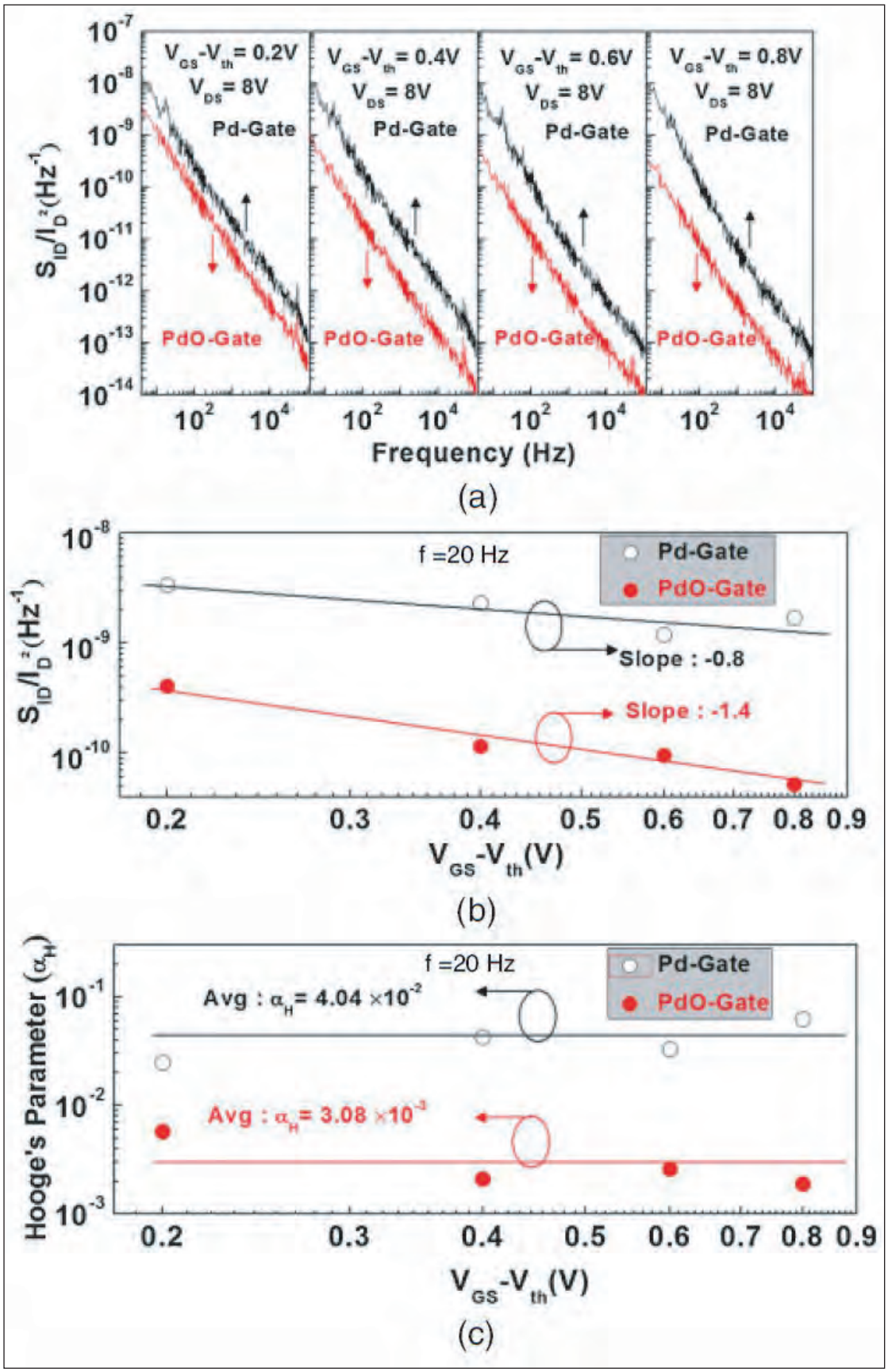

Figure 2. (a) Normalized current spectral density (S_{ID}/I_D^2) with various gate overdrive ($V_{GS} - V_{th}$) values; (b) S_{ID}/I_D^2 versus $V_{GS} - V_{th}$ at fixed frequency of 20Hz; (c) Hooge's coefficient versus $V_{GS} - V_{th}$ for both PdO- and Pd-Gate HEMTs.

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Author: Mike Cooke

High-frequency nitride HEMTs on silicon with high breakdown

Highest breakdown cut-off product for 0.3µm T-gate conventional SiN passivated transistors without field plates.

Singapore's Nanyang Technological University (NTU) has developed a passivation process for aluminium gallium nitride on gallium nitride (AlGaN/GaN) high-electron-mobility transistors (HEMTs) on silicon substrates that significantly improves breakdown voltage without impacting frequency performance [S. Arulkumaran et al, IEEE Electron Device Letters, 16 September 2013].

The Johnson figure of merit combining breakdown voltage and cut-off frequency (BV_{gd} x f_T) was 5.41 x10^{12}V/sec (Figure 1, Table 1), "which is the highest value reported so far for 0.3µm T-gate conventional SiN passivated AlGaN/GaN HEMTs on Si substrate without additional Γ-gate and/or source field plate."

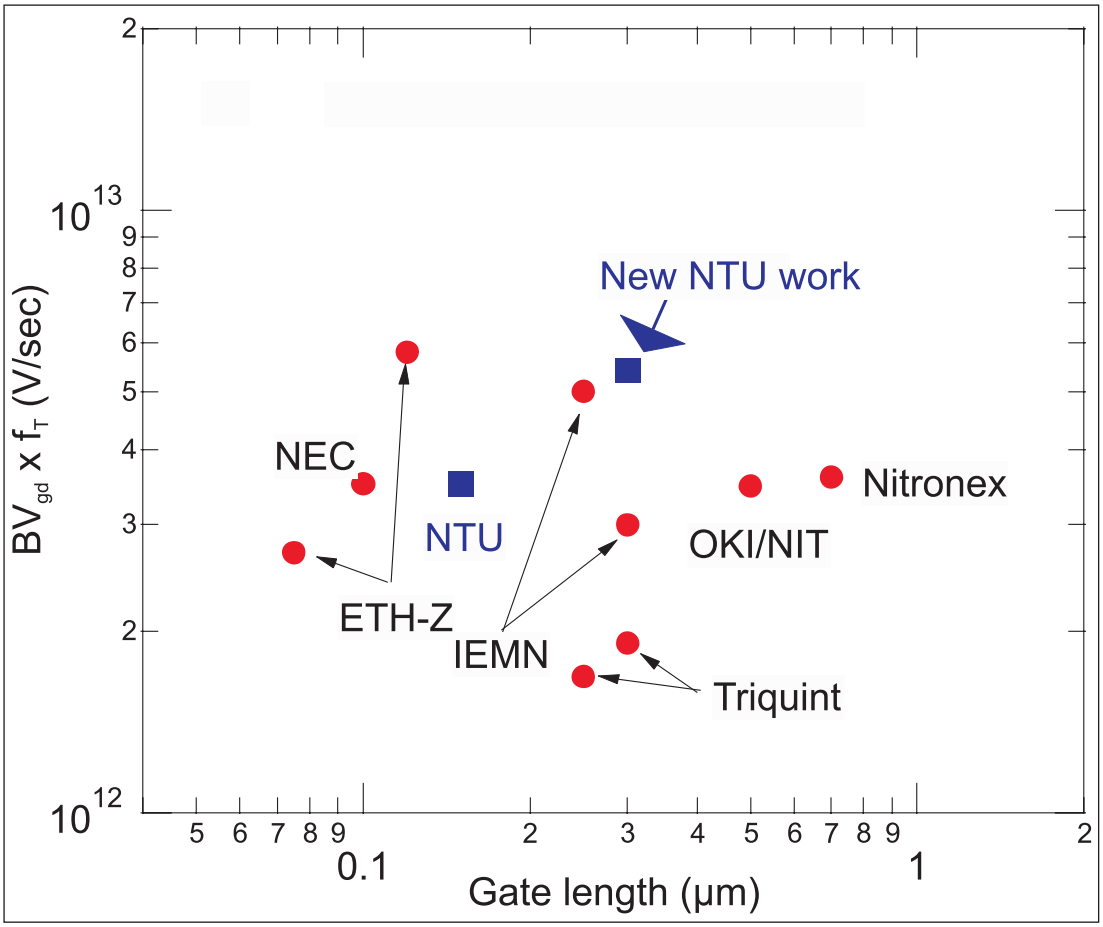

Figure 1. State-of-the-art Johnson figures of merit versus gate lengths for AlGaN/GaN HEMTs on silicon substrates.

Table 1. State-of-the-art f_T and BV_{gd} for conventional AlGaN/GaN HEMTS on Si.

Affiliation	f_T (GHz)	BV_{gd}(V)	BV_{gd} x f_T (x10^{12}V/s)	Gate type	Passivation
IEMN	50.0	100	5.00	T-gate	SiO_2/SiN
OKI/NIT	13.9	250	3.48	Γ-gate & SFP	SiN
ETH-Z	100.0	58	5.80	T-gate	SiN
NTU	39.0	90	3.51	T-gate (non-gold)	SiN
Triquint	24.0	70	1.68	T-gate & SFP	SiN
Nitronex	18.0	200	3.60	Γ-gate & SFP	SiN
NEC	60.0	55	3.30	T-gate	SiN
NTU treated HEMT	34.0	159	5.41	T-gate	$[(NH_4)_2Sx]$ + SiN

The AlGaN/GaN semiconductor layers (Figure 2) were applied to 4-inch high-resistivity (more than 6000Ω-cm) silicon substrates using metal-organic chemical vapor deposition (MOCVD). The mobility and carrier density of the two-dimensional electron gas (2DEG) channel were 1455cm^2/V-s and 9.6x10^{12}/cm^2, respectively.

Transistor fabrication began with plasma etch of the mesa isolation, and application and annealing of titanium/aluminium/nickel/gold ohmic source-drain electrodes.

Preparation for the silicon nitride passivation consisted of a 1-minute buffer hydrofluoric acid dip, and an ammonium sulfide ($(NH_4)_2S_x$) surface treatment at 50°C for 15 minutes. The silicon nitride was applied in a 50nm layer using plasma-enhanced chemical vapor deposition (PECVD at 300°C).

Gate formation consisted of electron-beam patterning and silicon nitride etch. The gate footprint was 0.3µm and the gate head was 0.7µm. The gate stack consisted of 50nm of nickel and 400nm of gold.

Final processing consisted of adding titanium/gold (50nm/1000nm) transmission lines and further passivation with 150nm of PECVD silicon nitride.

Comparison devices were also produced without the $(NH_4)_2S_x$) surface treatment.

The maximum drain current of the treated device was 646mA/mm, compared with 636mA/mm for the untreated HEMT. The respective peak extrinsic transconductances were 175mS/mm and 205mS/mm. A real difference in performance is seen in the on/off current ratios, which are three orders of magnitude higher in the treated HEMT.

Another improvement is the much lower subthreshold swing of the treated device: 77mV/decade, compared with 112mV/dec for the untreated device. The researchers consider the low subthreshold swing to be evidence of low interface trap densities as a result of the $(NH_4)_2Sx$ surface treatment.

A further benefit of treatment is a six-fold increase in gate–drain breakdown voltage (BV_{gd} for drain current 0.5mA/mm) to 159V. The higher breakdown voltage was achieved while maintaining a cut-off frequency (f_T) of 34GHz and maximum oscillation (f_{max}) of 52GHz. The cut-off gate-length product (f_T x L_g) was 10.2GHz-µm, a little smaller than the best value of 12.5GHz-µm reported in 2005 by Lille University.

Cap	GaN	2nm
Barrier	$Al_{0.26}Ga_{0.74}N$	18nm
Channel	GaN	800nm
Buffer	GaN	1400nm
Nucleation	AlN	100nm
Substrate	Si (111)	

Figure 2. Schematic structure of nitride semiconductor epitaxy on silicon for HEMT.

The researchers found that the improved breakdown performance is linked to three orders of magnitude lower surface current leakage in the treated devices by passivation of dangling bonds and interface traps between GaN and SiN.

The researchers also carried out 100Hz AC measurements, which showed "no significant drain current collapse" (Figure 3). ■

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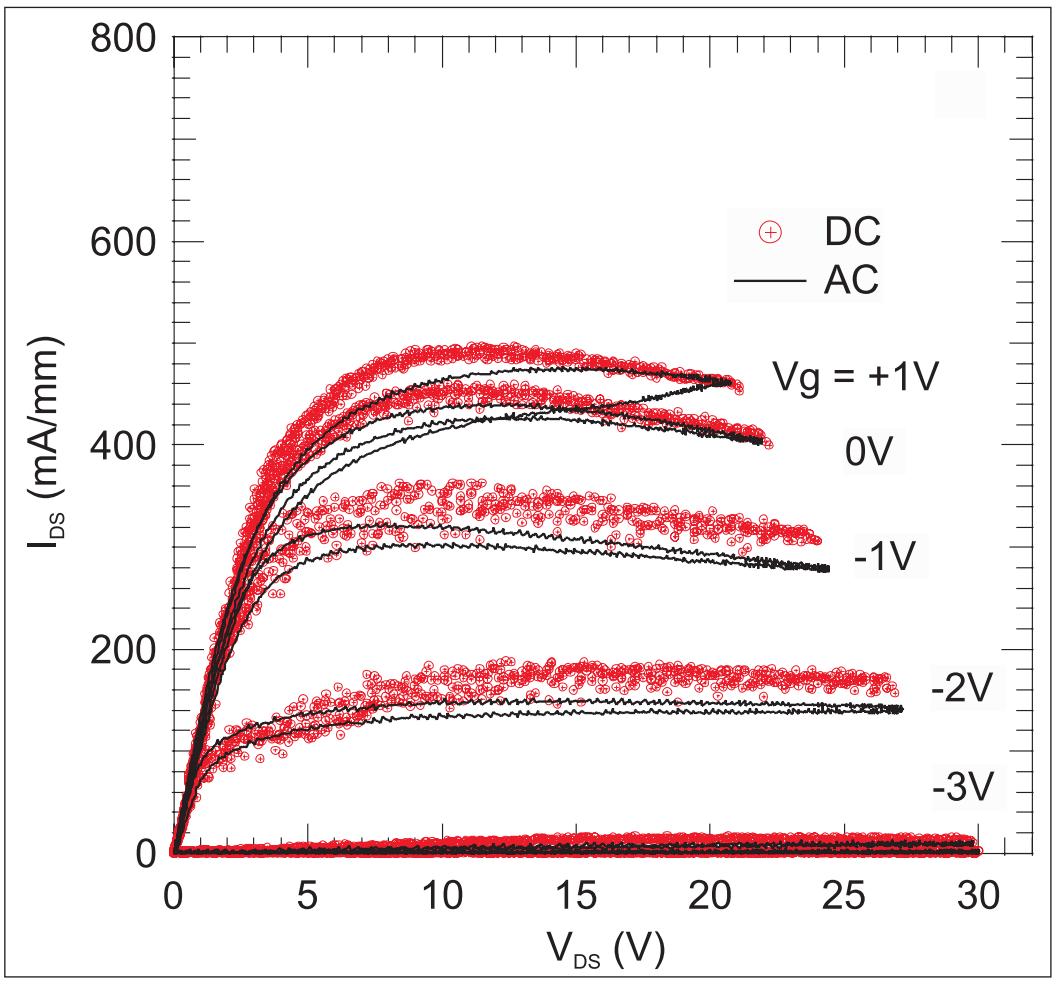

Figure 3. DC and AC (100Hz) drain current versus drain voltage characteristics of AlGaN/GaN HEMTs ($L_{sg}/W_g/L_g/L_{gd}$ = 1.0/(2x100)/0.3/3.0µm).

Fujitsu develops InP HEMT-based receiver chip with sensitivity boosted tenfold

Wireless devices operating in 240GHz millimeter-band promise 100x higher communications capacity.

At the Compound Semiconductor IC Symposium (CSICS 2013) in Monterey, CA on 13 October, Japan's Fujitsu Ltd and Fujitsu Laboratories Ltd presented details of a high-sensitivity receiver chip they have developed that, it is reckoned, will pave the way to high-capacity, gigabit-capable wireless devices operating at 240GHz in the millimeter-wave frequency band (30-300GHz).

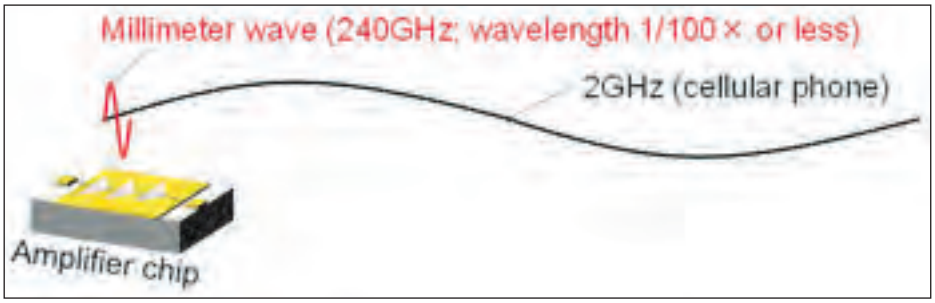

Figure 1: Comparison of wavelengths.

The explosive growth of smartphones and other wireless devices has brought about an increase in the use of mobile data communications for browsing the web or downloading music, alongside conventional voice communication. With an expected shift toward high-capacity data communications, including videos and movies, it is expected that demand will grow for devices that can instantly download such data. For that to happen, high-capacity wireless devices will need to use wider frequency ranges. Wireless devices that could use millimeter-wave frequencies in the 240GHz band would be able to take advantage of a frequency range 100 times wider than that of the 0.8–2GHz range used by existing wireless devices, so they should also be able to handle communications speeds 100 times greater (i.e. a 100-fold increase in communications capacity).

However, millimeter-wave transmissions, particularly at such high frequencies as 240GHz, become severely attenuated as the radio waves travel through the air. Receiving such a faint signal requires a highly sensitive receiver (comprised of an antenna, amplifier, and wave detector). The introduction of an amplifier with a high amplification ratio has hence been sought as an effective way of improving reception sensitivity.

A common way of increasing the amplification ratio of the amplifier is to connect multiple amplifiers as part of a staged construction. However, more stages result in bigger chip sizes. When applying this technique in the 240GHz band, the wavelength of the signal is very short (less than 1mm) so the length can be shorter than the chip itself (Figure 1). This creates technical problems that do not exist at the frequencies used by existing cell phones (that use the 2GHz band). Output signals from the amplifier can leak to ground on the chip's surface, and these leaked signals return to the amplifier's input pin, resulting in double amplification (Figure 2). When the leaked signal re-enters the amplifier, it is amplified again and produces even more signal leakage, which returns to the input pin yet again (creating the oscillator effect), making it difficult to receive these signals correctly. For this reason, creating a high

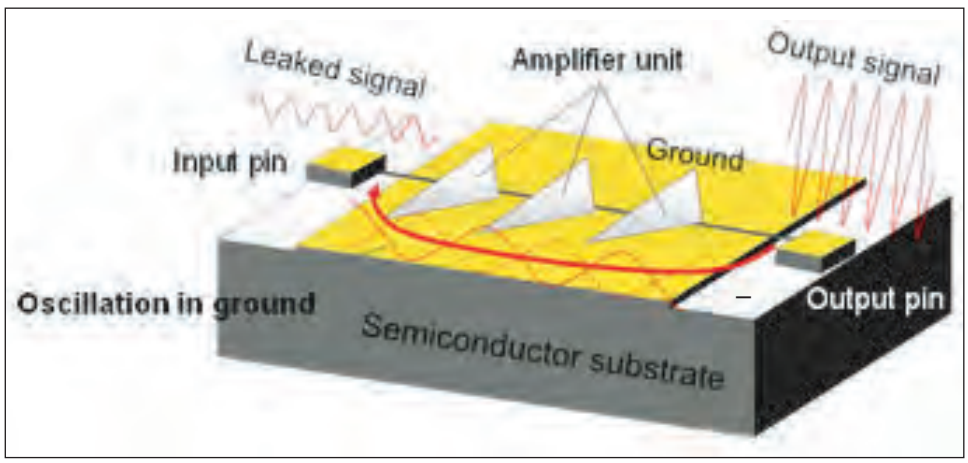

Figure 2: Signal leakage through ground.

amplification ratio with millimeter waves requires a technology that can suppress these oscillations without losing amplification levels.

Building on indium phosphide high-electron-mobility transistor (InP HEMT) technology developed by Fujitsu Laboratories, Fujitsu has developed a multi-stage amplifier that suppresses the oscillator effect while increasing the amplification ratio. Also developed was an impedance-matching technology that efficiently conveys the output signal from one stage to the next. The result is that the receiver chip's sensitivity is increased by about tenfold over previous designs, enabling the reception of large data volumes by smartphones or other mobile devices using a compact antenna.

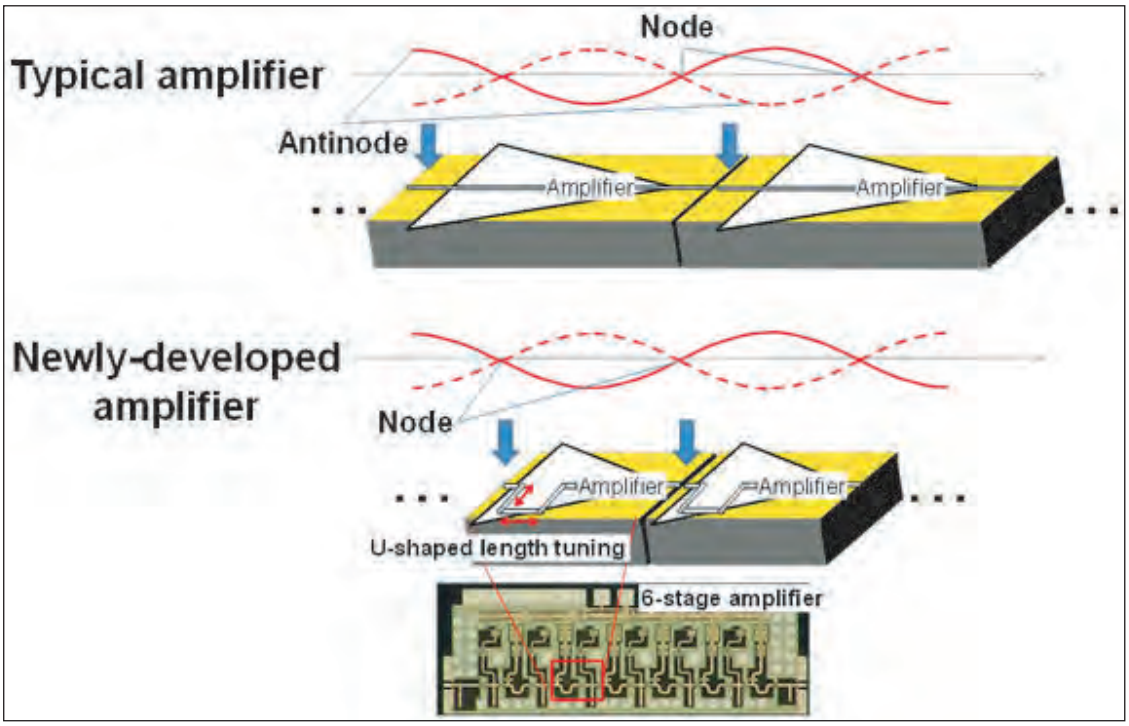

Figure 3: A conventional amplifier and the newly developed amplifier.

Key features of the technology are detailed as follows.

1. Multi-stage amplifier suppresses oscillator effect, increases amplification ratio

The leaked signal from an amplifier will always have 'anti-nodes' (at specific sites where that signal is at its greatest amplitude) and 'nodes' (where it has no amplitude at all). If the amplifier's input pin is located in a leaked signal's anti-node, then a stronger leaked signal will feed back into the amplifier, creating the oscillation effect (Figure 3, top). Conversely, if the input pin is located in a node, the leaked signal has no amplitude, and the amplifier will not re-amplify the leaked signal. Fujitsu has aligned the input pin and output pin with the nodes in the leaked signal (Figure 3, bottom). Connecting amplifiers designed this way into multiple stages results in high amplification ratios without an oscillator effect.

2. Impedance-matching technology efficiently transmits amplifier output signal to next stage

Efficiently transmitting the output signal from an amplifier to the next stage requires impedance matching on the lines that connect the amplifiers which, in turn, requires that the lines are of a uniform length. But aligning the input and output pins of the amplifiers with the nodes limits the dimensions of the amplifier, while the length requirements on the lines create another set of constraints, complicating the task of impedance matching. To resolve this problem, a U-shaped line was deployed and the length and width of the U were adjusted to enable impedance matching regardless of the limitations on the dimensions of the amplifier.

The above technologies have produced a roughly tenfold improvement in the sensitivity of a receiver chip compared with previous designs. These receivers could be used in smartphones and other wireless devices equipped with compact antennas, says Fujitsu. Also, because this would allow for antennas with broader relative directionality than existing devices, there would be no need to precisely align the transmitter to the handset (Figure 4), resulting in greater convenience for users.

Fujitsu says it is working to develop a compact package that integrates an antenna along with a receiver chip based on this technology, with the goal of conducting transmission testing sometime in 2015 and practical applications around 2020

Fujitsu says it is working to develop a compact package that integrates an antenna along with a receiver chip based on this technology, with the goal of conducting transmission testing sometime in 2015 and practical applications around 2020.

The research results were achieved partly through 'R&D Program on Multi-tens Gigabit Wireless Communication Technology at Subterahertz Frequencies' (commissioned by Japan's Ministry of Internal Affairs and Communications as part of its 'Research and Development Project for Expansion of Radio Spectrum Resources'). ■

http://jp.fujitsu.com/labs/en

MMICs: state of the industry in 2013 and future prospects

Engalco Research gives an overview of monolithic microwave integrated circuits of various types, and the main players and trends in the sector.

Globally, approaching 60 companies are involved in designing and/or manufacturing monolithic microwave integrated circuits (MMICs). These firms have their headquarters and main operations located variously worldwide, although the majority are in the USA (the countries of major operations are considered in more detail below).

Many of the smaller companies are dedicated exclusively to the design or manufacture of MMICs, and most players operate foundries active in at least one or two of the compound semiconductor technologies. Several of these players are fabless, i.e. they design and market MMICs that are actually manufactured at a MMICs foundry.

Many players (especially manufacturers) are now addressing China, both in terms of sales outlets and increasingly also local manufacturing. Additionally, China is rapidly developing its own indigenous MMIC industry. One example is the strongly growing Ya Guang Microwave Technologies. It is very likely that there will be some substantial consolidation within the industry in the future.

Figure 1 shows the proportions of players that are involved in using specific types of semiconductor materials to fabricate MMICs (in 2013).

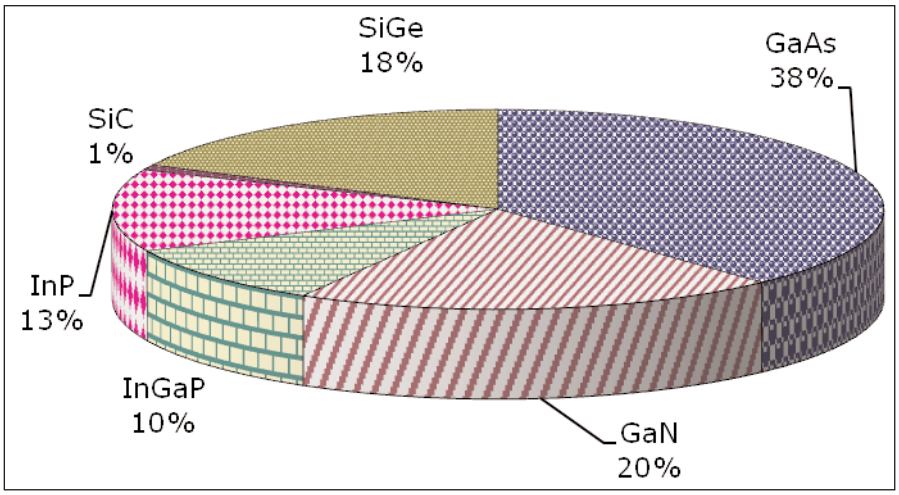

Figure 1. Proportions of players involved in each type of semiconductor substrate for MMICs (2013).

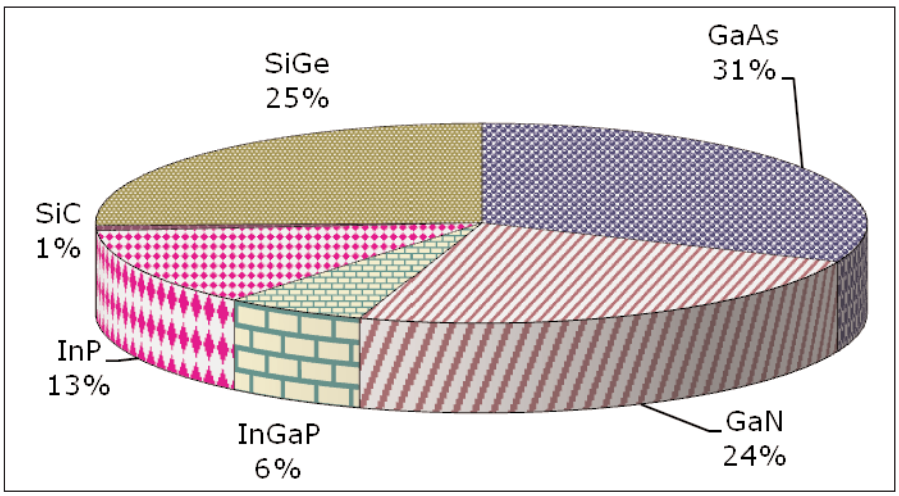

Figure 2. Proportions of players involved in each type of semiconductor substrate for MMICs (2018).

It can be seen that the majority (38%) continue to utilize GaAs — then GaN with 20% followed closely by SiGe with 18% of the total. The total number of GaAs-MMIC suppliers is 44. It is very important to appreciate that several of the players are involved with more than one semiconductor material – notably GaAs and GaN — and these are currently expanding their GaN portfolio.

These data are forecasted for 2018 in Figure 2.

Compared with the 2013 data, GaAs MMIC implementations have decreased by 7%, GaN has increased by 4% and SiGe has increased by 7%.

A brief perusal of the trade press reveals that some people dare to make statements such as: "GaAs is

dead, GaN is here from now onwards". *This kind of statement is totally incorrect regarding GaAs* — although absolutely right about GaN. For most applications, GaN MMIC power amplifiers (PAs) offer much more output power at substantially higher efficiencies than comparable GaAs MMIC PAs. However, it is always very important to remember:

- GaAs MMICs operate with DC supply rails of about 8V to 15V or so;
- BUT GaN MMICs require DC supply voltages of more like 30V or even 45V;
- AND this means that no GaN-based MMIC can ever be a plug-in replacement for a GaAs-based chip.

Meanwhile high-level PAs are regularly being offered today, implementing discrete GaN transistors (e.g. from MACOM).

SiGe BiCMOS is rapidly increasing in importance for short-range, Gigabit-data-rate millimeter-wave radios, with the global market for such MMICs forecasted to reach a value of $220m by 2018. Since the 2012 market was estimated to be about $20m this represents an 83% average year-on-year growth rate i.e. an overall market value increase by a factor of 11.

Players *exclusively* offering SiGe MMICs as well as those offering both GaAs MMICs and SiGe MMICs are identified in Table 1.

It can be seen from Table that a total of 21 players offer SiGe-based MMICs and 13 will supply either GaAs-based or alternatively SiGe-based MMICs.

RFMD and Skyworks are leading suppliers. Whilst the majority of operations are located in China or the USA, there are also important companies outside of these countries. The numbers involved are indicated in Figure 3.

In Japan companies such as Mitsubishi Electric, New Japan Radio, Sumitomo Electric and Toshiba are all influential in this business. Taiwan has Taiwan Semiconductor Manufacturing Company (TSMC — a very important silicon player that also operates a SiGe foundry) and the world-leading GaAs-based foundry WIN Semiconductor.

Most players offer MMIC products operating strictly somewhere within the microwave range of frequencies (500MHz to 18GHz) and some of these players offer both microwave (MW) and millimeter-wave (MMW: above 18GHz). It would appear that only Gotmic (Sweden), IHP of Germany and HRL (USA) offer exclusively millimeter-wave MMICs. This entire scenario (also bare die and package options) is summarized in Table 2.

Table 1 GaAs and SiGe MMIC Suppliers (Source: Engalco) — not intended to be a comprehensive listing but includes the main players.

Name	GaAs	SiGe
Avago Technologies1	√	√
BeRex		√
Freescale	√	√
GigOptix*	√	√
Hittite Microwave*	√	√
IBM Microelectronics		√
Infineon		√
MACOM	√	√
MAXIM		√
Mini-Circuits*	√	√
NXP Semiconductor		√
Plextek RFI*	√	√
RF Integration*	√	√
RFMD	√	√
Skyworks Solutions	√	√
Tahoe RF Semiconductors*		√
Tower Jazz		√
TSMC		√
Vectrawave*	√	√
ViaSat	√	√
Ya Guang Microwave Technologies	√	√

* Fabless players (use various foundries).
1 Avago Technologies use the Tower Jazz SiGe foundry.
2 Anadigics is omitted because this company focuses exclusively on GaAs MMICs.
3 TriQuint Semiconductor may possibly be involved with SiGe MMICs, although this situation is at present unclear.

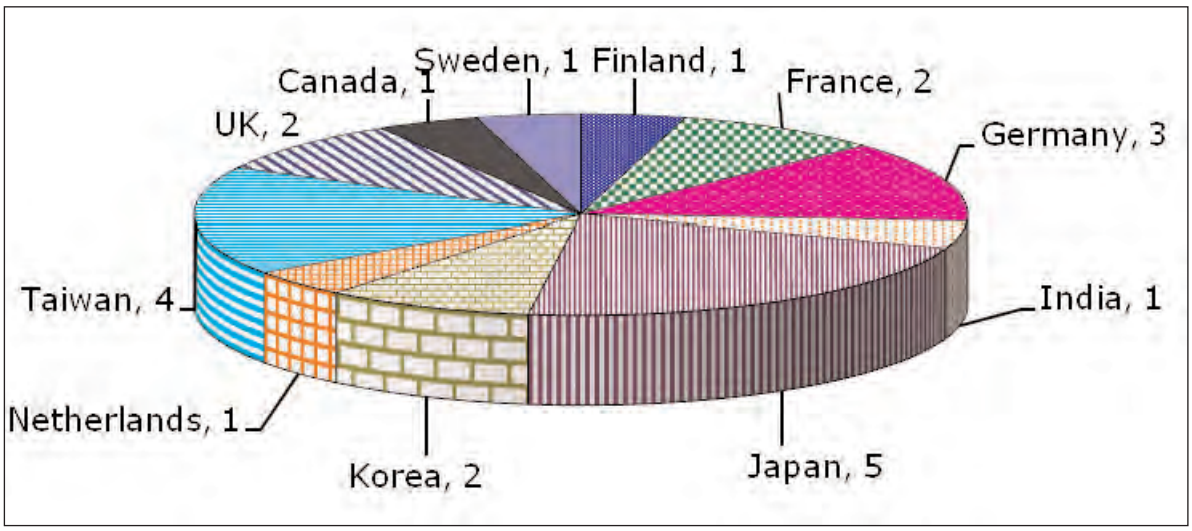

Figure 3. Number of players that have *main* operation outside China or the USA (2018).

Table 2 Players identified as offering MW, MMW, bare die and/or packaged MMICs (Source: Engalco).

Player	MW	MMW	Bare die (chip)	Package/s
Agilent Technologies	√	√	√	
AMCOM Communications	√ to 10GHz			SD-R, WM-R
Anadigics	√			(e.g.) MSL-3
Astra Microelectronic Technologies	√		√	
Auriga Microwave	√	√	√	
Avago Technologies	√ (mainly)	√ (a few bare die)	√	Mainly SMT
BAE Systems Electronic Solutions	√	√	(no	commercial information)
BeRex	√			SOT89 & SOT363
Bowei	√			SMT
Cree	√		√	Screw-down (GaN PA)
Custom MMIC Design Services (CMDS)	√	√ (to 77GHz)	√	
Fraunhofer IAF	√		√	
Freescale Semiconductor	√	√		QFN or LQPF
Gain Microwave	√		√	
GCS	√	√	√	
GigOptix (previously Iterra)	√	√ (to 40GHz)	√	
GotMic		√ (to 105GHz)	√	
Hittite Microwave [1]	√	√ (to ~90GHz)	√ (~80%)	LP4, ST89
HRL		√	√	
IBM Microelectronics	√ (mainly)		√	
IHP		√ (to 300GHz)	√ (mainly)	
Infineon Technologies	√	√ (to 77GHz)	√	SMD
MACOM	√	√ (to 42GHz)	√ (mainly, MMW)	QFN, SOT89
Maxim	√			QFN (to 48-lead), some SOT & WLP
METDA	√	√	√	BGA, SMT
Microsemi	√			SMT [2]
Microwave Technology (MwT)	√		√ (50%)	Some QFNO
Mini-Circuits	√			SMT
Mitsubishi Electric & Electronics	√			SMT (typ. 30-lead)
New Japan Radio	√			QFN, SMT
Nitronex	√			QFN16
Northrop Grumman	√	√	(no	commercial information)
NXP Semiconductor	√			SMD (mainly SOT)
Ommic	√	√	√ (mainly)	Some QFN & other
Plextek RFI	√	√	√	
RENESAS	√			Plastic QFN (typ.16-lead)
RFHIC	√			QFN [3], up to SOIC89
RF Integration	√		√	
RF Micro Devices (RFMD)	√ (~95%)	√ (~ 5%)	√ (small %)	Mainly QFN [3]
Skyworks Solutions	√			MCM, QFN
Sumitomo Electric Device Innovations (SEDI) [4]	√	√ (to 65GHz)	√ (mainly)	QFN (through Ka-band)
Tahoe RF Semiconductors	√		√	LCC [5]
Teledyne Scientific and Imaging LLC	√			324-pad µBGA
TLC Precision Wafer Technology	√	√ (~95%. to 100GHz)	√	
Toshiba	√			SOT (x1 product)
TowerJazz	√		√	
Transcom	√	√ (to 36GHz)	√ (~ 50%)	[6]
TriQuint Semiconductor [7]	√	√ (to 50GHz)	√ (~ 50%)	QFN (~ 50%)
TSMC	√		√	
United Microelectronics Corp (UMC)	√	√	√	
United Monolithic Semiconductor (UMS)	√	√ (to 77GHz)	√ (~ 50%)	QFN (~ 50%)
Vectrawave	√	√ (to 90GHz)	√ (~ 50%)	LPA, QFN (~ 50%)
Viasat	√	√ (to 94GHz)		
Viper RF	√	√ (to 100GHz)	√	(Various)
WIN Semiconductor	√	√ (to 100GHz)	√	
Ya Guang Microwave Technologies	√	√ (to 40GHz)		QFN & similar

Notes relating to the data in Table 2:

[1] Hittite offers a MMIC in an LP4 package (QFN) operating to at least 36GHz.

[2] This applies to Microsemi's range of SMT-packaged MW amplifiers.

[3] RFMD supplies products in the following package styles: ceramic micro-X, plastic micro-X, MCM, QFN, SOIC8 and SOT89 (3-lead).

[4] Most of SEDI's products come in bare die format (always for frequencies exceeding 36GHz). Several SEDI products remain labelled with the earlier Eudyna name.

[5] LCC = leadless chip carrier.

[6] Transcom offer many of their products in unusual package formats. All comprise 8-or-10-lead SMT styles with two fixing holes and signal ports (input and output) in co-planar waveguide (CPW) configurations.

[7] TriQuint's choice of packages mainly comprise: SLIM, ST, SLP or VQFN. Broadband LNAs represent exceptions – typically housed in 12-or-17-lead BGA packages.

A total of 17 players offer products in the QFN (or similar) package format — including Hittite's LP4. It is important to note that several of the major players, e.g. Avago, RFMD, Transcom, TriQuint and UMS, offer about a half or more of their products in either QFN or at least SMT formats. SM-packaged MMICs (mostly QFN) represent an increasingly significant portion of the total available on the market. With the relentless advance of integrated microwave assembly technology, individually connectorized MMIC-based components such as amplifiers and oscillators are already giving way to SM-packaged products, and this trend will doubtless continue.

Another important feature that can be deduced from Table 2 is the relative numbers of players involved in microwave products, millimeter-wave products — or indeed both categories. A total of 53 players are in the first category and 29 players in the second. This means that just below a half of all the MMIC players offer millimeter-wave products as well as microwave products.

Most of the millimeter-wave players offer products operating to at least 42GHz (important, as this encompasses the rapidly growing K/Ka-band SATCOM application sector) and the small German operation IHP can supply at least one product operating to 300GHz. An important subset of these players offer millimeter-wave chips operating in the increasingly significant unlicensed 60GHz band, the E-band and the 76–81GHz adaptive cruise control (ACC) band (W-band).

Concluding remarks

The following conclusions can be drawn:

- Monolithic microwave integrated circuits (MMICs) remain vital to the RF/microwave industry — with ever-expanding applications.
- Out of the approximately 60 MMIC players identified operating worldwide — mainly American-owned — 44 supply GaAs-based MMICs, 21 supply SiGe-based MMICs and 13 offer both types.
- The market for SiGe-based MMICs is growing strongly — notably for millimeter-wave applications including short-range Gbit/s links.
- Another important end-user area for SiGe-based MMICs is for W-band adaptive cruise control (ACC).
- The market for GaN-based MMICs is growing strongly although the number of players offering these types of MMICs is growing slowly.
- At least seven of the players operate using the fabless business model — Hittite Microwave and Plextek RFI are prominent examples. Foundries include IBM Microelectronics, TriQuint Semiconductor, TSMC and WIN Semiconductor.
- Most packages are QFN or similar — although many products are offered in bare die form, often as an option. ■

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www.svta.com

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7 Wafer processing materials

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www.airproducts.com/compound

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1254 Chestnut St. Newton,
MA 02464, USA
Tel: +1 617 965 5511
Fax: +1 617 965 5818
www.microchem.com

Power + Energy Inc
(see section 10 for full contact details)

Praxair Electronics
(see section 5 for full contact details)

8 Wafer processing equipment

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Power + Energy Inc
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9 Materials & metals

Goodfellow Cambridge Ltd
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www.plansee.com

10 Gas and liquid handling equipment

Air Products and Chemicals Inc
(see section 7 for full contact details)

Cambridge Fluid Systems
12 Trafalgar Way, Bar Hill,
Cambridge CB3 8SQ,
UK
Tel: +44 (0)1954 786800
Fax: +44 (0)1954 786818
www.cambridge-fluid.com

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www.powerandenergy.com

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USA
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Fax: +1 805 541 9399
www.saesgetters.com

11 Process monitoring and control

k-Space Associates
2182 Bishop Circle
East, Dexter,
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Fax: +1 734 426 7955
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k-Space Associates Inc specializes in in-situ, real-time thin-film process monitoring tools for MBE, MOCVD, PVD, and thermal evaporation. Applications and materials include the research and production line monitoring of compound semiconductor-based electronic, optoelectronic, and photovoltaic devices.

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www.kla-tencor.com

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Germany
Tel: +49 30 89 00 55 0
Fax: +49 30 89 00 180
www.laytec.de
LayTec develops and manufactures optical in-situ and in-line metrology systems for thin-film processes

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with particular focus on compound semiconductor and photovoltaic applications. Its know-how is based on optical techniques: reflectometry, emissivity corrected pyrometry, curvature measurements and reflectance anisotropy spectroscopy.

Optical Reference Systems Ltd
OpTIC Technium,
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St Asaph, LL17 0JD,
UK
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Fax: +44 (0)1745 535 186
www.ors-ltd.com

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Furtwangen im Schwarzwald,
Germany
Tel: +49 7723 9197 0
Fax: +49 7723 9197 22
www.wepcontrol.com

12 Inspection equipment

Bruker AXS GmbH
Oestliche Rheinbrueckenstrasse 49,
Karlsruhe, 76187,
Germany
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Fax: +49 (0)721 595 4587
www.bruker-axs.de

13 Characterization equipment

J.A. Woollam Co. Inc.
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Fax: +1 402 477 8214
www.jawoollam.com

Lake Shore Cryotronics Inc
575 McCorkle Boulevard,
Westerville, OH 43082,
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Fax: +1 614 818 1600
www.lakeshore.com

14 Chip test equipment

Keithley Instruments Inc
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Cleveland, OH 44139,
USA
Tel: +1 440.248.0400
Fax: +1 440.248.6168
www.keithley.com

SUSS MicroTec Test Systems
228 Suss Drive,
Waterbury Center, VT 05677,
USA
Tel: +1 800 685 7877
Fax: +1 802 244 7853
www.suss.com

15 Assembly/packaging materials

ePAK International Inc
4926 Spicewood Springs Road,
Austin, TX 78759,
USA
Tel: +1 512 231 8083
Fax: +1 512 231 8183
www.epak.com

Gel-Pak
31398 Huntwood Avenue,
Hayward, CA 94544,
USA
Tel: +1 510 576 2220
Fax: +1 510 576 2282
www.gelpak.com

Wafer World Inc
(see section 3 for full contact details)

Williams Advanced Materials
2978 Main Street,
Buffalo, NY 14214, USA
Tel: +1 716 837 1000
Fax: +1 716 833 2926
www.williams-adv.com

16 Assembly/packaging equipment

Ismeca Europe Semiconductor SA
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2301, Switzerland
Tel: +41 329257111
Fax: +41 329257115
www.ismeca.com

Kulicke & Soffa Industries
1005 Virginia Drive,
Fort Washington,
PA 19034,
USA
Tel: +1 215 784 6000
Fax: +1 215 784 6001
www.kns.com

Palomar Technologies Inc
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Carlsbad, CA 92010,
USA
Tel: +1 760 931 3600
Fax: +1 760 931 5191
www.PalomarTechnologies.com

TECDIA Inc
2700 Augustine Drive, Suite 110,
Santa Clara, CA 95054,
USA
Tel: +1 408 748 0100
Fax: +1 408 748 0111
www.tecdia.com

17 Assembly/packaging foundry

Quik-Pak
10987 Via Frontera,
San Diego, CA 92127,
USA
Tel: +1 858 674 4676
Fax: +1 8586 74 4681
www.quikicpak.com

18 Chip foundry

Compound Semiconductor Technologies Ltd
Block 7, Kelvin Campus,
West of Scotland,
Glasgow,
Scotland G20 0TH,
UK
Tel: +44 141 579 3000
Fax: +44 141 579 3040
www.compoundsemi.co.uk

United Monolithic Semiconductors
Route departementale 128,
BP46, Orsay, 91401,
France
Tel: +33 1 69 33 04 72
Fax: +33 169 33 02 92
www.ums-gaas.com

19 Facility equipment

MEI, LLC
3474 18th Avenue SE,
Albany, OR 97322-7014,
USA
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Fax: +1 541 917 3623
www.marlerenterprises.net

20 Facility consumables

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Fax: +43 5672 600 500
E-mail info@plansee.com
www.plansee.com

W.L. Gore & Associates
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MD 21921-4236, USA
Tel: +1 410 392 4440
Fax: +1 410 506 8749
www.gore.com

21 Computer hardware & software

Ansoft Corp
4 Station Square, Suite 200,
Pittsburgh, PA 15219, USA
Tel: +1 412 261 3200
Fax: +1 412 471 9427
www.ansoft.com

Crosslight Software Inc
121-3989 Henning Dr.,
Burnaby, BC, V5C 6P8,
Canada
Tel: +1 604 320 1704
Fax: +1 604 320 1734
www.crosslight.com

Semiconductor Technology Research Inc
10404 Patterson Ave., Suite 108,
Richmond, VA 23238, USA
Tel: +1 804 740 8314
Fax: +1 804 740 3814
www.semitech.us

22 Used equipment

Class One Equipment Inc
5302 Snapfinger Woods Drive,
Decatur, GA 30035,
USA
Tel: +1 770 808 8708
Fax: +1 770 808 8308
www.ClassOneEquipment.com

23 Services

Henry Butcher International
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UK
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Fax: +44 (0)20 7405 9772
www.henrybutcher.com

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Stuttgart,
Germany
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Fax: +49 711 8804 1950
www.mw-zander.com

24 Consulting

Fishbone Consulting SARL
8 Rue de la Grange aux Moines,
78460 Choisel,
France
Tel: + 33 (0)1 30 47 29 03
E-mail: jean-luc.ledys@neuf.fr

25 Resources

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Fax: +1 408 428 9600
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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

11–12 December 2013
MicroNanoConference '13
De ReeHorst, Ede, The Netherlands
E-mail: info@micronanoconference.org
www.micronanoconference.org

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

22–24 January 2014
TMCS IV: Theory Modelling and Computational Methods for Semiconductors
Salford, UK
E-mail: info@tmcsuk.org
www.tmcsuk.org/conferences/TMCSIV

28–30 January 2014
6th International Symposium on Optronics in Defence and Security (OPTRO 2014)
OECD Conference Center, Paris, France
E-mail: optro2014@aaaf.asso.fr
www.optro2014.com

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

10–11 February 2014
SolarTech Germany 2014
Berlin, Germany
E-mail: pl@greenworldconferences.com
www.greenworldconferences.com

12–14 February 2014
LED Korea
Convention and Exhibition Center (COEX), Seoul, Korea
E-mail: semiconkorea@semi.org
www.led-korea.org

23–26 February 2014
LED CHINA 2014
China Import and Export Fair Pazhou Complex, Guangzhou, China
E-mail: led-trust@ubm.com
www.LEDChina-gz.com

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23–27 February 2014
SPIE Advanced Lithography 2014
San Jose Convention Center and Marriott Hotel, CA, USA
E-mail: customerservice@spie.org
http://spie.org/advanced-lithography.xml

25–27 February 2014
15th Strategies in Light Conference
Santa Clara Convention Center, CA, USA
E-mail: registration@pennwell.com
www.strategiesinlight.com

9–13 March 2014
Optical Fiber Communication Conference and Exposition/National Fiber Optic Engineers Conference (OFC/NFOEC 2014)
Moscone Convention Center, San Francisco, CA, USA
E-mail: info@ofcconference.org
www.ofcnfoec.org

16–20 March 2014
29th annual IEEE Applied Power Electronics Conference and Exposition (APEC 2014)
Fort Worth Convention Center, TX, USA
E-mail: apec@apec-conf.org
www.apec-conf.org

18–20 March 2014
SEMICON China
Shanghai New International Exhibition Centre, China
E-mail: semichina@semi.org
www.semiconchina.org

18–20 March 2014
Laser World of Photonics China
Shanghai New International Exhibition Centre, China
E-mail: laser@mmi-shanghai.com
www.photonicschina.net

18–20 March 2014
Laser Optics – International Trade Fair and Congress for Optical Technologies and Microsystems
Berlin ExpoCenter City, Berlin, Germany
E-mail: kubeerkens@messe-berlin.de
www.laser-optics-Berlin.de

18–20 March 2014
Image Sensors (IS2014)
Park Plaza Victoria, London, UK
E-mail: rstead@smithers.com
http://image-sensors.com

25–27 March 2014
IPC APEX EXPO 2014
Las Vegas, NV, USA
E-mail: registration@ipc.org
www.IPCAPEXEXPO.org

25–27 March 2014
Intersolar China 2013
China National Agricultural Exhibition Center (CNAEC), Beijing, China
E-mail: pang@intersolarchina.com
www.intersolarchina.com

14–17 April 2014
SPIE Photonics Europe 2014
SQUARE Brussels Meeting Centre, Belgium
E-mail: customerservice@spie.org
http://spie.org/photonics-europe.xml

23–25 April 2014
SEMICON Singapore
Marina Bay Sands Expo & Convention Center, Singapore
E-mail: semiconsingapore@semi.org
www.semiconsingapore.org

5–9 May 2014
SPIE DSS 2014, incorporating:
SPIE Security + Defence 2014
SPIE Sensing Technology + Applications 2014
Baltimore Convention Center, MD, USA
E-mail: customerservice@spie.org
http://spie.org/defense-security-sensing.xml

11–15 May 2014
Compound Semiconductor Week 2014, inc:
41st International Symposium on Compound Semiconductors (ISCS 2014)
26th International Conference on Indium Phosphide and Related Materials (IPRM 2014)
Montpellier, France
E-mail: csw2014@csw2014.org
www.csw2014.org

11–16 May 2014
225th Electrochemical Society (ECS) Meeting
Orlando, FL, USA
E-mail: meetings@electrochem.org
www.electrochem.org/meetings/biannual/fut_mtgs.htm

14–15 May 2014
SEMICON Russia
Moscow, Russia
E-mail: yulia.solovieva@businessmediarussia.ru
www.semiconrussia.org

19–21 May 2014
25th annual SEMI Advanced Semiconductor Manufacturing Conference (ASMC 2014)
Saratoga Springs, NY, USA
E-mail: mkindling@semi.org
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