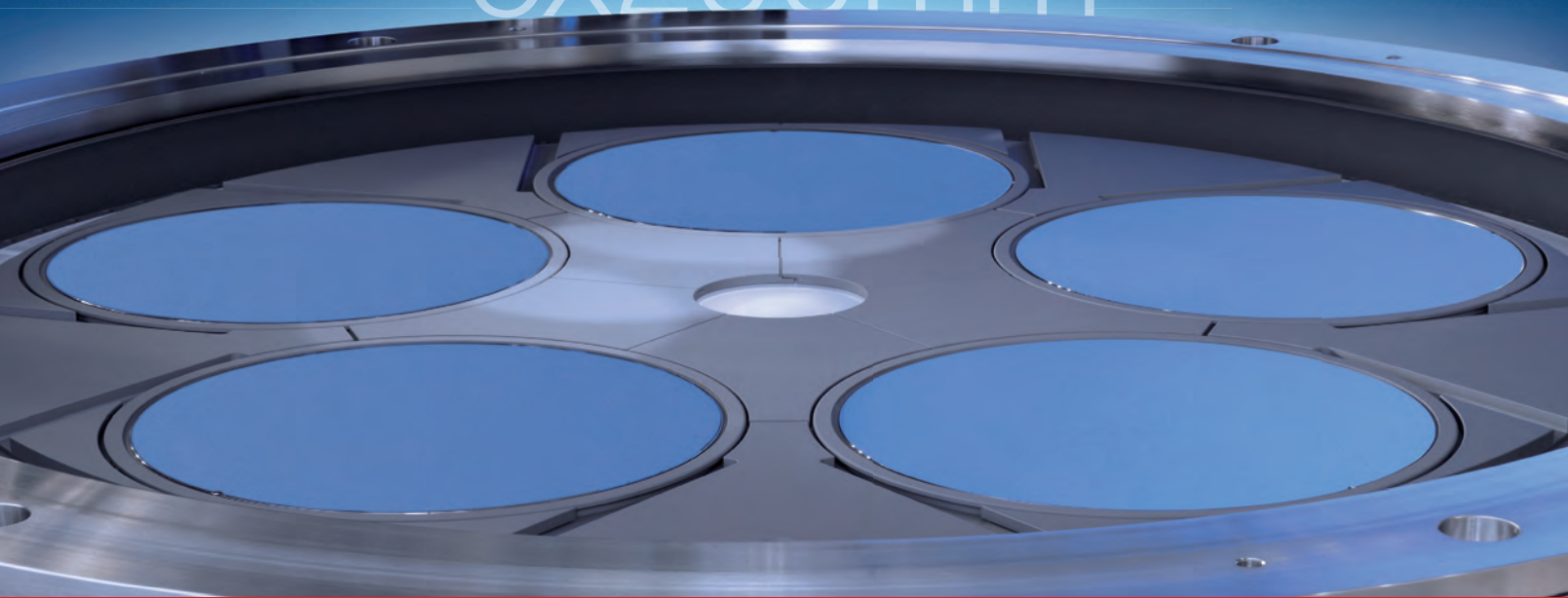


AIXTRON

200mm GaN-on-Si Batch Reactor

5x200mm



AIX G5+



AIX G5+ for GaN-on-Si

- Dedicated technology package
- Compatible with the AIX G5 HT platform
- Enables Si-style mass manufacturing
- Builds on planetary technology:
Excellent and symmetric uniformities,
controlled bow behavior,
using standard Si substrates.

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

Vol. 7 • Issue 5 • June/July 2012

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Developments in 200mm GaN-on-silicon

Micro-LED firms funded



China MOCVD purchases fall short • Gaas Labs buys Nitronex
Finisar to acquire RED-C • Abound suspends operations

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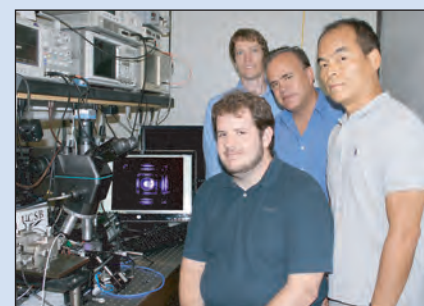
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p29 SemiSouth has doubled the current rating of its DPAK-packaged 1200V SiC diodes from 5A to 10A.



p58 Ireland Minister Seán Sherlock TD, IL Investments principal Najeeb Khalid and InfiniLED's CEO Joe O'Keeffe at InfiniLED's investment launch event.



p67 UCSB demonstrates first nonpolar m-plane GaN VCSEL. Left to right: Casey Holder, Daniel Feezell (back), Steven DenBaars, Shuji Nakamura.



Cover: The reactor chamber of Aixtron's new AIX G5+ 5x200mm GaN-on-Si package for its G5 MOCVD reactor. The firm has expanded its AIX G5 reactor platform to accommodate five 200mm wafers, targeting burgeoning applications for gallium nitride on silicon. **p46**

GaN-on-silicon epiwafer expansion provides power

In this issue we report on the annual IEEE Symposium on VLSI Technology, focusing on the increasing attention being paid to both III-V- and germanium-based high-mobility materials for enhancing transistor performance in mainstream silicon-based devices (see pages 98–102).

Also, in articles on pages 90–91, 92–93 and 94–95 we cover research on nitride transistors, including devices on silicon substrates. In particular, in the latter case, RWTH Aachen University and MOCVD reactor maker have been developing plasma oxidation of aluminium to incorporate an insulating layer between the transistor's gate and channel, as per silicon MOSFETs.

This work was done on 6" silicon wafers. However, Aixtron has just launched the G5+ version of its AIX G5 MOCVD reactor, providing an upgrade to accommodate 5x200mm (8") GaN-on-silicon wafers in mass production.

GaN-based LEDs grown on silicon wafers are increasingly being introduced into production, with Toshiba for example deciding to target this October for the start of production on a new line in an existing 200mm silicon wafer fab (page 56). However, the other potentially huge application that is gaining impetus is power semiconductor device manufacturing. Especially because of the larger die size, this gives added motive to scale up from existing commercial 6" GaN-on-Si wafer size to 200mm. In particular, GaN-on-Si epiwafer specialist AZZURRO Semiconductors of Germany has just received a €2.6m grant from the European Regional Development Fund and the Free State of Saxony to develop 200mm GaN-on-Si epiwafers, after having recently ordered a Veeco K465i MOCVD system for its existing 6" GaN-on-Si epi production (page 52). Meanwhile, Belgium-based EpiGaN has recently commissioned two Aixtron CCS MOCVD systems to commercialize its 6" GaN-on-Si epi technology, but also intends to use them to develop 200mm processes.

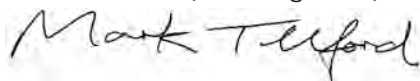
Although just a tiny fraction currently of the \$18bn silicon-dominated power semiconductor market (see page 11), the market for GaN-based power semiconductor devices is growing at more than 60% annually, and is forecast to reach \$1.75bn by the end of 2022 (see page 12).

The current hiatus in LED production (while awaiting the much anticipated take-off of solid-state lighting) has been exacerbated by the over-ambitious expansion plans of LED manufacturers in China. A market research report estimates that, of 46 Chinese LED chip projects planned in 2009–2010, just 20 have been put into production and, consequently, of 1220 intended MOCVD system purchases, just 436 have materialized (see page 10).

While this has led to a sharp downturn in orders for MOCVD system makers Aixtron and Veeco in the last few quarters, they are seeing a recovery in second-half 2012 (to be reported in detail with the Q2/2012 results next issue). In addition to capacity utilization improving at LED manufacturers, Aixtron for example is seeing increased non-LED business. So, despite the delay in solid-state lighting adoption, power semiconductors are forecast to provide a sizeable market opportunity for GaN devices long term, with the \$1.75bn in GaN power semiconductors comprising a large proportion of the expected \$2.6bn total GaN market (including LEDs) in 2022.

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Regular issues contain:

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

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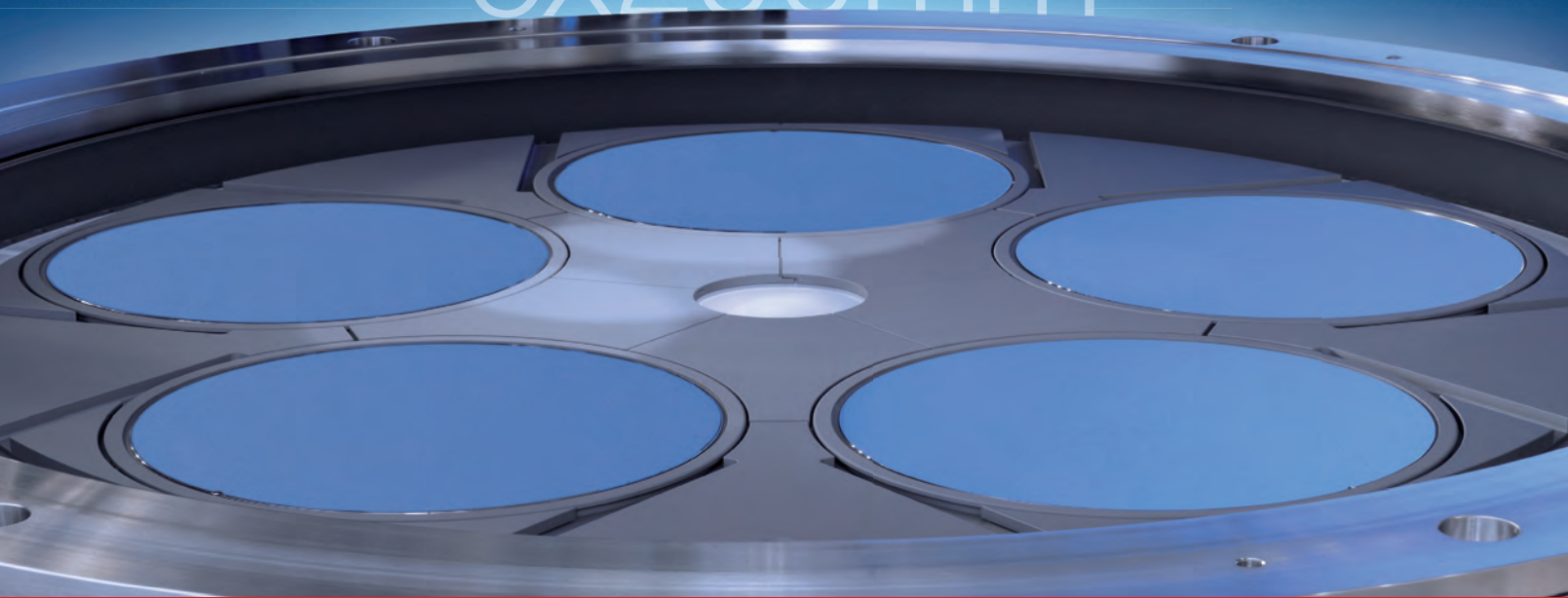
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European LED lighting market to grow seven-fold by 2015

The European LED lighting market is growing rapidly due to energy-saving awareness and, in particular, the high electricity prices in Europe, according to TrendForce's '2011–2015 European LED Lighting Market Report' by its LED research division LEDinside. For example, if a 7W LED light bulb (a replacement for 40W incandescent light bulbs) is used for 8 hours per day for a month (31 days), it can save 8kWh compared to using an 40W incandescent bulb. With electricity prices in the EU-27 (the 27 member states of the European Union), \$2 can be saved each month by adopting an LED light bulb instead of an incandescent bulb.

Given the global anti-nuclear trend and lack of scope for electricity prices to dip, energy-saving demands will only climb, reckons LEDinside. The market research firm predicts that LED prices will see a dramatic drop, starting from 2012, and it expects the European LED commercial lighting market to grow seven-fold from 2011 to \$1.9bn by 2015.

LEDinside notes that more money can be saved by adopting LED lights in outdoor and commercial lighting due to the high electricity consumption in those sectors. An LED light bulb's lower wattage and higher thermal dissipation efficiency result in better energy-saving efficiency, adds the firm. The high price of electricity is hence one of the most important factors spurring the surge in growth in the European LED lighting market.

As for indoor lighting, the European lighting market is dominated mainly by Philips, Osram and GE. In particular, Philips and Osram dominate trends in the European LED lighting market; they continue to put effort into the traditional lighting market and channels, but in the meantime they have been developing their LED products. European LED lighting firms take a more scientific stance on manufacturing LED products, reckons the market research firm, with an emphasis on an LED component's color temperature,

brightness and beam angle.

In terms of the color temperature for indoor lighting, Europeans prefer warm white, yellow light (2500–2700K), while for commercial lighting they prefer about 3000K with a color rendering index (CRI) above 80, says LEDinside.

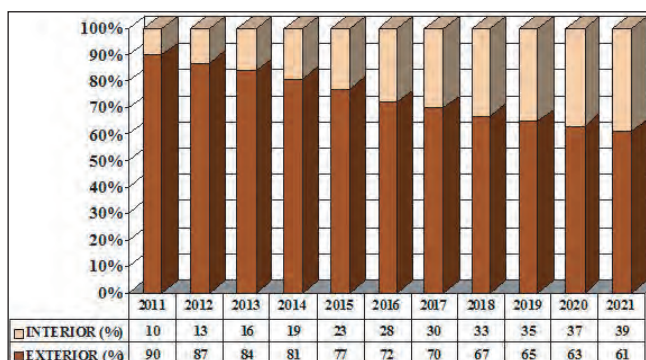
It is easy to buy 10W (and lower) LED light bulbs and candle lights at convenience stores and supermarkets in Europe. However, the LED still has a long way to go before it achieves wide adoption in the household lighting market, the firm notes; currently, LED lighting has been adopted mainly just for new buildings and luxury houses. Prices for LED lighting fixtures are still much higher than those of traditional lighting products. Also, existing LED light bulbs cannot replace traditional bulbs in terms of beam angle. For this reason, regular consumers are still conservative about using LED lights in their households, LEDinside concludes.

www.ledinside.com

Consumption of packaged LEDs in general lighting to approach 4.6bn units in 2012

Global consumption of packaged light-emitting diodes (LEDs) in solid-state lighting (SSL) general lighting by volume (quantity) will reach 4.6 billion units in 2012, estimates ElectroniCast Consultants in its new 10-year market forecast of the worldwide consumption of packaged component-level LEDs.

The consumption of component-level (packaged) LEDs in SSL general lighting applications by value will rise at 37% per year over 2011–2016, predicts ElectroniCast in the report 'LEDs Used in General Lighting, Global Market Forecast and Analysis (2011–2021)'. However, the firm expects faster overall growth in the second half of the forecast period



LEDs used in SSL general lighting market (\$m).

(2016–2021), with an overall annual average growth rate of 51%.

The use of packaged LEDs in residential, commercial and government exterior general lighting lamps (street, parking-lot, roadway-tunnels,

bridges, landscaping, pool/fountain, buildings, architectural and other general lighting) applications represented nearly 90% share of worldwide consumption in 2011.

The relative market share of component-level LEDs use in exterior lamps will fall significantly to 61% in

2021 but increase substantially in value, predicts ElectroniCast, while the relative market share of LEDs in interior lighting rises from just 10% in 2011 to 39% in 2021.

www.electronicast.com

LED lighting market to grow at 9.9% from \$19.5bn in 2012 to \$31.4bn in 2017

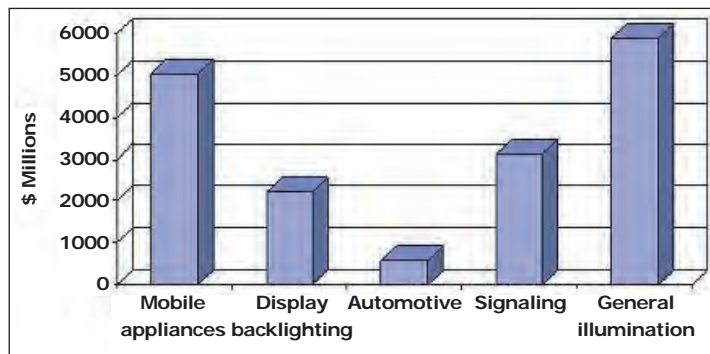
Display backlights to rise from 4th to 2nd, usurping mobile devices

According to a new report 'Light-Emitting Diodes (LEDs) for lighting applications (SMC018D)' from BCC Research, the market is projected to rise at a compound annual growth rate (CAGR) of 9.9% from \$19.5bn in 2012 to \$31.4bn in 2017.

The LED market can be broken down into five categories, says BCC: general illumination, mobile devices, signaling & signage, display backlighting, and automotive.

Of total LED shipments of \$16.8bn in 2011, shipments of \$5.88bn for general illumination applications accounted for the largest share (35%), followed by \$5bn for cell phones and other mobile devices (29.9%), \$3.1bn for signaling & signage applications (18.6%), \$2.2bn for display backlighting (13.1%) and \$580m for automotive (3.5%).

Shipments for general illumination are expected to rise at a five-year CAGR of 15.4% (the second-



Value of LED shipments by industry, 2011 (\$m)

fastest-growing sector), from \$7.6bn in 2012 to \$15.6bn by 2017 (remaining the largest sector).

Shipments of LED display backlights are expected to grow the fastest, at a CAGR of 16.9% to \$5.9bn by 2017 (becoming the second-largest sector).

Mobile devices formed the second-largest sector in 2011, with shipments worth more than \$5bn, but should fall behind display backlights by 2017.

Meanwhile, the signals & signage sector is expected to fall from third largest in 2011 to fourth in 2017, at \$3.6bn.

The automotive segment should remain the smallest of the five sectors analyzed, with shipments of

nearly \$858m by 2017.

High-brightness LEDs operate much more efficiently than traditional light bulb products. They use a fraction of the power needed for bulb technology, have much longer operating lifetimes, and contain substances that will not harm the environment. Different material structures are used to fabricate them, and their fabrication methods are unique.

www.bccresearch.com

Price of LED bulbs to halve to \$11 in 2020

Cost has long been crucial for LEDs. However, the focus is now shifting from the package to the surrounding system. Specifically, innovations in areas such as thermal management, drivers and optics are forecasted to contribute to a halving in the price of LED bulbs to \$11.06 in 2020, according to market analyst firm Lux Research in its new report 'Cheaper, Brighter, Cooler: The Need for Cost Reduction Past the Package' (part of the Lux Research Energy Electronics Intelligence service).

Costs of the central LED package will fall by more than 70% to \$2.14 in the next decade, constituting 19% of the bulb costs in 2020, predicts Lux. However, to drive overall costs lower — and to ensure adoption in a market still dominated by incandescent and compact fluorescent lamps (CFLs) — other sys-

tem costs need to keep pace.

"We find that today's balance of system technology solutions fall short of the dramatic cost reductions needed to mirror the LED package, and existing alternate solutions are ineffective and uneconomical, presenting opportunities for technology innovation," says analyst Pallavi Madakasira, lead author of the report. "LED lighting is by no means standardized, and potential disruptions to the component stack abound," she adds.

Lux Research analysts studied the key LED cost stack components of a 60W-incandescent-equivalent LED bulb as well as the technologies available to accelerate cost cutting in order to understand the true pathways to the potential of LED bulbs. Their findings include the following:

- Thermal management is the biggest target for cost reduction past the package. Active thermal management technologies such as Nuventix's SynJet will lead to cost savings over aluminium-based solutions, but only from 2017.
- Dimmable drivers are priced at a premium to non-dimmable drivers because they enable precise control of light output and yield energy savings. Innovation here will bring a cost saving of about 1% in 2020, boosting overall LED performance.
- Secondary optics account for about 5% of the total cost of a 60W-equivalent LED bulb. The field is dominated by specialists such as Ledil, Khatod and Fraen, and innovation lies in improving the shape of the beam and the ability to collect more light from primary optics.

www.luxresearchinc.com

LED front-end equipment market to see turbulent investment cycles

MOCVD market \$4.3bn over 2012–2017, while lithography, plasma etching, PECVD and PVD total \$650m

Yole Développement and EPIC have published the report 'LED Front-End Manufacturing', dedicated to the market for LED manufacturing technology & equipment, including MOCVD, lithography, plasma etching, PECVD and PVD tools. The report comments that, despite expectations that the packaged LED market will saturate in value by the end of the decade, it still presents significant opportunities for growth in the next five years.

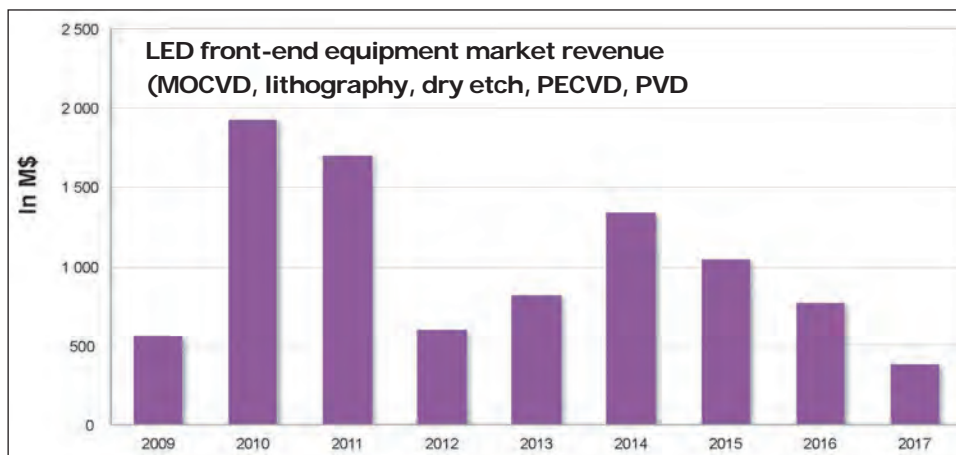
Gearing up for investment cycle

Led by metal-organic chemical vapour deposition (MOCVD) reactors, the LED front-end equipment market experienced an unprecedented investment cycle in 2010–2011.

The cycle was driven by demand in LCD backlight displays, anticipation of the general lighting market, and generous subsidies offered by the Chinese central and local governments in a bid to generate domestic chip production firms. However, this has resulted in a significant overcapacity situation that will take 12–18 months to absorb. The next investment cycle (driven by lighting applications) is expected to start in 2013 and to be more limited in value than the previous cycle due to improvements in equipment throughput and yields. The MOCVD equipment market represents a \$4.3bn opportunity in the 2012–2017 period.

Together, tools for lithography, plasma etching, PECVD (plasma-enhanced CVD) and PVD (physical vapour deposition) represent a \$650m opportunity and will essentially follow a similar trend, with some exceptions, says Yole.

The market for dry etching tools is still growing in 2012 due to the increasing adoption of patterned sapphire substrates (PSS). However, the market for most lithography tools will decline as the industry transi-



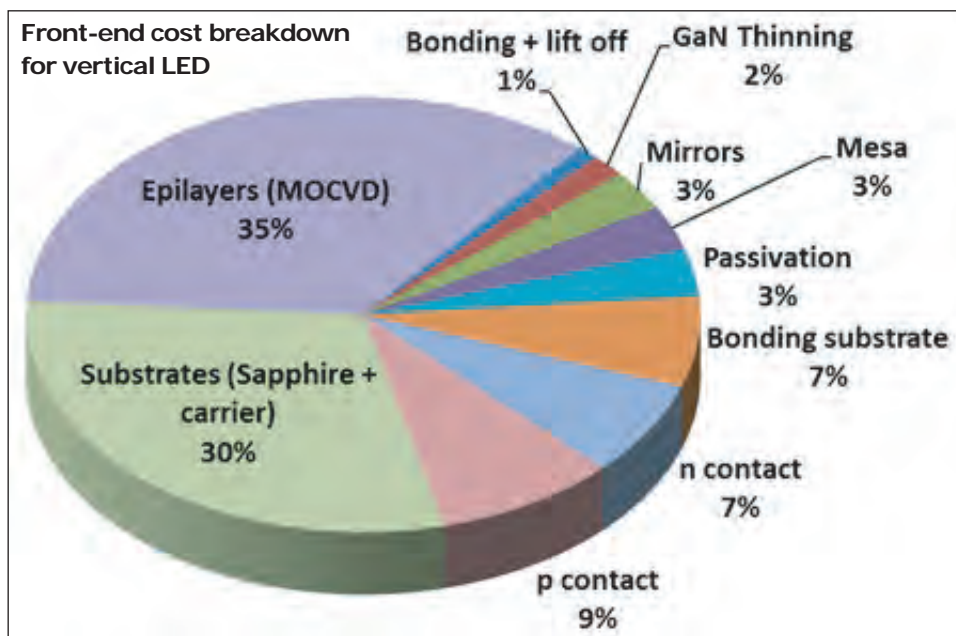
tions to larger-diameter substrates and the number of wafer starts initially increases moderately but starts decreasing in 2015, says Eric Virey, senior analyst, LED, at Yole.

PVD equipment will also experience moderate growth during the next investment cycle. Electron-beam evaporators have turned into commodities, with systems available from dozens of vendors at very low cost. But opportunities exist in promoting sputtering for indium tin oxide (ITO) deposition, and sputtering could also gain some traction in metal deposition if

the industry adopts large-diameter wafers and moves from batch processing to single-wafer processing. Sputtering equipment could then offer improved cost of ownership.

Learning from silicon industry

With nearly 100 firms involved in front-end LED manufacturing, the industry is too fragmented to generate significant economies of scale, reckons Yole. "We expect massive consolidation within the next three years (2012–2015), which should eventually speed up process and tool standardization and allow economy of scale," says Virey. ➤



► LED manufacturing still uses methods that would be considered outdated in most semiconductor industries. Consolidation and the emergence of LED 'giants' will also facilitate and speed up the adoption of manufacturing paradigms from the IC industry, expects Yole.

The adoption of silicon substrates for LED manufacturing could speed up those trends by rapidly moving LED epiwafer processing into existing, highly automated and fully depreciated CMOS fabs. This would also give LED makers access to extended 'process toolboxes', which could pave the way for entirely new LED structures, reckons Yole.

MOCVD still a key element for manufacturing cost reduction

To enable massive adoption in general lighting applications, significant technology and manufacturing effi-

ciency improvements are still needed to reduce the cost per lumen of packaged LED, says the market research firm. Front-end LED manufacturing typically represents about 50% of the total cost of a packaged LED and offers significant opportunities. Continuous progress is being made in terms of LED structures and materials to improve performance, manufacturability or reduce cost.

While MOCVD represents the single largest opportunity for front-end cost reduction, downstream the emergence of LED-dedicated tools has already contributed greatly to cost reduction in lithography, plasma and PVD processing, notes Yole.

Traditional large semiconductor equipment suppliers are mostly absent from LED manufacturing equipment markets. MOCVD tools are very different to epitaxy tools

used in mainstream semiconductor manufacturing. Designing and building such equipment requires significant and unique expertise that the leading MOCVD system makers Aixtron, Veeco and Taiyo Nippon Sanso have acquired over almost two decades, remarks Yole.

Other front-end LED manufacturing tools are similar in essence to those used in mainstream semiconductor. However, in order to deliver optimum performance and cost of ownership (COO) for LEDs they often require a full re-design, notes Yole. This has opened the door to smaller companies eager to capture the opportunity offered by this niche market, and those companies are now offering LED-dedicated tools delivering significant COO improvements, the firm adds.

www.i-micronews.com

Taiwan LED makers' revenues stayed flat in June

LED industry to face severe challenge in second-half 2012

June revenues of Taiwanese-listed LED makers totaled NT\$8.8bn (up 1.12% month-on-month, but down 5.6% year-on-year), according to LEDinside. Due to rising demand for consumer electronics and the traditional lighting peak season, the LED industry's revenue for second-quarter 2012 reached NT\$25.82bn (up 22.7% quarter-on-quarter).

The LED industry faces a severe challenge in second-half 2012, says LEDinside. Due to the lukewarm economic outlook and European debt crisis, the future for end markets seems poor, and peak season may fall short of expectations again.

In the LED backlight sector (TV, notebook or mobile phone) demand has been shrinking, so brand vendors have concerns about hitting their shipment targets. As for LED lighting, affected by the European debt crisis, orders from Europe and the US have also fallen. Hence, the outlook for Q3/2012 remains murky, and fierce competition will persist well into second-half 2012, says LEDinside.

Benefiting from the large backlight orders and high demand for consumer

electronic appliances, revenues for Taiwanese-listed LED chip foundries amounted to NT\$3.83bn in June (down 0.4% month-on-month and 11.5% year-on-year). Given the rising demand in the display market, Taiwanese LED packagers have started to receive orders from Chinese chip makers since May, says LEDinside. Those Chinese firms aim to make inroads into Taiwan's low-price LED market. So, Taiwanese firms need to focus more on product quality and reliability in order to set themselves apart from Chinese competitors, LEDinside reckons.

In June, revenue for LED epiwafer and chip maker Epistar rose 4.3% to NT\$1.73bn. Huga Opto's revenue was NT\$210m and its utilization rate rose to 70% due to orders from Korean firms. Revenues for FOREPI (Formosa Epitaxy Inc) and Chi Mei Lighting Technology Corp (CMLT) remained flat due to demand from Asus' new tablet PC.

June revenues for Taiwanese-listed LED packagers reached NT\$4.97bn (up 2.3% month-on-month but down 0.5% year-on-year). Lite-On's

revenue rose slightly, to NT\$1.09bn.

Lextar's lighting application business accounted for 40% of its revenue in June; aside from cashing in certain global brand vendors' orders, the firm's efforts in China also began to take effect and yield orders. Moreover, its Suzhou plant's lighting assembly lines were certified by clients and reached an economy of scale that triggered Lextar's lighting business and market share to grow in first-half 2012.

Further, the new model that Unity Opto Technology jointly developed with its client has gone into mass production. Also, the firm's backlighting orders grew considerably, coming from Taiwanese TV and tablet PC OEMs and Chinese TV brand vendors. Its revenue hence soared 19.9% in June to NT\$700m.

However, Taiwanese LED firms noted that, although the peak season is nearing, no prominent growth momentum is in sight. Coupled with weak consumer confidence, LED market outlook remains conservative, concludes LEDinside.

www.LEDinside.com

Of 46 Chinese LED chip projects planned in 2009–2010, just 20 put into production

Planned 1220 MOCVD system purchases boil down to just 436

A new market research report 'Global and China LED Industry Report, 2011–2012' from China Research and Intelligence Co Ltd (CRI) covers the recent development and future trends of the LED market; LED industry ranking; the LED industry in mainland China and Taiwan; trends in the upstream metal-organic chemical vapour deposition (MOCVD) and sapphire substrate sectors; and the world's 37 biggest LED makers.

While 2010 was the LED industry's springtime, 2011 was its wintertime, says the report. For most manufacturers, this may last until 2013 or 2014. In 2009, the notebook computer, monitor and TV sectors started to adopt LED backlight units (BLUs) to replace old cold-cathode fluorescent lamp (CCFL) BLUs. In 2010, the market grew dramatically and many firms saw annual revenue more than double, prompting a wave of capacity expansions among LED makers and luring many Chinese firms to tap into the LED arena. All this contributed to LED prices falling. In particular, front-end epitaxy saw a steep price drop, notes the report. Back-end packaging firms showed a mild downturn in revenue, but a larger decline in profit.

The LED industry is concentrated in four regions. The Europe–America region takes general lighting as its main focus and attaches great importance to high reliability and high brightness of the products. Of the main players (Cree, Philips Lumileds and Osram Opto Semiconductors), Cree leads in the general lighting market, aided by its silicon carbide substrate technology.

Japan boasts the most comprehensive technologies, both in general light and backlit displays. The main firms are Nichia Corp and Toyoda Gosei, developing LEDs for sectors such as general lighting, automobiles, mobile phones and TVs.

The third region includes South Korea and Taiwan, which specialize

in BLUs for notebook displays, LED monitors, LED TVs and mobile phone BLUs (featuring large shipments, low unit price, and low gross profit).

Mainland China focuses on outdoor displays, advertising screens and the signal light market. Applications place low demands on product technologies and appear in the form of projects, with customers widely spread.

The report lists the following reasons why manufacturers in mainland China are only producing red, yellow and green LEDs with minimal technical content. First, there is a shortage of LED expertise (nearly all manufacturers in mainland China recruit talent from Taiwanese firms by offering higher salaries, says the report). Second, the patents for blue LEDs and white LEDs are mostly controlled by Japanese, European and US manufacturers (with Nichia in particular having secured the most patents and often pursuing patent lawsuits). Third is the authority for procurement. Although mainland China is the world's largest producer of laptop computers, monitors and LED TVs, the procurement authority for 99% of these LED backlight products belongs to manufacturers in Taiwan and South Korea, which select LED suppliers in those countries with regard to management of the supply chain.

LED prices fell substantially in 2011. On the one hand, capacity expansion by manufacturers led to market oversupply. On the other hand, declining shipments of LED TVs in second-quarter 2011 and the adoption of LED chips with higher brightness reduced LED consumption. Firms in Taiwan and South Korea were hardest hit by the declining price, notes the report.

Since 2009, the LED industry in mainland China has witnessed a wave of investments that continued until the end of 2011. The number of LED chip projects initiated between 2009 and 2010 totaled 46.

However, of these, 16 have not gone into operation, 10 have been cancelled or seen no progress, and only 20 have entered production. The original 46 projects planned to buy 1220 MOCVD systems, but only 436 have been purchased.

Although there are a number of LED firms in mainland China, they do not represent any threat to foreign companies for the time being. China's largest LED enterprise, Sanan Optoelectronics, derived \$180m in revenue from LED chips in 2011, ranking only 19th worldwide.

However, LED lighting — for which LED makers hold much optimism — is by no means as promising as expected, says the report. There is a large disparity between the price of LEDs and that of compact fluorescent lamps (CFLs). Other than in Japan, the price of even the lowest-priced LED bulb is about five times higher than that of a CFL. In most regions, the sales of incandescents will be halted between 2012 and the end of 2015, but the CFL will be in use until at least 2020. Other than incandescents, the CFL is the LED's main rival. Nevertheless, LED lighting is expected to be widely applied as soon as 2015, when the price differential between CFL and LED narrows to two-fold, says the report.

Japan has the largest LED lighting market. For example, the global sales volume of LED bulbs reached 41 million units in 2011, of which Japan accounted for 62% and Europe just 16%. Fueled by the boom in the Japanese market, Nichia continues to widen the gap with its rivals, and its revenue from LED chips is estimated to exceed \$3bn. Dragged down by the European economy, Philips Lumileds and Osram Opto Semiconductors present weak performance. Moreover, they still lag behind Cree, Nichia and Toyoda Gosei in technology, concludes the report.

www.cri-report.com

Power semi market grows 9% to \$18bn despite challenges Growth of 32% for modules, but only 3% for discretes due to faster-reacting consumer goods market

Following a spectacular recovery in 2010, the power semiconductor discrete and module market grew by a more modest 9% in 2011 to just under \$18bn, according to the 15th edition of an annual report from IMS Research, which this year includes more comparisons of wide-bandgap (silicon carbide and gallium nitride) power semiconductor sales with silicon sales.

According to 'World Power Semiconductor Discretes and Modules report – 2012 edition', 2011 was a year of two very contrasting halves. The high growth rate of 2010 was sustained in first-half 2011, but demand started to tail off in Q2/2011. Global business confidence took a knock when the Euro crisis hit in August. The power semiconductor market slowed in Q3 and then declined sharply in Q4/2011, largely because of a prolonged inventory correction.

Compared with just 3% for discrete power semiconductors, in

2011 the market for power modules grew by a much faster 32%, driven mainly by solar energy, car production and consumer appliances. In contrast, discrete semiconductors are used in faster-moving goods such as TVs and notebook & desktop computers, so their sales respond quickly to changes in consumer confidence.

Against a background of pricing challenges and fluctuating demand and lead-times, Infineon remained the leading supplier of power discretes and modules, according to IMS. Other manufacturers whose share of the market grew included power module specialists Mitsubishi Electric, Fuji Electric and Semikron.

Overall, the top ten suppliers of power semiconductor discretes and modules in 2011 were (1) Infineon, (2) Mitsubishi Electric, (3) Toshiba, (4) STMicroelectronics, (5) International Rectifier, (6) Fuji Electric, (7) Fairchild, (8) Vishay, (9) Renesas, and (10) Semikron.

"Infineon further cemented its leadership in IGBTs [insulated-gate bipolar transistors] and was the fastest-growing supplier in the power MOSFET market," comments Richard Eden, senior market analyst in IMS' Power Management & Conversion Group. "Mitsubishi Electric maintained market leadership in power modules, enabling it to narrow the gap with Infineon in the total market," he adds.

For the second year running, Japanese manufacturers benefitted from the strengthening value of the Yen, which inflated their revenue share in terms of US dollars. Japanese suppliers now account for 51% of the power module market, up from 48% in 2010.

For this year's edition of the report, Greater China (China and Taiwan) has been separated out from the Rest of Asia, making five regions, with Europe, Middle-East and Africa (EMEA), Americas, and Japan.

www.imsresearch.com

Military applications continue to drive GaN development

Product announcements during the 2012 IEEE MTT-S International Microwave Symposium (IMS) in Montreal, Canada in late June highlighted how military applications will continue to grow and drive the fundamental development of semiconductor technologies such as gallium nitride (GaN), according to the Strategy Analytics Advanced Defense Systems (ADS) service report 'Defense Electronics Industry Review: June 2012'. The report also details significant defense industry news, including product announcements, milestones, contract activity and defense industry financial performance.

During IMS 2012, Strategy Analytics sponsored a breakfast session in conjunction with Microwave Jour-

nal, with participation from Cree, Nitronex, NXP, RFMD, TriQuint and UMS. Presentations confirmed the applicability of GaN to communications, electronic warfare, and radar requirement, comments Strategy Analytics.

"Panelists highlighted examples where GaN technology will improve performance, efficiency and bandwidth as the military invests in next-generation systems," notes Eric Higham, ADS service director North America.

Other product announcements at IMS 2012 included Toshiba's new X-band GaN hybrid IC (HIC), which is targeted at transmit-receive modules (TRMs) used in active electronically scanned array (AESA) and passive electronically scanned array (PESA) radar applications.

"Semiconductor technologies also underpinned military system-level activity in June," remarks Asif Anwar, director of the ADS service at Strategy Analytics. "Boeing and Raytheon received contracts related to AN/APG-79 AESA radar upgrades, while Northrop Grumman demonstrated the capabilities of the company's AN/AAQ-37 distributed aperture system (DAS) and AN/APG-81 AESA radar, both featured on the F-35," he adds.

Strategy Analytics notes that the Eurosatory 2012 conference in Paris, France also took place in June, where defense companies showcased new products and capabilities across communications, electronic warfare and radar, with a focus on land and air domains.

www.StrategyAnalytics.com

GaN power semi market to grow at 64% to \$1.75bn by 2022

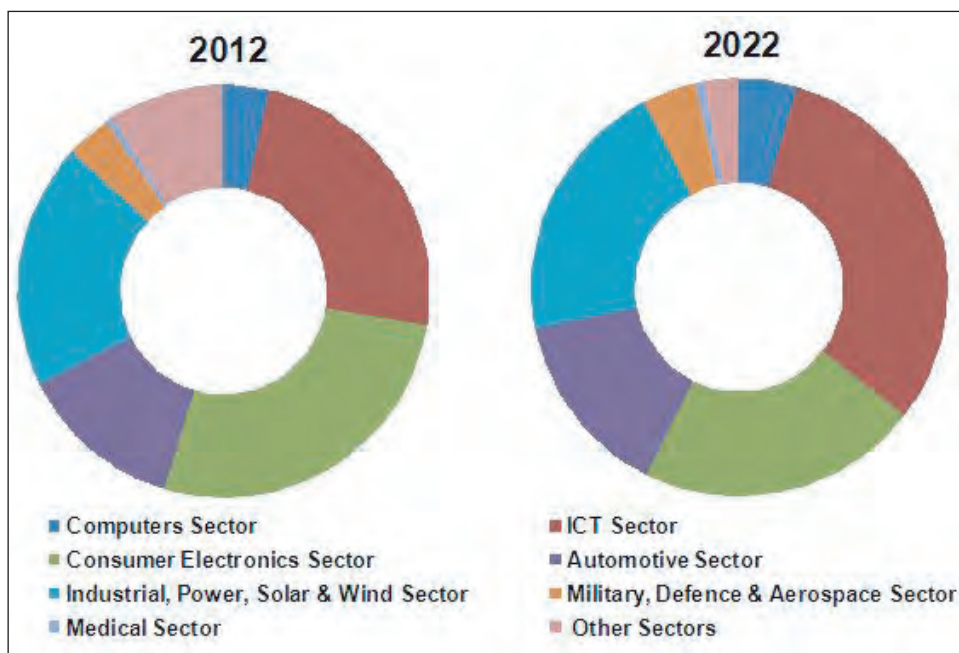
Total GaN semiconductor market to reach \$2.6bn

The gallium nitride (GaN) semiconductor device market is expected to reach \$12.6m by the end of 2012, and the phenomenal growth rate of 60–80% year-on-year is expected to continue in subsequent years, according to the report 'Gallium Nitride (GaN) Semiconductor Devices (Discretes & ICs) Market, Global Forecast & Analysis (2012–2022)' published by MarketsandMarkets, which defines and segments the global GaN semiconductor market (including both power semiconductors and optosemiconductors).

Specifically, revenue for GaN power semiconductors is forecasted to increase at an explosive compound annual growth rate (CAGR) of 63.78% over 10 years from 2012 to \$1.75bn by end of 2022. Apart from power semiconductors, GaN is predominantly used in optosemiconductors, for LEDs and laser diodes. Total market revenue for GaN semiconductors (including both power and optosemiconductors) is hence expected to reach \$2.6bn by 2022.

The report notes that the specific sub-sector of semiconductors & electronics where GaN-based devices have an edge over normal silicon-based counterparts is 'Power Semiconductors & Electronics' and, in terms of end-user application sectors (verticals), the two major upcoming sectors facilitating demand for GaN semiconductor devices are the Industrial & Power sector and the ICT sector, which has found use for GaN power discretes (particularly transistors in power amplification, rectification, and high-frequency switching).

GaN has turned out to be the choice for most power semiconductor applications, and is quickly replacing existing silicon technology. The various properties of GaN (such as wider bandgap, high breakdown voltage, larger critical electric field, and higher thermal



GaN semiconductor market revenue shares by application sector (2011–2022).

conductivity) allow GaN-based devices to operate at higher voltages and high switching frequencies, to handle higher power density, and to offer enhanced power efficiency than pure silicon devices. These properties allow GaN discrete such as Schottky diodes, FETs, HEMTs and other advanced transistor types to operate efficiently at much higher voltage levels, exceeding the limits of their silicon-based counterparts. GaN power semiconductors also help to reduce conduction and switching losses, offering higher efficiency in electronic systems. The major application segments for GaN power semiconductors are currently inverters (and converters), RF devices, power supply modules and motor drives (across all end-user sectors).

For GaN power semiconductor devices, growth is currently due primarily to penetration in the medium-voltage power electronics market, mainly among medium-voltage-range (300V to 1kV) applications across all the major end-user verticals. So, it is clear that most revenue is coming from

the rising number of advanced power applications in the industrial, power, solar & wind sector, and the sector's development globally. Currently, GaN power devices draw most of their revenue from the ICT sector, as they have been targeted solely at replacing their silicon counterparts in various RF power devices (particularly in RF communication applications) over the past few years.

Regarding features, GaN devices are much smaller and lighter but tougher and more efficient than silicon-based devices, and can serve as replacements for silicon counterparts that have hit maturity. With additional features such as low sensitivity to ionizing radiation and better stability in some radiation environments, GaN devices also have a future in solar cell arrays, satellites and high-end power appliances in the military, defense & aerospace sector, notes the market research firm. Apart from this sector, the devices also have huge revenue potential in the automotive and transportation sector, mainly in the electric vehicle & hybrid electric vehicle segment of

► the automotive sector.

The market's total competitive landscape currently has just a handful of players, but the number is expected to rise rapidly in the coming years, with several power semiconductor industry giants and new start-ups entering the field. Currently, GaN accounts for less than 1% of the \$34bn power semiconductors market (including power discretes and power ICs), but over the next 10 years the entire supplier base of power semiconductors & electronics players is expected to penetrate this new value chain, rapidly increasing GaN's market share.

Currently, there are many suitable power applications for GaN in several application segments, such as power distribution systems, industrial systems, heavy electrical systems, turbines, heavy machinery, advanced industrial control systems, electro-mechanical computing systems etc, including several new

power applications (clean-tech) such as high-voltage direct current (HVDC), smart-grid power systems, wind turbines, wind power systems, solar power systems, and electric & hybrid electric vehicles. Another application sector is ICT, with several communication application segments such as RF, radar and satellite communication offering huge revenue potentials owing to the unbeatable ability of GaN to operate at high frequency, including microwave frequencies.

The potential market size for these applications is currently in trillions of dollars, making the total addressable market for GaN power

The market's total competitive landscape currently has just a handful of players, but the number is expected to rise rapidly in the coming years

semiconductors worth billions.

Due to this vast addressable market, the GaN power semiconductor market is quickly gaining pace, says the market research firm. Several transistors and diodes (& rectifiers) have been on the market since 2008, with extraordinary growth in the volume of power discretes (HEMTs, diodes & rectifiers and FETs) boosting total revenue. Another factor for revenue growth is GaN power ICs, where power ICs such as MMICs and RFICs are being launched commercially every year by major industry players following extensive R&D effort to develop new technologies. In summary, the market research firm says that the GaN power semiconductor industry shifted to a mass-production scenario in 2011, with revenue potential attracts the attention of several giants in the power semiconductor sector.

www.marketsandmarkets.com

HCPV installed capacity to reach 697MW in 2017 31% CAGR to drive system market to \$1.6bn; module market to \$700m

High-concentrating photovoltaics (HCPV) — a decades-old technology to tap more of the sun's energy than other solar methods — is poised to finally hit its stride, with a compound annual growth rate (CAGR) of 31% until 2017, according to Lux Research's report 'Putting High-Concentrating Photovoltaics into Focus' (part of the Lux Research Solar Systems Intelligence service).

Driven by emerging markets with high solar resources, the installed capacity for HCPV will grow to 697MW in 2017, creating a system market worth \$1.6bn and a module market worth \$700m (reaching a system price of \$2.33 per Watt).

"HCPV has had very little success installing commercial systems to date," says Lux Research associate Ed Cahill (lead author of the report). "However, as markets shift due to subsidy cuts - from distrib-

uted installations in low-DNI (direct normal irradiance) environments such as Germany to large installations in high-DNI environments such as India - expect HCPV to grow at a faster rate than competing technologies," he adds.

Lux Research analysts evaluated the emerging solar landscape and the prospects for HCPV, which uses optics such as lenses to concentrate a large amount of sunlight onto a small area of ultra-high-efficiency photovoltaic cells. Their findings include the following:

- HCPV costs are coming down. HCPV systems will turn cost competitive with single-axis-tracked mc-Si (multi-crystalline silicon) in 2017, closing a 33% and 20% gap with fixed and tracked mc-Si systems, respectively. It also will gain cost parity with mc-Si for high-DNI, utility-scale projects in 2018.

The cuts will come through lower

shipping and labor costs, besides economies of scale.

- Funding is key to success. Well funded companies that expand intelligently will drive the HCPV market. For example, HCPV pioneer Amonix expanded too soon and too fast and has had to cut back; it is now struggling, which leaves the door open for emerging players such as Soitec, SunCore and SolFocus.

- Developers are racing to build the most efficient solar cell. With Solar Junction's record 43.5%-efficient cell and Spectrolab and Emcore scrambling to develop inverted metamorphic cells, the race to manufacture the most efficient solar cell is heating up. A steady roadmap to 45% efficiency in five years and 50% efficiency in 10 years is feasible, concludes Lux.

www.luxresearchinc.com

RFMD's quarterly revenue and margins grow, driven by diversified markets

September quarter revenue may fall 5%, before returning to growth in December quarter

For its fiscal first-quarter 2013 (to end-June 2012), RF Micro Devices Inc of Greensboro, NC, USA has reported revenue of \$202.7m. This is down 5.4% on \$214.2m a year ago but up 8% on the trough of \$187.9m last quarter, reflecting diversified growth in the Cellular Products Group (CPG) and Multi-Market Products Group (MPG).

CPG achieved robust sequential growth in sales of ultra-high efficiency 3G/4G power amplifiers (PAs), 3G entry PAs, and switch and signal conditioning products. CPG ramped volume production of multiple 3G/4G antenna control solutions and started volume shipments of its second-generation ultra-high-efficiency LTE PAs, both in support of a "leading manufacturer of smartphones". CPG also supported multiple smartphone OEMs with RF semiconductor solutions containing all 2G/3G PA and switch content for the entire cellular RF front end.

MPG grew sequentially across multiple diversified markets, led by high-performance WiFi front-end modules and broadband gallium nitride-based products for CATV. MPG captured a major 802.11ac WiFi reference design win with Broadcom for WiFi front-end modules, and expanded its portfolio of 802.11n and 802.11ac front-end modules and started production in support of consumer premises equipment (CPE) and mobile applications. Also, MPG's GaN Power Group added two major L/S-band radar customers.

"RFMD is capturing share on multiple flagship smartphones and diversifying across a broad set of customers," says president & CEO Bob Bruggeworth. "During the June quarter, we continued to realize the benefit of an expanding product portfolio with industry-leading products, highlighted by sales of

our ultra-high-efficiency 3G/4G PAs, 3G entry PAs, WiFi front-end modules, and cellular switch and signal conditioning products," he adds.

On a non-GAAP basis, gross margin was 34.1%, down on 38.5% a year ago but up on 32.4% last quarter as it continues to cover from the low of 30.2% in the December quarter.

Operating expenses have risen further, from last quarter's \$63.8m to \$65.9m, including R&D expenses of \$40.1m (up again, from \$39.2m). Although still well down on \$21.3m a year ago, net income was \$1.9m, rebounding from a loss of \$5.4m last quarter.

During the quarter, cash flow from operations was \$15.6m, down from \$20.5m last quarter (which itself was less than half of the prior quarter's \$46.2m). Capital expenditure has fallen back slightly from \$9.6m last quarter to \$9m.

Free cash flow was \$6.6m, down from last quarter's \$10.9m (which was down on the prior quarter's \$37.5m). However, RFMD also repurchased about 1.9 million shares of common stock and retired about \$48m principal amount of debt. Total cash, cash equivalents and short-term investments has hence fallen from \$300.4m to \$250m.

"While the macro economy and the timing of key customer smartphone programs is moderating our near-term outlook, RFMD is launching multiple incremental growth drivers in new segments, including antenna control solutions, WiFi

front-end modules, and GaN power devices, and we anticipate robust growth and market share gains in these segments as they continue to expand," says Bruggeworth. "We are especially enthusiastic about new key program ramps beginning later in the September quarter that we anticipate will support incremental growth beginning in the December quarter and continuing into calendar 2013," he adds.

"During the June quarter, RFMD's diversified revenue growth supported broad improvement in RFMD's financial performance," notes chief financial officer & VP of administration Dean Priddy. "Looking forward, we expect continued sequential improvement in gross margin in the September quarter," he adds. "In the December quarter, we anticipate broad improvement in RFMD's financial performance, highlighted by a return to sequential revenue growth, as well as continued margin expansion and improved operating leverage."

RFMD notes that its financial outlook reflects the timing of key customer program ramps and moderating growth among certain customers. During the September quarter, the firm expects to expand its alignment with leading customers and channel partners, targeting 3G/4G products and high-performance WiFi. It also expects multiple new customer product launches starting later in the current quarter.

RFMD believes that the demand environment in its end markets supports its expectation that September-quarter revenue will be flat to down sequentially by about 5%, prior to sequential growth resuming in the December quarter. The firm also expects gross margin to rise to 34.6%. Operating expenses should be roughly flat.

www.rfmd.com

RFMD is capturing share on multiple flagship smartphones and diversifying across a broad set of customers. We continued to realize the benefit of an expanding product portfolio

TriQuint enters loss in Q2 as Mobile demand falls 24%

Growth of 12% and recovery to breakeven expected in Q3

For second-quarter 2012, RF front-end component maker and foundry services provider TriQuint Semiconductor Inc of Hillsboro, OR, USA has reported revenue of \$178m, down 22% on \$228.8m a year ago and down 18% on \$216.7m in Q1/2012 (exceeding the 5% decline that quarter).

By market sector, Mobile Devices revenue was \$112.3m (63% of total revenue), down 24% on \$148.5m in Q1 (68% of total revenue) and down 30% on \$159.9m a year ago (70% of total revenue). TriQuint's largest customer (accounting for over a third of sales) is Foxconn Technology Group (Apple's Taiwan-based manufacturing partner). Apple uses TriQuint chips in both the iPhone and a version of the iPad, but has reported a quarter of lower-than-expected sales of the stop-gap iPhone 4S as buyers await the delayed launch of the new iPhone 5 model this fall.

Networks revenue was \$44.9m, down 5% on \$47.4m in Q1 and 2% on \$45.8m a year ago. Nevertheless, due to declining less than Mobile Devices, Networks has risen from 20% of total revenue a year ago to 22% in Q1 and 25% in Q2.

Defense revenue was \$20.8m (12% of total revenue), level with Q1 but down 10% on \$23.1m a year ago (10% of total revenue).

"Mobile devices demand was soft in the second quarter as the smartphone industry prepares for a seasonally strong second half," says president & CEO Ralph Quinsey. Even although 2G revenue more than halved (from \$9.3m in Q1 to \$4.3m in Q2), 3G/4G uncharacter-

istically fell as a proportion of Mobile Devices revenue (from 80% in Q1 to 77.4% in Q2), partly due to Connectivity revenue rising slightly.

Of Networks revenue, Radio Access has fallen from 39% share in Q1 to 25% in Q2, while Transport has risen from 44% to 59%, with Multi-Market falling only slightly from 17% to 16%.

"Our Defense and Networks revenue was slightly up year-to-date with a healthy outlook for the remainder of the year," Quinsey adds.

On a non-GAAP basis, gross margin was 27.9%, down from 30.4% last quarter and 41.4% a year ago, partly as TriQuint's manufacturing capacity constraints continued to limit its ability to capitalize on the increasing demand for smartphones. Operating expenses were \$64.3m (operating margin of 36% of revenue), up from \$61.4m last quarter.

Compared with net income of \$4.1m (\$0.02 per diluted share) last quarter and \$28.9m (\$0.17 per share) a year ago, TriQuint has reported its first quarterly net loss since early 2009.

However, the loss of \$15m, or \$0.09 per share, was better than the expected \$0.10–0.15. This was partly because litigation expenses (related to anti-trust and IP claims against Avago regarding BAW filters) actually fell from

\$3.9m to \$3.7m (rather than the expected rise to \$11m) due to settling the dispute prior to trial.

During the quarter, cash and investments fell by \$32.5m to \$162.4m, but this was due mainly to a stock repurchase of nearly 4.9 million shares for about \$25m.

During Q2/2012, TriQuint started shipping multi-mode power amplifier (MMPA) module and bulk acoustic wave (BAW) filter content for a new Samsung Galaxy phone (operating via Verizon), and launched what is claimed to be the industry's first 802.11ac Wi-Fi RF module for next-generation smartphones and tablets. The firm also closed major design wins for fiber-to-the-home (FTTH) and optical networks.

In addition, TriQuint booked \$13m in orders for the F-35 Lightning II Joint Strike Fighter and TPQ-53 Army radar, and announced a contract from the US Defense Advanced Research Projects Agency (DARPA) to lead a \$12.3m development program focused on ultra-fast gallium nitride (GaN) switch technology for the Microscale Power Conversion (MPC) program.

"TriQuint is well positioned for revenue growth and improved financial performance in the second half of 2012," believes Quinsey.

For third-quarter 2012, TriQuint expects revenue of \$195–205m (up about 12% on Q2, though still down 5% year-on-year). Non-GAAP gross margin should be 30–32%. Net income per diluted share is expected to recover to roughly breakeven.

www.triquint.com

Mobile devices demand was soft in the second quarter as the smartphone industry prepares for a seasonally strong second half

TriQuint launches 7-bit digital step attenuator with finer gradation

TriQuint has launched a 7-bit digital step attenuator (DSA) with finer gradation. Providing up to 31.75dB of attenuation in 0.25dB steps and operating at 0.4–3.5GHz,

the TQP4M9083 achieves low insertion loss, high speed, linearity and upgraded resolution.

TriQuint says these characteristics meet public safety and commercial

wireless base-station design requirements while supporting test equipment and many other similar applications with more system gain control choices.

RFMD showcases RF components at IMS 2012

At the 2012 IEEE MTT-S International Microwave Symposium (IMS) in Montreal, Canada (17–22 June), RF Micro Devices Inc of Greensboro, NC, USA showcased its portfolio of products and technologies for wireless and wired broadband markets.

RFMD exhibited products serving a wide range of end-markets, including: gallium nitride (GaN) power, point-to-point microwave radio, WiFi, wireless infrastructure, and smart energy AMI/ZigBee. It also introduced its 2012–2013 Product Selection Guide, which fea-

tures about 900 products, including over 80 recently released products.

GaN-based products on display included new high-power transistors and ICs. Booth demonstrations featured a new 25W GaN broadband power IC and a new GaN high-power RF switch. RFMD also showcased its point-to-point product portfolio for wireless backhaul applications, with MMICs operating at 10–20GHz, including up-converters, down-converters, MMIC voltage-controlled oscillators (VCOs), and power amplifiers.

For the 2.4GHz and 5GHz WiFi markets, RFMD promoted several new front-end products supporting smart-phones, wireless networking, computing, tablets, gaming consoles, printers, home automation, and automotive applications.

For wireless infrastructure and general-purpose RF applications, the firm displayed an expanded portfolio of variable gain amplifiers (VGAs), multi-stage low-noise amplifiers (LNAs), high-linearity power amplifiers (PAs), and attenuator products.

Analog-controlled VGA for 400–2700MHz broadband applications

RFMD has launched the RFVA0016, an integrated, analog-controlled, variable-gain amplifier (VGA) for broadband applications with external matching, allowing operation in all bands from 400MHz to 2700MHz with a single module.

Operating from a +5V supply, the device features what is claimed to

be exceptional linearity (OIP3 of more than 40dBm), and provides a gain control range of more than 30dB. Gain is 25dB. A mode logic pin enables the VGA to be selected for either a 0V to +3V or a +3V to 0V analog-controlled attenuation slope. The adjacent channel power ratio (ACPR) is better than –60dBc

at +10dBm P_{OUT} (for dual-carrier WCDMA).

The RFVA0016 is packaged in a small 5.2mm x 5.2mm leadless laminate multi-chip module (MCM) with thermal vias for ultra-low thermal resistance, and is externally matched to 50Ω at each individual band.

RFMD launches WiFi front-end modules covering multiple WiFi standards and frequency bands

RFMD launched four RF front-end modules (FEMs) for next-generation WiFi applications.

The RFFM8200, RFFM8500, RFFM8202 and RFFM8502 are highly integrated FEMs covering multiple WiFi standards and frequency bands, particularly IEEE802.11n and the emerging 802.11ac specification.

The WiFi market is growing rapidly, driven by increasing consumer demand for access to mobile broadband data and the expanding operator requirements for data offload to accommodate increased cellular and cable network services. By 2015, it is projected that the WiFi FEM mobile/embedded and consumer premises equipment markets will exceed \$1.8bn.

“RFMD’s newest WiFi front-end modules demonstrate industry-leading performance and are

aligned with the industry’s leading WiFi chipset providers on their most anticipated reference designs,” claims Rohan Houlden, general manager of RFMD’s wireless connectivity business unit. “By achieving superior linearity and dynamic EVM, RFMD’s WiFi front-end modules enable the proliferation of mobile broadband connectivity across an ever-expanding range of growth markets, including smart-phones, tablets, notebooks, ultra-books, PCs, TV/video, e-readers, gaming, and automotive,” he adds.

Dynamic EVM is a critical design specification for high-data-rate WiFi systems. RFMD claims that, while competitor solutions have traditionally measured static EVM performance, its FEMs achieve superior dynamic EVM to deliver best-in-class real-world WiFi system performance.

This enables optimum data throughput at increased operator range, current savings through optimal transmit and receive speeds, and an enhancement for video streaming, gaming, and other high-data-rate applications, the firm adds.

The 2.5GHz RFFM8200/8202 and 5GHz RFFM8500/8502 FEMs integrate the power amplifier (PA), low-noise amplifier (LNA), and switch functionality into a single plastic QFN package. Designed for both chip on board (COB) and system-in-package (SiP) implementations, both product families deliver what is claimed to be best-in-class linear output power while operating over a wide range of voltages. The highly integrated FEMs also significantly reduce external component count outside the core WiFi chipset.

www.rfmd.com

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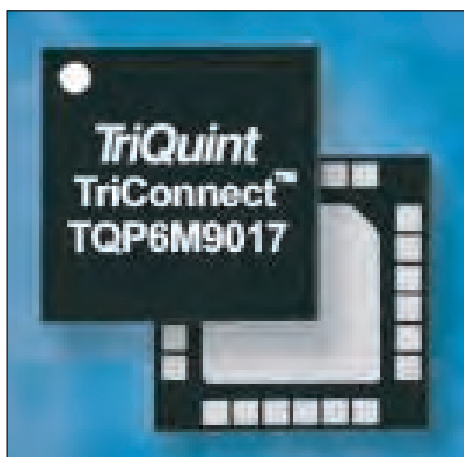


Innovation. Performance. Brilliant.

TriQuint launches the industry's first 802.11ac-ready Wi-Fi module for mobile devices

RF front-end component maker and foundry services provider TriQuint Semiconductor Inc of Hillsboro, OR, USA has launched what is claimed to be the first 802.11ac-ready Wi-Fi RF module for next-generation mobile devices. In addition to supporting faster download speeds, the TriConnect TQP6M9017 wireless local-area-network (WLAN) front-end module enables connectivity from greater distances, allowing nearly 60% further range than its predecessor (the TQP6M9002), due to advances in output power technology.

As demand for Wi-Fi proliferates worldwide, consumers have developed an ever-growing appetite for faster mobile data rates to support video streaming and other multimedia applications, says TriQuint. With data rates up to 1.3Gb/s, the new IEEE 802.11ac standard will deliver transfer rates 3–4 times faster than current-generation 802.11n Wi-Fi. Market research firm In-Stat predicts that 1 billion



TriQuint's TriConnect TQP6M9017 Wi-Fi RF front-end module.

devices with 802.11ac technology will ship by 2015.

"A major manufacturer has selected our new high-performance TriConnect component for its next-generation smartphone, and it's also included on a reference design by a leading chipset supplier," says Shane Smith, VP of global marketing for Mobile Devices at TriQuint. "Our 802.11ac technology expert-

ise also expands our future market opportunity for infotainment applications such as in-home video distribution," he adds.

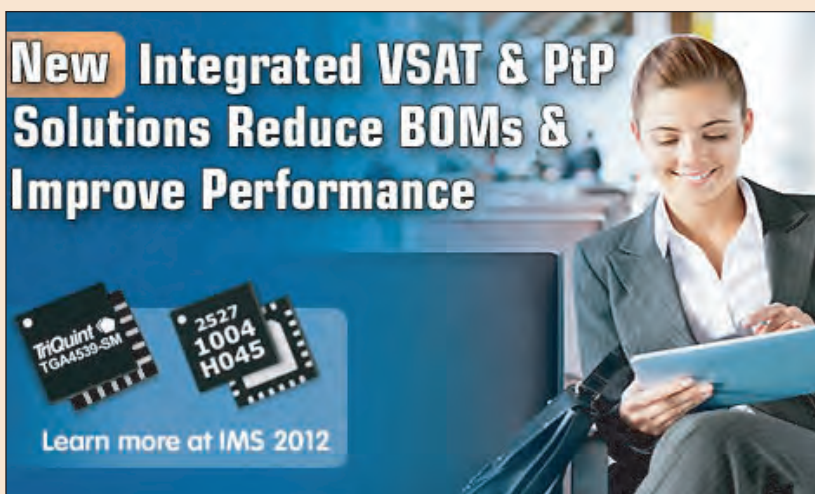
The TriConnect TQP6M9017 is a highly integrated, dual-band WLAN module that provides a complete solution for 802.11 a/b/g/n/ac Wi-Fi and Bluetooth applications, simplifying RF design for device manufacturers. It uses TriQuint's gallium arsenide (GaAs) enhancement/depletion-mode (E/D) pseudomorphic high-electron mobility transistor (pHEMT) and heterojunction bipolar transistor (HBT) technologies to integrate two power amplifiers (PAs) for the 2.4GHz and 5GHz frequency bands with a front-end switch, filtering, baluns and other active and passive components into an ultra-small 4mm x 4mm x 0.5mm ETSLP-24 Pb-free package.

Volume production of the TriConnect TQP6M9017 is planned for July.

www.triquint.com

TriQuint launches GaAs power amplifiers for PtP radio and VSAT

At the 2012 IEEE MTT-S International Microwave Symposium (IMS) in Montreal, Canada (17–22 June), TriQuint has launched two GaAs power amplifiers (PAs) that use its power pHEMT production process to provide high linearity and efficiency as well as 30dBm (1W) of output power at 1dB gain compression (P1dB). The target applications include point-to-point (PtP) and point-to-multipoint microwave radio as well as millimeter-wave systems including very small aperture terminal (VSAT) communications.



The TGA4539-SM and TGA2527-SM Ka-band and Ku-band power amplifiers, both in surface-mount 5mm x 5mm QFN packages.

The TGA2527-SM is a Ku-band PA available in a surface-mount 24-lead 5mm x 5mm x 0.85mm QFN package. Operating at

12.5–15.5GHz, it delivers small-signal gain of 25dB with 31dBm of saturated output power (P_{sat}). Efficiency is claimed to be 20% better than other products.

The TGA4539-SM is a Ka-band PA available in a surface-mount 20-lead 5mm x 5mm x 1.3mm QFN package. Operating at 28–30GHz, it typically provides small-signal gain of 20dB with 30.5dBm of saturated output power (P_{sat}).

Samples and evaluation boards are available on request.

<http://ims2012.mtt.org>

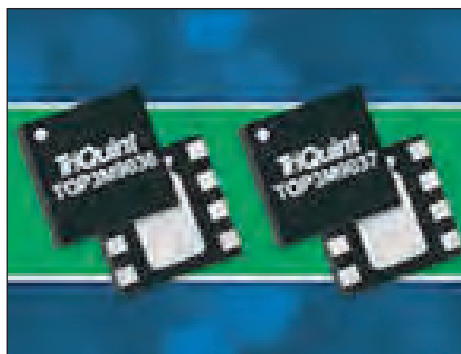
TriQuint samples 400–2700MHz LNAs with highly linear noise performance while cutting design complexity & cost

At the 2012 IEEE MTT-S International Microwave Symposium (IMS) in Montreal, Canada (17–22 June), RF front-end component maker and foundry services provider TriQuint Semiconductor Inc of Hillsboro, OR, USA has announced initial sample availability of two surface-mount low-noise amplifiers (LNAs) — based on the firm's GaAs E-pHEMT process — that deliver the lowest noise figure of any integrated, packaged solutions for base-station and similar applications, it is claimed.

- The TQP3M9036 operates at 400–1500MHz with 19dB gain at 900MHz, a noise figure of 0.45dB, +35dBm OIP3 linearity, and +20dBm P1dB RF output.

- The TQP3M9037 operates from 1500–2700MHz with 20dB gain at 1900MHz, a noise figure of 0.40dB, +36dBm OIP3 linearity, and +21dBm P1dB RF output.

With +22dBm overdrive capability, both devices are suited to infrastructure applications such as cellular base stations, tower-mounted amplifiers (TMAs),



The new TQP3M9036 and TQP3M9037 surface-mount low-noise amplifiers.

small-cell wireless networks, repeaters, 700MHz LTE networks, and emerging wireless systems using 'white spaces' in the UHF spectrum.

TriQuint says that its new solutions simplify RF design by integrating key functions on-chip and within the package that are typically performed by external components. They also address the growing TDD-LTE market with integrated digital shut-down biasing capability and can deliver high performance from bias voltages of +3–5V with-

out a negative supply voltage. The biasing network maintains stability over temperature through a current mirror and resistive feedback; it also provides the switching circuit for the digital power-down function. The firm adds that its new LNAs have been optimally configured on-chip to provide the best combination of noise figure, linearity and reliability.

Both the new devices are pin-compatible with similar products in TriQuint's portfolio and are housed in industry-standard, RoHS-compliant 2mm x 2mm, 8-lead DFN packages. They are extremely rugged and can block high-power interfering input signals or transmit power leakages greater than +22dBm. The devices are also unconditionally stable to eliminate potential oscillations. Both are internally matched to 50Ω and do not require any external matching circuitry for operation.

Initial samples are available now, and production volumes will be available in September.

www.triquint.com

GigOptix shows wideband amplifier and E-band solutions

GigOptix Inc of San Jose, CA, USA showcased its portfolio of wideband and E-band solutions at the 2012 IEEE International Microwave Symposium (IMS) in Montreal, Canada.

GigOptix provided demonstrations and showcase the following E-band solutions and wideband products:

- EXH2008 and EXH2009 MMIC DC–26.5GHz wideband 1W power amplifiers in surface-mountable QFN packages, for use in military electronic warfare (EW), radar, test & measurement, and broadband telecom equipment applications;

- E-band upconverter using GigOptix's E-band power amplifier chipset, consisting of six chips, a pre-amplifier driving two medium-power amplifiers that are coupled via two Lange coupler devices with

a power detector on the output, demonstrating higher output power for use in high capacity mobile backhaul links. GigOptix says that the chipset displays the firm's heritage in enabling E-band radio manufacturers to transmit more data further by significantly increasing the output power of their transmission systems over current solutions.

"We continue to see increasing bandwidth demands in the mobile backhaul from consumers using smartphones and tablets with high-speed 4G LTE network connections," says Padraig O'Mathuna, VP & general manager of the RF/MMIC product line. "Cisco, in its latest Visual Networking Index, forecasts that traffic from wireless devices will exceed traffic from

wired devices by 2016, with Wi-Fi and mobile devices accounting for 61% of IP traffic," he adds.

"With this significant market drive, we are excited to share our latest E-band solutions that will help address the demands of network operators seeking to provide the high-capacity gigabit and multi-gigabit wireless links needed to handle this increasing traffic via E-band point-to-point radio links," O'Mathuna says. "EJL Wireless Research, in its most recent report, forecast E-band point-to-point radio links as being one of the fastest-growing segments in the wireless mobile backhaul market, with greater than 100% compounded annual growth rate (CAGR) to 2016."

www.gigoptix.com

Skyworks' revenue and profit rebound more than expected from last quarter

For its fiscal third-quarter 2012 (to 29 June), Skyworks Solutions Inc of Woburn, MA, USA (which makes linear products, power amplifiers, front-end modules and radio solutions for handset and infrastructure equipment) has reported revenue of \$389m — again, split 65:35 between mobile wireless business and linear high-performance analog (HPA) business. Following a sharp drop of 29% to \$364.7m last quarter, revenue is up 6.7% on that and up 9.2% on \$356.1m a year ago, as well as exceeding guidance of \$383m.

The 10% customers were Foxconn and Samsung, but Nokia has fallen to “high single digits”. The mix of mobile wireless business was about 20% 2G and 80% EDGE/WCDMA (compared with 25:75 last quarter), as 2G continues to decline.

“Globally, consumer appetite for smartphones, for tablets, data cards and an array of other mobile Internet devices remains high, driven by the boom in social networking and driven by an accelerating shift towards cloud-based content, by mobile computing displacing traditional PCs, and the growing popularity of photo-sharing applications like Flickr, Instagram and Picasa, and the explosion in video conferencing and streaming video,” says president & CEO David J. Aldrich. “These global themes are in the early stages of adoption and should provide a tailwind for our business for years to come,” he adds.

“Skyworks outperformed our addressable markets,” says Aldrich. During the quarter, the firm started volume production of wireless networking solutions in support of Broadcom’s 802.11ac platforms, and ramped nine connectivity devices within a recently introduced ultra-thin notebook.

On a non-GAAP basis, gross margin remained the same as last quarter (43.2%, down on 44.9% a year ago). Operating expenses have risen again, from \$73.7m last quarter to \$76.3m,

due mainly to R&D expenses rising from \$45.4m to \$48.6m. Nevertheless operating income was \$91.7m (operating margin of 23.6%), up on \$83.9m last quarter (23% margin) but still down on \$97.6m a year ago (27.4% margin). Likewise, although still down on \$93m a year ago (\$0.49 per diluted share), net income has rebounded from the low of \$79.8m (\$0.42 per diluted share) last quarter to \$86.1m (\$0.45 per diluted share, \$0.01 better than guidance).

Cash flow from operations was \$44m (bringing the year-to-date total to \$244m). Capital expenditure has risen from last quarter’s \$26m to \$31m due to continuing capacity expansion across all facilities to support second-half product ramps. “These CapEx investments consist of equipment add-ons within our existing facilities, which have a very quick payback,” notes VP & chief financial officer Donald W. Palette. “That expands our product margins and our return on invested capital,” he adds. During the quarter, cash and cash equivalents rebounded from \$307.3m to \$327.9m.

“Our strategic diversification across OEMs and chipset partners [into new adjacent analog products and in complementary vertical markets] is enabling us to produce consistently strong operating results despite the macro economy,” says Aldrich. “Specifically, we are gaining share within adjacent vertical markets including automotive, medical, avionics, military, location services and broadband communications. At the same time, our innovative solutions are powering the world’s most popular smartphones, tablets, home automation platforms and network infrastructure systems,” he adds. “In short, we have created a differentiated business model that is delivering demonstrable, best-in-class mobile internet growth with analog semiconductor shareholder returns.”

During the quarter, Skyworks unveiled SkyOne (a front-end system for mobile platforms integrating all RF and analog content between the transceiver and antenna into a single, compact device); expanded its portfolio of ultra-low-noise amplifiers for smart energy, public safety radio, cellular infrastructure and other ISM-band applications; and launched high-power linear control ICs for TD-LTE base stations, repeaters and low-frequency military/microwave UHF and UVF radios.

The firm also deployed analog solutions for low-noise receivers being used in automotive toll-tag transponder systems; captured a receiver protection design win with

For fiscal Q4, Skyworks expects revenue to rise another 7% to a record \$415–420m

Medtronic for heart monitor applications; and secured initial power management design wins at three new OEM cus-

tomers with a suite of LED drivers. “Based on new program ramps and the depth of our product pipeline, we expect to outpace market growth in second-half 2012,” says Palette. For fiscal Q4, Skyworks expects revenue to rise another 7% to a record \$415–420m. Gross margin should be 43–43.5%. Operating expenses are expected to rise only slightly to \$77m, yielding operating margin of 25%. Diluted earnings per share should rise more than 10% sequentially to \$0.50–0.51.

“We see gross margins continuing to improve as we realize synergies associated with our recent acquisitions and as we capture the margin benefits of some of our recent capital investments,” says Palette. Target operating margin is 30%, which the firm expects to approach again as it continues to gain market share and grow its top line (by getting its acquisitions up to scale).

www.skyworksinc.com

Skyworks launches front-end incorporating all popular 2G, 3G and 4G bands plus switches and filters

First device to condense multi-band PAs and high-throw switches with all associated filtering, duplexing and control functionality

Skyworks Solutions Inc of Woburn, MA, USA (which makes high-reliability analog and mixed-signal semiconductors) has launched a front-end system that integrates all RF and analog content between the transceiver and antenna for simplified design within demanding next-generation mobile platforms.

Leveraging Skyworks' silicon integration expertise, manufacturing technologies and proprietary techniques, SkyOne is claimed to be 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, it is reckoned. It also provides what is claimed to be the best linearity and power-added efficiency (PAE) for smart RF integration. SkyOne hence offers smartphone, tablet and ultrabook OEMs advantages in board space savings, ease of implementation, performance and time to market, the firm adds.

Even as radio content and complexity continue to rise, consumers are demanding increasingly thinner and lighter mobile platforms with increased talk/data access time, says Skyworks. To meet this challenge, SkyOne optimizes performance beyond what is possible with less integrated devices and incorporates all popular 2G, 3G and 4G/LTE protocols, enabling seamless global network roaming and extended battery life, the firm claims.

"Our breakthrough architecture is the culmination of extensive R&D that leverages Skyworks' product depth, intellectual property scale



Skyworks' new SkyOne front-end system.

and system-level expertise," says Gregory L. Waters, executive VP & general manager of front-end solutions. "As OEMs focus on industrial design, application development and marketing, they are increasingly turning to Skyworks to deliver a complete, drop-in front-end solution that optimizes each band and imposes no additional requirements to match components," he adds. "SkyOne uniquely answers our customers' design, implementation and time to market needs by ensuring that all RF and analog functionality works in concert."

Skyworks' SkyOne family of front-end modules (FEMs) integrate the following in a single package: 2G/3G/4G power amplifiers; support for bands 1, 2, 3, 4, 5, 7, 8, 13, 17 and 20; quad-band GSM/EDGE power amplifiers and filters; all associated duplexer functionality; integrated CMOS switches and control functions; and DCS/PCS Rx filters.

Skyworks says that SkyOne enhances carrier connectivity independently of operator or region. Future devices will leverage the best of new process, circuit design and interconnect technology to create further improvements in size, performance and band integration, the firm adds.

www.skyworksinc.com

IN BRIEF

Analog solutions for automotive toll tag

Skyworks Solutions has launched analog solutions for low-noise receivers used in high-sensitivity RF automotive highway tag applications, including toll tag transponder systems. The firm's devices are being deployed across 40 million transponders supporting small-signal RF applications where primary DC power is not available.

"Electronic toll collection systems represent yet another application that leverages Skyworks' wireless expertise to combine the benefits of RFID, microwave technology and satellite positioning to enable increased interoperability, particularly as cities and transportation agencies look to reduce costs, ease traffic congestion, improve safety and minimize environmental impacts," says Liam K. Griffin, executive VP & general manager of high-performance analog.

Skyworks says that its solutions also suit other RF mixer and power detection wireless applications including 802.11 wireless networking, CATV/Satcom, infrastructure, medical, military and test/measurement.

In particular, the SMS7630-079LF is a surface-mountable, plastic-packaged silicon mixer device designed for RF and microwave mixers and detectors. The series includes low-barrier diodes and zero-bias detectors that combine Skyworks' semiconductor technology with low-cost packaging techniques. All solutions are 100% DC tested and deliver tight parameter distribution, minimizing performance variability. Wiring configurations include singles, common cathode, series pairs, unconnected pairs and dual-series pairs. Given their low capacitance, they may be used for frequencies up to 10GHz.

www.skyworksinc.com

IN BRIEF

42GHz SMARTSET transmit & receive chipset launched for point-to-point radio

At the 2012 IEEE/MTT-S International Microwave Symposium tradeshow in Montréal, Canada (19–21 June), M/A-COM Technology Solutions Inc launched a 42GHz SMARTSET chipset for point-to-point radio applications.

Using a systems-driven approach to integration, coupled with innovative IC and package design capabilities, the chipset enables OEM customers to achieve faster time-to-market with optimal performance, claims the firm. Offered in a convenient surface-mount package, it facilitates the use of common high-volume assembly lines in manufacturing operations.

"The new 42GHz chipset offers a complete millimeter-wave transmit and receive solution for this emerging high-capacity radio band," says David Richardson, PTP/Infrastructure market director.

The 42GHz SMARTSET chipset includes the following products:

- MAUC-010515 upconverter (40.5–43.5GHz) in a 6mm x6mm laminate package;
- MAAM-010513 driver amplifier (40.5–43.5GHz) in a 5mm x5mm laminate package;
- MAAM-010512 power amplifier (40.5–43.5GHz) in a 7mm x7mm laminate package;
- MADC-010736 downconverter (40.5–43.5GHz) in a 6mm x6mm laminate package;
- MAFC-010511 frequency doubler (16.0–24.0GHz) in a 3mm x3mm QFN;
- MAAT-010521 voltage variable amplifier (5.0–45.0GHz) in a 3mm x3mm QFN; and
- MAOC-0092xx voltage controlled oscillator (5.7–14.2GHz) in a 5mm x5mm QFN.

www.macomtech.com

M/A-COM Tech launches Edge QAM VGA exceeding DOCSIS 3.0 DFRFI specs with low harmonics

M/A-COM Technology Solutions Inc has launched a EQAM (quadrature amplitude modulation) variable gain amplifier (VGA) for CATV applications.

The MAAM-010399 is an integrated three-stage differential amplifier with an embedded voltage variable attenuator (VVA) to provide continuous power level control. The device serves as the output amplifier in a downstream EQAM RF modulator. It offers very high linearity, operating off a single 6V supply, with a nominal power consumption of less than 5.5W, says the firm.

"The MAAM-010399 simplifies CATV head-end design by integrating multiple gain stages and a highly linear voltage variable attenuator into a compact 5mm x 7mm [40-lead] PQFN package," says

product manager Graham Board.

"This variable gain amplifier exceeds DOCSIS 3.0 DFRFI specifications and is an ideal solution for EdgeQAM, Cable Modem Termination System (CMTS) and Ethernet-over-Coax (EOC) infrastructure applications," he claims.

The differential VGA is characterized in 75Ω and designed for operation from 50 to 1100MHz. The MAAM-010399 simplifies RF implementation and exceeds DOCSIS DFRFI specifications with 7dB typical performance margin. Exhibiting a high gain of 28dB, the VGA displays an input and output return loss of 20dB and an attenuation range of 25dB. It also has low harmonics, with 2nd and 3rd harmonics of –65dBc.

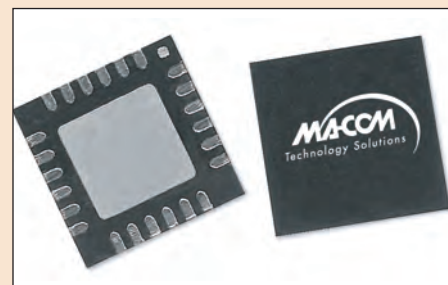
M/A-COM Tech launches 1.2–1.4GHz 6-bit digital phase shifter for L-band radar & coms

M/A-COM Technology Solutions Inc has launched a 6-bit addition to its family of digital phase shifters for communication antenna and radar applications.

The MAPS-011007 is a GaAs pHEMT 6-bit 1.2–1.4GHz digital phase shifter (with an integrated CMOS driver) that provides 360° phase-shift range with a step size of 5.6°. Housed in a 4mm 24-lead PQFN package, the footprint is smaller than is typically available for a digital phase shifter with an internal driver, the firm claims.

M/A-COM Tech says that the MAPS-011007 is suited to applications where high phase accuracy with minimum loss variation is required. The design has been optimized to minimize variation in attenuation over the phase-shift range, and facilitates easy implementation, it adds.

The firm claims that the GaAs pHEMT 6-bit phase shifter meets



the performance requirements of communications and radar system manufacturers, optimizing for fast switching speed, low phase error, and serial or parallel control capability. Insertion loss is 3.8dB, with a low 0.4dB RMS attenuation error over the 1.2–1.4GHz frequency range.

"The MAPS-011007 was specifically designed for L-band radar and communication applications," says product marketing manager Kevin Harrington. "It's ideal for customers looking for the lowest RMS phase and attenuation error from 1.2GHz to 1.4GHz."

Anadigics launches ProEfficient WCDMA/LTE PAs for 4G devices

RF and mixed-signal semiconductor maker Anadigics Inc of Warren, NJ, USA has launched the ProEfficient WCDMA/LTE power amplifier (PA) product family, optimized for the next generation of 4G devices by delivering efficiency across all power levels.

The firm claims that the new PAs uniquely combine greater talk time in low-power mode with longer data application use in high-power mode, resulting in extended battery life across all operating conditions of modern smartphone and tablet devices as well as lower overall system cost.

"4G devices enable users to tap into ultra-fast broadband speeds, resulting in greater data use," says Jerry Miller, VP of business development & marketing. "This change in use patterns drives the power amplifier to operate more frequently in high-power mode," he adds. "By delivering outstanding efficiency in both high- and low-power modes, Anadigics' new ProEfficient power amplifiers are helping manufacturers set the standard for 4G battery-life."

ProEfficient power amplifiers use the firm's exclusive InGaP-Plus technology to achieve what is reckoned to be industry-leading efficiency at both high and low power modes — as well as low quiescent current — in order to maximize 4G battery-life without the use of a DC-DC converter. The power amplifiers are also optimized for use with average power tracking (APT) to further increase efficiency and reduce current consumption at medium and low operating powers.

ProEfficient power amplifiers also deliver what is claimed to be best-in-class linearity (ACLR1) to ensure a stable connection for clear voice and high-speed data.

The 3mm x 3mm package of the PAs integrates internal voltage regulation, integrated DC blocks on RF ports, and RF matching (optimized for output power, efficiency and linearity in a 50Ω system).



Anadigics' new ProEfficient PAs.

The first ProEfficient PAs are available for use in the most widely used 3G/4G frequency bands (such as bands 1, 2, 3/4/9/10, 5 and 8) as follows:

- the 1920–1980MHz AWT6651 for Band 1 has efficiency of 48% at +28.5dBm and 23% at +17dBm, and linearity (ACLR1) is –40dBc at +28.5dBm;
- the 1850–1915MHz AWT6652 for Band 2, 25 has efficiency of 48% at +28.3dBm and 23% at +17dBm, and linearity (ACLR1) is –40dBc at +28.3dBm;
- the 1710–1785MHz AWT6654 for Band 3, 4, 9 & 10 has efficiency of 48% at +28.6dBm and 23% at +17dBm, and linearity (ACLR1) is –40dBc at +28.6dBm;
- the 814–849MHz AWT6655 for Band 5, 18 & 26 has efficiency of 47% at +28.3dBm and 22% at +17dBm, and linearity (ACLR1) is –40dBc at +28.3dBm; and
- the 880–915MHz AWT6658 for Band 8 has efficiency of 47% at +28.5dBm and 22% at +17dBm, and linearity (ACLR1) is –40dBc at +28.5dBm.

The ProEfficient PAs are compliant with LTE; WCDMA, HSPA and HSPA+; and CDMA/EVDO. Samples are available now for qualified programs.

www.anadigics.com

IN BRIEF

GigOptix samples low-power 26.5GHz distributed PA

GigOptix has started engineering sampling of its EXH2008, an MMIC wideband power amplifier in a surface-mountable 7mm x 7mm QFN package, for use in military electronic warfare (EW), radar, test & measurement equipment, and broadband telecom equipment applications.

Key features include: wideband performance from 10MHz to 26.5GHz; typical drain voltages of +8V_{DC} with supply current of 350mA; up to 29dBm typical Psat; low power dissipation of less than 3W; gain of up to 10dB across the band, with gain flatness of better than ±1dB; and internally matched 50Ω RF input and output.

"The EXH2008 represents another powerful addition to the growing family of GigOptix's wideband amplifier solutions," says Pdraig O'Mathuna, VP & general manager of GigOptix's RF/MMIC product line. "The EXH2008 leverages GigOptix's high-speed packaging expertise to enable a wideband packaged amplifier that demonstrates excellent performance into the K-band and provides similar performance to die-based solutions," he adds.

"Moreover, the EXH2008 utilizes GigOptix's industry-leading low-power MMIC design that dissipates significantly less power than similar competing solutions," O'Mathuna claims. The EXH2008 package is fully RoHS compatible, and compatible with industry-standard SMT manufacturing techniques, making it suitable for lowering the cost of military as well as test & measurement designs, he adds.

The EXH2008 is offered as a 7mm x 7mm SMT QFN package.

www.gigoptix.com

IN BRIEF

Amalfi ships 100 millionth CMOS PA; opens Asia office

Amalfi Semiconductor of Los Gatos, CA, USA, a fabless semiconductor firm specializing in highly integrated CMOS silicon RF and mixed-signal ICs, says that it has now shipped more than 100 million CMOS power amplifiers.

"Shipping more than 100 million transmit modules highlights not only our capacity to bring to market high-quality CMOS power amplifiers in volume, but also our ability to translate strong global demand into new business," says CEO & president Mark Foley. "Current forecasts predict Amalfi will ship more than 150 million units by the end of the year," he adds. "All of these developments underscore the fact that we are quickly gaining significant share in the worldwide mobile phone market."

The firm began shipping its family of CMOS 2G GSM/GPRS transmit module (TxM) IC in 2009. In August 2011, it launched its second-generation AdaptiveRF architecture, which is designed to deliver performance at competitive costs compared to traditional GaAs-based modules.

The firm has also opened an office in Shanghai to expand its product development efforts and to offer extended services for local businesses and customers across Asia. The office will provide sales, customer applications, corporate applications and engineering design functions.

"We are making a significant investment with our new facility in China, which will allow us to offer the highest level of service to our customers, while exploring new, lucrative markets throughout Asia," says Foley.

www.amalfi.com

Freescal launches GaAs MMIC to boost performance of small-cell to macro-cell base stations

At the 2012 IEEE MTT-S International Microwave Symposium (IMS) in Montreal, Canada (17–22 June), Freescale Semiconductor of Austin, TX, USA, which provides RF power technology for cellular markets, has launched new Airfast transistors engineered to boost the efficiency, peak power and signal bandwidth of next-generation base stations. The firm says that, with the new offerings, its flagship Airfast RF power product line now includes at least one solution for each cellular band and supports both small- and large-cell base-station deployments.

The cost-effective, small-configuration Airfast RF power solutions are designed to help network equipment manufacturers and operators support multiple wireless standards, manage escalating data transmission rates, and keep capital and operating costs low.

The Airfast devices are made using LDMOS silicon technology. But, to complement them, Freescale is also announcing a new class of highly integrated GaAs MMIC control circuits called advanced Doherty alignment modules (ADAM) that enables real-time digital adjustment of phase and amplitude for the optimization of traditional Doherty power amplifiers. The modules are designed to work with Airfast devices to boost overall system performance, including increased power efficiency, output power and linearity across the frequency band.

Specifically, the MMDS25254H ADAM is a GaAs monolithic microwave integrated circuit (MMIC) based on E-pHEMT and InGaP HBT technology (and housed in an RoHS-compliant industry-standard QFN 6mm x6mm package) that allows phase and peaking adjustments from 2300 to 2800MHz. The device has a constant 90 degree phase offset between port 2 and port 3 versus frequency (500MHz

bandwidth). Field adjustment is possible to optimize power amplifier performance under different conditions (power level, supply voltage, temperature). Product families for 700–1000MHz and 1800–2200MHz are also in development.

The AFT18HW355S is an in-package Doherty device for high-power PCS- and DCS-band applications. Delivering 56dBm of peak power in a single device with efficiency exceeding 48% at average power of 8dB OBO, it offers performance that rivals more expensive GaN-based solutions, it is claimed. Capable of operating at either 1805–1880MHz or 1930–1995MHz, the compact device uses Freescale's enhanced video bandwidth technology to enable full-band, multi-carrier operation.

The AFT09S282N is a 900MHz, 28V LDMOS device that offers RF performance at 720–960MHz and delivers what is claimed to be the highest peak power in OMNI plastic over-molded packaging on the market (490W load pull peak power).

The AFT18S230S is a 1.8GHz, 28V RF power LDMOS transistor that delivers a symmetric Doherty efficiency of 45% and 17dB of gain at 8dB OBO (a level of efficiency typically achieved by more complex and expensive solutions employing asymmetric-only Doherty techniques; when used in asymmetric Doherty PAs, the device can deliver even higher-efficiency performance).

The AFT21S230S is a 2.1GHz 28V device delivering high efficiency for a 230W-rated RF power LDMOS transistor. Housed in NI-780S-6 packaging for VBW up to 100MHz, it is designed for use in either symmetric or asymmetric Doherty applications. In symmetric deployment it is engineered to deliver 45% efficiency at 8dB OBO and 15.5dB of gain.

www.freescale.com/RFpower

Peregrine launches its highest-linearity switches for LTE

At the 2012 IEEE MTT-S International Microwave Symposium (IMS) in Montreal, Canada (17–22 June), Peregrine Semiconductor Corp of San Diego, CA, USA, a fabless provider of radio-frequency (RF) integrated circuits (ICs) based on silicon-on-sapphire (SOS), announced its highest-linearity switches for 4G LTE applications.

The HaRP technology-enhanced SP10T PE426161 switch meets the second-harmonic (2f₀) requirement of –80dBm for Band XIII, making it the highest-linearity switch in the firm's portfolio. In addition to eight symmetric TX ports with low insertion loss of 0.35dB at 900MHz, 0.45dB at 1900MHz, and 0.60dB at 2690MHz, the PE426161 switch features two Super TX (STX) ports that each support low insertion loss of 0.20dB at 700MHz, and 0.55dB at 2690MHz.

The SP12T PE426171 switch features 12 fully symmetrical transmit ports. The high-isolation PE426171 switch supports four LTE bands, six UMTS bands and four GSM bands, with co-banding applied. This switch has low insertion loss of 0.35dB at 900MHz, 0.45dB at 1900MHz, and 0.60dB at 2690MHz; and high isolation of 38dB at 900 and 1900MHz, on all paths.

All TX ports give designers the flexibility to freely configure any combination of ports for any mode, and any band, through the bi-directional, two-wire serial-bus control interface.

These low-loss, flip-chip switches address industry demands for linearity

Both switches are MIPI compliant, and have a wide supply range of 2.3–4.8V for operation from VBAT, as well as high ESD tolerance of 4kV Human Body Model at the ANT port, and 2kV all pins. Both also include an on-chip SAW filter over-voltage protection.

The PE426161/71 switches are available in a flip-chip package.



Peregrine's 8GHz SP4T RF switch.

"These low-loss, flip-chip switches address industry demands for linearity," says Dylan Kelly, VP of Peregrine's Mobile Wireless Solutions business unit. "The PE426161 switch meets the critical Band XIII 2f₀ requirement which is necessary for LTE network co-existence with GPS."

www.psemi.com

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ADS chosen for complete silicon RFIC implementation

Sivers IMA AB of Kista, Sweden, which makes microwave products for telecoms, industrial and test & measurement applications, has chosen the Advanced Design System 2011 electronic design automation (EDA) platform of Agilent Technologies Inc of Santa Clara, CA, USA for complete silicon-based RFIC/MMIC implementation.

"We are expanding our peak-performance millimeter-wave product portfolio toward silicon-based, proprietary MMIC designs to leverage the advantages of higher integration and reduced cost," says Sivers IMA's chief technology officer Christer Stoj. "We selected ADS for the complete front-to-back implementation of corresponding devices because it delivers proven RF circuit simulation, integrated EM solvers and RF-relevant backend support," he adds. "ADS is designed for our type of application, allowing us to introduce new unique products

for E-band and V-band radio links, with full control of the millimeter-wave architecture."

ADS provides a complete RFIC design flow — including layout, enhanced foundry-certified process design kits, layout versus schematic (LVS) and design rule checker (DRC) — which is crucial for implementing wireless front-ends, says Agilent. The scalable front-to-back solution facilitates RFIC design from the beginning, and integrates with other domains such as RF modules and RF system-in-package design.

Key ADS features help to simplify and speed design flow, e.g. ADS Layout features an RFIC toolbar for easier, more efficient physical design and trace routing. Desktop DRC and LVS help to verify and correct layouts against foundry design rule checks prior to tape-out and catch errors early in the design cycle, all from the user's desktop. ADS' integrated 3D planar EM simulator, Momentum,

combines full-wave and quasi-static EM solvers for simplified passive, interconnect and parasitic modeling. Also, the ADS design kit for the IHP 0.13µm silicon germanium process (SG13S) used in a first project supports a complete ADS front-to-back design flow with design rule check for most recurring rules.

"The popularity of the ADS platform for silicon-based RFIC design has grown tremendously over the years, bolstered by our significant expansion of ADS design kit support," says Jürgen Hartung, RFIC marketing manager for Agilent EEs of EDA.

"Customers can now use these kits for a variety of RF CMOS, RF SOI and SiGe BiCMOS technologies to enjoy full back-end support that includes schematic-driven layout creation, layout-versus-schematic check, and integrated 3D planar electro-magnetic and 3D-FEM simulators."

www.siversima.com

www.agilent.com/find/eesof-ADS

Infineon launches rugged high-frequency low-noise SiGe:C RF transistors for 5–6GHz consumer wireless

At IMS 2012 in Montreal, Canada (17–22 June), Infineon Technologies launched the BFX840xESD series of SiGe:C (silicon-germanium: carbon) HBT devices for low-noise amplifier (LNA) applications, suited to the design of consumer wireless products operating at 5–6GHz (including current and next-generation WiFi access points and modules).

The new transistors allow engineers to boost the overall performance of WiFi systems to achieve both wider coverage areas and the very high throughput defined in the upcoming IEEE 802.11ac standard. Additional applications include WiMAX and UWB (ultra-wideband) wireless and satellite communications.

Infineon says this eighth generation of its SiGe:C process technology is engineered with inherent power and noise matching in the 5GHz band, so it achieves best-in-class

system performance (18dB gain and 0.96dB noise figure) with only eight external passives and a single inductor in WiFi LNA application circuits (four fewer than alternatives).

"This evolution of the Infineon SiGe:C portfolio provides designers with the means to achieve RF performance goals in compact, low-power wireless systems," says Houssein Chouik, product marketing manager for RF Transistor Solutions at Infineon. "Based on the eighth generation of our HBT process technology, these new devices once again meet or exceed the RF performance levels of alternatives and provide cost savings by reducing the number of passive devices needed in system design," he adds.

BFX840xESD series transistors, when measured at the device level in the test fixture, achieve 22–23dB maximum gain and have what are

claimed to be best-in-class noise figures of 0.65–0.85dB in the 5GHz band, allowing engineers to meet design goals of total system noise levels below 2dB. WiFi LNA designs using these transistors need 50% fewer external parts than other available solutions.

Features of the BFX840xESD series that contribute to system reliability and design flexibility include:

- on-chip ESD protection up to 1.5kV HBM and RF power overdrive handling capability of 20dBm;
- operation from a supply as low as 1.2V with no performance deterioration, suiting battery-driven systems;
- availability in three different package types for design-in to different platforms, including standard SOT-343, flat-lead TSFP-4-1, and ultra-low-height (0.31mm) TSLP-3-9 for RF module applications.

www.infineon.com

Javelin's CMOS PA shipping in Samsung's Galaxy Appeal smartphone for AT&T

Javelin Semiconductor Inc of Austin, TX, USA says that South Korea's Samsung Electronics Co Ltd is shipping its CMOS-based 3G power amplifier (PA) in the new Galaxy Appeal for AT&T.

Samsung's Galaxy Appeal is an Android-based 3G smartphone with a 3.2-inch touchscreen, 800MHz processor, side-slider QWERTY keyboard, 3 megapixel camera, Bluetooth, GPS and Wi-Fi.

"Javelin's proven monolithic CMOS PA technology is now shipping in numerous handsets," says Javelin's president & CEO Brad Fluke. "The JAV550X PA family is in full production supporting the most popular 3G bands for worldwide coverage," he adds.

Javelin says that its PAs deliver high efficiency across the wide range of required output power levels to extend handset battery life. Also, with integrated filtering and



Javelin CMOS 3G PA in Samsung Galaxy Appeal.

what is claimed to be the best noise performance on the market, the PA can eliminate the cost of transmit surface acoustic wave (SAW) filters, enhance wireless receiver sensitivity and improve overall smartphone performance by minimizing interference with wireless

radios such as Bluetooth, GPS and Wi-Fi.

Using a standard CMOS process, Javelin has implemented a mixed-signal architecture that achieves the highest levels of quality, reliability and robustness, it is claimed, combined with supply assurance from the world's

largest foundry. Javelin offers a family of CMOS 3G PAs for all major 3G bands in a standard 3mm x 3mm package that are software compatible with existing 3G base-band platforms.

www.javelinsemi.com

www.samsung.com

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Number of SiC wafer & epi patents show lack of correlation with \$80m total revenues

72% of patent applicants Japan-based, but 75% of revenue US-based

Despite a cumulative silicon carbide (SiC) raw wafer and epiwafer market that will not exceed \$80m in 2012, the body of related patents comprises more than 1772 patent families and over 350 companies since 1928, according to the report 'SiC Patent Analysis single crystal, wafer and epiwafer manufacturing' to be published by market research firm Yole Développement at the end of July. Of total patents, 83% of patents represent a method while 17% of them claim an apparatus.

Since 1978 the main technique for growing bulk single crystals of SiC has been physical vapor transport (PVT, a seeded sublimation method), which represents 36% of published patents. The PVT technique deals mostly with the hexagonal polytype nH-SiC ($n=2,4,6$). An alternative route to grow SiC is liquid-phase epitaxy (LPE), for which early efforts date back to 1961. LPE allows the growth of crystals with low dislocation densities and at relatively low temperatures (attractive for cubic polytype 3C-SiC).

About 37% of patents involve chemical vapor deposition (CVD), which is now used almost exclusively to manufacture SiC epiwafers. In contrast, molecular beam epitaxy (MBE) is only mentioned in 1% of patents. The polytype (hexagonal or cubic) is explicitly claimed in 15% of patents. Numerous strategies to reduce crystal defects (micropipes, carrots etc) and make semi-insulating material are proposed in 23% and 10% of patents, respectively. **R&D investment uncorrelated with revenue**

The number of patent applicants involved in SiC crystal/epiwafer technology totals about 350, located mainly in Japan (72%) and the USA (12%). The five main applicants (based on their number of patents) are Denso, Sumitomo,

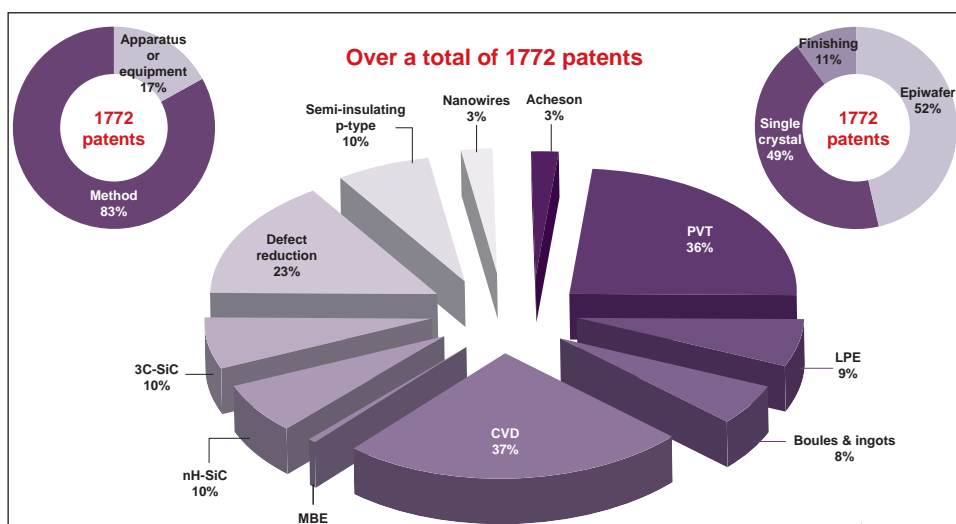


Figure 1: Distribution of SiC crystal, wafer and epiwafer patents by technology.

Nippon Steel, Bridgestone and Toyota (representing about 35% of the patents, collectively). The US firm Cree Inc ranks only 6th. However, this distribution is totally uncorrelated with the reality of the market, where 75% of SiC wafer business is generated by US-based companies, namely Cree, II-VI Inc and Dow Corning. Japan is only responsible for 5% of revenue (at least before the acquisition of Germany-based SiCrystal by Japan's Rohm). Similar observations are seen in Europe and Asia (outside Japan) where patent-to-revenue ratio is currently very weak. **Japan leading in IP, but China and Korea taking off**

Japan has been increasingly involved in SiC technology since the 1980s. The USA was an early player and is still active. In contrast, only three Japanese companies are commercially active in SiC material: Showa Denko (epiwafers), Bridgestone (wafers) and Nippon Steel (wafers and epiwafers).

In the last five years, China and Korea have emerged as new players, with the establishment of companies in China such as Epiworld, TianYue, TYSTC, and Tankeblue, as well as Korea's SKC. However, the

market shares of these companies remains very low at the moment.

SiC material: a question of expertise?

It seems obvious that IP considerations do not create a differentiating factor for success in the SiC substrate business. For example, Cree leads the industry with about 50% market share on a worldwide basis, and has the best reputation in terms of quality, diameter and reproducibility, says Yole. However, it does not own the widest patent portfolio. Thus, it seems that expertise and patent numbers do not correlate.

The only field where the number of patents and business size appears to be more balanced is for semi-insulating (SI) SiC technology, where both Cree (vanadium-free) and II-VI Inc (vanadium-doped) have extensively patented their respective developments.

How to enter the SiC substrate business?

The barriers to entry into the SiC substrate domain are very high: the current state-of-the-art stands at 6" diameter, with no micropipea and very low dislocation density. Only Cree seems to be able to offer such a product today, notes Yole. ➤

► Why is this so?

First of all, over these last 20 years Cree has been widely funded by contracts from the US Department of Defense (DoD), Department of Energy (DoE), Defense Advanced Research Projects Agency (DARPA) and Navy, so it has been in a comfortable position for conducting much R&D and improving its

technology for both LED and power electronics applications. So mastering SiC growth is probably a question of money, but also clearly a question of development time, which cannot be compressed. Yole says it seems reasonable then to think that there has been cross-fertilization between its LED and power electronics businesses that has allowed Cree to benefit from LED mass production (which is probably less stringent at the wafer level), fueling the power electronics

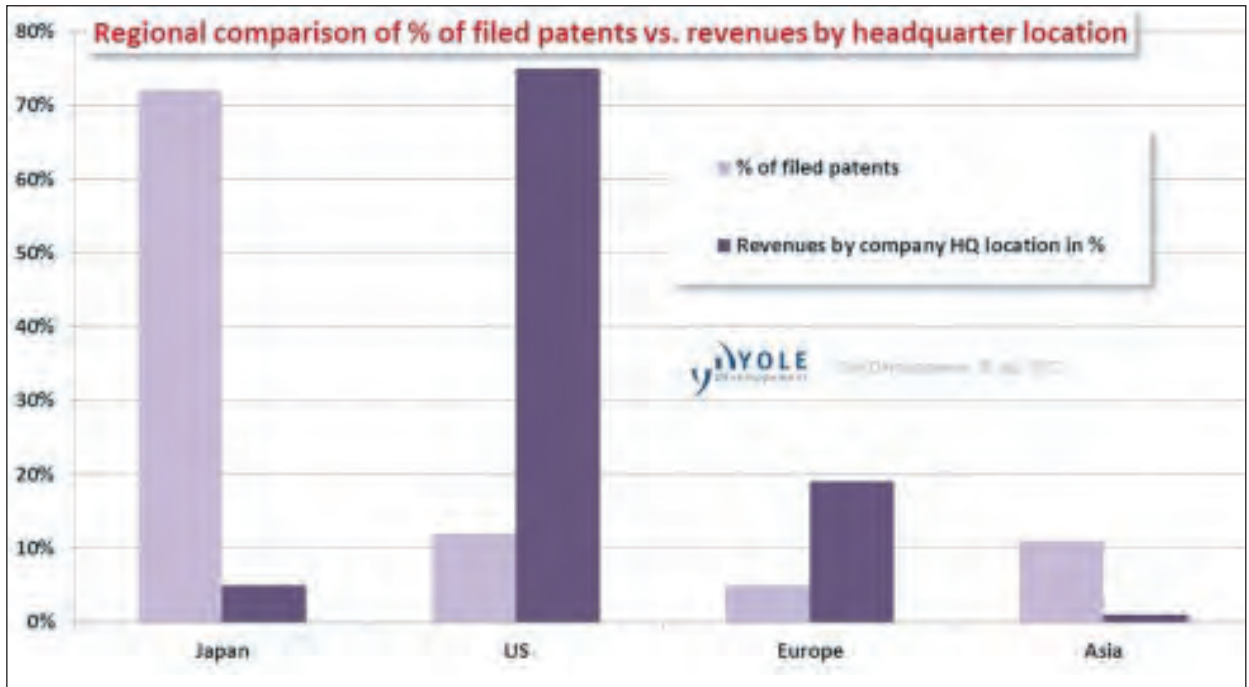


Figure 2. Regional comparison of percentage of filled patents vs revenue, by headquarters location.

side of the business. Finally, R&D efforts have never ceased, maintaining Cree's lead, says Yole.

Apart from receiving funding to develop the technology, the only other options for quickly entering the SiC substrate sector appear to be through merger & acquisition (M&A) of an existing operation or through buying a license and related know-how (paying royalties in return). But which operations are for sale? Virtually nobody at this current time. Beyond the top five

SiC substrate leaders, Yole does not see any clear positioning of firms that may want to participate in the sale or merger of their SiC business.

Ultimately, says the market research firm, attention should be paid to the new developments regarding LPE being made by Toyota, Denso or Sumitomo, as well as cubic-polytype 3C-SiC, which may disrupt the existing dominance of the PVT technique.

www.i-micronews.com

SemiSouth doubles rating of 1200V SiC diodes to 10A

SemiSouth Laboratories has doubled the current rating of its DPAK-packaged 1200V SiC diodes from 5A (for the SDB05S120 in a TO-252 package, launched last October) to 10A (for the new SDB10S120 in a TO-252-2L package).

The 1200V/10A SDB10S120 features a positive temperature coefficient for ease of paralleling, and temperature-independent switching behavior. The maximum operating temperature is 175°C. The devices also exhibit zero forward and reverse recovery current. Total capacitive charge is 40nC.



SemiSouth's SDB10S120 1200V/10A diodes in TO-252-2L packages.

The true two-lead DPAK (TO-252-2L) package has a mounted footprint (nominal) of 9.8mm x 6.6mm and measures just 2.29mm high.

"By again extending our leadership position in silicon carbide with these new 1200V/10A diodes we are enabling manufacturers of products such as solar inverters, SMPS [switched-mode power supplies], induction heaters, UPS [uninterruptible power supplies] and motor drives — and well as anyone building PFC circuits — to benefit from increased performance and reduced space," says senior VP of sales & marketing Dieter Liesabeths.

Volume production started in June. Pricing is \$8.66 in 1000-unit quantities.

www.semisouth.com

Mitsubishi Electric to sample SiC power modules for more compact, efficient electronic equipment

Tokyo-based Mitsubishi Electric Corp says that, at the end of July, it will begin shipping samples of five kinds of silicon carbide (SiC)-based power modules for home appliances and industrial equipment.

The modules were showcased at the POWER SYSTEM JAPAN 2012 trade show as part of TECHNO-FRONTIER 2012, an exhibition in Tokyo on electro-mechanical parts and devices (11–13 July).

Inverters are widely used in home appliances such as air conditioners and refrigerators, as well as in industrial devices, to increase energy efficiency. While Mitsubishi Electric already offers a wide variety of low-loss power semiconductor modules for inverters, the SiC modules offer significant reductions in power loss and improvements in high-speed switching, achieving even higher efficiency and down-sizing, says the firm.

Of the five new types of SiC power module samples, three types are for home appliances, while two are for industrial devices such as inverters and servos.

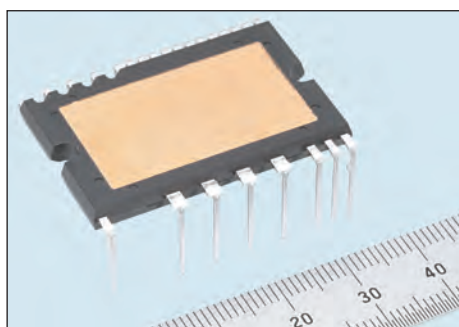
The modules for home appliances include:

- the 600V/15A 6in1-connection Hybrid SiC DIIPM (dual-in-line package intelligent power module, to begin shipping at the end of July);
- the 600V/20Arms interleave-connection Hybrid SiC DIPFPC (dual-in-line package power factor correction, to begin shipping in August); and
- the 600V/20Arms interleave-connection Full SiC DIPFPC (to begin shipping in August).

The modules for industrial devices include:

- the 1200V/75A 6in1-connection Hybrid SiC-IPM (to begin shipping in October); and
- the 1200V/800A 2in1-connection Full SiC Module (to begin shipping in January 2013).

The Hybrid SiC DIIPM uses a SiC Schottky barrier diode (SBD).

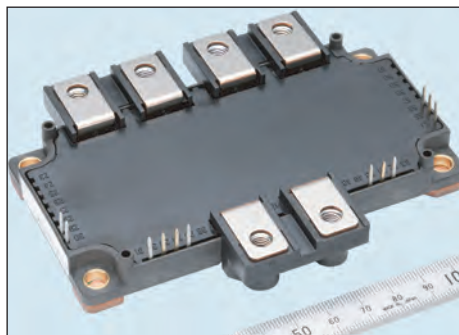


SiC module for home appliances.

Power loss is reduced by about 12% compared to a DIIPM using silicon, the firm reckons. The shape, size (24mm x 38mm) and pin configuration are the same as those of the Si-based Super mini DIIPM, while it also offers the same protection (built-in gate driver, under-voltage protection, and short-circuit protection).

The Hybrid SiC DIPFPC uses a SiC-SBD and achieves a maximum of 30kHz high-frequency switching, contributing to the downsizing of peripheral components such as reactors and heat-sinks. The installation of a power factor correction (PFC) and driving IC also contributes to downsizing through reduction of the mounting surface area and

The SiC modules offer significant reductions in power loss and improvements in high-speed switching, achieving even higher efficiency and down-sizing



Industrial hybrid SiC intelligent power module.

simplified wire patterning. The 24mm x 38mm package is also compatible with the Super mini DIIPM. Protection also includes over-temperature protection.

The Full SiC DIPFPC uses a SiC metal-oxide-semiconductor field-effect transistor (MOSFET) as well as a SiC-SBD. Power loss is reduced by about 45% compared to Si-based products, it is reckoned. The adoption of SiC achieves a maximum of 50kHz high-frequency switching, while the 24mm x 38mm package (compatible with the Super mini DIIPM) also includes a PFC and driving IC.

The Hybrid SiC-IPM uses a SiC-SBD. Power loss is reduced by about 25% compared to its predecessor PM75CL1A120 of the IPM L1 series, contributing to the downsizing and improved product efficiency. The shape, size (67mm x 131mm) and pin configuration are the same as those of the PM75CL1A120, while it offers the same protection (built-in gate driver, under-voltage protection, short-circuit protection, and over-temperature protection).

The Full SiC-Module uses a SiC-MOSFET and a SiC-SBD. Power loss is reduced by about 70% compared to its predecessor CM400DY-24NF silicon-based insulated-gate bipolar transistor (IGBT) module (used in a parallel configuration), contributing to improved product efficiency. The module significantly reduces package size (62mm x 152mm), while reducing mounting area by about 60% compared to the CM400DY-24NF, contributing to downsizing and weight reduction. The module also adopts a low-inductance package to fully utilize the superior performance of SiC.

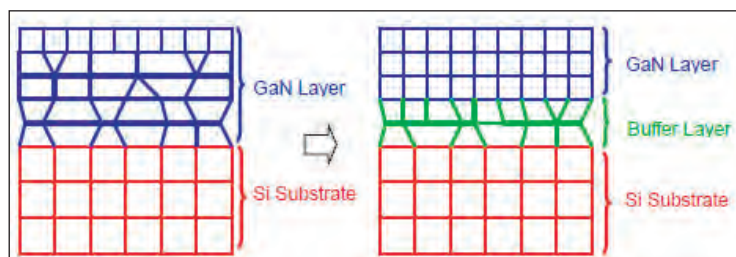
Mitsubishi Electric says that the new SiC modules are compliant with RoHS (European Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment).

www.MitsubishiElectric.com

Mitsubishi develops 170W, 70%-efficiency GaN-on-Si power amplifier for base-station transmitters

Tokyo-based Mitsubishi Electric Corp has developed a prototype 2GHz power amplifier (PA) for mobile communications base stations that features a gallium nitride (GaN) transistor on a silicon (Si) substrate instead of more costly silicon carbide (SiC), achieving power output of 170W and power conversion efficiency of 70% (claimed to be unprecedented among 2GHz PAs with outputs of 150W or higher).

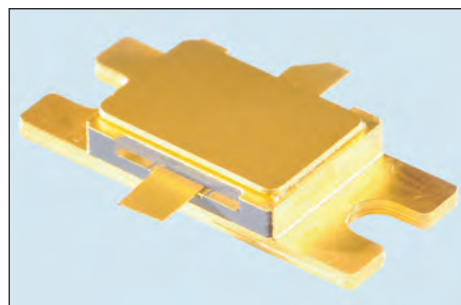
While amplifiers that use GaN transistors consume less power and have a higher output than amplifiers made with silicon transistors, they typically require a more robust substrate made of SiC, which elevates the cost. Initial efforts to develop a GaN transistor using a silicon substrate were hampered by deformation between the GaN layer and Si substrate, which led to increased loss and decreased power conversion efficiency. However, the firm has designed a high-performance transistor by



Optimized crystal structure of GaN-on-Si substrate.

optimizing the GaN crystal structure and inserting a buffer layer between the GaN layer and Si substrate.

Mitsubishi Electric's new GaN-on-Si power amplifier achieves a power conversion efficiency of 70%



Mitsubishi Electric's 170W, 2.1GHz GaN-on-Si power amplifier.

at 2.14GHz, improving upon the 58% conversion efficiency of 2.17GHz Si transistor amplifiers currently available com-

mercially, it is reckoned.

The amplifier is expected to lead to the development of smaller and more power-efficient base-station transmitters. The installation of such equipment in tighter spaces should help to expand wireless network coverage to accommodate increasing wireless traffic due to smartphone proliferation, the firm says.

In future, Mitsubishi Electric expects to further downsize the power amplifier and its power supply and cooling units to enable even smaller mobile communications base stations.

www.mitsubishielectric.com

Australia's Griffith University gains AUS\$1m grant to develop SiC-on-Si chip production processes

Partner SPTS to help commercialize technology

Griffith University's Queensland Micro- and Nanotechnology Centre in Brisbane, Australia has been awarded AUS\$1m in research funding by the Queensland Government to develop production processes for a silicon carbide (SiC) microchip.

"The superior properties of silicon carbide enable smaller, more efficient, sensitive and robust devices that are able to operate in harsh chemical and temperature environments," comments professor Sima Dimitrijevic, lead researcher of the Semiconductor Microfabrication Program.

"This Griffith University breakthrough has far reaching implications in terms of engaging with

major international industry and bringing frontier technologies to Queensland," believes Queensland Micro- and Nanotechnology Centre's operations director Alan Iacopi.

The potential of the new platform technology has resulted in a joint development agreement with plasma etch, deposition and thermal processing equipment maker SPTS Technologies Ltd of Newport, Wales, UK, which will develop the thermal process and equipment expertise necessary to commercialize the technology. In May 2011, SPTS and Griffith announced a three-year joint development agreement (JDA) targeting the commercialization of SiC-on-silicon

technology, targeting applications in the LED, micro-electro-mechanical systems (MEMS) and power markets.

"Our industry partner, SPTS will help us take the next critical step of making our SiC production processes ready for industry to adopt," says Iacopi. Ultimately, this will permit the exploration of new market opportunities with the world's largest semiconductor manufacturers, the university believes. The funding boost should also open up opportunities for research students and enable three new research fellows to be appointed.

www.griffith.edu.au

www.spts.com

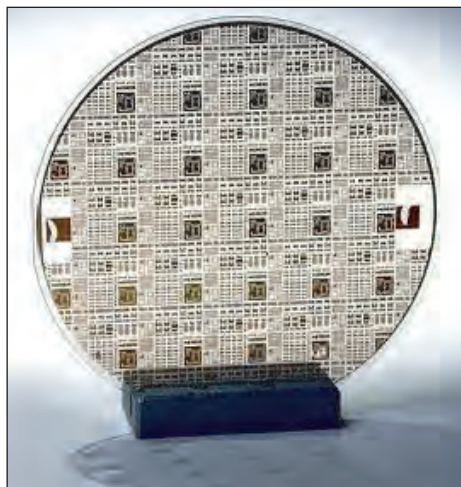
NXP highlights gallium nitride portfolio at IMS, targeting 'mainstream GaN'

First-gen products ramping to volume production in second-half 2012

Recognized as a compelling alternative to silicon for many RF applications, gallium nitride (GaN) technology has generated significant industry interest due to its performance advantages, but has faced significant challenges related to cost, says NXP Semiconductors N.V. of Eindhoven, The Netherlands, which provides mixed-signal and standard product solutions. At the 2012 IEEE MTT-S International Microwave Symposium (IMS) in Montreal, Canada (17–22 June), NXP demonstrated its full portfolio of first-generation GaN products, and discussed its vision and roadmap related to GaN. Core to that vision, says the firm, is the concept of 'mainstream GaN' — bringing economies of scale and over 30 years of experience in RF power transistors to facilitate a secure, reliable supply chain for RF GaN products.

"Since announcing our commitment to 'mainstream GaN' last year, we've received a great deal of interest in our GaN offerings and have worked intensively with a handful of key customers to refine our first-generation GaN portfolio," says Mark Murphy, director of marketing, RF power product line. "At the same time, by offering our customers a choice between high-performance GaN and LDMOS — and in some situations a mix of both — we're in the unique position of being able to offer unbiased choices for fully optimized designs, depending on the specific requirements of each application," he adds.

NXP currently offers engineering samples of its first-generation GaN products, including the CLF1G0035-50 and CLF1G0035-100 amplifiers for 50W and 100W broadband applications. At IMS2012, NXP demonstrated live application examples, including a multi-stage GaN line-up covering a



A GaN wafer fabricated by NXP.

200–2700MHz frequency band. Using the new CLF1G0060-10 driver, as well as the CLF1G0035-50 amplifier for the output stage, the GaN line-up features 50V GaN technology and what is claimed to be best-in-class linearity. Due to the higher impedance levels of the 50V GaN process, broadband amplifiers can be designed on a single transistor.

Based on a 0.5µm gate-length technology developed in collaboration with the Fraunhofer Institute for Applied Solid State Physics (Fraunhofer-IAF) in Freiburg, as well as United Monolithic Semiconductors (UMS) in Ulm, Germany, NXP's first-generation GaN amplifiers feature what is claimed to be excellent linearity without compromising power, ruggedness and efficiency, significantly reducing component count and amplifier footprint. The collaboration with UMS and Fraunhofer IAF Institute also establishes a Europe-based supply chain for GaN technology.

NXP will be ramping up for volume production and offering engineering samples of additional GaN amplifiers in Q3 and Q4/2012.

At IMS 2012, NXP also highlighted applications using GaN, including a live Class E amplifier tuned for

2.45GHz, showing the efficiency enabled by GaN. Featuring a transistor with internal Class E harmonic matching, the amplifier achieves efficiency of 75.2% at 24W. Based on a 0.25µm gate-length technology currently under development, NXP plans to make its high-efficiency Class E narrow-band GaN solutions available in 2013.

NXP is also developing a digital power amplifier using GaN switching transistors that offer higher efficiency than linear amplifiers. These switched-mode power amplifiers (SMPAs) can be used in multiple bands without any modification to the hardware, and will be a key driver of the 'ultimate' base station

By offering our customers a choice between high-performance GaN and LDMOS — and in some situations a mix of both — we're in the unique position of being able to offer unbiased choices for fully optimized designs

of the future, reckons the firm. Like its other GaN processes, the 0.25µm GHSM process uses SiC substrates for better reliability, superior RF performance, and enhanced thermal management, underscoring the advantages of an unbiased approach to GaN, the firm adds.

NXP says that, while RF GaN has already gained significant traction in the aerospace and defense market, it is also focusing on future growth areas including wireless infrastructure and base stations, energy transfer, and the sensing and imaging markets.

www.nxp.com/techzones/hprf-techzone/technologies/gan.html



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HBTs pHEMTs BiFET/BiHEMTs

Toshiba launches high-gain, high-power X-band GaN hybrid IC supporting AESA & PESA radar

At the 2012 IEEE MTT-S International Microwave Symposium (IMS) in Montreal, Canada (19–21 June), Toshiba America Electronic Components Inc (TAEC) and its parent company Toshiba Corp of Tokyo, Japan have launched the TGM9398-25 gallium nitride (GaN) hybrid IC (HIC), optimized for high gain and power. Available in small hermetically sealed packages, the gain-enhanced HIC is targeted at transmitter and receiver modules (TRMs) used in radar applications, such as active electronically scanned array (AESA) and passive

electronically scanned array (PESA).

The new X-band hybrid IC operates in the 9.3–9.8GHz range, and has output power at 1dB gain compression point (P1dB) of 25W, or 44.0dBm (typical), linear gain (GL) of 25dB (typical) and power-added efficiency of 35%.

After Toshiba launched the TGI8596-50 50W discrete GaN internally matched HEMT for the X-band in 2008 followed by the TGI0910-50 in 2010, the new device is in a package that is foot-print-compatible with the existing

discrete internally matched GaN HEMT, supporting easy upgrades for legacy designs.

"The high power density of GaN technology makes this possible," says Homayoun Ghani, business development manager, microwave devices, for TAEC's Discrete business unit. "With the energy-saving features associated with higher gain, this hybrid IC will help our customers design more advanced telecommunication systems," he believes.

Samples of the GaN hybrid IC will be available in Q4/2012.

Ka-band high-power GaN MMIC for satellite communications

TAEC has announced a Ka-band high-power GaN MMIC with what it claims is one of the highest power and efficiency performances in its class. Targeted at satcom applications such as high-definition video broadcast and broadband datacoms, the firm plans to release a complete family of Ka-band products to support these applications.

Ka-band satcom has been on the rise, and is continuing to show steady growth to support broadband communication and increasing demand for higher bandwidth in satcom frequencies, says Toshiba.

Due to the limited availability of high-power microwave solid-state devices, replacing tube-based amplifiers with solid-state power amplifiers (SSPA) for the Ka-band has previously not been a cost-effective design option. However, Toshiba says that its new Ka-band MMIC will provide a solution to support the anticipated surge of solid-state amplifiers to the millimeter-wave frequency range for satcom applications.

Target specifications for the Ka-band high-power GaN MMIC include an operating frequency range of

29–31GHz, output power P_{out} of 15W, linear gain G_L of 15dB, and power efficiency of 20% (typical).

"As a longtime supplier of high-performance GaN and GaAs microwave devices for wireless applications in various frequency bands, Toshiba plans to continue efforts to expand the product line with new solutions," says Homayoun Ghani, business development manager, microwave devices, for TAEC's Discrete business unit.

A datasheet for the new MMIC will be available in Q4/2012, with sampling beginning in Q1/2013.

Toshiba adds gain- and efficiency-optimized C-band GaAs FET PAs for microwave radios and block up-convertors

TAEC has expanded its GaAs FET lineup with the addition of two power amplifiers (PAs) optimized for power-added efficiency, targeted at microwave radios and block up-convertors (BUCs).

The new C-band GaAs FETs for microwave digital radios support point-to-point and point-to-multi-point terrestrial communications, and the BUCs support satellite communications. Operating in the 5.3–5.9GHz and 5.9–6.4GHz ranges, respectively, the TIM5359-16EL

and TIM5964-16EL have an output power at 1dB gain compression point (P1dB) of 16W, or 42.5dBm (typical), linear gain at 1dB gain compression point (G1dB) of 11.5dB (typical), and power-added efficiency of 38%.

"High gain and high power-added efficiency features will help designers build energy-efficient microwave radios," says Homayoun Ghani, business development manager, microwave devices, for TAEC's Discrete business unit.

"By combining our new 16W product along with the linearity-enhanced broadband C-band 4W microwave monolithic integrated circuit (MMIC), Toshiba's TMD0608-4, a simple two-chip design solution is provided for microwave radio applications," he adds. "The improved gain will help microwave designers reduce the number of parts in their overall system."

Samples of the high-gain GaAs FET family are available now.

www.toshiba.com/taec

Sumitomo launches next-gen GaN HEMT for L- and S-band satellite

At the 2012 IEEE MTT-S International Microwave Symposium (IMS) in Montreal, Canada (17–22 June), wireless and optical communications component and module provider Sumitomo Electric Device Innovations USA Inc of San Jose, CA, USA (SEDU, a subsidiary of Japan's Sumitomo Electric Industries Ltd, or SEI) is featuring its enhanced line of gallium nitride (GaN) high-electron-mobility transistor (HEMTs) for satellite applications.

The firm says that its GaN HEMT devices for L/S-band applications offer high efficiency, ease of matching, greater consistency and broad bandwidth, with 50V operation and higher gain than competing power

transistor solutions, it is claimed. Sumitomo says that its space-level Quality Assurance Program assures the highest reliability and consistent performance for space-grade-level products. The product family is in production and shipping to multiple customers. Sumitomo is also developing a 100W unmatched device for the UHF band.

Sumitomo Electric claims to have been first to market with L/S-band discrete HEMT devices with 100W of output power for space use. The GaN devices cover frequencies up to 2.5GHz with output power ranging from 4W to 100W. The firm claims to be the market leader for GaN devices for space applications.

www.sei-device.com

IN BRIEF

Sumitomo shows E-band MMICs for radio links

At IMS, SEDU showcased its E-band MMICs for radio link applications.

The E-band chip-set uses wafer-level chip-scale package (WLCSP) technology. The firm says that this technology achieves excellent frequency performance and easy, reproducible mounting by incorporating flip-chip, 3D MMIC technology in products spanning from C-band up through E-band. Sumitomo says that its low-cost SMT chip-set enables the design of compact, economical E-band transceivers.

Next-generation GaN HEMTs demonstrated for S and X-band radar

At IMS 2012, SEDU exhibited its full line of GaN HEMTs.

A feature was the firm's latest GaN devices designed for L/S/X-band radar applications. In particular, Sumitomo is offering a

2.9–3.3GHz 600W discrete S-band transistor. A 600W 50 ohm pallet version is also available. For broadband radar, the firm offers a 2.9–3.5GHz 300W transistor. The devices offer operation for both

short pulse and long pulse.

Sumitomo Electric demonstrated the 600W S-band and 100W X-band transistors in operation at IMS 2012.

www.sei-device.com

Eyelit's integrated MES software chosen by GCS

Eyelit Inc of Toronto, Canada, which provides manufacturing software for visibility, control, and coordination of manufacturing operations, says that ISO-certified pure-play III-V compound semiconductor wafer foundry Global Communication Semiconductors LLC (GCS) of Torrance, CA, USA has selected Eyelit Manufacturing software to replace its FactoryWorks MES (manufacturing execution system).

Eyelit says that, with its increasing spectrum of fabrication technologies, GCS determined it was necessary to change systems and implement a next-generation MES to handle its complex manufacturing operations. Eyelit's solution is targeted at helping GCS to rap-

idly introduce and manage dynamic process technologies, improve quality, and reduce costs. GCS expects significant improvements in operations by implementing Eyelit MES, Eyelit Asset Management, Eyelit Reporting, and Eyelit Automated Data Services.

"We run high-mix process flows on GaAs, GaN and InP wafers, and Eyelit's combination of flexibility and power will be a huge step up in capability from our current system," reckons GCS' VP of operations Franklin Monzon. "We expect that improvements, especially in configurability and traceability, will lead to reductions in scrap and cycle time, and to increases in productivity," he says. "We also intend

to take advantage of Eyelit's capability to streamline our lot-tracking system, which right now relies on detailed paper travelers alongside our MES, into an electronic system that will reduce errors and facilitate corrective actions," Monzon adds.

"With this implementation at GCS, Eyelit builds further on its tradition of replacing MES systems from other vendors, including Applied Materials' WorkStream, PROMIS, and FactoryWorks products," says Dan Estrada, Eyelit's VP of sales & marketing, who adds that the firm's software should enable GCS to reduce infrastructure costs and long-term cost of ownership.

www.gcsincorp.com

www.eyelit.com

Gaas Labs acquires GaN power transistor firm Nitronex Ocampo's investment firm to lend strategic and operational expertise

Silicon Valley-based Gaas Labs LLC, a private investment fund targeting the communications semiconductor market, has acquired privately held Nitronex Corp of Durham, NC, USA, which designs and makes GaN-based RF power transistors for the defense, communications, cable TV, and industrial & scientific markets.

Founded in 1999, Nitronex provides gallium nitride on silicon (GaN-on-Si) semiconductor solutions using its proprietary SIGANTIC manufacturing process, which combines the superior power, efficiency and bandwidth performance of GaN with the reliability, ease of use and low-cost advantages of industry-standard silicon substrates.

Led by industry veteran John Ocampo, Gaas Labs is focused on providing financing and operational expertise to help grow companies addressing communications semiconductor and related markets. The firm partners with entrepreneurs and management teams to increase portfolio companies'

growth and profitability.

"We are excited to add Nitronex, a leading innovator in GaN-based RF solutions, to our portfolio of RF semiconductor companies," says Gaas Labs' co-founder & president John Ocampo. "We look forward to helping Nitronex further leverage its products and technologies and extend its RF market leadership."

Prior to creating Gaas Labs, Ocampo co-founded Sirenza Microdevices Inc of Broomfield, CO, USA (a diversified supplier of RF semiconductors and related components for the commercial communications, consumer and aerospace, defense & homeland security markets), serving at various times in key roles including president & CEO, chief technology officer, and chairman. After leading Sirenza through an IPO and eventual sale to RF Micro Devices Inc of Greensboro, NC in 2007, Ocampo served on RFMD's board of directors.

In 2009, Gaas Labs acquired M/A-COM Technology Solutions Inc of

Lowell, MA, USA (a supplier of semiconductors, components and subassemblies for use in RF, microwave and millimeter-wave applications). Subsequently, in mid-2010, M/A-COM Tech acquired Mimix Broadband Inc of Houston, TX, USA.

"John Ocampo and Gaas Labs have demonstrated their ability to build and develop companies that realize their full growth potential," comments Nitronex's CEO Charles Shalvoy. "Partnering with Gaas Labs is an important milestone for Nitronex, which will enable us to deliver greater value to our customers in the rapidly growing, high-performance GaN RF power device market," he believes. "We are thrilled to continue advancing our GaN-on-silicon technology and expanding our market presence with Gaas Labs' backing and the aid of their strategic and operational expertise."

www.nitronex.com

www.gaaslabs.net

TriQuint launches gallium nitride devices for defense & commercial RF applications

At the 2012 IEEE MTT-S International Microwave Symposium (IMS) in Montreal, Canada (17–22 June), RF front-end component maker and foundry services provider TriQuint Semiconductor Inc of Hillsboro, OR, USA launched four new GaN devices that aim to improve RF efficiency, reduce overall costs and enhance system ruggedness.

"Our internal product development programs are creating new commercial and defense lower-voltage devices," says James L. Klein, VP & general manager of Defense Products and Foundry Services for TriQuint.

Specifically, TriQuint is launching three new GaN power amplifiers that deliver greater efficiency,

wideband coverage and what is claimed to be excellent performance for communications, defense and civilian radar: the 14–16GHz TGA2572-FL (available now) and the 14–15.5GHz TGA2579-FL and the 13–15GHz TGA2593-GSG (available in July). TriQuint is also announcing availability of the T1G6003028-FS, a 30W wideband GaN packaged transistor that can cut the number of driver circuits in a typical power amplifier design by 50%.

In public forums at IMS 2012, TriQuint is exploring high-performance GaN capabilities and ways that the technology can enable smaller circuits, as well as better-performing low-voltage and high-

power systems. In addition to outperforming silicon, GaAs and other semiconductor technologies, GaN-based integrated circuits are also seen as being key to future 'green' RF and DC–DC power solutions that can reduce network electrical consumption, enable greater range in electric vehicles, or extend smartphone battery life, the firm adds.

Hosted by distributor Richardson RFPD at IMS 2012, TriQuint's GaN product developments were the focus of a presentation in which it will lead a discussion on newly released RF power amplifiers, switches, transistors and integrated assembly/package capabilities.

www.triquint.com/defense

Fujitsu develops first high-output, single-chip 10GHz transceiver using GaN HEMT

Chip footprint cut 90%, shrinking radar & wireless comms equipment

At the IEEE MTT-S International Microwave Symposium (IMS 2012) in Montreal, Canada (17–21 June), Fujitsu Laboratories of Kawasaki, Japan presented what it claims is the first high-output, single-chip transceiver that uses gallium nitride (GaN) high-electron-mobility transistor (HEMT) technology and operates in the 10GHz frequency band.

In line with the advancement of a network-based society, radio wave demand in a variety of wireless systems is expected to increase even further, notes Fujitsu. For example, aircraft radar uses the 10GHz frequency band, which can measure the distance and direction of physical objects with high precision.

Existing radars are configured with separate equipment for transmitters and receivers. In contrast, a transceiver chip that integrates both functions would enable everything to be integrated in one piece of equipment, allowing systems to be more compact.

The transceiver chips necessary to make radar and other equipment more compact must deliver high-capacity communications and high output in order to cover a large area. To simultaneously handle strong transmission signals and weak incoming signals in the same chip, it is necessary to efficiently switch between outgoing and incoming signals, while reducing the impact that outgoing signals have on incoming signals. However, until now, it has been technologically difficult to accomplish both of these objectives in tandem.

Fujitsu Laboratories says it has resolved this issue by developing a duplexer with low signal loss using a GaN HEMT, and through high-output circuit integration design technology that controls the signal interference between the outgoing and incoming signals. The result is a transceiver chip operating at 10GHz with output of 6.3W that

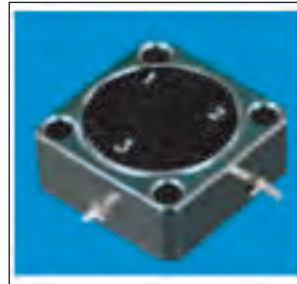


Figure 1. Conventional electromagnetic duplexer and newly developed switch

measures just 3.6mm x 3.3mm (a footprint less than 10% of the size of the multiple chips required until now — see Figure 1).

The firm says that, with this technology, it is now possible to configure a high-output transceiver using just one chip, enabling systems such as radar equipment and wireless communications equipment to be made more compact.

Features of the new transceiver chip are as follows:

- Ultra-compact transmit/receive switch. The GaN HEMT-based duplexer measures 1.8mm x 2.4mm, with 1.1dB transmission loss in the 0–12GHz range (much smaller and lighter than earlier switches using magnetic materials — less than

the release of unwanted signals. In addition, the locations and layouts of signal wiring and circuitry were optimized using three-dimensional analysis of electromagnetic radiation to suppress unwanted signal interference (see Figure 2). This ensures stable operation, preventing the oscillations of high-power circuitry from causing malfunctions.

These technologies were integrated into a single prototype chip that combines a duplexer, a transmitting amplifier, and a receiving amplifier (see Figure 3). The overall chip measures 3.6mm x 3.3mm, less than a tenth the size of earlier multi-chip systems.

The new technology makes it possible to design a high-output

transceiver around a single chip, with applications in radar and broadband communications, promising smaller, lighter systems, says Fujitsu.

The firm says that it intends the technology to be used in a wide range of applications that require compact modules with high output, including wireless communications and radar systems.

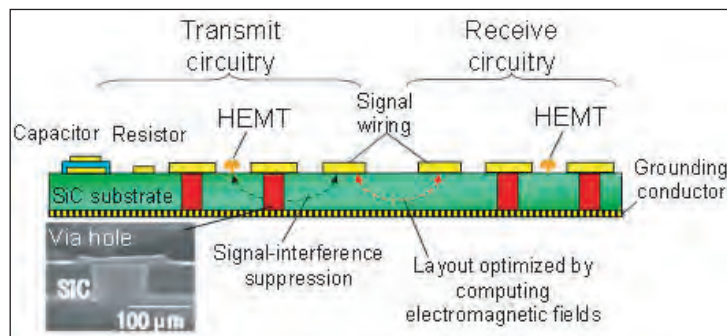


Figure 2. Technologies to suppress unwanted signal interference.

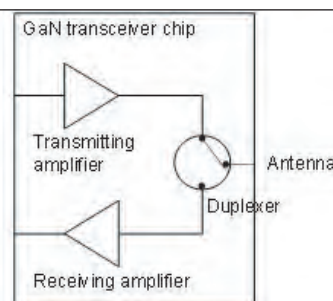
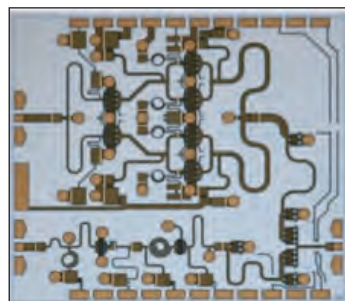


Figure 3. Photo and diagram of new GaN transceiver chip. www.fujitsu.com

Cree launches 40V, 0.25µm GaN-on-SiC HEMT-based solid-state amplifier platform

Cree Inc of Durham, NC, USA has launched a 40V, 0.25µm, GaN-on-SiC HEMT process die product family, with power and bandwidth capabilities through the Ku-band that enables the replacement of travel-wave tubes with solid-state amplifiers (yielding improved efficiency and reliability). The firm showcased its performance capabilities at the 2012 IEEE International Microwave Symposium in Montreal, Canada (17–22 June).

“Cree’s 0.25µm GaN HEMT die product family offers significant improvements in gain, efficiency and power density compared to GaAs transistors over the same frequency range,” claims Tom Dekker, director RF sales & marketing.

“The higher gain allows for more effective power-combining schemes and enables solid-state power amplifiers to be produced with hundreds to multi-kilowatts at C-band, X-band and Ku-band,” he adds.

Applications include marine radar, medical imaging, industrial and satellite communication. Compared

to GaAs transistors, solid-state amplifiers can improve reliability, reduce costs and boost efficiency while shrinking the size of not only the power amplifier but also the power supply. The higher efficiency of GaN HEMT power amplifiers can result in reduced transmitter power consumption.

“Cree’s 0.25µm GaN HEMT products demonstrate breakthrough performance in improved efficiency and bandwidth by enabling new classes of transistor operation not achievable with GaAs-based transistors,” claims RF business development manager Ray Pengelly.

“Good examples are switch-mode HPAs, which have been reported to offer greater than 80% power-added efficiency at microwave frequencies,” he adds. “GaN HEMT HPAs have been produced with instantaneous bandwidths from 6 to 18GHz at power levels exceeding 10W. These 0.25µm GaN performance levels provide system engineers leapfrog advantages to re-invent their GaAs and tube transmitters.”

The new GaN HEMT die products (CGHV1J006D, CGHV1J025D and CGHV1J070D) are rated at output powers of 6W, 25W and 70W at a drain voltage of 40V with an operating frequency range through the Ku-band.

This latest die family is supported by Cree’s proprietary, scalable large-signal device models that are compatible with Agilent Technologies’ Advanced Design System (ADS) and AWR’s Microwave Office simulator platforms, enabling RF design engineers to accurately simulate advanced RF amplifier circuits, which can significantly reduce design cycle times (a most desirable requirement for the higher microwave frequencies). The 0.25µm GaN-on-SiC HEMT process has been qualified to operate up to a drain voltage of 40V with what is claimed to be industry-leading reliability. The mean-time-to-failure exceeds more than 1 million hours at channel temperatures up to 225°C.

www.cree.com/rf

Cree releases PDK update for GaN-on-SiC HEMT foundry via Agilent’s ADS electronic design automation software

Cree has released an updated process design kit (PDK) based on Agilent Technologies’ Advanced Design System (ADS) software that will provide microwave and RF design engineers with a comprehensive suite of design and simulation tools for developing gallium nitride-on-silicon carbide (GaN-on-SiC) high-electron-mobility transistor (HEMT) devices. The free PDK integrates the latest version of Agilent’s ADS electronic design automation (EDA) software with Cree’s GaN-on-SiC process technology parameters and design rules, so engineers can now develop monolithic microwave integrated circuits (MMICs) more quickly.

“The latest version of this PDK enables RF design engineers to access the Cree GaN-on-SiC MMIC foundry capabilities through Agilent’s 2011 release of ADS,” says Jim Milligan, director, Cree RF and microwave. “This integrated front-to-back design system provides highly accurate, scalable nonlinear models, parametric layout cells, design rule checking, seamless layout interoperability and a streamlined design cycle to help accelerate time-to-market for our customers,” he adds.

Our mutual customers now have access to Cree’s proven GaN-on-SiC MMIC process technology

“Our mutual customers now have access to Cree’s proven GaN-on-SiC MMIC process technology, along with the Agilent integrated design system, which is uniquely suited to producing reliable, leading-edge, high-power HEMT devices for today’s most challenging applications,” claims Juergen Hartung, foundry program manager, Agilent EEs of EDA.

To demonstrate the new PDK, the two firms hosted a joint workshop on 20 June at the 2012 IEEE MTT-S International Microwave Symposium (IMS) in Montreal, Canada, that enabled RF design engineers to experience several different MMIC design examples using the new Cree/Agilent PDK.

Cree releases Verilog-A RF device models to speed GaN adoption in 4G/LTE telecom infrastructure

Cree Inc of Durham, NC, USA has released a new suite of Verilog-A proprietary nonlinear device models for its gallium nitride RF devices (available free to Cree's RF customers), developed for use with leading RF design platforms from Agilent Advanced Design System (ADS) and AWR Microwave Office. Verilog-A is an industry-standard language used to describe transistor behavior for simulation purposes.

The new device models support more complex circuit simulations including modulation envelope analysis for use in the latest broadband and multi-mode RF power amplifiers for 4G cellular telecoms. The cross-platform models were made available on the Cree Model portal in connection with the 2012

IEEE MTT-S International Microwave Symposium (IMS) in Montreal, Canada (19–21 June).

"The release of this new suite of device models enables RF design engineers to predict nonlinear performance using harmonic balance, conduct robust transient analysis as well as use 'real-world' arbitrary modulation signals with envelope simulation for Cree's GaN HEMT devices," says Jim Milligan, director RF and microwave, Cree. "The Verilog-A models, together with envelope simulators, allow designers to directly investigate higher-efficiency circuit approaches, such as Doherty amplifiers, to improve adjacent channel power ratios (ACPRs), spectral re-growth and error vector magnitude (EVM),

while assessing if amplifier performance meets spectral mask requirements for LTE deployments. As these models also take advantage of multi-core processors, simulation times can be greatly reduced," he adds.

"Transient analysis allows insight into switched-mode power amplifier configurations that may also be driven directly from digital signals," says Ray Pengelly, RF business development manager, Cree. "Combined with such approaches as Chireix out-phasing, unprecedented efficiencies of greater than 70% have been demonstrated," he adds.

The models are available free to Cree's RF customers.

www.cree.com/rf

GaN Systems and Converter Technology partner on application support for power control and conversion

Power system design and test & analysis capabilities to speed adoption of GaN power switches

GaN Systems Inc of Ottawa, Ontario, Canada, which is a fabless provider of gallium nitride (GaN)-based power switching semiconductors for power conversion and control applications, and UK-based Converter Technology Ltd, which provides design consultancy and hardware prototyping services for power electronic design, have announced a joint strategic agreement to advance the adoption of new GaN applications. The firms will work to develop application notes, reference designs, training material and technology demonstrators to accelerate commercialization of GaN Systems' technology.

Working with customers, the aim is to develop new applications where the performance of GaN Systems' switches and solutions will deliver maximum impact. To support adoption of the new applications, GaN

Systems and Converter Technology intend to promote industry engagement, and demonstrate key benefits to GaN Systems' customers. The engagement should further accelerate adoption of GaN System's technology into the next generation of power conversion systems in a power devices market that is reckoned to be worth \$14bn.

GaN Systems claims its patented power switch technology promises new levels of performance with advantages in size, weight, cost and efficiency. Aided by its technical expertise and global relationships, Converter Technology facilitates the introduction of technology into high-volume production across a wide range of end-user applications.

"The remarkable performance level available from GaN Systems' technology presents an ideal opportunity to push the limits in

power conversion, and we look forward to demonstrating what can be achieved in real-world customer designs," says Converter Technology's technical director Dr Iain Mosely.

"Working with the Converter Technology team and directly with Dr Mosely, we are keen to give our customers expert technical support and best-in-class system-level solutions," says GaN Systems' VP business development Geoff Haynes. "Mosely's deep roots in power system design, his strong customer relationships and the company's excellent test and analysis capabilities make this an ideal catalyst to accelerate the adoption of GaN power switches," he adds. "We expect this relationship to become a model for local customer support for our components across the globe."

www.gansystems.com

www.convertertechnology.co.uk

AWR Design Forum expands to China

AWR Corp of El Segundo, CA, USA, a supplier of electronic design automation (EDA) software for designing RF and high-frequency components and systems, has expanded its AWR Design Forum (ADF) 2012 Asia Pacific tour to include two stops in China: Xi'an on 25 September and Chengdu on 27 September. The call for papers for both is now open.

ADF is an open event at which designers of microwave and RF circuits and systems — such as monolithic microwave integrated circuit (MMIC), RF printed circuit board (RF PCB) and LTE communication systems — can network and share useful information and resources pertinent to high-frequency design, discuss AWR products and technologies, and collaborate on industry issues and trends.

Proposed agenda topics, given by AWR as well as partner firms, include:

- Optimizing the Design and Verification of 4G RF Power Amplifiers;
- Design of a Novel Multi-Slot Antenna;
- Simulating an NXP Doherty Power Amplifier with Digital Pre-Distortion;
- Electrical/Thermal Coupled Solutions for Flip Chip Designs;
- Design and Simulation of Modern Radar Systems;
- Fully Integrating 3D Electromagnetic (EM) Simulation into Circuit Simulation;
- System Simulation Featuring Signal Processing Blocks;
- RF Link Prediction - A New and Novel Approach;
- Linking RF Design Through to Test;
- RF: Moving Beyond a Linear Datasheet;
- MMIC Design in AWR 2011; and
- The AWR Design Flow Advantage - Introduction to New Features and Capabilities.

The AWR Design Forum also provides an opportunity for the presentation of papers from customers and partners working in the microwave & RF industry, as well as from research and educational institutions.

Participants interested in presenting should submit an abstract to adf2012@awrcorp.com by 17 August. Suggested topics include, but are not limited to, RFIC and MMIC design, EM analysis of planar components and 3D passive interconnect, and LTE communications system and radar applications, as well as microwave components, RF and microwave circuit boards, and RF SoCs, SiPs, and module design.

Prizes will be awarded for best paper/presentation at each location. Additionally, all presentations will be made available for download from the AWR website after the event.

www.awrdesignforum.com/call-for-

StratEdge launches copper-moly-copper laminate packages for high-power compound semi devices

At the IEEE MTT-S International Microwave Symposium (IMS 2012) in Montreal, Canada (19-21 June), StratEdge of San Diego, CA, USA (which designs and produces packages for microwave, millimeter-wave, and high-speed digital devices) launched the LL family of leaded laminate copper-moly-copper (CMC) base packages, which dissipate heat from high-power compound semiconductor devices such as gallium nitride (GaN), gallium arsenide (GaAs), and silicon carbide (SiC). The packages handle applications through 6GHz for use in RF radios for communications, radar, and high-power millimeter-wave signals.

The series includes two laminate power packages, both with a ratio of 1:3:1 CMC, providing a good thermal match for alumina-based materials and a GaN chip.



StratEdge's laminate package for high-power GaN devices.

The LL802302 is 0.8" (20.32mm) long x 0.39" (9.91mm) wide with two leads and a raised lid with an epoxy seal. This is a flange package with a bolt hole on each end so the package can be bolted to the printed circuit board. The LL362302 is a flangeless, fully hermetic

version of the LL802302 package, and has a flat ceramic lid.

StratEdge offers both flange and flangeless styles to accommodate manufacturing processes to either bolt down or solder the package. Hermeticity is especially critical in aerospace and defense applications.

"StratEdge's new laminate power packages solve thermal problems encountered when using GaN devices," says president Tim Going. "The excellent thermal conductivity of the CMC base enables use of GaN devices in high-power applications, and the flange package facilitates manufacturing," he adds.

"StratEdge is continuing to develop packages to handle the requirements of today's new materials and devices," concludes Going.

www.stratedge.com



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P+E hydrogen purifier for SemiSouth's SiC epi expansion

Power+Energy Inc of Ivyland, PA, USA has provided a 9000MS Series hydrogen purifier to SemiSouth Laboratories Inc of Starkville, MS, USA, which designs and makes silicon carbide (SiC) devices for high-power, high-efficiency, harsh-environment power management and conversion applications. The purifier will be used to support a major capacity expansion at SemiSouth's SiC fabrication plant.

"We are very impressed by P+E's hydrogen purifier with the ease of operation and excellent purity," comments SemiSouth's senior equipment specialist Chris Myrick. "The compact purifier is a great fit for our MOCVD process," he adds.

The 9000MS Series purifier will purify liquid-source hydrogen for existing and additional MOCVD tools. The palladium hydrogen purifier has already produced improved process results after replacing a regenerable catalytic purifier.



P+E's 9000MS Series.

"Nitrogen and hydro-carbon contamination negatively affect our SiC epi process and we are pleased to see the improved results

after installing the P+E palladium purifier to remove all impurities in our hydrogen supply," Myrick notes.

The 9000MS purifier uses patented micro-channel palladium membrane technology to remove all impurities to parts-per-trillion levels. P+E says the durable, production-worthy hydrogen purifier supports any flow rate and any inlet gas source quality. The compact design can be wall-mounted to provide ultra-high-purity (UHP) hydrogen for MOCVD

epitaxial processes.

"SemiSouth is part of our growing customer base doing SiC manufacturing," says Stuart Bestrom, P+E's director of global sales. "P+E has been supporting customers in SiC processing for over 12 years, including many leading suppliers of SiC materials and epiwafers," he adds. "Many of these customers have purchased multiple systems as they have migrated and expanded their capacities from lab to production."

P+E says hydrogen gas purifiers are critical to the rapidly expanding high-efficiency power devices industry, whether silicon carbide or gallium nitride. The firm says its product lines, all based on its micro-channel Pd membrane technology, allow users to continue to employ the same technology in high-volume production, regardless of source gas quality.

www.powerandenergy.com

www.semisouth.com

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II-VI promotes Marlow's general manager to lead Advanced Products Group, including Wide Band Gap Inc

II-VI Inc of Saxonburg, PA, USA has named Kevin MacGibbon as general manager of Marlow Industries Inc of Dallas, TX, leading its global operations (including research, finance, sales/marketing, manufacturing, European and Asian operations, serving the defense, space, photonics, telecoms, medical, automotive, power generation, consumer and industrial markets).

Marlow's prior general manager Barry Nickerson, who served as its president for the past 14 years and oversaw global operations, has been promoted to general manager of II-VI Inc's Advanced Products Group, which includes not only Marlow Industries but also Wide Band Gap Inc. The latter manufac-

tures single-crystal silicon carbide substrates. Nickerson reports to II-VI's executive VP Chuck Mattera.

"This organizational leadership change should allow both Marlow and WBG to sustain their profitable growth performance, product and technology leadership, operational excellence, and further leverage the talent of its people worldwide," says Mattera. "This change is consistent with the corporation's Leadership Development Initiative, and a great opportunity for WBG to learn from Marlow's experiences while reducing overall operating costs by leveraging Marlow's existing investments to grow the business," he adds.

www.ii-vi.com/wide-bandgap-materials-group

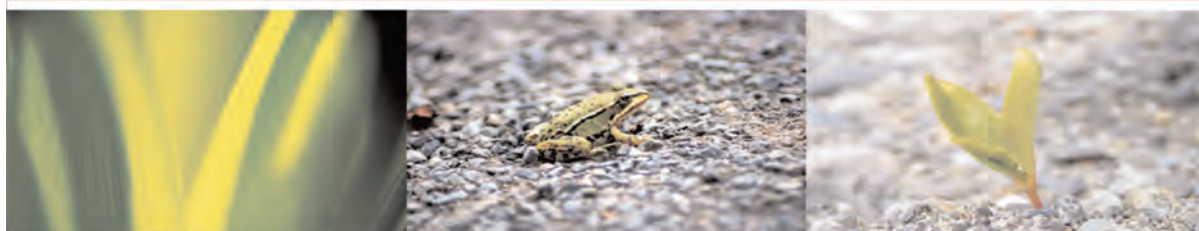
IN BRIEF

Riber sells Compact 21 MBE system to German research institute

At the end of June, Riber S.A. of Bezons, France, which manufactures molecular beam epitaxy (MBE) systems as well as evaporation sources and effusion cells, completed the sale of a Compact 21 research MBE system to a research institute in Germany.

The system will be devoted to the growth of III-V epitaxial nanostructures for applications in nanoelectronics and photonics, and will significantly increase the institute's applied technology research and development capabilities.

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Veeco hosts Taiwan LED makers at MOCVD User Meeting

Epitaxial deposition and process equipment maker Veeco Instruments of Plainview, NY, USA says that more than 150 LED manufacturing customers recently attended its metal-organic chemical vapor deposition (MOCVD) User Meeting in Tainan, Taiwan. Attendees included representatives from most of Taiwan's top LED makers such as Epistar Corp, FOREPI, Genesis Photonics Inc (GPI), Huga Optotech Inc, Tekcore Co Ltd, Epileds, and Arima Optoelectronics.

During his presentation, invited speaker Dr Charles Li, GPI's vice president of R&D, spoke about 'The Trend of LED Chips for Lighting'. He addressed key drivers that will help to commercialize LEDs for general lighting, such as cost reduction, which can be achieved by developing better high-current LED chip technology.

"Our MOCVD User Meeting provides an excellent forum where we



Taiwan's LED makers at Veeco's MOCVD User Meeting in Tainan.

focus on our customers' manufacturing challenges and provide solutions to maximize their productivity and yield, while reducing costs — all critical factors to their success," says Tim Liu, Veeco's VP & Greater China country manager. "Veeco recently introduced a new suite of MOCVD systems based on its industry-leading TurboDisc technology to accelerate worldwide adoption of LED lighting by reducing manufacturing costs," he adds.

Other topics presented at the meeting included 'Driving Down LED Manufacturing Costs with TurboDisc MOCVD Products' presented by Jia Lee, Ph.D., Veeco's senior director of marketing & business development; and an update on 'GaN on Silicon LED Manufacturing' by Kenny Sun, Ph.D., Veeco's director, Taiwan Technology Center (TTC), located in Hsinchu Park. Dr Sun also presented the mission of Veeco's TTC and technical projects since its establishment a year ago.

Veeco's TTC is equipped to conduct process demonstrations, arrange rapid start programs to transfer best known methods, provide early access to evaluate system upgrades, and support joint technology development programs. It is equipped with the firm's MOCVD systems, including a multi-chamber TurboDisc MaxBright MOCVD system.

www.veeco.com

IN BRIEF

Praxair Asia raises process gas prices

Industrial gas provider Praxair Inc of Danbury, CT, USA says its Asian operating unit Praxair Asia Inc of Shanghai, China has notified its electronic gases customers of a price rise of 10–20% on select electronic process gases (effective 1 July, as contracts permit).

The price rise is due to escalating raw material and production costs for electronic process gases. The increase will allow Praxair Asia to sustain product quality standards and make ongoing investments to support growth of its customers. Praxair Asia is also implementing a range of productivity programs to improve overall cost structure.

Products include precursors, dopants, reactants, etchants, inerts, as well as bulk, on-site, and associated distribution equipment.

www.praxair.cn

Korean etch and CVD system maker Femto Science selects UVOTECH Systems as US representative

To enhance its service to customers throughout the USA, South Korea's Femto Science Inc, which manufactures plasma cleaning systems, etching (RIE and ICP) systems and Parylene coating systems (CVD), has selected UVOTECH Systems Inc of Newark, CA, USA as its US sales and support representative.

UVOTECH is a scientific equipment distributor with the expertise to provide a full range of technical and support services. It specializes in UV-ozone and plasma cleaning systems as well as plasma etching, reactive ion etching (RIE) and chemical vapor deposition (CVD) systems used in semiconductor, MEMS (micro-electro-mechanical system), optoelectronics, solar, and biotechnology industries.

"With more than 12 years of industry experience, UVOTECH Systems

was selected to represent Femto Science based on their experience, knowledge, customer support and responsiveness," says Femto Science's founder & president Ms Chang.

"We are building a complete support operation in the United States while increasing our presence among new customers," she adds.

"The addition of UVOTECH Systems as our US distributor will greatly benefit this effort by providing excellent service to educational, government and private institutions."

www.uvotech.com

<http://femtoscience.co.kr>

Riber's first-half revenue falls 28% year-on-year as Q2 falls 16% on Q1

...but orders rise 19% year-on-year to €21.5m

For second-quarter 2012, Riber S.A. of Bezons, France, which manufactures molecular beam epitaxy (MBE) systems as well as evaporation sources and effusion cells, has reported revenue of €3.2m, down 56% on €7.2m a year ago and 16% on €6.2m in Q1/2012. For first-half 2012, revenue was €9.4m, down 28% on €13m in first-half 2011. Of first-half 2012 revenue, 39% came from Asia, 37% from Europe and 24% from North America.

In a difficult economic climate affecting the semiconductor industry, revenue shows a change in product mix in favor of MBE systems sales unmatched since 2002, says Riber.

Compared with three machines in first-half 2011, the number of machines invoiced doubled to six in first-half 2012, consolidating the firm's market position particularly in the research sector. Total system

revenue was €6.4m, up 89% on €3.4m in first-half 2011.

Revenue for services & accessories was €2.2m, down 15% on €2.6m in first-half 2011, due to a slowdown in demand in Europe and the USA.

Revenue for evaporation sources and cells was just €0.8m, down 89% on €7m in first-half 2011. However, the latter included the delivery of a major investment order for organic LED (OLED) production equipment.

In Q2/2012, Riber booked four MBE system orders for research laboratories in Germany,

China, France and Japan, doubling from just two research systems booked in Q2/2011.

For first-half

Revenue shows a change in product mix in favor of MBE systems sales unmatched since 2002

2012, system order value was €18.8m, up 24% on €15.1m in first-half 2011. Services & accessories orders remained almost level, down just 2% to €1.7m.

However, orders for evaporation sources and cells were €1m, down 17% on €1.2m in first-half 2011. As previously announced, this drop is occurring during a transition period between two waves of investments in the OLED sector.


Riber is continuing the development of a new range of OLED cells in order to strengthen its market position in what it calls a promising sector.

The total order book at the end of June was €21.5m (up 19% on €18m a year ago), with 16 systems to be delivered in 2012 and 2013.

Riber will announce full results for first-half 2012 as well as its outlook for full-year 2012 on 19 September.

www.riber.com

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Wafer World, Inc. is a privately held company founded by Sean Quinn in 1997. The 12,000 sq ft facility is situated in Palm Beach County, FL. Wafer World, Inc. is an ISO 9001:2008 and AS9100:2004 certified manufacturing facility for Silicon, Gallium Arsenide, Germanium, Indium Phosphide, Sapphire and Quartz.

Wafer World, Inc. has satisfied customers in 45 countries on 6 continents. Our on-line, fully secured shopping cart is available 24/7 with short lead times. Wafer World has established great relationships with Fortune 100 companies, universities, government labs, and worldwide brokerage houses. Customer Service is our top priority at Wafer World, Inc.

Customers who need 25 wafers once a year and customers who require 1000 wafers/week receive the same high quality service.

[Download the Wafer World Presentation](#)

[View the Wafer World, Inc. Timeline](#)

IN BRIEF

Taiwan's National Chung Hsing University to use Aixtron CCS MOCVD system for GaN-on-Si research

Deposition equipment maker Aixtron SE of Herzogenrath, Germany says that new customer National Chung Hsing University (NCHU) in Taiwan has placed an order for a Close Coupled Showerhead (CCS) MOCVD system in 3x2"-wafer configuration.

NCHU will use the system for research into hetero-epitaxial growth of gallium nitride alloys on silicon wafers (GaN-on-Si). One of Aixtron's local service support teams has already installed and commissioned the new reactor in a dedicated clean-room facility at NCHU's site in Taichung.

"The reactor has demonstrated its versatility, ease of operation and reproducibility over the range of parameters of interest to us," says professor Horng of the Graduate Institute of Precision Engineering at NCHU. "We therefore will be able to produce high-quality GaN-on-Si epilayers and other novel structures", he adds.

Since 2001, the research team led by professors Wu and Horng at NCHU has developed many unique LED technologies for both GaN and AlGaInP materials. Their integrated laboratory (from epitaxial growth to device processing and packaging) has now established itself as one of the leading research center in Taiwan, says Aixtron. Many of its academic-industry cooperation projects have also been awarded by the National Science Council of Taiwan.

www.nchu.edu.tw
www.aixtron.com

Aixtron launches AIX G5+ 5x200mm GaN-on-Si package for G5

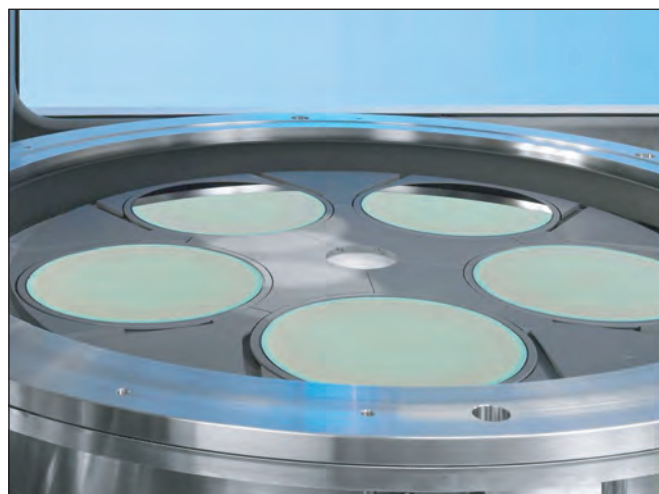
AIX G5 reactor platform expanded to take five 200mm wafers

With its latest product, AIX G5+, deposition equipment maker Aixtron SE of Herzogenrath, Germany has launched a 5x200mm gallium nitride on silicon (GaN-on-Si) technology package for its AIX G5 Planetary Reactor metal-organic chemical vapor deposition (MOCVD) platform.

Following a customer-focused development program, the technology was designed and created in Aixtron's R&D laboratory and consists of specially designed reactor hardware and process capabilities. It is now available as a part of the AIX G5 product family, and any existing G5 system can be upgraded to this latest version. Details of G5+ have already been disclosed to some of Aixtron's key customers.

"GaN-on-Si is the technology of choice for the emerging power electronics market segment, and also a very promising candidate for future high-performance and low-cost high-brightness LED manufacturing," says VP marketing Dr Rainer Beccard. "The wafer size and material plays a crucial role when it comes to cost-effective manufacturing processes, and thus the transition to 200mm standard silicon wafers is a logical next step on the manufacturing roadmaps, as it offers unique economies of scale," he adds.

"Being convinced that uniformity and yield are the key success criteria in 200mm GaN-on-Si processes, Aixtron conducted a dedicated R&D program," says Dr Frank Wischmeyer, VP & program manager Power Electronics at Aixtron. "We started the



The AIX G5+'s reactor chamber.

development process by conducting an extensive simulation program, which enabled us to design fundamentally new hardware components that provide unique process performance in our 5x200mm processes, while still being compatible with the well-proven AIX G5 reactor platform," he adds. The results are extremely stable processes, providing much better uniformity of material properties and enabling higher device yield than any other MOCVD platform, says Aixtron, whilst offering a reactor capacity of 5x200mm.

The firm says that initial feedback from customers confirms the success of the technical development. Many have noted in particular that the fully rotationally symmetrical uniformity pattern on all five 200mm wafers, the use of standard thickness silicon substrates and the controlled wafer bow behavior is what they require for silicon-style manufacturing, Aixtron adds.

"This uniformity pattern has been an inherent feature of Aixtron's Planetary Reactor technology, which we can now successfully obtain on 200mm GaN-on-Si wafers," concludes Wischmeyer.

www.aixtron.com

LayTec training center opened at Taiwan's Challentech

LayTec AG of Berlin, Germany says that on 21 June Challentech International Corp, its partner for sales and service in Taiwan, opened its new training center in Hsinchu. LayTec's president & founder Thomas Zettler and general manager of sales Tom Thieme attended the opening ceremony.

At the training center, tools such as the EpiCurve TT AR Blue and the first PreCurve, LayTec's new product for ex-situ measurement of wafer-bow before and after epitaxial growth, are demonstrated and used for training purposes.

www.challentech.com.tw/En



Tom Thieme (general manager sales at LayTec), Thomas Zettler (CEO & president of LayTec), and C.M. Liu (president of Challentech International) in front of the new training center.

LayTec enlarges its sales team

LayTec (which makes in-situ metrology systems for thin-film processes, focusing on compound semiconductor and photovoltaic applications) has appointed Stephanie Fritze as a new sales team member, supporting activities in Taiwan and China.

Fritze has a diploma in physics on x-ray diffraction and fluorescence analysis of nitride semiconductors from Otto-von-Guericke-Universität in Magdeburg. Her PhD research topic was gallium nitride on silicon (GaN-on-Si) epitaxy and characterization, with a special focus on GaN-based LED growth on large-diameter substrates. She was also involved in the construction and start-up of a lithography laboratory for conventional and thin-film LED processing. LayTec adds that Fritze has broad knowledge of the growing field of GaN-on-Si applications.

In addition, Emilie Quillet has joined LayTec's sales force to support business in Europe. She obtained her engineering degree in materials science at the University of Technology of Troyes (France) and did her M.Sc. thesis at Helsinki University Technology (now Aalto University), where she



Fritze, Quillet and Blank.

studied the influence of plasmonic coupling on light extraction of InGaN/GaN SQW-based GaN LEDs. Afterwards, as a sales engineer for LED lighting at Ekolicht MMK GmbH, she gained experience in product integration, customer networking and relationship management.

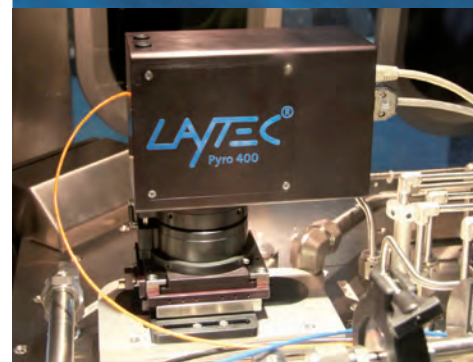
Finally, new sales team member Volker Blank will focus predominantly on supporting activities in South Korea. He received his Diploma in Physics from Johann Wolfgang Goethe-University of Frankfurt-am-Main for studying photo-induced charge carriers in organic semiconductors by time-resolved terahertz-spectroscopy. For his PhD he worked on broadband terahertz radiation from optically driven air plasmas, targeting ultra-broadband THz pulses for spectroscopic applications.

www.laytec.de

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University of Magdeburg buys Oxford Instruments' etch tool for HB-LED and power semiconductor research

UK-based Oxford Instruments plc has received an order for a PlasmaPro System100 ICP180 etch tool from Otto-von-Guericke University Magdeburg, Germany. The system will run GaN-on-Si etch processes to facilitate the university's power semiconductor and high-brightness (HB-LED) research.

Oxford Instruments says that GaN-on-Si offers a step change in technology for the HB-LED and power semiconductor device markets. Through lower-cost and larger-diameter substrates, the overall cost of devices can be dramatically reduced. Etching forms a vital part of the device manufacturing process, and the PlasmaPro100-ICP180 enables high etch rate and low damage, the firm adds.

"In the past few years research at



Oxford Instruments' PlasmaPro System100 ICP180 etch tool.

the university has gone through a decisive change from applied to

innovative pure research," explains professor Alois Krost of University Magdeburg. "As the use of HB-LED and power devices continues to grow, these technologies play an important role for improving the environmental impact of global energy and power consumption. We chose the Oxford Instruments tool for our research because of the excellent technical specification and well founded reputation of the processing tools backed up by expert specialist support," he adds.

"As an exciting area of research, GaN-on-Si fits perfectly with our philosophy of excelling in developing research and then driving the technology to production," says Mark Vosloo, sales, marketing and CS director at Oxford Instruments Plasma Technology (OIPT).

www.oxford-instruments.com

Plasma processing workshop at Cornell University

Plasma process equipment maker Plasma-Therm LLC of St Petersburg, FL, USA is providing a workshop at Cornell University in Ithaca, NY, USA on 21 August focusing on the 'Fundamentals of Plasma Processing (Etching and Deposition)'.

Lectures will include the basics of plasma reactors and mechanisms for etching and deposition, and will review plasma processing technologies as applied to semiconductor, micro-electro-mechanical systems (MEMS), and nanofabrication.

Talks cover compound semiconductor, dielectric, and deep silicon etching as well as plasma-enhanced chemical vapor deposition (PECVD) and high-density plasma CVD (HDPCVD) of silicon-based materials. Essential concepts and new ideas for end-point detection and sample thermal budget management will be presented, along with an introduction to design-of-experiments (DOE) and a concluding presentation on designing robust processes.

Speakers include David Lishan, who has a Bachelor's degree in Chemistry from University of California, Santa Cruz, and M.S. and Ph.D. degrees from University of California, Santa Barbara, in Solid State Electrical Engineering. In his career he has worked and published on a range of material, semiconductor, and chemistry R&D projects in photochemistry, x-ray mask fabrication, physical vapor deposition (PVD), and plasma processing. Lishan joined Plasma-Therm nearly 14 years ago and is currently principal scientist and director in the Technical Marketing Group. His primary focus is on the application of plasma processing for MEMS, photonics, data storage, and compound semiconductor applications.

For registration inquiries, e-mail: Mallison@cnf.cornell.edu. Registration is free, but online pre-registration is required by 13 August.

www.cnf.cornell.edu/cnf_workshopreg.html

● Plasma-Therm says that its recent plasma processing workshop at Sweden's Lund University provided fundamental and advanced technology used in semiconductor device and materials research. Attendees from Scandinavia participated in a day of presentations focusing on applying plasma etching and deposition to fabricating electronic, photonic, bioscience, and nano-scale devices and structures.

"It provided us with a good introduction into the basics of plasma processing and at the same time it was very useful for those who already work with plasma etching or deposition," says Dr Ivan Maximov, deputy director of Lund Nano Lab (LNL) and head of its Nano-process Laboratory. "The workshop has undoubtedly improved our understanding of reactive ion etching processes of III-Vs and silicon and associated PECVD processes which we use in our labs on a daily basis."

www.plasmatherm.com

Oxford Instruments launches latest PlasmaPro 100 system for both production and R&D users

UK-based Oxford Instruments plc has launched its latest-generation PlasmaPro 100 etch and deposition tool. Suited to key market applications including micro-electro-mechanical systems (MEMS), high-brightness (HB)-LEDs, semiconductor electronics, failure analysis, and photovoltaics, the system has been developed to address the exacting needs of production users demanding not only the latest technological innovations but also customer support.

Oxford Instruments says that the latest system offers:

- an evolution of plasma-enhanced chemical vapor deposition (PECVD) hardware delivering step changes in deposition rate of high-quality SiO_2 and SiN_x , with corresponding reductions in cleaning overhead;
- the latest generation of the Cobra ICP source, which delivers improvements in etch rate and fea-



Oxford Instruments' latest-generation PlasmaPro 100 etch & deposition tool.

ture control capability;

- industry-recognized robotic handler and capability, strengthening the firm's position as a supplier of 'plug and play' hardware and optimized processes; and

- enhanced system control infrastructure and software interface that delivers improved diagnostics,

reliability and serviceability.

Providing a common platform for all Oxford Instruments Plasma Technology's processes and technologies, the PlasmaPro 100 is a highly configurable system, with process chambers available as standalone modules or in cluster configurations.

"All our tools boast industry-leading technology and automation that are well proven with over 90% uptime," claims senior product manager Ian McKinlay. "This latest product release offers genuine process improvements delivering excellent uniformity and high-throughput processes on a range of applications," he adds, noting that users have access to the firm's exclusive library of over 6000 process recipes, built up over 25 years, as well as comprehensive backup.

www.oxford-instruments.com

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www.oxford-instruments.com/plasma

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Edwards launches dry vacuum pump for LED and compound semiconductor manufacturing

Vacuum and exhaust-abatement equipment maker Edwards Ltd of Crawley, UK has launched the iXH645H dry pump, which is optimized for MOCVD processes used in LED manufacturing, as well as for compound semiconductor manufacturing using III-V materials in gate stacks.

The iXH645H delivers very high gas flow capability and can operate continuously at the high loads required for the latest-generation LED manufacturing tools. The pump's technology minimizes maintenance requirements and maximizes uptimes, helping to lower cost-of-ownership, it is claimed.

"This new addition to our iXH family of dry pumps is designed to address the needs of two rapidly growing segments of high technol-

ogy manufacturing," says LED market sector manager Wei Shao. "Due to their superior lighting efficiency, LEDs are increasingly being seen as an environmentally friendly alternative to incandescent lighting, as shown by recent legislation passed in China, Korea, Japan and the UK to phase out traditional high-power lighting," he adds. "At the same time, the use of III-V materials in compound semiconductor manufacturing is enabling the continuation of Moore's Law to next-generation design nodes."

Both LED and compound semiconductor manufacturing processes typically use high flows of light hydrogen and highly corrosive ammonia gasses. The iXH645H has been optimized to support these requirements with superior hydrogen pumping performance and a

corrosion-resistant design, including a patented nitrogen purge barrier to protect the pump seals.

The high-temperature capabilities of the pump help to prevent condensation of the phosphorous compounds that may be present.

Furthermore, its oil lubrication and seal technology eliminate periodic maintenance requirements, while its thermal and motor design prevent overheating, motor overloads or zones of limited operation, says the firm.

The pump's optimized temperature control system ensures that the pump is ready for process within about 30 minutes of start-up.

Edwards exhibited the iXH Series in July at the InterSolar and the SEMICON/West 2012 events in San Francisco.

Edwards sells its 10,000th abatement system

Edwards says that it has sold more than 10,000 abatement systems since it entered the business nearly 20 years ago. In addition, Edwards has placed second in VLSI Research's 'Top 10 Suppliers of Critical Subsystems 2011' report for the semiconductor and flat panel display industries.

"The growing concern about the environment and climate change has spurred increasing awareness of the need to abate a variety of potentially harmful industrial by-products," says exhaust management systems product manager Steve Cottle. "In 2011, our systems were responsible for abating the equivalent of 8,500,000 metric tons of carbon dioxide at our customer facilities, equal to 98% of the net carbon dioxide emitted annually by industrial processes in the UK," he adds.

"2011 was a record year for suppliers of critical subsystems,"



Edwards' Atlas exhaust-abatement system.

says John West, chief executive officer of VLSI Research Europe. "Sales grew 9.3% to reach a

value of \$7.88bn. The main driver for the industry was capital expenditures on semiconductor manufacturing equipment for 32nm and below technology nodes," West adds.

Most of the abatement systems sold have been from Edwards' inward fired combustor product range, which includes its TPU (Thermal Processing Unit) and Atlas products. The company says that the proven performance and reliability of its unique inward-fired combustor design have made these products the top-selling combustion abatement systems for the past ten years.

Geographically, the USA remains the firm's largest market for abatement systems. However, the Asia Pacific region is also a key market, due to the rapid growth of high-tech manufacturing and increasing environmental regulations.

www.edwardsvacuum.com

Brooks launches MFC and capacitance manometer

At the Intersolar North America 2012 trade show in San Francisco in July, Brooks Instrument LLC of Hatfield, PA, USA, a provider of low-flow and pressure/vacuum analytical instruments, unveiled its new XacTorr CMX0 capacitance manometer and the new EtherCAT capabilities of its GF40/80 mass flow controller (MFC), as well as showcasing other mass flow, pressure and vacuum products for the solar and semiconductor industries.

Brooks says that the XacTorr CMX family of capacitance manometers provides solar and semiconductor manufacturers with highly stable and repeatable measurements for pressure-sensitive processes. It offers full-scale ranges from 1000 Torr to 100mTorr, as well as 0.15% of reading accuracy. With its

patented Mark IV sensor the XacTorr lasts up to three times as long in aggressive processes compared to other capacitance manometers, it is claimed. The rapid recovery feature allows the sensor to recover from large changes in pressure faster than other vacuum gauges on the market, significantly decreasing downtime.

The CMX0 offers an unheated option with the same full-scale ranges and an accuracy of 0.25% of reading. It allows drop-in replacement and unique diagnostic features for preventative maintenance such as tracking remaining zero adjustment range to allow scheduled maintenance, which reduces unplanned interruptions. Additionally, the CMX0's digital communication protocol monitors and troubleshoots

problems without interfering with the tool communication system.

The GF40/80 is a highly modular, user-programmable mass flow controller designed for solar and thin-film processes. Using MultiFlo technology, it combines what is claimed to be exceptional flow repeatability, sub-one-second flow control response time, the most comprehensive gas and flow range programmability, and long-term reliability.

The GF40/80 is now equipped with EtherCAT, a new communication protocol that has been adopted by leading-edge manufacturers in the solar and microelectronics industries. EtherCAT makes it easier to network flow control and other devices for advanced process control and diagnostic capabilities, says Brooks.

www.BrooksInstrument.com

Lake Shore launches cryogen-free probe station for new material research and electronic device development

Lake Shore Cryotronics Inc of Westerville OH, USA, which makes scientific sensors, instruments and systems for precise measurement and control, has launched the Model CRX-6.5K, a general-purpose cryogen-free probe station that is claimed to be both cost effective and convenient to use. The new tool is suitable for engineers and scientists performing new material research and electronic device development who want to characterize material or test device behavior before undertaking full device development.

The firm says that, with the Model CRX-6.5K, engineering and test laboratories can now enjoy the same stable, precise temperature control and accurate sample measurement technology that low-temperature physicists have had access to for years.

Whether testing photonic and electro-optical materials and devices, organic and molecular electronics, microwave materials



and test devices, or nanoscale electronics, quantum devices and novel semiconductors, it offers reliable, convenient, and non-destructive testing in a stable environment that eliminates unwanted thermal variability, Lake Shore claims.

The probe station suits researchers conducting liquid-nitrogen-based measurements, or needing a convenient environment capable of accurately controlling

temperatures from under 10K to 350K (-263°C to 77°C), with an option for up to 675K (400°C). Safer, easier, and more precise than using liquid cryogen dunk tanks, the Model CRX-6.5K is also more flexible than optical cryostats and accommodates larger samples, the firm adds. A self-contained closed-cycle refrigerator (CCR) enables safe and convenient cryogen-free operation, so no supervision is required during cool down.

The system also offers flexible, expandable probing, with up to six independent probe arms and a variety of probe tip and sample holder options to accommodate a broad range of device types and measurement needs. Special design features such as cooled probe arms with calibrated temperature sensors allow extra confidence in the actual temperatures of samples. Like all Lake Shore products, the Model CRX-6.5K comes with a standard 3-year warranty.

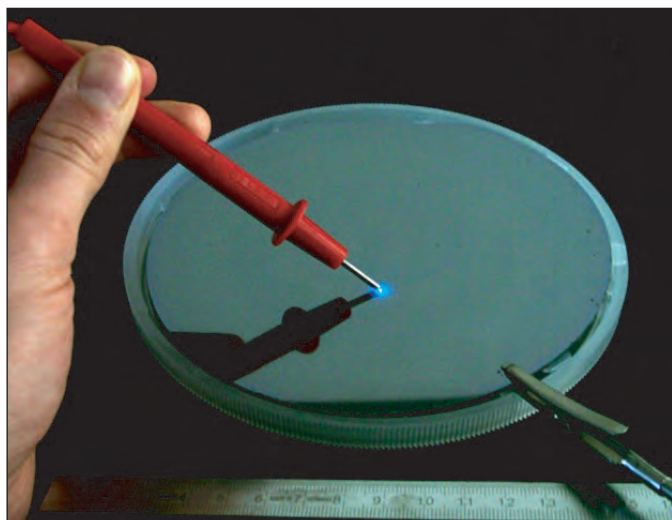
www.lakeshore.com

AZZURRO receives €2.6m grant for 200mm GaN-on-Si

AZZURRO Semiconductors AG of Magdeburg, Germany, which makes gallium nitride (GaN) epitaxial wafers based on large-area silicon substrates, says that its development of next-generation GaN on 200mm silicon substrates is being supported by the local government of Saxony (the location of the firm's production facility, in Dresden). Specifically, the 200mm GaN-on-Si wafer project is being financed with €2.6m from the European Regional Development Fund (ERDF) and the Free State of Saxony.

The official grant note was handed over to the firm during a visit by Saxony's minister for science and technology professor Sabine von Schorlemer, who welcomed AZZURRO as another partner in 'Silicon Saxony'. "The company's move is another recognition of this great semiconductor location," she added.

The firm addresses the LED and power semiconductor markets (valued at more than \$10bn and \$15bn in 2010, respectively). For these markets dynamic technology development is a key factor, AZZURRO reckons. The company says that, compared with current-generation wafers, its large-diameter GaN-on-Si-wafers enable



An existing 150mm GaN-on-silicon wafer produced by AZZURRO Semiconductors.

customers to use low-cost standard silicon processing lines to produce energy-efficient LEDs and power semiconductor devices.

AZZURRO currently

AZZURRO can execute its strategic development of the 200mm technology platform for power semiconductors and LEDs and quickly attend to the strong customer demand

working on extending this performance to 200mm.

"Based on the technology grant, AZZURRO can execute its strategic development of the 200mm technology platform for power semiconductors and LEDs and quickly attend to the strong customer demand," says VP technology Dr Stephan Lutgen (who heads the development and cooperation with project partner NaMLab GmbH), commenting on the support from the ministry and the local development bank SAB.

www.azzurro-semiconductors.com

has 150mm GaN-on-Si-wafers in production. With the development of 200mm GaN-on-Si-wafers for LED and power semiconductor applications, the firm wants to build on its existing technology to strengthen its competitive position. The performance data achieved on 150mm wafers is already unique, it claims.

With the additional funding, AZZURRO is

Veeco K465i MOCVD system chosen for GaN-on-Si epi production

Epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA says that AZZURRO Semiconductors recently put the TurboDisc K465i GaN metal-organic chemical vapor deposition (MOCVD) system into production. The system is used to make gallium nitride on silicon (GaN-on-Si) wafers for power semiconductors, LED wafers and LED template wafers.

"Our technology provides high-quality, crack-free GaN layers on 150mm standard silicon wafers with very good crystal quality and extremely low bow values," says

AZZURRO's VP operations Dr Markus Sickmoller. "We chose Veeco's K465i to produce these high-efficiency GaN-on-Si stacks because of its performance, process stability, and high throughput," he adds. "Our GaN-on-Si technology will trigger a new wave of highly efficient and cost-optimized components for the LED and power semiconductor industry," he believes.

"The power electronics device market is forecasted by Yole Developpement to be \$25bn by 2015, and GaN has the ability to make devices with higher efficiency and switching speed than tradi-

tional Si devices," notes Veeco's senior VP, MOCVD, Jeff Hawthorne. "Further, LEDs made with GaN-on-Si technology will enable lower LED costs. We anticipate that the demand for MOCVD tools for these GaN-on-Si applications will grow as technology moves from R&D into production," he adds. "Veeco's K465i systems offer key advantages for GaN-on-Si production, including low particle count and excellent yields, and we're looking forward to continuing to support AZZURRO's growing GaN-on-Si business."

www.veeco.com

PAM-XIAMEN expands free-standing SI GaN substrates to 2" square; 3" & 4" round substrates in development

China's Xiamen Powerway Advanced Material Co Ltd (PAM-Xiamen), which supplies ultra-high purity crystalline GaN and AlGaIn materials and other related products and services, has announced the availability of 2"-diameter native semi-insulating GaN (SI GaN) substrates. The firm says that the new product represents a natural addition to its native SI GaN substrate product line, which already includes 10mm x 10mm, 25mm x 25mm and 38mm x 38mm substrates.

Founded in 1990, PAM-XIAMEN develops crystal growth and epitaxy technologies, manufacturing processes, engineered substrates and semiconductor devices. It has been involved in GaN research since 2001, and since 2009 it has been mass producing GaN epitaxy on sapphire substrates as well as free-

standing GaN single-crystal substrates, for applications including ultra-high-brightness (UHB)-LEDs and laser diodes. Using hydride vapour phase epitaxy (HVPE) growth technology, PAM-XIAMEN currently offers low-defect-density native (free-standing) GaN in customer-defined orientation including polar (c-plane Ga-face or N-face) and non-polar (a-plane and m-plane) GaN and AlN templates grown on sapphire and silicon or silicon carbide (SiC) substrates, as well as ultra-high-purity polycrystalline GaN.

"We are pleased to offer larger native SI GaN to our customers including many who are developing better and more reliable high-frequency, high-power GaN transistors," says the firm's Dr Shaka. "Our 50mm-diameter native SI GaN product has excellent resistivity

properties, just like our smaller SI GaN substrates, as corroborated by recent electrical resistivity mapping measurements carried out. The larger size and availability improve our native SI GaN boule growth and wafering processes," he adds.

"Our customers can now benefit from the increased device yield expected when developing advanced transistors on a larger square substrate," says Shaka. "Our larger square SI GaN substrates are natural by products of our ongoing efforts; currently we are devoted to continuously develop round 3" and 4" native SI GaN substrates."

PAM-XIAMEN notes that its improved SI GaN product line has benefited from strong technical support from Native University and Laboratory Center.

www.powerwaywafer.com

Soitec and Silian to jointly develop GaN template wafers

Soitec of Bernin, France, which makes engineered substrates including silicon-on-insulator (SOI) wafers (as well as III-V epiwafers through its Picogiga International division), and Chongqing Silian Optoelectronics Science & Technology Co Ltd, which supplies materials, devices and systems for the lighting industry, have partnered to jointly develop gallium nitride (GaN) template wafers using hydride vapor phase epitaxy (HVPE). The resulting GaN template wafers are expected to present cost savings for LED manufacturing.

The joint development agreement aims to validate the manufacturability and enable the commercialization of GaN template wafers using Silian's sapphire substrates and Soitec's unique HVPE technology. The partners plan to begin sampling GaN template wafers this year.

"Our strategy was to use production-proven silicon epitaxy equipment features and add our innovative gallium source and delivery system

to create high-productivity HVPE equipment," says Chantal Arena, VP & general manager of Soitec Phoenix Labs Inc of Tempe, AZ, USA, where the HVPE technology was developed. "We then successfully developed high-growth-rate processes that, combined with our low-cost precursor, leads to a more cost-effective GaN template than the ones produced by metal-organic vapor phase epitaxy," she claims.

"With our extensive sapphire substrate manufacturing expansion activities in China, we are very well positioned to take advantage of this opportunity and offer these high-quality templates in a cost-effective manner to our sapphire substrate customers," says Silian's chief operating officer David Reid.

"This development of HVPE technology introduces a revolutionary business model and allows LED makers to free up as much as 60% of their MOVPE capacity," reckons Soitec's president & CEO

André-Jacques Auberton-Hervé.

"LED makers can now focus on improving the more custom-designed layers that make up the light-emitting part of an LED," he adds. "In addition to this business opportunity, we are exploring the possibility of expanding our cooperation with Silian into the field of LED lighting, leveraging Soitec's expertise in epitaxial growth developed by our Soitec Phoenix Labs subsidiary in Arizona."

"Soitec and Silian have very attractive complementary technologies," comments Xiaobo Xiang, chairman of Silian's holding company China Silian Instruments Group (which entered the sapphire substrate sector in 2008 by acquiring Honeywell's sapphire business). "We look forward to exploring with Soitec the mutual beneficial business opportunities offered by the vast markets of materials, LEDs and lighting."

www.soitec.com

www.silianopto.com

EpiGaN starts 8-inch GaN-on-Si development

Aixtron SE of Herzogenrath, Germany says that new customer EpiGaN of Hasselt, Belgium, a start-up manufacturer of III-nitride epitaxial material, has commissioned two new MOCVD systems, able to operate in either multiple 6" or 8" configurations. It will use the systems to commercialize 6" GaN-on-silicon wafers for a range of power and RF electronics devices as well as to develop the next generation of 200mm GaN-on-silicon wafers.

The reactors were installed and commissioned by Aixtron Europe's service support team at EpiGaN's purpose-built facility in Research Campus Hasselt, Belgium.

Incorporated in 2010, EpiGaN was founded by chief executive officer Dr Marianne Germain, chief technology officer Dr Joff Derluyn, and chief operating officer Dr Stefan Degroote, as a spin-off of nano-electronics research center Imec in Leuven, Belgium. For more than 10 years, the founders jointly developed GaN-on-Si technology on

4" and 6" wafers at Imec, part of which has been licensed to EpiGaN. Early this month, EpiGaN closed its first capital round of €4m, to allow it to start volume production of GaN-on-Si epi material. Investors include Capricorn Cleantech Fund, Robert Bosch Venture Capital, and LRM.

EpiGaN aims to provide device manufacturers with early access to a unique, proven power-management and RF technology addressing key market segments such as power supplies for consumer electronics devices, and renewable and cleantech energy sources such as hybrid electric vehicles and solar inverters, RF power for wireless base stations, and smart-grid applications. The firm is also taking part in the EU project HiPoSwitch ('High Power Switch') to develop more compact and more powerful energy converters.

"After completing our funding round, we were ready to implement the strategic plan to establish our production capacities," says EpiGaN's Dr Marianne Germain. "After several

years of efficient joint collaboration with Aixtron towards GaN-on-Si, it was evident that these Close Coupled Showerhead systems from Aixtron perfectly suit our needs. The EpiGaN team has worked with Aixtron CCS MOCVD systems at Imec and we have jointly published numerous papers on GaN-on-Si development," she adds. "There are challenges ahead for high-voltage 200mm GaN-on-Si, but we are confident that the combination of our enduring expertise and the leading-edge equipment and process technology from our partner Aixtron will deliver all our objectives rapidly and efficiently."

"Aixtron is pleased to partner with EpiGaN as they advance equipment, processes and materials for larger area GaN-on-Si wafers," says Dr Frank Wischmeyer, Aixtron's VP & program manager Power Electronics, describing EpiGaN as one of Europe's newest and most promising start-ups.

www.epigan.com

ARC's CHES sapphire produces 5% brighter LEDs

Advanced RenewableEnergy Company LLC (ARC) of Nashua, NH, USA, a provider of c-axis sapphire growth technologies and turnkey solutions for the LED solid-state lighting market, has issued the white paper 'LED Manufacturing Study on CHES Sapphire' showing that sapphire grown from its proprietary CHES (Controlled Heat Extraction System) technology yields 5% greater LED brightness than the industry standard.

The study purposefully included sapphire material exhibiting a wide range of etch-pit density (EPD) levels to determine whether or not EPD affects LED manufacturing. The study took sapphire through the complete LED chip manufacturing process and concluded that all material passed LED standards and that no correlation was found between LED performance and EPD level of CHES wafers.

"We are pleased to see CHES achieving significantly higher LED brightness," says chief technology officer Dr Rick Schwerdtfeger.

ARC's study is the first subject in a series called 'CHES Foundations', explaining how CHES technology and CHES furnaces are enabling sapphire growth companies to meet increasing demand. Several customers have already announced that their CHES sapphire has been qualified by multiple LED makers.

ARC says that a key advantage of its CHES furnaces is much higher material utilization due to sapphire growth on the c-plane. This produces large-diameter substrates at much lower cost. Over 75% material utilization can be achieved using c-plane CHES furnaces while other methods are limited to 35%, it is claimed. CHES furnaces are also highly automated, reducing operating costs

and providing consistent output.

ARC says that its CHES furnaces are designed to produce higher-performance sapphire at larger wafer sizes compared to older technologies. They produce high-yield sapphire up to 10" diameter, providing higher efficiency downstream in the LED manufacturing process and upstream as c-plane growth significantly reduces waste.

The study results show that CHES-grown sapphire is capable of production-level performance, says the firm. As the HB-LED market expands, CHES provides sapphire growers with advantages including higher yield, a scalable technology, and better LED chip performance, it adds. ARC offers CHES furnaces and a variety of support services for crystal growth companies seeking addressing the HB-LED sector.

www.arc-energy.com



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Toshiba to start mass production of GaN-on-Si white LEDs in October

New line to be built at Kaga Toshiba Electronics' 200mm wafer fab

Tokyo-based semiconductor maker Toshiba Corp says that in October it will start mass production of white LEDs on a new production line that it will built in the 200mm wafer fabrication plant at Kaga Toshiba Electronics Co Ltd, a production base for discrete products in northern Japan.

The firm notes that, due to their energy efficiency and long life-span, white LED are gaining wide-scale adoption in general purpose lighting, TV backlighting etc, and the market is expected to grow from ¥700bn (\$8.75bn) to ¥1 trillion in fiscal 2013.

Toshiba is applying gallium nitride-on-silicon (GaN-on-Si) technology to the development of white LEDs.

Since January it has collaborated on white LED chip development with Bridgelux Inc of Livermore, CA, USA (which makes LED solid-state light sources specifically for the lighting industry).

In May, Toshiba said that, by combining its 200mm silicon wafer processing and manufacturing technology

By combining its 200mm silicon wafer processing and manufacturing technology with Bridgelux's crystal growth and LED chip structure, a prototype chip had been developed

with Bridgelux's crystal growth and LED chip structure, a prototype chip had been developed with a maximum optical output of 614mW from a 1.1mm-square chip (with an operating voltage of 3.1V and a drive current of 350mA). Toshiba aims to build on this to start mass production of white LEDs.

Toshiba says it is positioning white LEDs to be the next-generation growth area in its discretes business, which it aims to boost through establishing white LED production in addition to power devices (its current strategic product focus).

www.bridgelux.com

www.toshiba.co.jp/index.htm

Taiwanese LED maker Genesis investing \$35m this year in its China plant construction

Completion targeted for Q3/2012, with monthly capacity of 20,000–30,000 epiwafers

Taiwan-based LED chipmaker Genesis Photonics Inc of Southern Taiwan Science Park (STSP) in Tainan is scheduled to invest US\$35m this year on the construction of its plant in Kunshan, southern China (which began in September 2010, and should complete in third-quarter 2012), according to Digitimes.

The plant is a joint venture between Genesis and the Kunshan municipal government, which are providing 49% and 51% of the funds, respectively. Total investment is about US\$200m. Genesis' investment in the first phase amounts to US\$35.88m.

The firm is the largest provider of green epiwafers in China, and its order visibility has extended to the end of 2010. It started shipping blue LED chips in March, and expects the new line to account for 30–40% of its revenues in 2010.

Founded in 2002, Genesis pro-

vides gallium nitride (GaN)-based LED epiwafers and chips for lighting, display, backlight, and automotive lamp applications, as well as powerful LED chips for scientific, industrial and research applications. Before 2009, the firm focused mainly on producing green LED chips for outdoor billboards in China, with 90% of its products being green LED chips and just 10% being blue LED chips. However, as demand for white light LEDs has been growing, Genesis has been focusing on blue LED products, which accounted for 80% of total products in first-half 2012 compared with just 20% for green LED products.

According to chairman David Chung, China is the second-largest market for Genesis, comprising about 40% of its total revenue in 2011.

As the Kunshan plant is scheduled to be completed in Q3/2012, Gene-

sis will provide technologies and management while the municipal government will provide government resources and assist in business development, says Chung. The plant will procure 2-inch metal-organic chemical vapor deposition (MOCVD) equipment, and expects to have a monthly capacity of 20,000–30,000 epitaxial wafers as commercial production begins.

In the future, Genesis will have three production bases in the Greater China region: Tainan in Taiwan and Dongguan and Kunshan in mainland China. The Tainan plant will focus on technologies R&D and sales to international customers, according to the firm. Chung plans for the two mainland China-based plants to be solely responsible for supplying the firm's LED chips in China by 2015.

www.gpiled.com

www.digitimes.com/news/a201207

UCSB receives \$500,000 for SSLEC as Speck named Seoul Optodevice chair in solid-state lighting

At University of California Santa Barbara (UCSB) the Solid State Lighting and Energy Centre (SSLEC), a hub for research in energy-efficient lighting, power electronics and solar energy technology, has received a \$500,000 endowment from Korea's Seoul Optodevice Company to further its research on gallium nitride (GaN) for use in electronics and solid-state lighting.

UCSB professor of materials James Speck, a member of SSLEC's Executive Committee and director of the Interdisciplinary Center for Wide Band-Gap Semiconductors, has been named the campus' first Seoul Optodevice Chair in Solid State Lighting.

"Chung Hoon Lee and the Seoul Optodevice Company are leaders in the field, and have been long-standing supporters of UC Santa Barbara's Solid State Lighting & Energy Center, which is advancing the frontiers of research in energy-efficient solid-state lighting," says chancellor Henry T. Yang. "Professor Speck is world-renowned for his pioneering research in electronic materials and physical properties, and is the ideal

choice to hold this prestigious endowed chair."

The endowment represents an important partnership between UCSB and the Seoul Optodevice Company. Established in Korea in 2002, the firm engineers products with applications including outdoor and architectural lighting, LCD technology, and both visible (V-) and ultraviolet (UV-) LED products.

"Under the visionary leadership of Mr Chung Hoon Lee, Seoul Semiconductor and Seoul Optoelectronic Device Companies are leading the transformation to solid-state lighting," says Speck. "UCSB and the SSLEC have greatly benefited from the strong support from these two companies."

Most silicon-based semiconductors in existing electronics, such as those found in computer microprocessor chips and transistors, are highly inefficient in their use of energy, says UCSB. New processors that use the wide-bandgap semiconductor GaN (which can be used for high-frequency, high-power transistors capable of operating at high temperatures) offer increased

data processing capabilities while using minimal power.

"This endowment by Seoul Optodevice Company is critically important because our research in gallium nitride semiconductors places the college at the forefront of energy-efficiency technology," says Rod Alferness, dean of the College of Engineering. "Professor Speck is leading this charge and understands how our relationship with industry is a driving force behind discoveries in solid-state lighting."

Speck's research focuses on the relationship between thin-film electronic materials growth, and microstructure, as well as the link between microstructure and physical properties. He has worked extensively on the materials science of GaN and related alloys. Speck received the Quantum Device Award from the International Symposium on Compound Semiconductors in 2007. In 2010, he received the IEEE Photonics Society Aron Kressel Award for his work on nonpolar and semipolar GaN-based materials and devices.

<http://engineering.ucsb.edu>

Seoul Semiconductor launches nPola LED technology to boost brightness 5–10 times over existing LEDs

South Korean LED maker Seoul Semiconductor Co Ltd has unveiled a new LED product based on patented 'nPola' technology, which has been in development for over 10 years. The firm claims to be first to announce production of LEDs based on non-polar GaN. "This new product is the culmination of 20 years of core technologies development," says CEO Chung Hoon Lee.

Seoul Semiconductor says that the brightness of a power chip LED in mass production is currently about 100lm in warm white, but the new product produces 500lm. Brightness has hence been improved five-fold over the con-



LED bulb using nPola technology requires just one LED.

ventional LED based on equivalent die surface area. The firm expects further improvements to increase this to more than 10 times existing LEDs. As an example, when making an LED bulb for a 60W household bulb replacement, typically 10–20 packaged LEDs are used, but by using the new product the same brightness can be achieved with only 1–2 packaged LEDs.

GaN LED pioneer Shuji Nakamura, a professor at University of California, Santa Barbara (UCSB) and an advisor to Seoul Semiconductor, was present at the launch event to comment on the new technology.

www.seoulsemicon.com/en

InfiniLED announces access agreement with Ireland's Tyndall National Institute

μ LEDs to be made in institute's compound semiconductor cleanrooms

InfiniLED, a portfolio company of ScienceWorks Ventures plc (a London-based IP commercialization company with an operations centre in Cork, Ireland), has announced an access agreement with Tyndall National Institute, UCC (University College Cork), from which InfiniLED was spun off in April 2011. The access agreement allows InfiniLED's engineers to work within the institute's ISO 9001-certified compound semiconductor cleanrooms to fabricate the firm's μ LED (MicroLED) technology.

The μ LED technology was invented by a team led by Brian Corbett in Tyndall's III-V Materials and Devices group, supported and funded by Enterprise Ireland (EI). Based on free-standing gallium nitride (GaN), the μ LEDs have been developed as a next-generation source for miniature lighting applications. Advantages are said to include: a 10-fold reduction in the active light-emitting layer; minimal power consumption; optimum extraction efficiency (up to eight times more efficient than conventional LEDs when coupled to an application); a quasi-collimated beam; the formation of addressable arrays; a color range spanning UV-blue-green-yellow-orange; and good coupling efficiency with both glass and plastic optical fiber (POF).

"The μ LED technology brings huge technological advances to customers by controlling the light directly at the point where it is created," says InfiniLED's chief commercial officer & co-founder Dr Bill Henry (who worked on the development of the technology and the commercial opportunities while at Tyndall). "The μ LED technology solves important problems, such as the extraction efficiency of light from the chip and the beam angle of the emission," he adds. "Not only does this provide performance



Ireland's Tyndall National Institute.

advantages to the customer but it also simplifies the surrounding components of the system, resulting in cost savings."

In early June, InfiniLED closed a first-round investment of up to €1.6m, led by IL Investment Group of Quebec, Canada and including support from Enterprise Ireland. It will result in the formation of eight new high-tech positions, with up to 16 targeted by the end of 2013.

The investment should allow InfiniLED to continue development of its μ LED technology — marking the next step in moving the research from the lab into the market place — and enable it to grow the existing commercial interest, the firm reckons. It should also allow InfiniLED to build its team, to ramp-up development of the technology and to target new opportunities.

Post-investment, ScienceWorks remains InfiniLED's largest shareholder, along with senior management.

Under Enterprise Ireland's Business Partner Programme, Science-

Works chief operating officer Joe O'Keeffe, who had already spun out a series of companies and became InfiniLED's CEO, evaluated the commercial potential of the μ LED.

"The skills, infrastructure, ISO certification and capabilities at the Tyndall National Institute are unique with Ireland and the UK," says Joe O'Keeffe. "For InfiniLED to be able to access these capabilities will enable us to deliver products to customers in an efficient and timely manner. It will also allow InfiniLED to build on our technology base and to further enhance the performance," he adds. "The availability of wafer growth, chip fabrication and advanced photonic packaging & test facilities at the Tyndall National Institute allows InfiniLED to develop devices from raw materials to full systems without incurring the cost of acquiring such equipment and facilities itself. It means that InfiniLED can provide a range of solutions to customers based on μ LED technology in a form that is most suited to their requirements," he continues.

"This access agreement further strengthens the two-way relationship between Tyndall National Institute and InfiniLED," says Kieran Flynn, head of business development at Tyndall. "It demonstrates Tyndall's flexibility in working with Irish indigenous spin-out companies and assisting them in their growth trajectory. Tyndall will continue to work with InfiniLED's technology and team to incorporate the μ LED into future Tyndall client companies system solutions while InfiniLED brings their own extensive market and customer knowledge in their identified target growth areas. This is another example of the importance of the Government's investment in ICT (Photonics) convergence into new markets at Tyndall," he adds.

"As well as our core devices,

► InfiniLED also delivers unique solutions for customer needs," says Henry. InfiniLED is developing a range of LED light source modules based on its patented μ LED technology, licensed from Tyndall. "Technology developments currently under way will further boost the performance of the μ LED, including improved light collimation directly from the chip and further components integrated with the LED," notes Henry. "This engagement with Tyndall allows InfiniLED to develop solutions that are tailored at the chip level and to include all the required optical and control supports," he adds. "This enables InfiniLED to deliver plug-and-play solutions to customers across a range of markets including diagnostic devices, LED printing, microscopy and others."

" μ LED technology can reduce power consumption in displays,



At the InfiniLED investment launch event, Minister Seán Sherlock TD, IL Investments principal Najeeb Khalid and InfiniLED's CEO Joe O'Keeffe.

which results in increased battery life for devices such as mobile phones, laptops

Engagement with Tyndall allows InfiniLED to develop solutions that are tailored at the chip level and to include all required optical and control supports

or other consumer products. It enables new medical devices that are smaller, more efficient and more accurate," says Joe O'Keeffe. "The technology can also be used in individually switchable arrays. This allows their use for faster LED printing, microscopy and lithography applications," he adds. "Any product that requires controlled or the efficient use of light may benefit from this unique technology."

InfiniLED says that it has on-going development contracts with international customers, and expects to grow its customer base further in the coming months, aiming to bring the first μ LED-based products to market by the end of 2012. "The addressable market for InfiniLED's products and technologies are over €1bn," reckons Henry.

www.infiniled.com
www.tyndall.ie

mLED secures £378,000 in equity funding

Micro-LED start-up to increase staffing, enhance IP and market technology to initial customers

Scotland-based Braveheart Investment Group plc has announced a further investment in micro light-emitting diode company mLED Ltd of Glasgow, UK.

mLED's proprietary microLED platform technology was developed over a 10 year period at the Institute of Photonics at the University of Strathclyde, where over £7m was invested in research leading to the core patent. The firm was spun off in June 2010 with a £150,000 round of seed funding, led by investment from Braveheart via both the Strathclyde Innovation Fund (SIF) and the Alpha EIS Fund, supplemented by Scottish Enterprise's Scottish Seed Fund.

The micro-LEDs consist of dense arrays of thousands of high-brightness light emitters in a compact, integrated package. Unlike other micro-display technologies, micro-LEDs are pattern programmable and do not require external compo-

nents such as optics and switching matrices to modulate the light pattern, making them more compact and efficient, the firm claims.

The programmable micro-pixelated LED technology is reckoned to bring an order-of-magnitude improvement in light intensity over current micro-display approaches.

mLED reckons that its microLEDs can open up new segments within the nascent market for embedded pico projectors (in a broad range of portable devices, from bar code scanners to smart-phones). It is therefore developing

The additional funding will enable the firm to increase its personnel, enhance its intellectual property, and market its proprietary technology to initial customers

a roadmap of products aimed at a range of high volume embedded applications, and is already commercially engaged with leading system integrators.

In the latest equity funding round, led by Braveheart, mLED has secured an additional £378,000 from Braveheart's established network of private clients, the Scottish Enterprise Co-Investment Fund and members of both mLED's board and technical advisory council.

The additional funding will enable the firm to increase its personnel, enhance its intellectual property, and market its proprietary technology to initial customers, says Braveheart. "We are pleased to support this company, which has pioneering technology and an impressive management team," comments Braveheart's chief executive Geoffrey Thomson.

www.mled-ltd.com
www.braveheartinvestmentgroup.co.uk

SemiLEDs reports revenue up 16.5% quarter-to-quarter

Margins fall back due to excess capacity and Cree litigation settlement

For its fiscal third-quarter 2012 (to end-May), LED chip and component maker SemiLEDs Corp of Hsinchu Science Park, Taiwan has reported revenue of \$9.2m, up 16.5% on \$7.9m last quarter and 64% on \$5.6m a year ago, and exceeding the forecast 6% growth to \$7.9–8.9m.

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

Operating margin has fallen back from last quarter's negative 73% to negative 87% (compared with negative 70% a year ago). Margins were negatively impacted by excess

capacity charge of \$1.6m and a provision for potential patent litigation settlement of \$1.5m. In late June, SemiLEDs and LED chip, lamp and lighting fixture maker Cree Inc of Durham, NC, USA agreed to end their respective patent infringement litigation against each other. As part of the settlement, SemiLEDs agreed to make a one-time payment to Cree for past damages, and agreed to an injunction (effective 1 October) prohibiting the importation and sale of its accused products in the USA. The parties also agreed to withdraw the remaining claims without prejudice to the right to assert their respective claims in the future.

On a non-GAAP basis, net loss was \$8m, up from \$6.1m last quarter and almost double the \$4.3m of a year ago. However, cash used in operating activities has been cut from \$4.5m last quarter to \$2.5m. Hence, although cash and cash equivalents fell from \$66.4m to \$62.9m during the quarter, this cash burn is less than last quarter.

"While we have been prudent in our spending this past year, we have continued to invest in R&D [for which expenses have more than doubled from \$1m a year ago to \$2.2m]," says chairman & CEO Trung Doan.

In late June, SemiLEDs launched its Enhanced Vertical (EV) LED product series, which features the firm's vertical chip structure on a patented metal alloy substrate, offering advantages in optical output and high thermal conductivity, it is claimed. However, the EV LED has been designed to also have higher thermal endurance, ensuring better reliability at higher temperatures.

"These products, which we are introducing globally, increase our addressable market and are the foundation for future revenue growth. We have already received interest and have some customers that have begun the evaluation process," Doan adds. "We look forward to announcing more innovative products in the months to come."

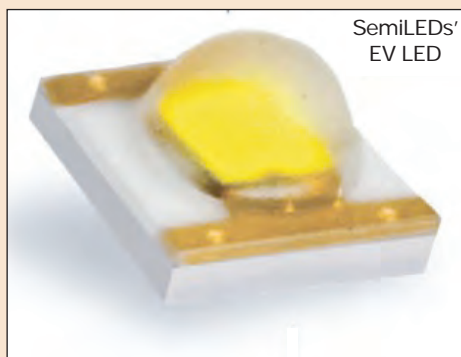
Enhanced Vertical LEDs launched for higher thermal endurance

SemiLEDs has launched its new 'Enhanced Vertical' (EV) LED product series.

The new device features SemiLEDs' vertical chip structure on a patented metal alloy substrate, offering advantages in optical output and high thermal conductivity, it is claimed. However, the EV LED has been designed to also have higher thermal endurance, ensuring better reliability at higher temperatures.

The EV LEDs are available for global sales and immediate sampling in blue, green and UV and chip sizes of 0.4mm x 0.4mm through 1.5mm x 1.5mm.

The first LED to be launched, the C35, features narrow binning, low thermal resistance and a special optical design.



The C35 is SemiLEDs' first series of products to feature new Color-Precision technology, which offers greater flexibility when making color choices. The C35 can yield consistent color within a single 7-, 4- or 2-step MacAdam ellipse centered in ANSI-defined standard color spaces.

Also, the C35 uses a ceramic submount, which gives it low thermal

resistance ($R_{th} < 8^{\circ}\text{C/W}$). Lower thermal resistance allows heat to be effectively driven from an LED's junction, both extending the lifetime of the LED and providing better light quality and reliability. Luminaires will experience more stable lumen maintenance and consistent correlated color temperature (CCT) over time due to the C35's advantages in thermal management, SemiLEDs reckons, suiting general lighting applications.

Another key feature is the special optical design, which makes it easy to integrate with secondary optics, the firm adds. The design ensures that light is distributed uniformly across the beam and diminishes the 'yellow ring' effect typically found in white LEDs, it is claimed.

www.semileds.com

Luminus opens Asia office in Taiwan

In response to growing demand in the Asian market, Luminus Devices Inc of Billerica, MA, USA, which makes PhlatLight (photonic lattice) LEDs for illumination applications, has opened an office in Taoyuan County, Taiwan.

Managed by Robin Hung, sales director for the Asia Region, the office offers sales support, customer service, field application engineering, and operational engineering to key customers, suppliers and contract manufacturing partners in Asia.

Hung oversees a growing staff that will be responsible for managing Luminus' current relationships and future business opportunities in display, entertainment and specialty lighting vertical markets across Asia.

"Opening an office in Taiwan expands our global commercial and technical support reach, as the

office's location provides a strategic hub for Luminus Devices that will drive improved customer service, help us to better technically serve our customers, as well as improve our speed to market for many of our products," says president & CEO Keith T. S. Ward. "We have seen our business in Asia grow dramatically over the past few years in each of our vertical market segments," he adds. "The Taiwan office is central to Asia, which is the hotspot for LED technology and manufacturing, and it will only enhance our ability to provide world class innovative solutions for our customers. Further, many of our channel partners are located in the region, and the new office will allow the company to improve communications and business with these partners."

www.luminus.com

Wavien demos million-candle-power flashlight using Luminus LED

At the InfoComm 2012 trade show in Las Vegas (13–15 June), Wavien Inc of Valencia, CA, USA demonstrated an LED flashlight producing output of 1 million candle power, utilizing proprietary Recycling LED (RLT) technology and the new SBT 70 round white LED (launched in April) made by Luminus. The flashlight far surpasses the brightness of currently available LED flashlights using standard technologies, Wavien claims, and is within the brightness range of arc-lamp-based flashlights and spotlights.

Wavien's RLT technology recycles high-angle emissions from the LED into low-angle emissions to be collected by the output lens system, increasing the system's light output at small angles and hence increasing its brightness.

"The net result is a narrower beam with higher brightness at the target," says president & CEO Dr Kenneth Li, who is also the inventor of the recycling technology.

"This unique design enables LED-based products to have increased total brightness by over 80% for most LEDs, and it was recently found that, for high-performance LEDs, the brightness increases by over 100%," Li adds. "This brightness improvement is provided by adding a simple low-cost reflector with an aperture to standard LED packages," he explains. "The diameter of the opening — which determines the amount of recycling — and the total size of the reflector can be scaled to meet the user's needs," Li continues.

"We continue to optimize the RLT system and are actively developing a variety of other applications, including gobo projectors, downlights, search lights and general lighting uses," Li concludes.

Wavien made evaluation samples of RLT LEDs available for purchase at InfoComm, as well as through its online Wavien Shop.

www.wavien.com/shop

IN BRIEF

LEDs displace lasers in Smart Vision Lights machine vision illumination source

Luminus Devices says that its Big Chip LED technology has been selected by machine vision lighting maker Smart Vision Lights of Muskegon, MI, USA for its new product line of illumination sources. Luminus' SST-90 LED is at the heart of Smart Vision Lights' SP30 Series LED structured light pattern projector for the machine vision industry.

Luminus says that, compared with laser-based pattern projectors, its LEDs enable higher-resolution lines with sharper edges and more uniform illumination — and without laser speckle artifacts.

"Luminus has an established track record of displacing traditional high-power illumination sources with its Big Chip LED technology," says Chuck DeMilo, global director of product marketing. "In general lighting and entertainment lighting we are enabling the conversion from metal halide to LED. In projection display we are displacing UHP [ultra high pressure] mercury sources. Now in machine vision we are seeing success in converting lasers based systems to LED," he adds.

"We selected the Luminus SST-90 for the large die footprint and high lumen output," says Smart Vision Lights' design engineer Matt Pinter. "The SST-90 gives us better uniformity across the pattern and provides much higher output than typical 1mm² LEDs," he adds. "The new SP30 Series structured light LED source is selling really well. We are competing against and taking business from lasers," Pinter concludes.

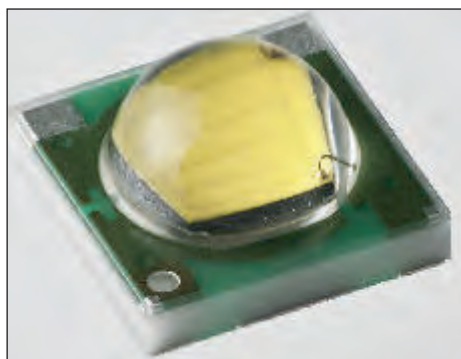
www.smartvisionlights.com

Cree launches XLamp XP-G2 LEDs, boosting efficiency by 20% in XP footprint

LED chip, lamp and lighting fixture maker Cree Inc of Durham, NC, USA has launched the XLamp XP-G2 LED to deliver luminaire manufacturers up to 20% more lumens per watt and 2.5 times the lumens-per-dollar over the original XP-G LED. Cree says that the brighter, more efficient XP-G2 LED provides a boost in performance and enables manufacturers to use fewer LEDs to get the same brightness at lower cost or to increase brightness levels using the same LED count and power.

Characterized and binned at 85°C, the XP-G2 LED leverages the same footprint (3.45mm x 3.45mm) and is compatible optically with the original XP-G, providing drop-in-ready performance enhancements to shorten the LED fixture design cycle and improve customer time to market. The XP-G2 can enable a broad range of high-lumen applications, from indoor and outdoor to portable and lamp retrofits, says Cree.

"We have many designs using



Cree's new XLamp XP-G2 LED.

Cree's XLamp XP-G LED," says William Weiss, partner and director of technology at LED lighting product maker MSI Solid State Lighting of Deerfield Beach, FL. "The new XP-G2 allows us to take full advantage of the benefits of Cree's latest technology without any significant design changes, improving time-to-market," he adds.

Built on Cree's SC³ Technology Platform, the XP-G2 LEDs combine high light output, reliability and efficacy to deliver up to 151 lumens

per watt at 350mA, 85°C or 165 lumens per watt at 350mA, 25°C in cool white (both at a color temperature of 6000K). In warm white (3000K), the XP-G2 LED delivers up to 133 lumens per watt at 350mA, 85°C or 145 lumens per watt at 350mA, 25°C. The SC³ Technology Platform leverages Cree's silicon carbide (SiC) technology, features advancements in LED chip architecture and phosphor, and showcases a new package.

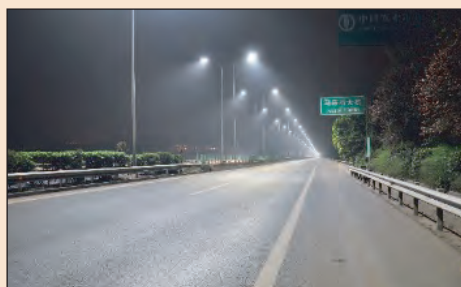
Luminaire makers seeking ENERGY STAR qualification will have access to specification and performance data, including LM-80 reports, which can speed time to market, says Cree. XP-G2 LEDs are a 'successor' product to the original XP-G LED for LM-80 data — accelerating qualification of luminaires using just 3000 hours of LM-80 data, instead of the normal 6000 hours. The XP-G2 LED is also UL-recognized and features a level 4 rating.

www.cree.com/xpg2

China's largest municipal street lighting project completed

The Beibei district of Chongqing, China has completed the installation of more than 20,000 street lights featuring 1.9 million XLamp XP-E and XP-G LEDs made by Cree. The country's largest municipal intelligent lighting control project began in July 2011, and includes nearly 16 miles of highway, with Cree LED-based luminaires installed along 119 streets and one tunnel. It is estimated that the installation will result in annual maintenance and electricity savings of more than RMB19.5m (about \$3m) and 17.6 million kWh.

The Municipal Bureau of the Beibei District initiated the project to improve the living environment for local citizens and to meet China's stringent roadway lighting requirements for light efficacy, brightness, luminance, heat dissipation and service lifespan.



LEDs installed on Yuwu Highway.

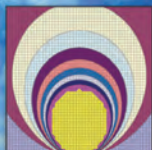
Engineered by China-based LED lighting firm Chongqing Silian Optoelectronics Science and Technology Corp, the new street lights replace sodium-vapor lighting along the Yuwu Highway, extending from Chongqing to Wusheng. Silian developed and manufactured the intelligent lighting control system, which features a wireless network management system that

detects lighting issues with sensors and can adjust the brightness of the LED street lights in accordance with vehicle and pedestrian traffic flow, enabling optimal lighting and energy efficiency.

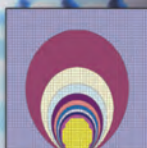
"Cree LEDs emit high-quality light with low heat dissipation that meets China's lighting standards while saving the municipality millions of Renmenbi," comments Silian's chief operating officer David Reid.

"Cree LEDs are perfect for large-scale lighting projects such as the Beibei District installation," reckons Tang Guoqing, senior advisor, Cree Hong Kong Ltd. "Designed to last more than 50,000 hours, Cree XLamp LEDs offer the high efficiency and easy integration with intelligent lighting systems needed to reduce overall costs," he adds.

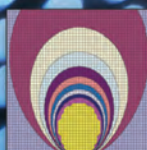
www.cree.com



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IN BRIEF

Cree expands CR Series of LED downlights

Cree Inc of Durham, NC, USA has launched a new 4" CR4 LED downlight and a higher-lumen-output 6" CR6 downlight. Both are powered by Cree TrueWhite Technology to deliver a color rendering index (CRI) of 90+. The new downlights install into most standard 4" and 6" recessed housings, suiting both residential and light commercial, new construction or retrofit applications.

The CR4 LED downlight delivers 575lm and more than 60lm/W, and is a direct replacement for a 50W 4" incandescent downlight.

The CR6 LED downlight delivers up to 800lm and up to 67lm/W, and is a direct replacement for a 90W 6" incandescent downlight. Cree adds that the downlight uses 87% less energy than comparable incandescent lighting. In particular, the CR6-800L uses 12W of input power. With typical commercial usage of 12 hours per day and the national average \$0.11 per kWh electric costs, lighting-related HVAC impact and re-lamp maintenance reductions, many upgrade installations will pay for themselves in less than one year, it is reckoned.

The CR Series is dimmable to 5%, designed to last 50,000 hours and has a five-year warranty.

"We continue to see high demand for Cree's original CR6-575lm LED downlight but, with the introduction of the CR4 LED downlight and the new high-lumen-output CR6 downlight, Cree now addresses even more applications, provides a remarkable price-point and meets the needs of our residential and commercial spaces," comments said Rick Helsel, senior account manager, Rexel USA.

www.cree.com/cr4

www.cree.com/cr6

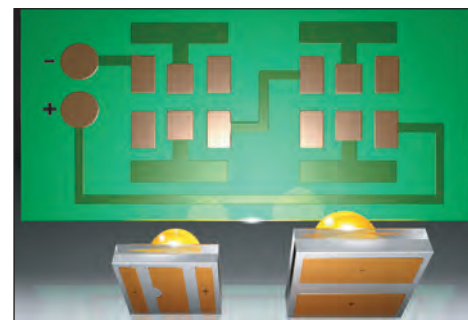
Osram offers uniform solder pad design based on Oslon LEDs to enable second sourcing

Since not all LEDs are the same (regarding not only their performance and dimensions but also their solder pads and processing options), Osram Opto Semiconductors GmbH of Regensburg, Germany has developed a concept for uniform solder pads based on its Oslon LED family that makes it easier to use LEDs from different (second source) manufacturers and reduces the costs of storage and process modification.

Second sourcing is a standard practice for LED components because of the need for security of supply, says Osram Opto. Ideally, it should be possible to incorporate second-sourced products into current production without incurring additional costs. However, components from different manufacturers generally differ in terms of their dimensions and shape of their solder pads. As a result, typically two different soldering boards are needed for LEDs from two different manufacturers, driving up costs for procuring and storing the boards and also for modifying the process to fit each board.

Osram Opto has developed a concept for ceramic LED components, such as the Oslon family, that makes the board solder pad design so adaptable that it can be used for LED components from at least two different manufacturers. The concept can also be used for metal core, FR4 and ceramic boards.

"Only a small adjustment to the process is needed, and the benefits are real and long-term," says Dr Christian Gartner, Oslon project manager in Product Development General Lighting. The combined board design comes from the design of one of the two LED components. The individual solder surfaces are divided into segments —



Osram uniform solder pad design.

electrically connected and electrically disconnected. By selecting appropriate spacings between the solder surfaces, the second LED product — rotated by 90° — can be attached to the uniform board design. The anode and cathode of the two LED components are connected to the same electrically contacted segments. By dividing the solder surfaces, the two LED types automatically align themselves to the edges of the solder surfaces during the reflow solder process. For both LED components, the luminous area is in the same lateral position on the board — i.e. in the same alignment in the board plane. If the LEDs have the same emission behavior, the same secondary lenses and reflectors can be used. So, neither the LED components nor the end application are changed in terms of their characteristics.

Osram Opto says that the new concept makes it much easier to handle LED components from different manufacturers because there is no longer the need to make modifications to the board design. Also, there is no need for duplicated storage, reducing costs still further. "The concept for a flexible solder pad design gives our customers the freedom to incorporate a second source for our high-power LED components without having to suffer restrictions due to mechanical parameters," summarizes Gartner.

www.osram-os.com

Only one adjustment to the board layout is required

Osram Opto's Oslon Signal blue LED boosts visibility for emergency vehicle lighting

Osram Opto Semiconductors GmbH of Regensburg, Germany has launched the Oslon Signal LED, which uses special thin-film chip technology to provide powerful blue light. This enables much brighter signal lighting to enhance the visi-



Osram Opto's new Oslon Signal LED provides powerful blue light.

bility that is critical for police and emergency services vehicles. The LED can be operated at a high current and provides steady brightness even in the most demanding applications, the firm adds.

The Oslon Signal emits blue light with a wavelength of 472nm with luminous flux of 52lm at a drive current of 350mA. All color bins (groups) comply with the US and EU standards for signaling, in particular for emergency vehicle lighting. The Oslon family's package platform (which consists of a ceramic substrate with built-in connecting contacts and a silicone lens) remains stable and resistant to aging caused by the short-wave blue light.

The Oslon Signal incorporates the firm's UX:3 chips, which can operate at very high performance levels even at extremely high currents. This is a key aspect, says Osram, as blue signal light is often pulsed and therefore requires even greater luminous power at high current. Despite this, the LED measures just 3mm x 3mm and is equipped with an electrically isolated heat slug, so it can be mounted easily and conveniently in combination with a conventional FR4 board. In addition, the lens has a radiation angle of 80° and provides a highly symmetrical light output. The Oslon Signal can also be easily mounted in existing emergency vehicle lighting applications to provide significantly brighter signal lighting.

"Our development team has succeeded in a very short time in doubling the brightness of blue LEDs, resulting in our being able to offer the world's brightest product in this sector," says marketing manager Jennifer Rieder. "It significantly contributes to greater road safety, as emergency vehicles can be seen sooner and better."

The Oslon family of LEDs also includes other colors such as red, yellow, green and white. They all use the latest thin-film chip technologies, making them effective in a broad range of applications including emergency vehicle lighting, auxiliary signaling, warning beacons and other such applications.

www.osram-os.com



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IN BRIEF

TRUMPF selects AIX 2800G4-TM system for As/P-based high-power laser production

TRUMPF Photonics Inc of Princeton, NJ, USA has taken delivery of an Aixtron AIX 2800G4-TM MOCVD reactor for high-power laser applications.

"TRUMPF Photonics has been delivering high-quality laser components to the high-power laser industry for over 10 years. The recent increase in market demand has required us to upgrade our manufacturing capabilities," says Dr Carl Miester, head of production semiconductors at TRUMPF Photonics. "We have performed an exhaustive search of the current MOCVD technologies. The enhancements Aixtron has made in the control of the MOCVD process has made it the ideal platform for the challenging structures required for the high-power laser market," he adds.

"Aixtron has maintained its investment in the development of MOCVD technology for all compound semiconductor material systems such as As/P materials for the solid-state laser markets," says Aixtron's chief operating officer Dr Bernd Schulte.

"TRUMPF's decision to continue to use our platform provides confirmation that these investments have been successful."

TRUMPF Photonics Inc was formerly part of Princeton Light-wave Inc, before acquisition by industrial laser manufacturing subsidiary TRUMPF Inc of Farmington, CT. The TRUMPF Group has 58 subsidiaries and branch offices in more than 26 countries, employs over 8500 people, and generates sales exceeding \$2.76bn.

www.aixtron.com

Osram's low-profile Mini Midled 850nm infrared LED claims highest radiant intensity of its size class

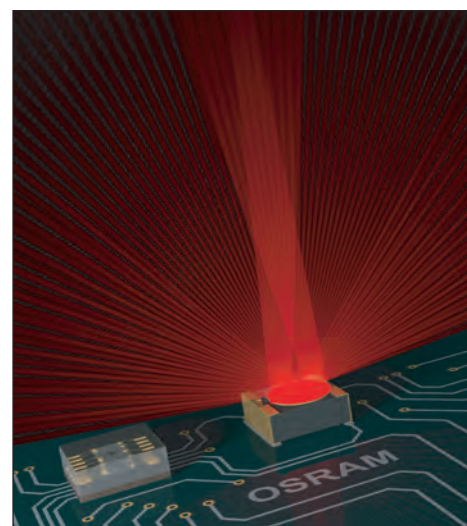
Osram Opto Semiconductors GmbH of Regensburg, Germany says that its new infrared Mini Midled is only 0.9mm high but produces a narrow and intense beam of infrared light. With radiant intensity of 60 milliwatts per steradian (mW/sr) at a drive current of 100mA, it is claimed to outperform other comparable devices. The low-profile surface-mountable emitter particularly suits proximity sensors in devices where space is limited and for light barriers.

Osram Opto says that in many sensor applications it is not only the optical power of an emitter that is important but also whether the available light is widely spread or concentrated in a narrow high-power beam, characterized by the half-angle. The radiant intensity (in watts per steradian) indicates the optical power within a solid angle and hence defines the intensity of the emitted light beam.

The Mini Midled's emission half-angle is just 17°, producing a narrow light beam and a radiant intensity of 60mW/sr at 100mA by focusing the light with a metalized reflector integrated into the device. The new infrared LED offers a high output despite its small dimensions of just 2.3mm x 1.95mm x 0.9mm.

The Mini Midled is the second SMT device from Osram Opto in MID (molded interconnected device) technology after the 1.6mm-high Midled. Due to new package technologies, Osram has managed to reduce the total height of the new infrared emitter to less than 1mm, but the new device can still be processed in the usual way.

Small and powerful infrared diodes with a wavelength of 850nm, such as the low-profile narrow-beam Mini Midled, offer major benefits in applications where there is little space but where high radiant intensity is needed, says the firm. Typical applications include light barriers, smart



Mini Midled's narrow intense light beams offer zero crosstalk, suiting light barriers and proximity sensors.

phones and optical touch screens.

"The low-profile Mini Midled is particularly suitable as an emitter for proximity sensors in smart phones and similar devices because it takes up very little space and yet delivers high power," says marketing manager Bianka Schnabel. "Thanks to its sophisticated design, it also considerably reduces optical crosstalk, so no optical shielding is required, which makes life easier for designers."

Proximity sensors are a combination of an emitter and a detector. The emitter illuminates an approaching object, and light reflected from the object is received by the detector. For proximity sensors to operate properly it is key that no light from the emitter reaches the detector directly (crosstalk). This is precisely what often happens with devices not equipped with a metalized reflector, notes Osram Opto. However, with the Mini Midled there is no need for shielding and the overall design is much simpler, the firm claims.

Also, the non-metalized surfaces are dark colored, so the Mini Midled can be mounted inconspicuously behind a smart-phone cover.

www.osram-os.com

UCSB develops first violet nonpolar vertical-cavity laser

Polarization-locked electrically injected VCSEL on m-plane GaN operated at room temperature

University of California, Santa Barbara (UCSB) have developed what is claimed to be the first violet nonpolar vertical-cavity surface-emitting lasers (VCSELs) based on m-plane gallium nitride (GaN).

The latest development is reckoned to open up possibilities for higher-optical-efficiency lasers at greatly reduced manufacturing costs for a variety of applications.

"We have demonstrated working, electrically injected nonpolar m-plane nitride VCSELs lasing at room temperature, and have shown that such devices are naturally polarization-locked along the crystallographic a-direction of the wurtzite crystal," says Dr Daniel Feezell, project scientist with Nakamura's lab. "This is in contrast to the majority of VCSELs, which are typically randomly polarized," he adds. Feezell directed the research effort with professor Shuji Nakamura and professor Steven DenBaars, co-directors of UCSB's Solid State Lighting and Energy Center (SSLEC), and graduate student Casey Holder. Their findings have been submitted for publication.

"This is the first report of a non-polar VCSEL," claims Nakamura, a professor of Materials at UCSB. "The nonpolar VCSEL has a lot of advantages in comparison with conventional c-plane devices. One major advantage is that the light polarization is locked to one direction," he adds. "This device could be used for a variety of applications, such as lighting, displays, sensors, and technology that requires energy efficiency and small form-factor."

VCSELs offer advantages over conventional edge-emitting laser technology for some applications, explains UCSB. On-wafer testing of VCSEL arrays during the manufacturing process, for example, can save costs compared to edge-emitting lasers that require additional steps before they can be tested.

Also, VCSELs exhibit low threshold currents, circular and low divergence output beams, and are easily integrated into two-dimensional arrays.

The nonpolar VCSEL platform also provides high optical gain, which helps to increase optical efficiency

of devices. "The nonpolar VCSEL could enable new products and applications, such as pico-projectors for smartphones, mobile cinema, or even automotive lighting," says DenBaars, professor of Materials.

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Finisar to acquire RED-C Optical Networks

EDFA, Raman & Hybrid amplifier technology to boost 40-100G ROADMs

Fiber-optic communications component and subsystem maker Finisar Corp of Sunnyvale, CA, USA has agreed to acquire RED-C Optical Networks Inc, a Delaware corporation with subsidiary operations in Tel Aviv, Israel. Founded in 2000, RED-C has more than 140 subsidiary employees, all in Israel.

The acquisition will broaden Finisar's product lines primarily for telecom applications by adding key amplification technologies, including erbium-doped fiber amplification (EDFA), Raman amplification and dynamic Hybrid amplification modules. These technologies are considered critical for reconfigurable optical add-drop multiplexer (ROADM) line-cards and are increasingly important in cost-effectively extending the reach of transceivers and transponders, especially for 100Gb/s and 40Gb/s coherent transmission, ultra-long repeaterless links, and low latency networks.

"RED-C has been an innovator in optical amplification, which we view as an increasingly critical technology as networks get faster and more complex," says Finisar's CEO Eitan Gertel. "As we have further penetrated the line-card market with our differentiated WSS [wavelength-selectable switch] technology, we see this acquisition as a tremendous opportunity to further innovate for our customers and advance our vertical integration strategy," he adds.

"We expect RED-C's high-performance EDFAs and Raman amplifiers, currently deployed in optical networks around the globe, to continue to deliver strong growth for the RED-C business," says John Clark, Finisar's executive VP, technology and global R&D.

"Going forward, we anticipate additional growth opportunities for the novel Hybrid Raman EDFA platform," he adds. "The continuing rapid growth in global bandwidth demand is driving a major transition to coherent transmission and mesh topologies for optical networks. These new networks can deliver lower cost per bit and improved resilience, but are expected to require advanced optical amplification technologies to deliver optimum performance," Clark continues. RED-C's Hybrid amplifier products, based on RED-C's core underlying IP, are unique in providing improved performance versus standalone EDFA and Raman optical amplifiers, it is claimed.

"We expect RED-C's Hybrid optical amplification platform to replace standard EDFAs for next-generation LH [long-haul] and ULH [ultra-long-haul] optical networks," he adds.

"We have been impressed with the RED-C amplifiers in terms of their performance and quality," comments Mohamad Ferej, VP R&D of Transmode of Stockholm, Sweden, which supplies packet-optical networking solutions for the transport of data, voice and video traffic.

"For next-generation networks, there will be an increased need for advanced EDFA, Raman and Hybrid amplifier solutions that RED-C provides," he adds. "With the addition of optical amplifiers from RED-C, Finisar is now offering a complete portfolio of optical components and sub-systems to support our mission to develop innovative network solutions."

The acquisition will be effected by the merger of RED-C with a subsidiary of Finisar. Finisar will pay about \$23.7m in cash in initial consideration for all of RED-C's outstanding equity. As of 31 March, RED-C had \$3.2m of cash and no debt. Finisar will also pay to stockholders and certain RED-C employees up to an additional \$20m payable in cash or shares of Finisar common stock at Finisar's option, subject to the achievement of financial performance targets related to RED-C products and technologies during 2013 and continued employment with Finisar.

Following the acquisition, RED-C will operate as a subsidiary of Finisar, with principal operations continuing at its current facility in Israel. Finisar expects the acquisition to be slightly positive to non-GAAP earnings per share in its fiscal year to end-April 2013. The acquisition is expected to be completed by end-July, subject to certain closing conditions.

www.red-c.com

www.finisar.com

NeoPhotonics' preliminary Q2 revenue estimate exceeding projections, rising 20% year-on-year

Based on preliminary estimates, NeoPhotonics Corp of San Jose, CA, a vertically integrated designer and maker of both InP and silica-on-silicon photonic integrated circuit (PIC)-based modules and subsystems, expects revenue for second-quarter

2012 to exceed its previously stated revenue guidance of \$55–61m, rising more than 20% from \$52.1m a year ago (rather than the forecast 11%) to set a new revenue record. This would also be up significantly on last quarter's \$54.2m.

The acceleration of revenue growth was driven primarily by increased demand in a range of products for high-speed coherent networks, high-speed client applications and access networks.

www.neophotonics.com

Oclaro and Opnext complete merger

Optical communications and laser component, module and subsystem makers Oclaro Inc of San Jose, CA, and Opnext Inc of Fremont, CA, USA have announced shareholder approval of their merger (announced in late March). Opnext shareholders will receive a fixed ratio of 0.42 shares of Oclaro common stock for each of their Opnext shares. The combined firm will operate under the Oclaro name, but has unveiled a new logo and brand identity.

"The new Oclaro boasts one of the broadest and vertically integrated product lines in the industry," reckons chairman & CEO Alain Couder. "By transmitting data over fiber at increasing speeds, our customers have made possible new and fast-growing applications such as social networking, video streaming, and cloud computing," he adds. "The ability to control the power of lasers as a heat and energy source is transforming healthcare, material processing and consumer electronics. Through this merger, we have

assembled the optical technologies, products and expertise at the heart of this new world of innovation."

Oclaro is now reckoned to be the second largest provider of optical components, modules and subsystems to the optical communications, industrial and consumer laser markets, with \$833m in combined revenue for the fiscal year ended 2 July 2011, and about 3200 staff. The firm gathers over 30 years of combined optical technology expertise from firms such as Hitachi, Nortel, Alcatel, Marconi, Corning, Opnext, Bookham and Avanex.

The firm's portfolio of products includes components, modules and subsystems that transmit, receive and amplify light signals over fiber-optic networks to deliver high-speed services in the core optical network, enterprise and data-center markets. Also, its laser diodes deliver the power needed for cutting, marking, welding, heating and illumination for applications in consumer electronics, industrial and medical markets.

New board & management team

Alain Couder has been named chairman & CEO of the combined firm, with Opnext chairman & CEO Harry Bosco joining the board, which also includes the following independent directors: Edward Collins, Kendall Cowan, Greg Dougherty, Lori Holland, Dr David Lee, Marissa Peterson, Bill Smith, and lead independent director Joel A. Smith III.

Reporting to Couder on the executive team are: Jim Haynes, president, Global Business; Yves LeMaitre, chief commercial officer; Terry Unter, chief operating officer; Kei Oki, president, Oclaro Japan Inc; Tadayuki Kanno, chief operating officer, Oclaro Japan Inc and general manager, Modules and Devices business unit; Jerry Turin, chief financial officer; Kate Rundle, executive VP, general counsel & corporate secretary; Kathy Zwickert, executive VP, human resources & communications; and Bob Quinn, chief information officer.

www.oclaro.com

Opnext demos record 3300km transmission distance using 100G coherent PM-QPSK subsystem on SURFnet DWDM infrastructure

Opnext and SURFnet, the National Research and Education Network (NREN) in The Netherlands, have announced a successful 100Gbps coherent field trial between the National Supercomputing Center (SARA) in Amsterdam and CERN (Conseil Européen pour la Recherche Nucléaire) in Geneva. Opnext used its OTS-100FLX 100G digital coherent subsystem for the field trial, utilizing next-generation 100G single-carrier technology and soft-decision forward error correction (SD-FEC) to optically link Amsterdam to Geneva with a transmission distance of 1650km using only erbium-doped fiber amplifiers (EDFAs).

To further demonstrate the subsystem's performance, the embedded fiber link consisted of a combination of the relatively high-nonlinear TW+ and TWRS fibers.

Furthermore, the circuit was optically looped back in Geneva, creating a 3300km circuit. The looped-back 3300km link operated error-free for more than 23 hours (bit-error rate, BER < 10⁻¹⁵) over the entire C-band and over a range of launch powers, highlighting the upgrade potential of the link to 8Tbps in the future using 100G coherent transponders.

"This trial is another clear demonstration that coherent 100Gbps PM-QPSK [polarization multiplexed quadrature phase-shift keying] transmission technology is tolerant to a very large range of impairments (i.e. chromatic dispersion, polarization mode dispersion, noise) and allows the use of alien wavelengths in research networks over DWDM [dense wavelength division multiplexing] systems from multiple vendors," says Roeland Nuijts,

Optical Network Architect for SURFnet. "Transmission distance and tolerance against different impairments will be critical going forward as we look to build out international networks across geographic and administrative borders in order to realize a global facility for research networking," he adds.

The Opnext subsystem consists of a suite of OTS-100FLX 100Gbps flexponder line cards and a newly released OTS-mini ETSI shelf with a 4RU small form factor.

"It is great to see the results of our 100Gb coherent product development deliver both the capacity and reach needed to scale next-generation optical networks around the world," says Mike Chan, president of Opnext's subsystems business unit.

www.surfnet.nl/en

www.opnext.com

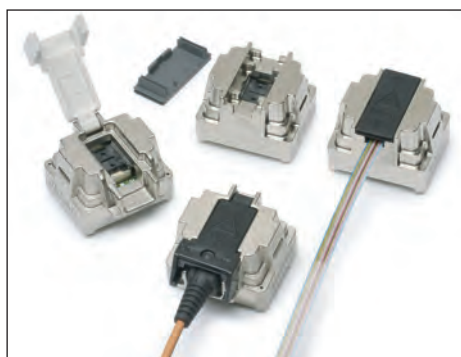
Avago launches 120Gbps parallel-optic modules for cloud computing and data centers

Avago Technologies has announced the availability of production volumes of 120Gbps multi-channel optical transmitter and receiver modules for 'inside-the-box' data-center applications and a CXP pluggable transceiver for board-edge 'box-to-box' and 'rack-to-rack' communications.

The firm says that, driven by exploding demand for online media and applications in a cloud computing environment, the modules suit communications within data centers, server farms, network switches, telecom switching centers and other high-performance embedded applications that require high-speed data transfers. System applications include data aggregation, backplane communications, proprietary protocol data transfers, and other high-density/high-bandwidth applications.

"Avago is delivering the industry's highest optical port density, resulting in the best bandwidth per dollar and the lowest power," claims product line manager Sharon Hall. "No matter what a customer's high-density optical interconnect specifications are, Avago has a solution and form-factor to meet their needs," she adds.

The stand-alone MiniPOD transmit



Avago's new MiniPOD 120G modules.

and receive modules — the AFBR-81uVxyZ and AFBR-82uVxyZ, respectively — each contain 12 uni-directional channels (lanes) that can each transfer data at 10.3125Gb/s using 64b/66b encoding for an aggregate data rate of 120Gb/s for each module. The CXP pluggable edge-mount transceiver module (AFBR-83PDZ) is an integrated solution that contains 12 transmit and 12 receive lanes that operate at the same data transfer rates as the MiniPOD modules.

The MiniPOD modules deliver what is claimed to be the highest front panel density in the industry, with 36 times the density of standard SFP+ solutions. For users needing a pluggable solution, the

CXP transceivers are half the cost per 10Gbps lane compared with standard pluggable SFP+ solutions, it is reckoned. Both MiniPOD and CXP solutions operate at 25% the power per 10Gbps lane compared with SFP+ modules, the firm adds. In addition, the optical components have superior jitter performance, high signal integrity, and low EMI emissions.

The MiniPOD optical modules and CXP transceiver can transmit data up to 100m using OM3 fiber, and up to 150m using OM4-grade fiber. All the optical components are compliant to 100 Gigabit Ethernet specifications 802.2ba (100GBASE-SR10 and nPPI) as well as the QDR Infiniband standard. Avago's vertical-cavity surface-emitting laser (VCSEL) arrays (operating at a wavelength of 850nm) are used for the transmitters, and the firm's PIN diode array is used for the receivers.

The MiniPOD modules are available in two package options to support either flat ribbon or round fiber jumper cables. Evaluation boards are available for both the CXP transceiver module (AFBR-83EVK) and MiniPOD modules (AFBR-800EVK).

www.avagotech.com/fiber

Gao launches Extreme-compatible 10GBASE-SR XENPAK transceiver

Gao Comm Inc of Toronto, Canada has launched an Extreme-compatible 10GBASE-SR XENPAK transceiver, for use in switches and modules that support XENPAK transceivers.

The model C018XX01 is a fully integrated 10.3Gb/s optical transceiver module that consists of an 850nm-wavelength optical transmitter and receiver, XAUI interface, and mux and demux with clock and data recovery (CDR). It is hot Z-pluggable and features up to 10.3GBd bi-directional data links and RoHS compliance.

The transceiver uses an 850nm vertical-cavity surface-emitting laser (VCSEL) to achieve a transmission reach of up to 300m over 50/125µm multi-mode fiber. It also allows for MDIO and DOM and has SC connectors. In addition, the transceiver is compliant with XENPAK multi-source agreement (MSA) Rev 3.0. Its optical interface is compliant with IEEE802.3ae and 10GBASE-SR.

The 10GBASE-SR XENPAK transceiver belongs to GAO's family of Extreme-compatible transceivers. This line includes a wide range of

transceivers such as its 10GBASE-ER XENPAK transceiver, which uses a cooled 1550nm externally modulated laser (EML) to achieve transmission reach of up to 40km over standard single-mode fiber. The line also includes a 1000Base-LX GBIC transceiver, consisting of two sections: the transmitter section incorporates a Fabry-Perot (FP) laser, and the receiver section uses an integrated InGaAs detector preamplifier (IDP) mounted in an optical header and a limiting post-amplifier IC.

www.gaocomm.com

Infinera reports Q2 revenue down 10.7% on last quarter

Firm becoming more cautious on second-half 2012 CapEx spending

For second-quarter 2012, 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), has reported revenues of \$93.5m, down 10.7% on \$104.7m last quarter and 2.6% on \$96m a year ago.

On a non-GAAP basis (excluding non-cash stock-based compensation expenses), gross margin has fallen further, from 41% a year ago and 40% last quarter to 37%. Net loss was \$18.6m, up on \$11.2m

last quarter and \$11.7m a year ago.

"We executed well on our commitment to deliver the DTN-X to the market in the second quarter, completing critical customer trials and shipping the platform to customers for deployment as promised," says president & CEO Tom Fallon.

"Reception to the DTN-X, featuring 500Gb/s long-haul super-channels along with WDM and integrated OTN switching, has been very positive and broad-based," he adds.

"To date, we have received purchase commitments for the DTN-X from ten customers, including three

customers new to Infinera. These customers represent a cross section of our markets, including cable, subsea, internet content, research & education, and Tier 1 providers," says Fallon. "We remain on track to recognize revenues from DTN-X sales beginning in the third quarter," he adds. "While we are growing more cautious regarding the macro-economic environment and the outlook for capex spending in the second half of 2012, we are pleased with the market acceptance of the DTN-X."

www.infinera.com

Infinera ships DTN-X with first 500Gb/s super-channels

Infinera has made the first shipments of its DTN-X platform to customers for deployment.

Infinera continues to undertake multiple trials and has received purchase orders from new and existing customers. To date, it has announced plans to deploy the DTN-X platform with two new customers: Cable&Wireless Worldwide for its Europe Persia Express Gateway (EPEG) and DANTE for its GÉANT European Research and Education Network.

The DTN-X platform delivers what are believed to be the first 500Gb/s long-haul FlexCoherent super-channels, enabling service providers to deploy massive optical transport while lowering operational costs. The platform features 5 Terabits per second (Tb/s) of optical transport network (OTN) switching capacity. Integrated switching enables service providers to build highly efficient networks with switching activated wherever it is needed to improve wavelength fill and decrease the number of wavelengths that must be deployed. Infinera says that this results in networks with a high network efficiency quotient and potentially lowers the total cost of

ownership (TCO). The DTN-X also features a GMPLS control plane that makes the platform easy to use and further simplifies operations, the firm claims.

Infinera first began shipping the DTN platform in 2004, offering the only optical networking solution based on 100Gb/s PICs. The DTN-X builds on this and features third-generation 500Gb/s PICs, delivering to service providers a solution that focuses on simplicity, scalability, efficiency and reliability, the firm says.

"While our competitors talk about their roadmaps for metro 400Gb/s super-channels, Infinera is delivering the industry's first 500Gb/s long-haul FlexCoherent super-channels," says co-founder, executive VP & chief strategy officer Dave Welch. "With DTN-X, we are also bringing the largest-capacity OTN switch to market and delivering the industry's first deployable FlexCoherent capability," he adds. "Infinera delivers on the capabilities that help service providers scale, simplify and make their networks more efficient to lower overall lifecycle TCO."

At the WDM & Next Generation Optical Networking 2012 confer-

ence in Monaco (18–21 June), Infinera demonstrated hands-on live DTN-X demonstrations on the Infinera Express mobile demonstration lab, located on the conference show floor.

Infinera's 100Gb/s PIC was named 'Best Optical Component Product — 100G' at the Next Generation Optical Networking Awards 2012.

Infinera's first-generation PIC was recognized for the disruptive impact it has made in the optical network industry. Integrating over 60 components on a pair of chips, the 100Gb/s PICs are embedded into Infinera's DTN platform and boast more than 725 million hours of field operation without a known failure in live networks worldwide.

The award was established to celebrate and recognize the achievements made by service providers and solutions providers in the optical networking industry. Infinera's award was accepted by VP of corporate marketing Michael Capuano.

"Our PICs change the dynamics of the optical networking industry by dramatically increasing optical transport network efficiency while reducing total cost of ownership," believes Capuano.

<http://nextgenerationoptical.com>

Emcore reaches pre-flood capacity on key products

Pre-flood levels expected on all impacted lines by October

Emcore expects to be fully recovered from the impact of the Thailand floods on its manufacturing operations, and able to achieve pre-flood production levels on all of its continuing product lines by October. The firm expects increased shipments for its fiber-optics segment in the coming quarters as manufacturing volume ramps to normal levels.

Last October, flood waters severely impacted the inventory and production operations of Emcore's primary contract manufacturer Fabrinet Co Ltd in Thailand. The impacted areas included product lines for the Telecom and Cable Television (CATV) market segments (the Photovoltaics segment was unaffected). Since then, Emcore has implemented a plan to rebuild the impacted production lines at other locations, including an alternate Fabrinet facility in Thailand, as

well as its own manufacturing facilities in China and the USA.

The production line for ITLAs (integrable tunable laser assemblies) for 40 and 100Gb/s coherent telecom applications has been up and running since March at Fabrinet, ahead of schedule. Production line qualification has been completed and most customers completed full-line audits and started taking shipments in April. As of this quarter, the ITLA line is operating at pre-flood capacity run-rates. The CATV laser module and transmitter production lines at Emcore's facility in China reached pre-flood capacity levels in mid July. Emcore expects the tunable XFP (TXFP) transceiver line at Fabrinet to reach volume production levels by October. In the meantime, TXFP manufacturing is continuing at Emcore's facility in Newark, CA, USA.

"We are very appreciative of our customers' understanding, cooperation, and support during the rebuild of impacted production lines the past 9 months," says Jaime Reloj, VP of business development. "Our customers have demonstrated their commitment by closely working with us to accelerate product qualification from the new lines. Based on the strong demand for certain product lines, such as ITLA, Emcore is increasing production capacity to exceed pre-flood levels to support orders for 40 and 100Gb/s coherent applications," he adds.

"Emcore would like to thank our customers and manufacturing partners for their cooperation and assistance during this difficult period," says CEO Dr Hong Hou. "We are almost fully recovered from the flood disaster."

www.emcore.com

Advanced Photonix's revenue down 17% year-on-year

Telecom customers hit by Thailand flooding

For fiscal 2012 (to end-March), Advanced Photonix Inc of Ann Arbor, MI, USA (which designs and makes silicon, InP- and GaAs-based APD, PIN, and FILTRODE photodetectors, HSOR high-speed optical receivers, and T-Ray terahertz instrumentation) has reported net sales of \$29.5m, up 2% on \$28.8m for fiscal 2011, driven by the telecom, homeland security and medical markets. However, for fiscal fourth-quarter 2012, net sales were \$6.5m, flat on last quarter but down 17% on \$7.8m a year ago.

"The two major natural disasters in Japan and Thailand had a significant effect on our results this last year, slowing our growth to 2%," notes chairman & CEO Richard Kurtz. "The tsunami in Japan limited our supply from a key vendor which restricted our first-half growth on our 100G HSOR products," he adds.

"The flooding in Thailand did not impact our supply chain directly but did severely impact our customers, which resulted in a drop in our telecommunication revenues in the last half of fiscal 2012."

For full-year fiscal 2012, operating expenses were \$14.5m (49.2% of revenue), up from \$13.2m (45.7% of revenue) in fiscal 2011. However, for Q4, operating expenses were just \$3.2m, down from \$3.6m last quarter and \$3.7m a year ago.

Gross margin has fallen from 43.9% a year ago and 41.5% last quarter to 34.2% in Q4, due to lower volumes as well as price pressures in the high-speed optical receiver (HSOR) product line prior to cost-reduction efforts. Gross margin for full-year fiscal 2012 was 40%, down from 43% in fiscal 2011.

For Q4, adjusted EBITDA (earnings before interest, taxes, depreciation, amortization and stock

compensation) was negative \$416,000, compared to +\$236,000 last quarter and +\$498,000 a year ago. For full-year fiscal 2012, adjusted EBITDA was \$257,000, down from \$2m for fiscal 2011. The firm finished the year with \$3.2m in cash, down from \$4.7m a year ago as it de-levered by paying down \$1.4m in debt. Working capital as of end-March was \$7.5m.

"We see increasing signs of significant pent up demand in the telecommunications market and increasing adoption of our T-Ray products that lead us to believe that revenues in the second half of our fiscal 2013 should be approximately 35% higher than the first half, assuming our supply chain can respond accordingly," says Kurtz. "This coming year we look forward to a more normal business environment and continued growth."

www.advancedphotonix.com

Emcore adds 1550nm transmitter and next-gen software services for Japan CATV/SAT-IF transport over 100km

At Japan's Cable Tech Show 2012 in Tokyo (18–19 July), Emcore Corp of Albuquerque, NM, USA, which makes components, subsystems and systems for the fiber-optic and solar power markets, is announcing the addition of the J-Type Medallion 6000 to its 1550nm cable television (CATV) fiber-optic transmitter product portfolio.

Now available for evaluation, the J-Type Medallion 6000 series of externally modulated transmitters has been developed specifically for Japan and other markets requiring long-distance and concurrent fiber-optic transport of CATV and Satellite-Intermediate Frequency Signals (SAT-IF). The J-Type Medallion 6000 supports operational bandwidths up to 2.8GHz with an adjustable SBS (stimulated Brillouin scattering) suppression range of 11–17dBm, plus extended adjustable AGC (automatic gain control), and very high OMI (optical modulation index) for exceptional link performance.

In parallel, Emcore is announcing the next-generation WEB GUI and Simple Network Management Protocol (SNMP) software service offering for the entire Medallion 6000 platform. Emcore says that the new WEB GUI and SNMP interfaces offer many new capabilities to serve the evolving and

growing needs of the most advanced networks.

The J-Type transmitter's performance is enabled by Emcore's proprietary high-power, narrow-linewidth CW (continuous wave) laser technology. When deployed with one or more Emcore optical amplifiers, transmissions of 100km and beyond have been demonstrated. The feature-rich WEB GUI and SNMP enhancements bring a whole suite of operator monitoring and configuration options to the platform, allowing for secure, simplified and future-ready functionality for the next generation of intelligent networks, the firm says.

"Building upon the strength of our popular Medallion 6000 series, our new J-Type model is the ideal solution for the transmission of CATV and SAT-IF signals over 100km and beyond," claims Grant Olecko, product marketing director at Emcore Broadband. "The 6000 family of transmitters is also ideal for extending traditional CATV systems including head-end consolidation, broadcast transport, and RF overlay for FTTH (fiber-to-the-home) PON (passive optical network), and RFoG (radio frequency over glass) projects in countries around the world," he adds. "This capability allows us to capitalize on a significant and growing market opportunity."

The Medallion 6000 series of CATV transmitters deliver high-quality video with full QAM (quadrature amplitude modulation) loading to 1GHz for shorter-reach and long-haul applications. Monitoring and configuration is supported via a convenient front-panel display, an RS-232 port, and an Ethernet port with SNMP, Telnet, and Web GUI. The platform is mechanically designed for flexibility and space efficiency including universal rack-mount features, modular front-panel design for private label convenience, and optional front and rear port placement. Dual redundant field-replaceable fans and power supplies are standard.

Emcore says that network providers are demanding high quality and economical delivery of video to their customers, while extending capacity and improving network management intelligence. The firm reckons that it is well positioned to take advantage of this trend due to its portfolio of broadband solutions. The enhanced features and cost-effective designs leveraged from its long-established experience in 1550nm transmitter technology meet the demanding needs of CATV networks, reckons the firm.

www.emcore.com

www.catv-f.com

Emcore sees 100th satellite deployed with its solar cells/panels

Emcore recently achieved its 100th successful satellite launch and deployment with primary power supplied by its solar cells or panels.

The 100th on-orbit spacecraft powered by Emcore solar equipment was launched in June. Built by geostationary commercial satellite provider Space Systems/Loral (SS/L, a subsidiary of Loral Space & Communications) and powered by solar panels equipped with Emcore's multi-

junction solar cells, the satellite will provide C- and Ku-band capacity for a variety of communications services.

"We are especially proud to have achieved this milestone with zero on-orbit failures," says Emcore's chief operating officer Christopher Larocca. "Emcore currently has a total of 120 more satellites under contract to be launched and powered by Emcore solar equipment over the next several years."

Emcore claims to be the world's largest manufacturer of highly efficient radiation-hard solar cells for space power applications. With a beginning-of-life (BOL) conversion efficiency nearing 30% and the option for a patented, onboard monolithic bypass diode, the firm's multi-junction solar cells can provide the highest available power to interplanetary spacecrafts and earth-orbiting satellites, it adds.

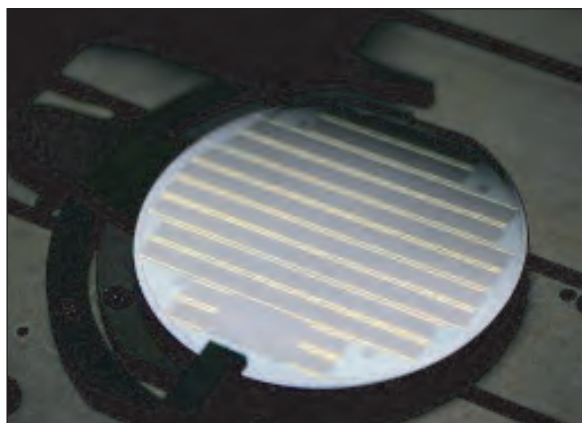
www.ssloral.com

IQE receives its first major orders for CPV solar wafers, worth nearly \$2m

Epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK has announced its first major orders for concentrating photovoltaic (CPV) wafers from Solar Junction Corp (SJC) of San Jose, CA, USA, which manufactures III-V multi-junction solar cells for CPV modules.

The orders are worth a total of \$1.95m, comprising \$1m for the first production wafers and \$950,000 for development wafers for improving further the efficiency of Solar Junction's CPV products. IQE signed a seven-year exclusive wafer supply agreement with Solar Junction in February. The agreement included the transfer of CPV technology, the establishment of wafer manufacturing capability, and the subsequent ramp into high-volume production.

The CPV wafer production order follows Solar Junction's announcement in late May of its first 5MW order from CPV system maker SolFocus Inc of Mountain View, CA, USA, which has been chosen as the system supplier for the 450MW



A CPV wafer using Solar Junction technology.

project in Baja, Mexico, the largest CPV project announced to date, funded by Grupo Musa and Synergy Technologies LLC. IQE says that CPV project announcements during 2012 are exceeding industry projections, with more than 650MW project announcements so far.

In April 2011, Solar Junction set the record for CPV cell efficiency at 43.5% and, in conjunction with IQE's proprietary internal wafer technology, aims to develop cell architectures with efficiencies exceeding 50%. The cost of gener-

ating electricity using CPV in hot sunny areas such as California is already at cost parity with all other forms of power generation (according to GTM Research) and increasing cell efficiency will further lower the cost of CPV power generation substantially, says IQE.

"This order from Solar Junction is clear indication that CPV technology is gaining significant traction in large-scale power genera-

tion projects in sunny areas," says IQE's president & CEO Dr Drew Nelson. "Our long-term, exclusive wafer supply agreement with the world record holders in cell efficiency, coupled with the large-scale manufacturing capacity now in place following our deal to acquire RFMD's in-house MBE production capacity [announced in early June], position IQE to be a major wafer supplier to the rapidly emerging CPV industry, by far the most efficient of any solar technology," he adds.

www.iqep.com

Emcore replaces legacy systems in fab and backend with Camstar semiconductor suite

Software provider Camstar Systems Inc of Charlotte, NC, USA says that Emcore Corp of Albuquerque, NM, USA, which makes components, subsystems and systems for the fiber-optic and solar power markets, will replace multiple legacy manufacturing systems with the Camstar Enterprise Platform, which includes manufacturing execution (MES), quality management, statistical process control (SPC) etc. The solution should simplify system complexities inherent in running Emcore's wafer and cell processing, and assembly, test and panel manufacturing.

"Emcore's customers rely on our

leading photovoltaic technology to power critical space operations," says Emcore VP & general manager Brad Clevenger. "Camstar will enable us to more rapidly deliver customized products that meet their exacting requirements, and continuously improve business performance through streamlined operations," he adds.

"With Camstar we can replace a multitude of disparate applications with a single, flexible platform," notes Mike Brown, Emcore's VP of information technology. "We will simplify the IT architecture and reduce support efforts, while improving our flexibility and

responsiveness to change," he adds.

"My prior experience with Camstar gives me confidence that this implementation will be rapid and successful," comments Lawson Hise, IT Manager, Software Development for Emcore.

"Camstar's Enterprise Manufacturing platform provides industry leaders like Emcore more agility, enabling rapid product builds based on specific customer requirements while insuring their rigorous quality standards are met," states Camstar executive VP Rob Rudder.

www.camstar.com

www.emcore.com

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Sandia's InGaN nanowire template permits flexible solar energy absorption

Array to boost proportion of solar spectrum available for conversion

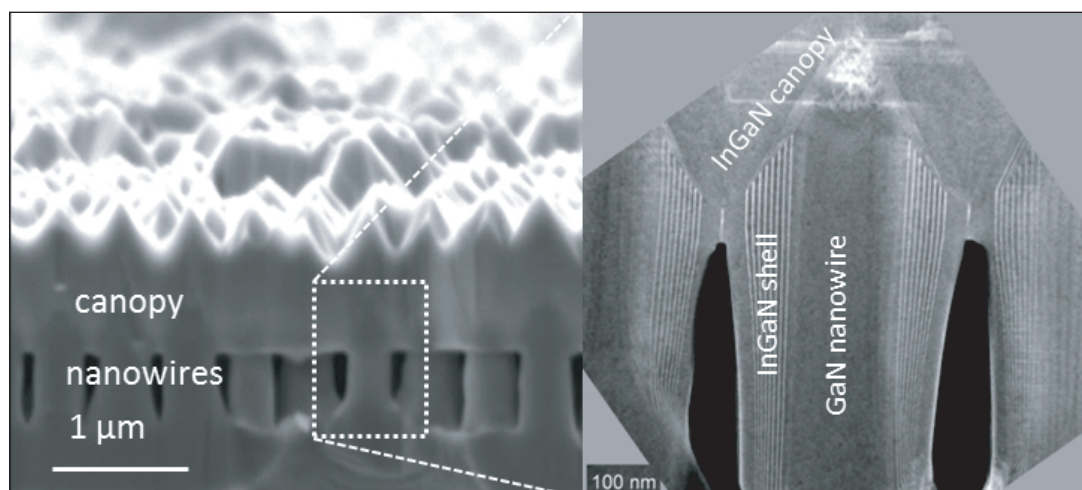
Researchers in solar energy want to convert as many of the sun's wavelengths as possible to achieve maximum efficiency. They hence see indium gallium nitride as a valuable future material for photovoltaic systems.

Changing the concentration of indium allows tuning of the material's response so it collects solar energy from a variety of wavelengths. The more variations designed into the system, the more of the solar spectrum can be absorbed, leading to

increased solar cell efficiency. In contrast, the photovoltaic industry's incumbent material (silicon) is limited in the wavelength range that it can 'see' and absorb.

However, indium gallium nitride (InGaN) is typically grown on thin films of gallium nitride (GaN). Because GaN layers have different crystal lattice spacings from InGaN layers, the mismatch leads to structural strain that limits both the layer thickness and the percentage of indium that can be added. Thus, increasing the percentage of indium that is added broadens the solar spectrum that can be collected, but reduces the material's ability to tolerate the strain.

Recently, funded by the US Department of Energy (DOE) Office of Science through the Solid State Lighting Science Energy Frontier Research Center (SSLSEFRC) and by Sandia National Laboratories' Laboratory Directed Research and Development program, Sandia scientists including Jonathan Wierer Jr and George Wang have reported that, if the indium mixture is grown on a phalanx of nanowires rather than on a flat surface, then the small surface areas of the nanowires allow the indium shell layer to partially 'relax' along each wire, easing



Cross-sectional images of InGaN nanowire solar cell (Sandia National Laboratories).

strain (Jonathan J Wierer Jr et al, 'III-nitride core-shell nanowire arrayed solar cells', 2012 Nanotechnology 23 194007). This relaxation allowed the team to create a nanowire solar cell with indium percentages of about 33%, higher than any other reported attempt at creating III-nitride solar cells.

This initial attempt also lowered the absorption base energy from 2.4 eV to 2.1 eV (the lowest of any III-nitride solar cell to date) and made a wider range of wavelengths available for power conversion. Power conversion efficiencies were low — only 0.3% compared to about 15% for a standard commercial cell — but the demonstration took place on imperfect nanowire-array templates. Refinements should lead to higher efficiencies and even lower energies.

Several unique techniques were used to create

the III-nitride nanowire array solar cell. A top-down fabrication process was used to create the nanowire array by masking a GaN layer with a colloidal silica mask, followed by dry and wet etching. The resulting array consisted of nanowires with vertical sidewalls and uniform height.

Next, shell layers containing the higher indium percentage of InGaN were formed on the GaN nanowire template via metal-organic chemical vapor deposition (MOCVD). Lastly, $\text{In}_{0.02}\text{Ga}_{0.98}\text{N}$ was grown, in such a way that caused the nanowires to coalesce. This process produced a canopy layer at the top, facilitating simple planar processing and making the technology manufacturable.

Although modest, the results represent a promising path forward for III-nitride solar cell research, says Wierer. The nano-architecture not only enables a higher indium proportion in the InGaN layers but also increased absorption via light scattering in the faceted InGaN canopy layer, as well as air voids that guide light within the nanowire array.

<http://iopscience.iop.org/0957-4484/23/19/194007>

<http://science.energy.gov/bes/efrc>
www.sandia.gov

The nano-architecture not only enables a higher indium proportion in the InGaN layers but also increased absorption via light scattering in the faceted InGaN canopy layer



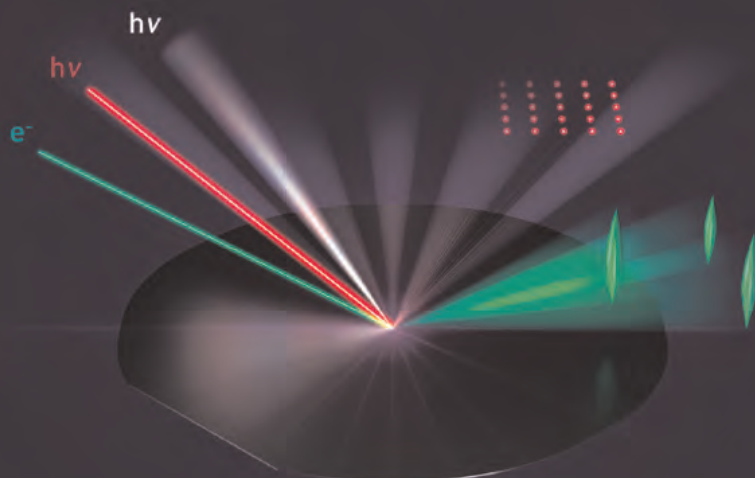
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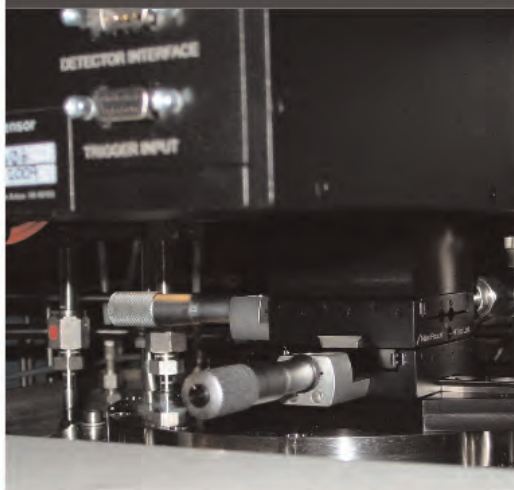
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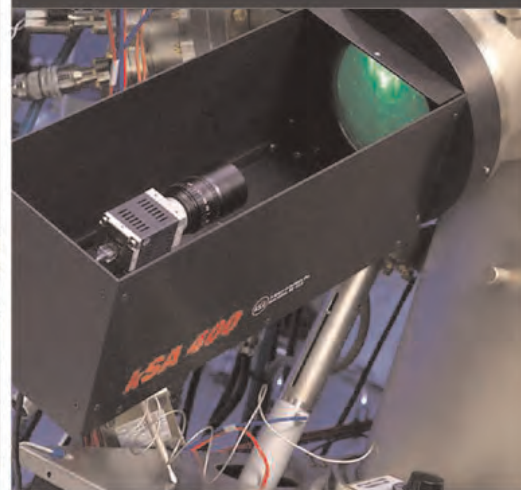
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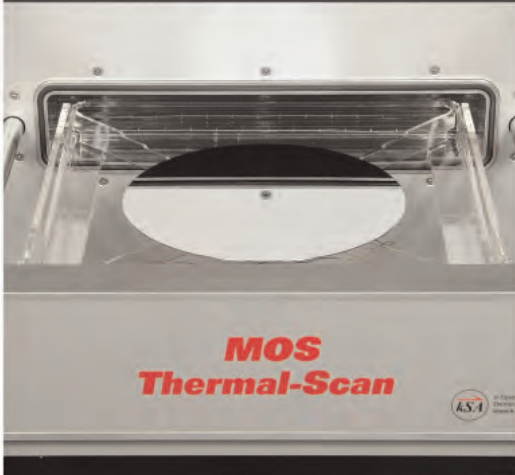
kSA MOS and kSA Mini-MOS Thin-Film Stress



kSA 400 Analytical RHEED



kSA MOS Ultra-Scan and Thermal-Scan Stress Mapping



kSA Rate Rat Pro Thickness & Deposition Rate



kSA BandiT PV Process Tuning



Abound Solar suspends operations

Cadmium telluride (CdTe) thin-film photovoltaic (PV) module maker Abound Solar of Loveland, CO, USA says that it intends to file a petition for protection under US Bankruptcy Code in Delaware this week. Suspension of operations will impact about 125 staff.

Earlier this year, Abound ceased production of its first-generation 10.5%-efficient PV module and has been working to scale up manufacturing for its high-efficiency, second-generation 'AB2' PV module, which was tested and verified by the US National Renewable Energy Laboratory (NREL) to deliver 85W per panel and 12.5% efficiency. Abound has been in discussions with potential buyers over the last several months, but ended negotiations when the involved parties were unable to come to an agreement on terms.

Abound's funding has come from \$300m in private investment and \$70m from a DOE loan guarantee program. The firm had used \$70m of the awarded \$400m DOE loan guarantee for construction of solar panel manufacturing lines in Colorado. Abound has not drawn down any further DOE funds since August 2011, when the DOE determined that challenging market conditions in the solar industry did not merit additional funding risk. The firm says that it is appreciative of the significant investment from private investors and the DOE.

Abound believes that, at scale, its US-made CdTe panel technology has the ability to achieve lower cost per watt than competing crystalline silicon technology made in China. However, aggressive pricing actions from Chinese solar panel compa-

nies have made it very difficult for an early stage startup company like Abound to scale in current market conditions. According to the US Commerce Department, the US solar market has seen the prices for panels drop by more than 50% in the past year at a time when the value of imports of Chinese-made solar cells nearly quadrupled from \$639m in 2009 to \$3.1bn in 2011. The firm says that it supports recent initiatives to enforce fair trade with import tariffs, but this action is unfortunately too late for the firm.

Abound says that it believes that competitive solar energy remains important to US energy security and job creation, and that longer-term, consistent renewable energy policy is critical to encourage further private investment in the sector.

www.abound.com

First Solar installs 10 millionth power plant PV module

First Solar Inc of Tempe, AZ, USA says its Engineering, Procurement & Construction (EPC) team has installed its 10 millionth CdTe PV module in a utility-scale solar project.

The installation was at the 550MW_{AC} Desert Sunlight Solar Farm project that it is constructing for NextEra Energy Resources LLC and GE Energy Financial Services (which each acquired 50% of the project from First Solar last October).

Located near the community of Desert Center in Riverside County, CA and creating an average of 400

construction jobs, the project is part of First Solar's 2.7GWAC utility-scale project pipeline in North America, which will support 7000 supply chain and construction jobs over the next several years.

First Solar is the largest PV solar power plant construction firm, and was recently recognized by Engineering News-Record as the fifth largest construction firm in the power sector. "It's also fitting to install our 10 millionth EPC module at the Desert Sunlight project, which will set a solar record as

well," says Jim Lamon, First Solar's senior VP of engineering, procurement & construction and operations & maintenance. "When completed in 2015, it will be one of the two largest PV solar projects in the world, along with the 550MW Topaz project we're building in San Luis Obispo County," he adds.

First Solar has cumulatively produced almost 80 million of modules, i.e. peak generating capacity of more than 6GW (enough to power 3 million homes and displace over 4 million tons of CO₂ per year).

First Solar appoints chief operating officer

First Solar has appointed Georges Antoun as chief operating officer, initially responsible for manufacturing, R&D, quality and product management. Reporting to him will be Tymen DeJong, senior VP of global operations; Raffi Garabedian, chief technology officer; and Tom Kuster, VP of product man-

agement & customer support.

Antoun was most recently a partner at Technology Crossover Ventures. Previously, he was head of Product Area IP & Broadband Networks for Ericsson. He joined Ericsson in 2007, when it acquired Redback Networks, where he was senior VP of Worldwide Sales and Operations.

Antoun was then promoted to CEO of Redback. Prior to Redback, he spent five years at Cisco Systems, where he was VP of Worldwide Systems Engineering and Field Marketing, VP of Worldwide Optical Operations, and VP of Carrier Sales.

www.firstsolar.com

Agua Caliente CdTe PV project reaches 200MW milestone

NRG Energy Inc of Princeton, NJ, MidAmerican Solar of Phoenix, AZ (a subsidiary of MidAmerican Renewables LLC) and First Solar Inc of Tempe, AZ have announced that the 290MWAC Agua Caliente solar project, currently under construction in Yuma County, AZ., is more than two-thirds complete and now delivering more than 200MW to the electric grid. The project is the world's largest operating photovoltaic power plant.

Owned by NRG and MidAmerican Solar, the facility employs a daily average of 400–450 workers during construction. Due to be completed in 2014, it uses solar plant controls and forecasting capabilities to integrate its output with the power grid.

First Solar designed and is constructing the project using its CdTe PV modules and will operate and maintain the facility for NRG and MidAmerican Solar. PG&E has a long-term power purchase agreement for the project's electricity generation (enough to supply more than 225,000 homes), which is projected to offset about 5.5 million metric tons of carbon dioxide over 25 years (equivalent to taking more than 40,000 cars off the road annually). The project is being financed with the support of a loan guarantee from the US Department of Energy's Loan Programs Office.

"The Agua Caliente project sets the highest standard for what we can accomplish with today's solar

technology when combined with a strong public-private partnership at the national level," comments NRG Solar's CEO Tom Doyle. "First Solar's performance on this project, from their technology and execution to their outstanding safety record, has exceeded all our expectations," he adds.

"Solar projects like this are helping PG&E provide its customers with some of the nation's cleanest electric power, more than half of which comes from sources that are renewable or emit no greenhouse gases," says John Conway, PG&E's senior VP for Energy Supply.

www.nrgenergy.com

www.midamerican.com

www.firstsolar.com

First of 3.8 million First Solar CdTe PV panels installed at Antelope Valley Solar Ranch One in Los Angeles County

First Solar has announced the installation of the first of 3.8 million PV modules at the 230MW_{AC} Antelope Valley Solar Ranch One power plant in Los Angeles County.

Representatives from Los Angeles County's departments of Public Works and Regional Planning joined First Solar senior management and project workers in installing the 2-foot by 4-foot module, marking the start of installation (which the county approved on 21 June).

First Solar and Public Works worked to achieve agreement on code certifications to ensure that all applicable building codes were met by the project.

"This process has paved the way for future projects in a region with enormous potential for solar energy development," says Tony Perrino, First Solar's director of engineering, procurement & construction.

Located on 2100 acres of former farmland, Antelope Valley Solar

Ranch One is one of the largest construction projects under way in Los Angeles County. More than 385 workers are now being employed on the 2100-acre site.

When complete in 2013, the PV power plant will generate enough electricity for about 75,000 average California homes, while displacing 140,000 metric tons of CO₂ annually (equivalent to taking 30,000 cars off the road each year).

www.firstsolar.com

First Solar to supply modules to Catalina Solar Project

Renewable energy project developer enXco of San Diego, CA, USA (an EDF Energies Nouvelles Company) has signed a solar module supply agreement for First Solar Inc of Tempe, AZ, USA — which manufactures thin-film photovoltaic modules based on cadmium telluride (CdTe) as well as providing engineering, procurement and construction (EPC) services — to supply it with 61 Megawatt-peak (MWp) of modules, starting this September, for a portion of its

Catalina Solar Project in Kern County, CA.

Catalina Solar will be built in two phases: the first phase of about 60MWp is targeted to go online by the end of 2012 and the remainder of the project by June 2013. The plant will generate enough energy to power the equivalent of about 35,000 homes annually and will offset about 74,000 metric tons of greenhouse-gas emissions per year.

"First Solar has been and continues

to be a good partner," comments Kristina Peterson, VP of enXco's Solar business unit. "Their technology remains one of the lowest LCOE [levelized cost of energy] solar PV solutions," she adds.

"First Solar has a long-standing relationship with EDF Energies Nouvelles [which is based in Paris, France] and we're excited to extend this to the US with enXco," says Dana Diller, First Solar's VP for US business development.

www.enxco.com

High-temperature solar-blind AlGaN photodetectors

Researchers in China produce devices with femtoamp dark-current and four-decade solar rejection.

Researchers in Nanjing, China have reported the first fabrication and characterization at high temperature of high-performance solar-blind photodetectors (PDs) based on an aluminium gallium nitride (AlGaN) absorption layer and planar metal–semiconductor–metal (MSM) electrode layout [Feng Xie et al, IEEE Sensors Journal, vol12, p2086, June 2012]. The participating institutions were Jiangsu Provincial Key Laboratory of Advanced

Photonic and Electronic Materials/Nanjing University and Nanjing Electron Devices Institute.

The new devices have an ultra-low dark current in the femtoamp ($fA = 10^{-15}A$) range, even at $150^{\circ}C$. At room temperature (RT), the solar-blind/ultraviolet rejection ratio is four orders of magnitude, and even at $150^{\circ}C$ its value is more than 8000. The researchers comment on their device: “The ultra-low dark current and the high rejection ratio at $150^{\circ}C$ suggest that such PDs are suitable for high-temperature applications.”

These potential applications include missile plume sensing, flame detection, environmental monitoring, chemical/biological agent detection, and covert space-to-space communications.

Presently, solar-blind detection is achieved using fragile photomultiplier tubes or silicon photodetectors, which need complex and expensive filters, and bulky high-voltage power supplies. Also, these devices and their support systems can be sensitive to harsh environments such as that found in gas turbines.

Aluminium gallium nitride (AlGaN) is naturally solar blind due to its large bandgap. The wide bandgap of the material also allows higher-temperature operation. Radiation hardness is another attractive feature.

The epitaxial device structure (Figure 1) was grown

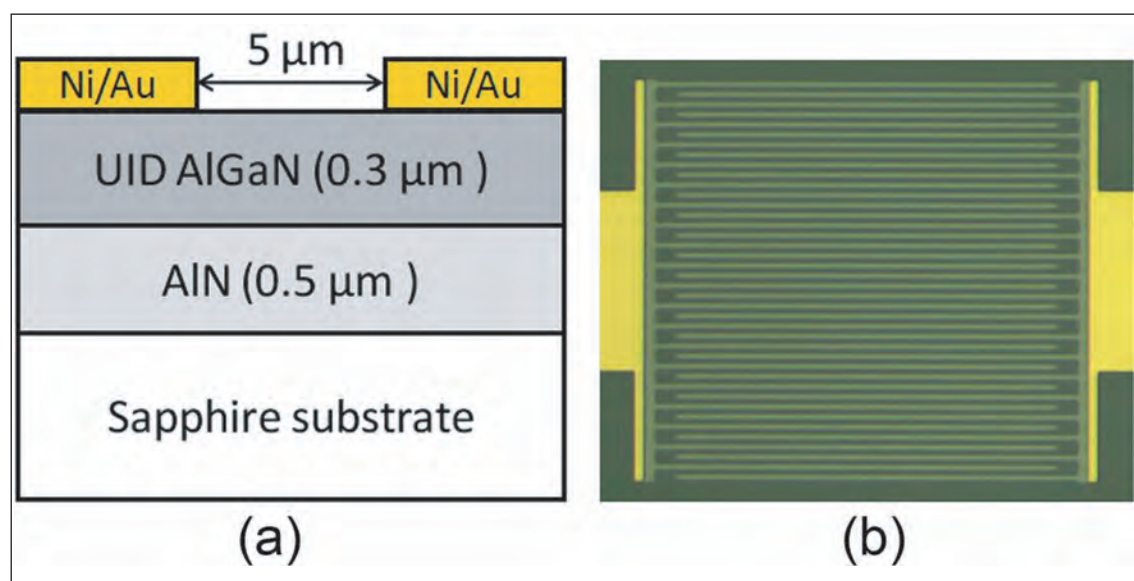


Figure 1. (a) Schematic of the device structure and (b) top-view image of one fabricated photodetector with an effective device area of $400\mu m \times 400\mu m$.

on 2-inch sapphire substrate using metal-organic chemical vapor deposition (MOCVD). The $1100^{\circ}C$ AlGaN layer was not intentionally doped. The 40% Al content of the AlGaN layer was confirmed by a 272nm cut-off in optical transmission spectroscopy. The AlN buffer was designed to be highly resistive, and was grown according to the researchers' proprietary high-temperature recipe.

The device processing began with applying thin semi-transparent layers of 5nm nickel and 5nm gold, forming a Schottky contact. Lithography and lift-off processing was used to define interdigitated electrodes that were $400\mu m$ long and $5\mu m$ wide. The electrode separation was $5\mu m$. The nickel-gold contacts had a transmittance of 35–43% in the 200–400nm ultra-violet wavelength range.

The devices were completed by adding 200nm-thick titanium-gold contact pads and annealing at $300^{\circ}C$ for 3 minutes in nitrogen.

The dark current at room temperature (RT) is less than $1fA$ ($1.25 \times 10^{-12}A/cm^2$ density) and, for $150^{\circ}C$ operation, is still in the fA range for bias voltages less than 20V. The RT breakdown occurs at more than 300V.

The very low dark current is attributed to the high Schottky barrier height of the nickel contact metal,

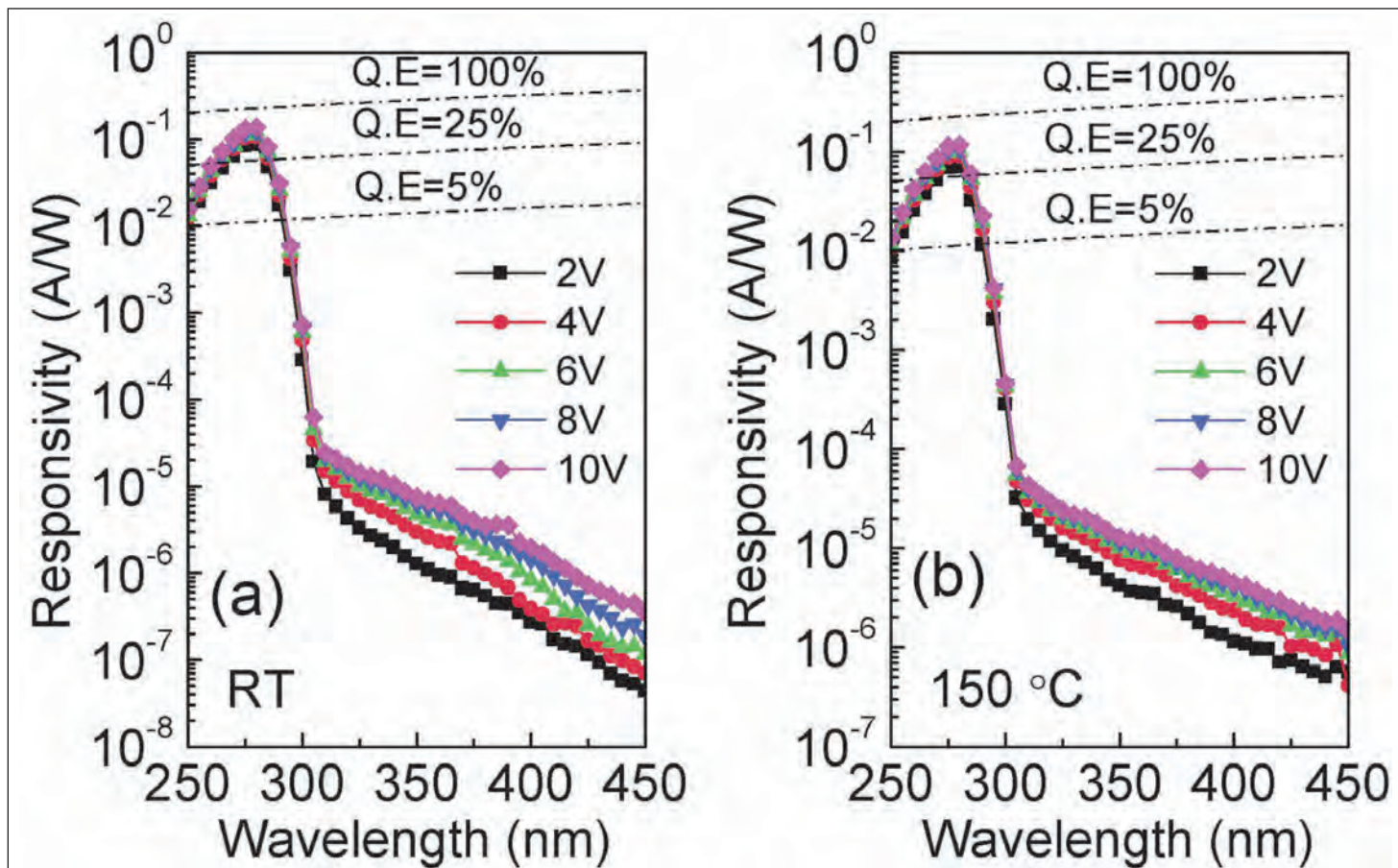


Figure 2. Bias-dependent spectral response of the MSM photodetector measured at (a) RT and (b) 150 °C.

along with the use of a high-temperature AlGaIn absorption layer and the coplanar configuration of the metal–semiconductor–metal structure. Although there are still threading dislocations in the AlGaIn buffer, it is thought that these terminate at the highly resistive AlN, so any lateral conductive path between the electrodes is cut off.

The photocurrent increases rapidly with biases below 2V, but then increases more slowly beyond that. At 150 °C, the photocurrent is 20–40% lower than that at RT. The researchers explain this as being due to enhanced carrier recombination loss at higher temper-

atures. The devices show a peak response around 275 nm wavelength and a cut-off above 280 nm that corresponds to the band edge of the AlGaIn absorption layer (Figure 2). At 10V bias, the peak responsivity is 143 mA/W, corresponding to a peak quantum efficiency of 64%. At the same bias, the solar-blind/UV rejection ratio (comparing responses at 275 nm and 350 nm) is as high as 1.8×10^4 at RT and is still high (8.6×10^3) at 150 °C. ■

<http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=6132454>

Author: Mike Cooke

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AlGaN buffers on semipolar gallium nitride offer route to ultraviolet laser diodes

UCSB demonstrates electrically injected devices lasing at 384nm.

University of California Santa Barbara (UCSB) has developed ultraviolet (UV) laser diodes (LDs) based on semipolar aluminum gallium nitride (AlGaN) buffer layers [Daniel A. Haeger et al, Appl. Phys. Lett., vol100, p161107, 2012]. The aim was to provide an alternative route to UV laser diodes compared with those grown on AlN or sapphire substrates.

Potential commercial and industrial applications include bio-agent detection, chemical processing, photo-lithography, and sterilization/purification. Using laser diodes in these applications should increase power efficiency, make for more compact equipment, increase reliability, and significantly reduce capital and operating costs compared with traditional UV lasers.

With nitride semiconductor light-emitting devices, the reduction of defect densities is usually one of the key steps to high performance. Since the materials are often grown on substrates with different lattice parameters from that of the light-emitting region, they are prone to contain threading dislocations.

UCSB has been developing AlGaN buffer layers on semipolar GaN as a means to transition between the substrate lattice constant and that of the active region. The researchers have found that such buffer layers relax plastically through misfit dislocations near the heterointerface, offering "the potential for significantly higher-quality AlGaN pseudo-substrates at any Al-mole fraction".

The new UV laser diode structures were grown on free-standing (20-21) GaN substrates supplied by Mitsubishi. (Kenji Fujito of Mitsubishi Chemical Corp is the only non-UCSB representative on the paper's 11-author list.) Metal-organic chemical vapor deposition (MOCVD) was used to grow the nitride layers of the

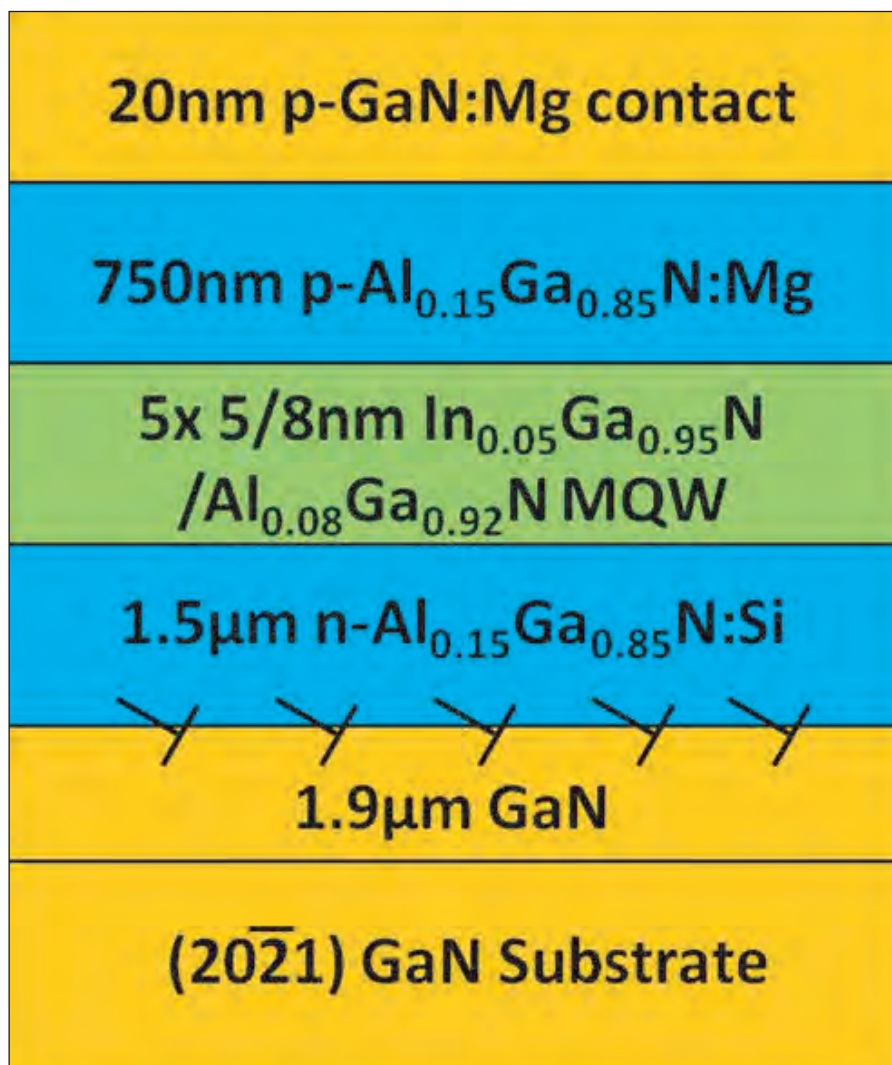


Figure 1. Schematic cross section of laser diode epitaxial structure. Stress relaxation occurs only at the GaN/n-AlGaN interface by the formation of misfit dislocations. There is no electron-blocking layer.

laser (Figure 1). The growth conditions and doping were not optimized.

The epitaxial material was processed into various ridge-waveguide LDs. The ridge direction was [10-14]. The facets were not coated.

X-ray analysis of the epitaxial material suggests that the strain between the substrate and AlGaN buffer is indeed relaxed through misfit dislocations. The researchers found that the only relaxation was at the GaN/n-AlGaN interface, with no measureable secondary relaxation at the p-cladding or active region interfaces.

Transmission electron micrographic (TEM) studies give an upward limit for threading dislocation density in the laser structure of mid $10^7/\text{cm}^2$, comparable to the density value for the GaN substrate and one magnitude lower than that for AlGaIn films grown previously.

The resulting devices had UV lasing frequencies of 384nm. A $5\mu\text{m} \times 1500\mu\text{m}$ device had a threshold current of 1.17A ($15.7\text{kA}/\text{cm}^2$ density), threshold voltage of 13.7V, and slope efficiency of $0.061\text{W}/\text{A}$ (Figure 2).

Temperature-dependent measurements gave a characteristic temperature of 91K for $2.5\mu\text{m} \times 1200\mu\text{m}$ devices, lower than for visible nitride laser diodes but comparable to the values for previously reported UV laser diodes.

Cavity-length-dependent measurements suggest a low carrier injection efficiency of below 3%. The researchers comment: "We speculate that this low injection current is due to defects near the active region/p-cladding interface as well as low electron barrier heights. We believe this can be mitigated with growth condition optimization and improved carrier confinement structures."

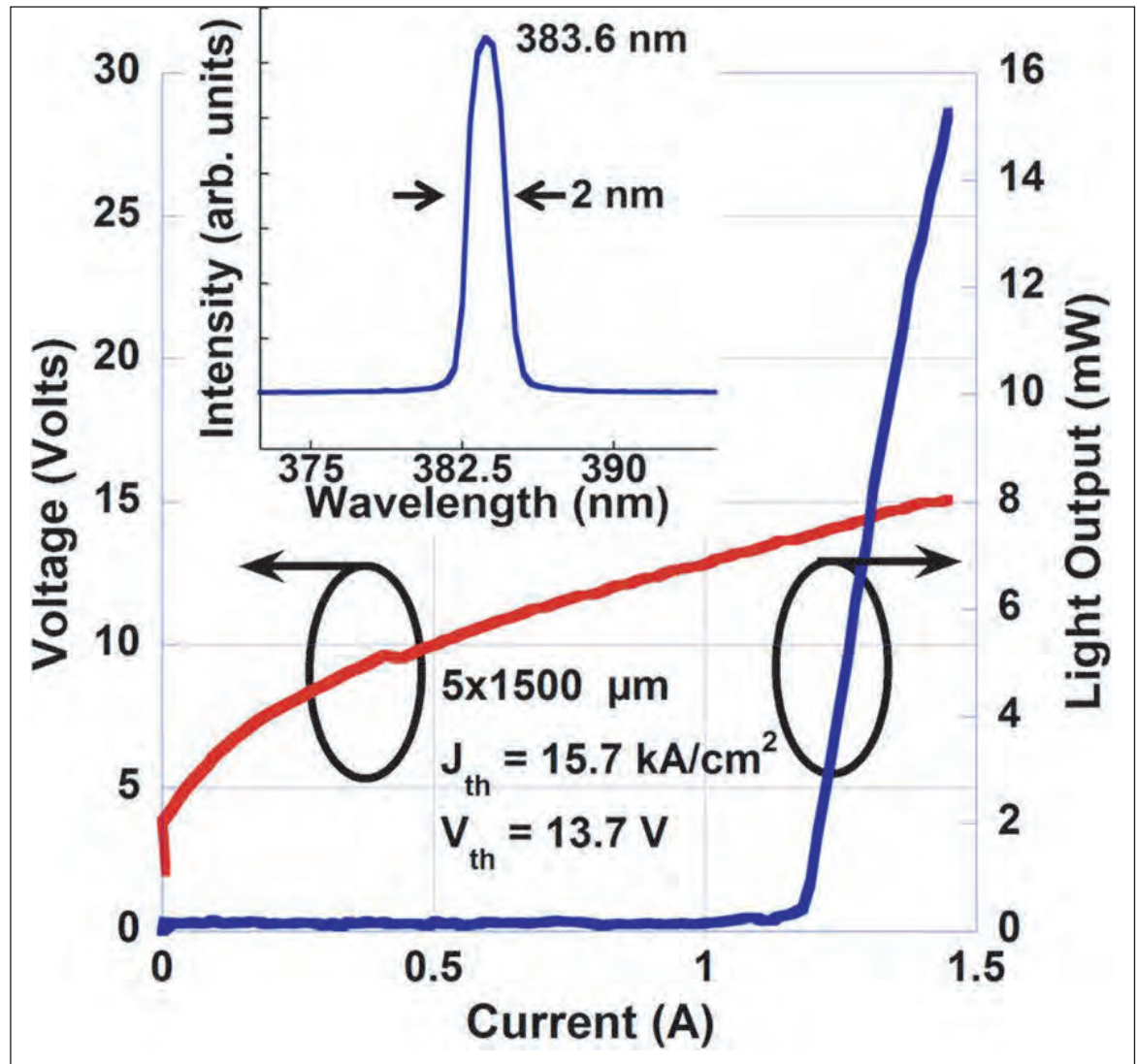


Figure 2. Dependence of output power and voltage on current under pulsed operation. Inset: output spectra at lasing threshold.

The team hopes to "significantly improve the optical confinement" by reducing the stress relaxation of the cladding/waveguide layers at given alloy composition and increasing the lattice constant of the epilayers. This will allow the maximum thickness of layers to be increased and alloy composition contrast to be enhanced in the active light-emitting region

Internal modal losses were also high, at more than $60/\text{cm}$. "It is clear that extensive optimization of the waveguide structure to reduce the optical mode width and thus the internal losses will be critical for the reduction of threshold current densities and for the realization of deeper UV laser diodes," the UCSB researchers report.

The team hopes to "significantly improve the optical confinement" by reducing the stress relaxation of the cladding/waveguide layers at given alloy composition and increasing the lattice constant of the epilayers. This will allow the maximum thickness of layers to be increased and alloy composition contrast to be enhanced in the active light-emitting region.

The work received funding from US Defense Advanced Research Projects Agency (DARPA) Compact Mid-Ultraviolet Technology (CMUVT) program and the Solid State Lighting and Energy Center (SSLEC) based at UCSB. ■

<http://link.aip.org/link/doi/10.1063/1.4704560>
[www.darpa.mil/Our_Work/MTO/Programs/Compact_Mid-Ultraviolet_Technology_\(CMUVT\).aspx](http://www.darpa.mil/Our_Work/MTO/Programs/Compact_Mid-Ultraviolet_Technology_(CMUVT).aspx)

Vertical-stand surface-roughened nitride LEDs with 118.5% increased output

Benefits seen from side mounting and self-assembled conical arrays on free-standing GaN.

Researchers in China have used a combination of surface texturing and vertical-stand mounting to increase light output from nitride semiconductor LEDs by up to 118.5% [T. B. Wei et al, IEEE Electron Device Letters, published online 7 May 2012]. The researchers were based at Chinese Academy of Sciences' Semiconductor Lighting Technology Research and Development Center, Institute of Semiconductors, and at Tsinghua University.

The LED epitaxial structures were grown on 350 μ m two-sided polished c-face free-standing GaN substrates using metal-organic chemical vapor deposition (MOCVD) — see Figure 1a. Indium tin oxide (ITO) was used as a transparent conductor on the

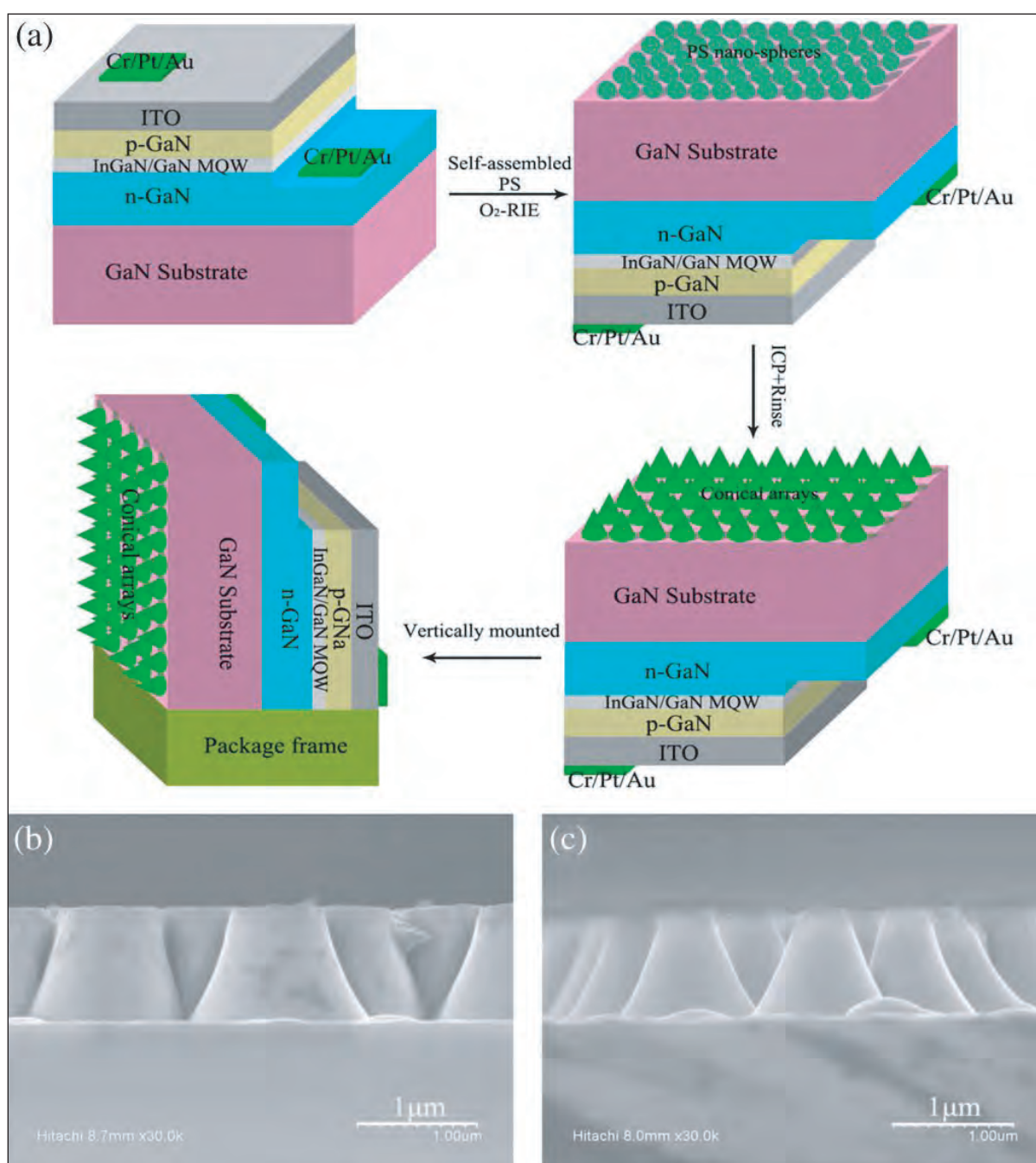


Figure 1. (a) Fabrication flowchart of a VLED with the self-organized conical arrays on an N-face GaN substrate. Cross-sectional view of (b) truncated cone and (c) cone fabricated on LED backside by ICP etching.

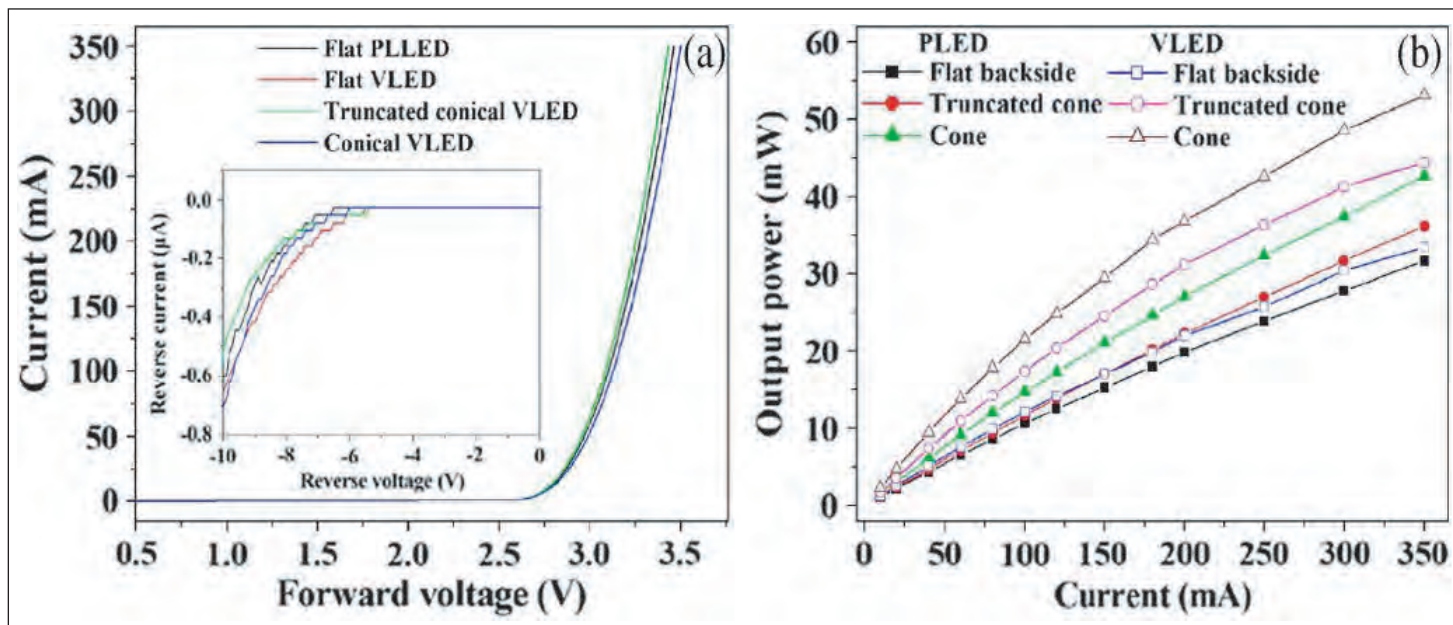


Figure 2. Comparison of (a) forward current–voltage and (b) light output power–current characteristics of planar (PLEDs) and various fabricated vertical-stand (VLEDs) LEDs. Inset: reverse current–voltage characteristics.

p-GaN top surface. A diode mesa was then etched and contact electrodes applied.

The backside was textured by spin-on of polystyrene (PS) balls and inductively coupled plasma reactive-ion etch. After removal of the PS residue, the GaN surface consisted of truncated conical shapes. The purpose of such texturing is to scatter the light at different angles, allowing more light to eventually emerge from the structures. Flat GaN–air interfaces have a very narrow escape cone for light of around 23° , due to the large difference in refractive index (2.5:1).

The amount of truncation of the conical structures was controlled by factors such as etch time and gas flow, and the PS sphere size. The researchers investigated truncated and almost untruncated conical layers to increase light output. In both cases, the average cone base diameter was around $1.2\mu\text{m}$ and

For flat backside devices the increase in light output at 20mA current injection was 16.5%. In the planar arrangement, the 'conical' anti-reflection layer gave 39.8% enhancement, and the truncated cone layer only 12.1%. The vertical-stand arrangement showed improved performance over the corresponding planar-mounted devices of 56.1% and 48.9%, respectively. The full enhancements over the planar-mounted device with flat back-side were 118.5% for the vertical device with conical layer and 66.8% for the truncated cones

the height was $1\mu\text{m}$.

Square LED chips measuring 1mm were mounted vertically (i.e. on their sides) in TO-cans with the n-contact up to avoid short circuits. The attachment of the GaN chip sidewall to the package frame was made with high thermal conductivity silver paste. Conventional LEDs were also planar-mounted without mirrors for comparison. The vertical mounting allowed light to escape from both sides of the chip.

While the electrical performance was similar, the light output powers of the vertical-stand devices were increased over those of the planar comparison LEDs (Figure 2). For flat backside devices the increase in light output at 20mA current injection was 16.5%. In the planar arrangement, the 'conical' anti-reflection layer gave 39.8% enhancement, and the truncated cone layer only 12.1%. The vertical-stand arrangement showed improved performance over the corresponding planar-mounted devices of 56.1% and 48.9%, respectively. The full enhancements over the planar-mounted device with flat back-side were 118.5% for the vertical device with conical layer and 66.8% for the truncated cones.

The devices also benefit from the better thermal conductivity of GaN over sapphire, showing reduced thermal degradation effects up to 350mA current. Also, the red-shift of the peak wavelength is small, at 0.7nm for the planar-mounted devices and 1.9nm for the vertical-stand devices.

Angular emission studies suggest the VLEDs emit more light through their p-GaN surfaces, compared with roughened N-faces where the conical structures are formed. ■

<http://ieeexplore.ieee.org/xpl/articleDetails.jsp?tp=&arnumber=6196174>

Author: Mike Cooke

Electrical efficiency and current crowding in vertical InGaN/SiC LEDs

Series resistance accounts for 25% of power loss at high current, according to Ukraine-based group.

Researchers at Ukraine's Lashkaryov Institute of Semiconductor Physics have been studying current crowding and electrical efficiency degradation in vertical indium gallium nitride (InGaN) light-emitting diodes (LEDs) made from material grown on silicon carbide (SiC) substrates [Volodimir K. Malyutenko et al, IEEE Photonics Technology Letters, published online 25 April 2012].

The researchers stress the importance of power conversion efficiency (PCE) — the ratio of output to input — as the key figure of merit for LEDs. Degradation effects for PCE include optical losses from non-radiative recombination and poor light extraction and electrical losses such as shunt and series resistances from contact metals and thick device layers.

The team was particularly keen to seek out the ways in which the PCE of high-power devices could be improved. SiC is an interesting substrate for such devices since it has high thermal conductivity and can be made in an electrically conducting form. This is in contrast to the main commercial substrate for nitride semiconductor light-emitting devices — sapphire — which is both thermally and electrically insulating.

The use of an electrically conducting substrate allows for vertical current flow through the device, which reduces the operating voltage and series resistance, improves current spreading and thermal management, and allows for a wider light-emitting area. Sapphire substrate devices must have their two electrical contacts on the same side of the device, with the current needing to flow laterally to reach the active region.

The researchers used commercial 475nm blue InGaN multi-quantum well LED epitaxial structures grown on conductive silicon carbide (SiC) substrates. The use of conducting SiC allows vertical LED structures. The

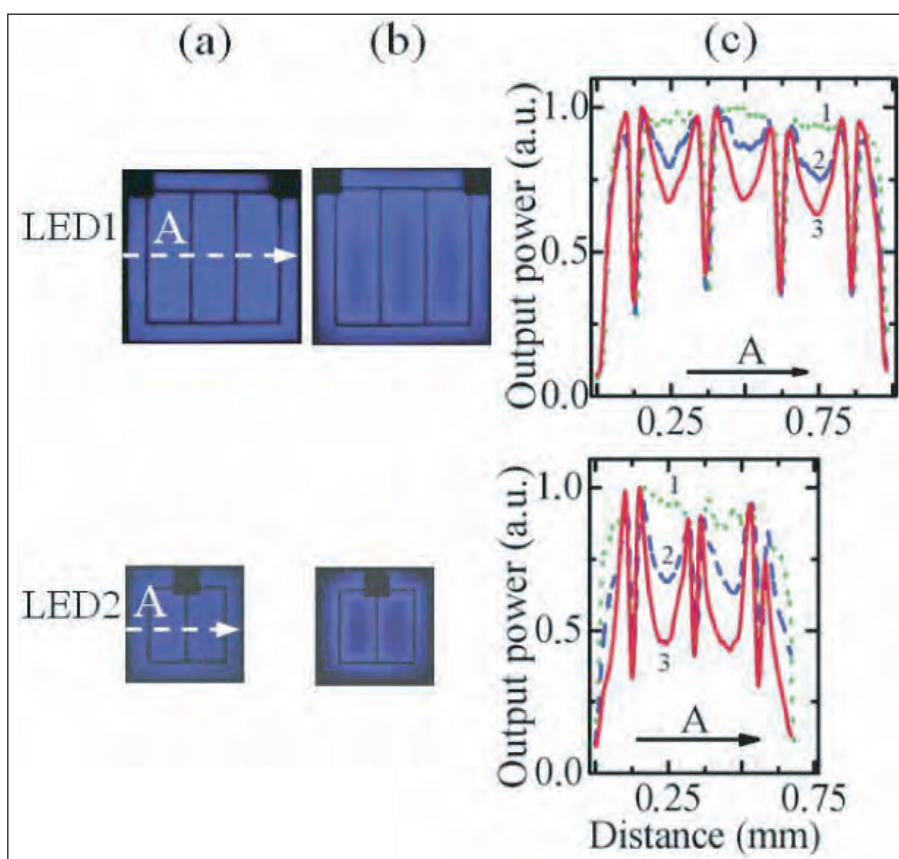


Figure 1. Summary of the optical characterization of LEDs. Near-field maps of light escaping devices at (a) 1mA current, and (b) maximum rated current; (c) shows light profiles in LEDs along the line A at (1) 1mA, (2) 0.5A, and (3) maximum rated current.

Lashkaryov researchers applied a continuous metal electrode to the p-contact and two types of grid pattern (Figure 1) to the n-contact to allow light extraction. The junction areas of the LEDs were square, of sides 950μm (LED1) and 650μm (LED2). The LED1 grid had three loops separated by 225μm, while the two-loop LED2 had 200μm separations. The contact stripes of LED1 were twice as long as LED2's.

The maximum rated pulsed forward currents of LED1 and LED2 were 1.25A and 1.0A, respectively. The researchers found that these currents fall in the domain where the series resistance losses of the

devices are significant. The series resistances of the devices were similar at 0.83Ω (LED1) and 1.15Ω (LED2), despite LED1 having twice the area of LED2. At the maximum rated currents, the researchers estimate that around 25% of the input power in either device was lost due to series resistance.

The LEDs were soldered p-side down to a massive heat sink. Measurements were carried out at room temperature using pulsed currents to avoid self-heating effects.

Near-field light-emission profiles were gathered by scans across the devices with an optical microscope and measurement by CCD (Figure 1c). As the current increases to the maximum rating value, the LED emissions are seen to be more concentrated near the electrodes due to current-crowding effects. At the maximum current, light emission in the center of the loops is only 60% of maximum for LED1 and 45% for LED2. The researchers estimate that the current-spreading lengths from the electrode at maximum current are $90\mu\text{m}$ and $60\mu\text{m}$ for LED1 and LED2, respectively.

Since the light emission in the electrode-free region is much reduced, these current-

crowding effects lead to more light being blocked by the n-contact.

The effective emitting region is therefore much smaller than the active device area. The result is degradation of both internal quantum efficiency (IQE) and external quantum efficiency (EQE).

The researchers comment: "Such observations coincide well with the results of previous studies performed on vertical AlGaInP,

The researchers believe that efforts to improve light extraction (involving roughening the emission surfaces to reduce reflection of light back into devices) could significantly increase series resistance, enhance current-crowding effects, and reduce the current spreading length. "All these could impair the benefit in optical power emitted at given current by decreasing the electrical efficiency and PCE through the need to increase both voltage and input power," they say

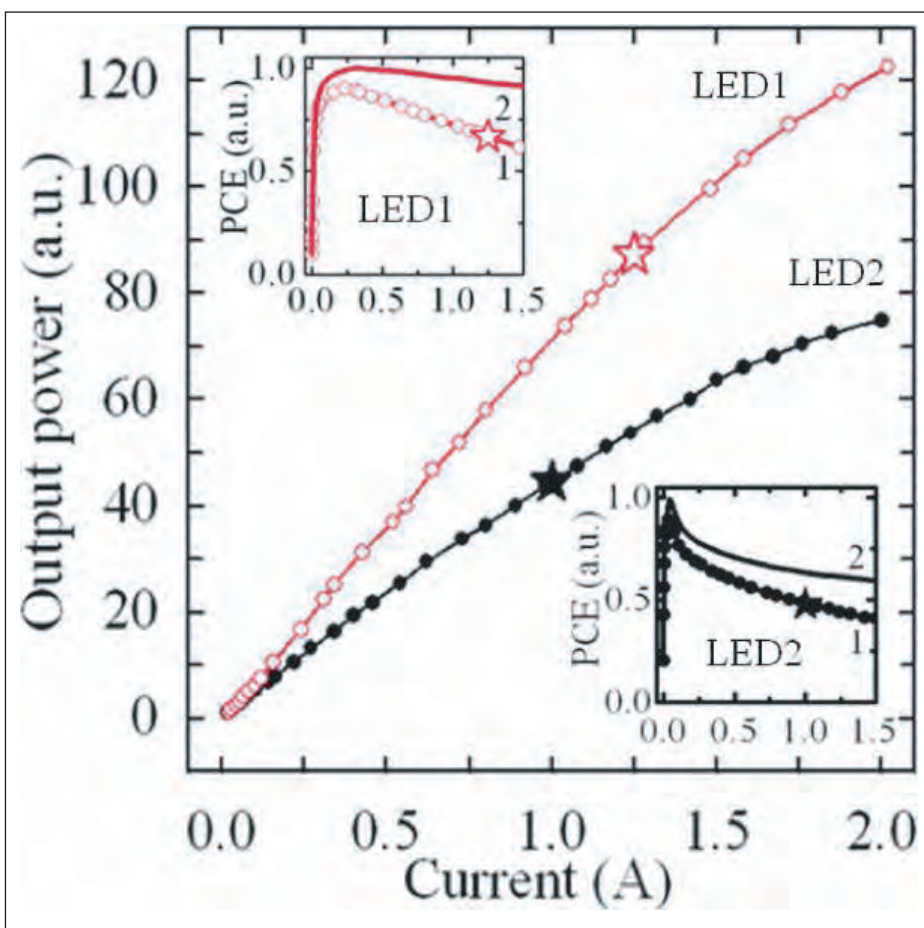


Figure 2. Experimental light output power versus current. Both curves are normalized to the light intensity at 20mA. Insets: power conversion efficiency as (1) a function of current calculated for the input power and (2) the power consumed by the junction.

AlGaAs and InAsSbP LEDs, and demonstrate the critical need for developing a current-crowding-free vertical design for high-power LEDs."

The researchers also carried out total light output power measurements as functions of injection current to determine the effects of series resistance on performance. The behavior of the power conversion efficiency showed a typical droop effect at high current. The PCE fell from maximum light output (at 340mA for LED1 and 43mA for LED2) to that at the maximum rated current was 26% for LED1 and 48% for LED2. Removing the losses from series resistance reduced these falls to 10% for LED1 and 37% for LED2.

The researchers believe that efforts to improve light extraction (involving roughening the emission surfaces to reduce reflection of light back into devices) could significantly increase series resistance, enhance current-crowding effects, and reduce the current spreading length. "All these could impair the benefit in optical power emitted at given current by decreasing the electrical efficiency and PCE through the need to increase both voltage and input power," they say. ■

<http://dx.doi.org/10.1109/LPT.2012.2196426>

Author: Mike Cooke

Nanoporous gallium nitride for vertical LED lift-off

Yale University researchers have used an electrochemical etch to create a nanoporous GaN/sapphire template for vertical current-flow LEDs.

Yale University has developed techniques to release nitride semiconductor layers and transfer them to other substrates, allowing vertical current-flow light-emitting diodes (LEDs) [Yu Zhang et al, Appl. Phys. Lett., vol100, p181908, 2012].

The Yale technique creates a nanoporous (NP) layer of gallium nitride (GaN) using an electrochemical etch. Further nitride layers are then grown. A new substrate can then be applied to the top of the structure and the growth substrate removed at the weakened nanoporous region.

Nitride LEDs are grown commercially on sapphire substrates. However, sapphire is electrically and thermally insulating, which are not ideal properties for LEDs.

With such devices both the contact pads are usually placed on the nitride layers and some of the current flow through the device is in a lateral direction, creating current bunching effects that reduce efficiency.

Vertical current flow can be arranged by releasing the nitride layers from the growth substrate. Various techniques have been developed such as laser lift-off and under-etching. However, these techniques can be slow or expensive to implement in manufacturing.

In the Yale method, a silicon-doped n-GaN layer was first grown on sapphire using a standard two-step metal-organic chemical vapor deposition (MOCVD) process. The GaN layer was then subjected as the anode in an oxalic acid electrolyte to electrochemical etching with a platinum cathode. By controlling the electric potential, the porosity of the GaN can be varied from sparse

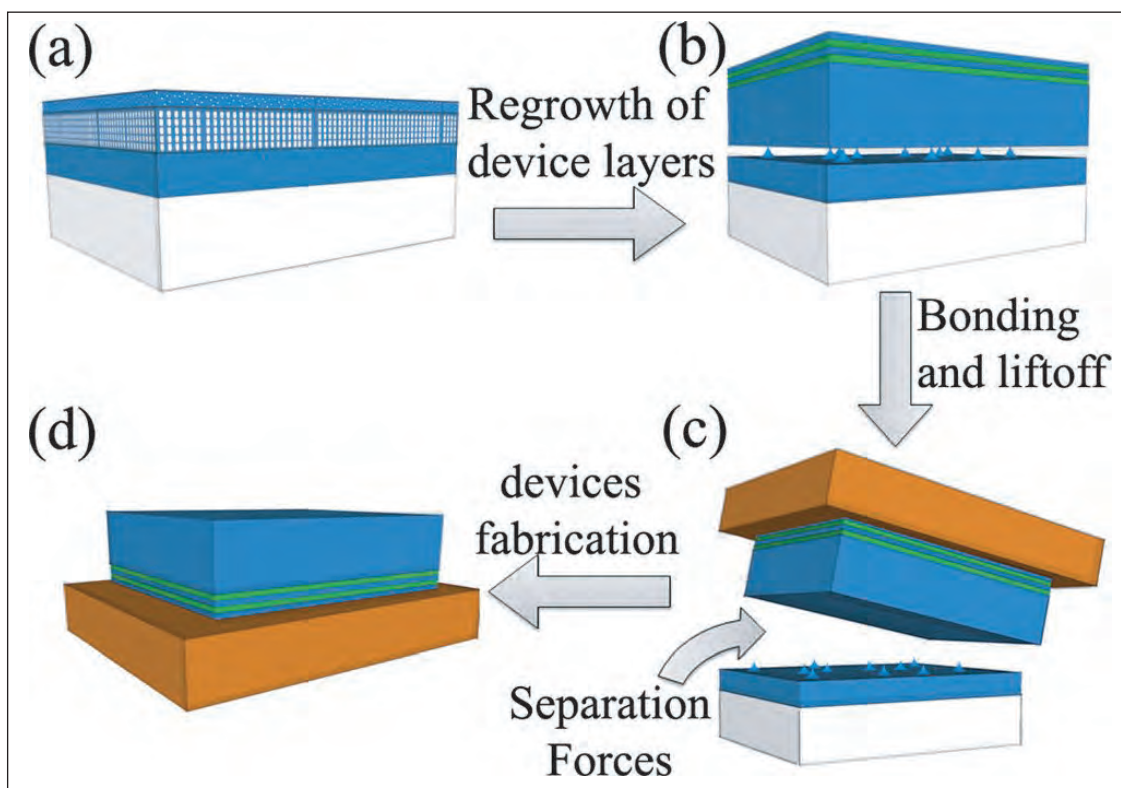


Figure 1. Conceptual process flow of epitaxial lift-off beginning from (a) preparation of GaN with designed porosity profile, (b) MOCVD overgrowth of GaN device layers and transformation of NP GaN into voided region for subsequent lift-off, (c) wafer bonding after GaN growth, and (d) room-temperature separation and layer transfer for thin-film vertical LED devices.

narrow pores (10%) to electropolishing (>60%).

The etching proceeds selectively near pore tips following electric field/current flow lines.

For epitaxial lift-off purposes (Figure 1a), the researchers used a two-step etch with a change in bias midway, giving a 300nm-thick high-porosity (>50%) layer capped with a 240nm low-porosity (~10%) layer.

After cleaning, the wafers were subjected to further MOCVD of 5x InGaN/GaN multi-quantum wells between a 3µm n-GaN buffer and a 200nm p-GaN cap (Figure 1b). During the MOCVD process, the initial pores are transformed into air gaps. The overgrown material is tethered to the template by mesoscale pillars with a density of 10⁵/cm².

A large-area lift-off demonstration was performed by bonding a glass slide to the top with a two-part epoxy with a pressure of 30kPa. The lift-off was found to be

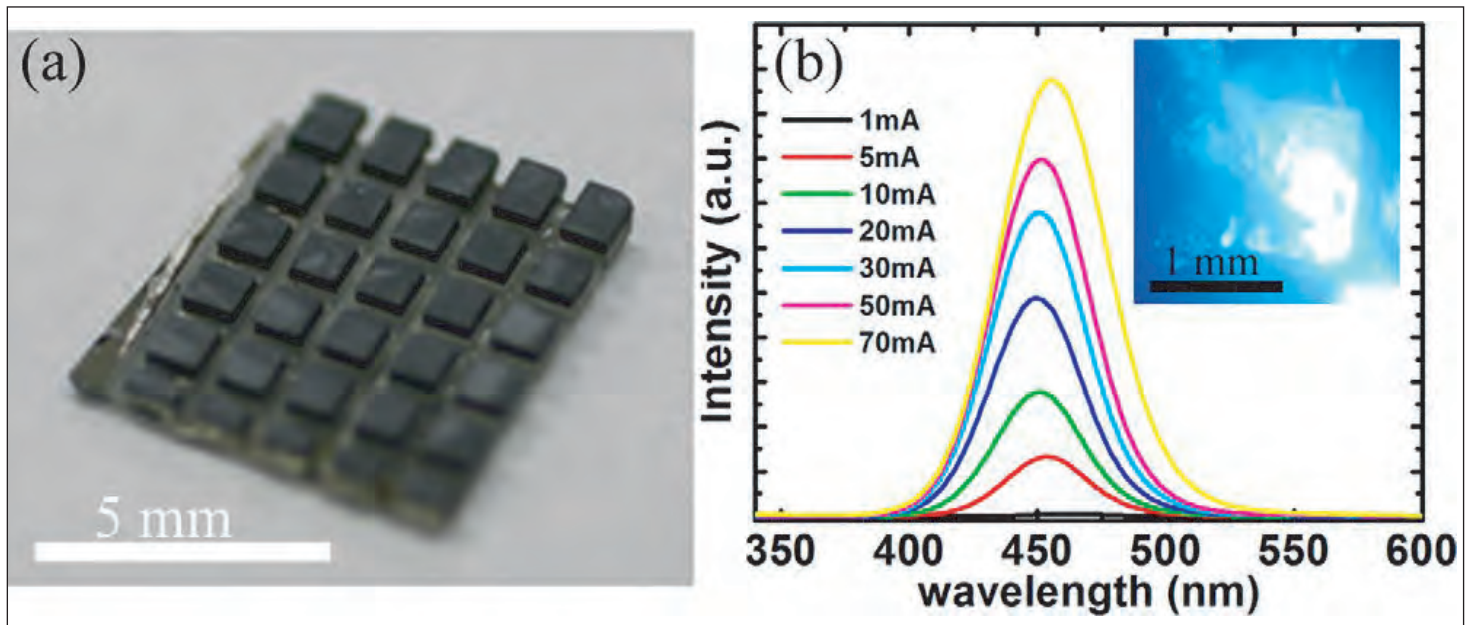


Figure 2. (a) Image of diced, 1mm-square InGaN LED thin films bonded to p-Si wafer and (b) room-temperature electroluminescence spectra and optical image at 5mA current injection of vertical LED from lift-off process.

crack-free. Also, the strain from growth on the lattice-mismatched substrate, measured using Raman spectroscopy, was fully relaxed upon separation by lift-off.

The lift-off technique was also used to create vertical current-flow LEDs by bonding the epitaxial material to p-type silicon. The bond between the nitride and silicon semiconductors consisted of titanium/nickel p-contact

metals and silver epoxy. The bonded wafers were diced into 1mm squares using a diamond saw. The sapphire substrate pieces were removed using tweezers.

Preliminary electroluminescence spectra have been measured at room temperature (Figure 2). ■

<http://link.aip.org/link/doi/10.1063/1.4711218>

Author: Mike Cooke

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Selective area growth recessing for improved normally-on nitride HFETs

Researchers in China have achieved a maximum current of 300mA/mm compared with 64mA/mm for an etched device.

Researchers in China based at State Key Laboratory of Optoelectronic Materials and Technologies, Sun Yat-Sen University, have demonstrated a selective area growth (SAG) method for recessing gates in aluminium gallium nitride (AlGaN) semiconductor heterostructure field-effect transistors (HFETs) [Zhiyuan He et al, Jpn. J. Appl. Phys., vol51, p054103, 2012]. The resulting device had higher performance than one produced using conventional recessing techniques by avoiding the damage associated with plasma etch.

Recessing refers to the creation of a trench in the barrier layer of the HFET, reducing the distance between the gate electrode and channel. This can shift the threshold voltage of the transistor in a positive direction, even enabling normally-off behavior (off at zero gate potential) as opposed to the usual normally-on operation of simple nitride HFETs. Normally-off operation is desirable for reducing power consumption and for fail-safe operation in power devices.

The HFET structures (Figure 1) were grown on silicon (111) substrates using metal-organic chemical vapor deposition (MOCVD). The buffer consisted of 1.4 μm of high-resistance intrinsic GaN. The barrier layer was $\text{Al}_{0.25}\text{Ga}_{0.75}\text{N}$. The SAG process for recessing consisted of patterning a silicon dioxide mask layer on top of a 10nm AlGaN barrier. A further 15nm growth was then carried out to leave a recessed stripe for the gate electrode.

Comparison devices with (ICP-HFET) and without (C-HFET) recessing from inductively coupled plasma (ICP) etch into the 25nm AlGaN barrier layer were also produced.

The devices were isolated with mesa etching. The ohmic source-drain contacts consisted of 830°C-annealed titanium/aluminum/nickel/gold. The gates consisted of nickel/gold Schottky contacts. The gate length was 3 μm . The gate-source and gate-drain distances were 1.5 μm and 4 μm , respectively. The gate width was 15 μm .

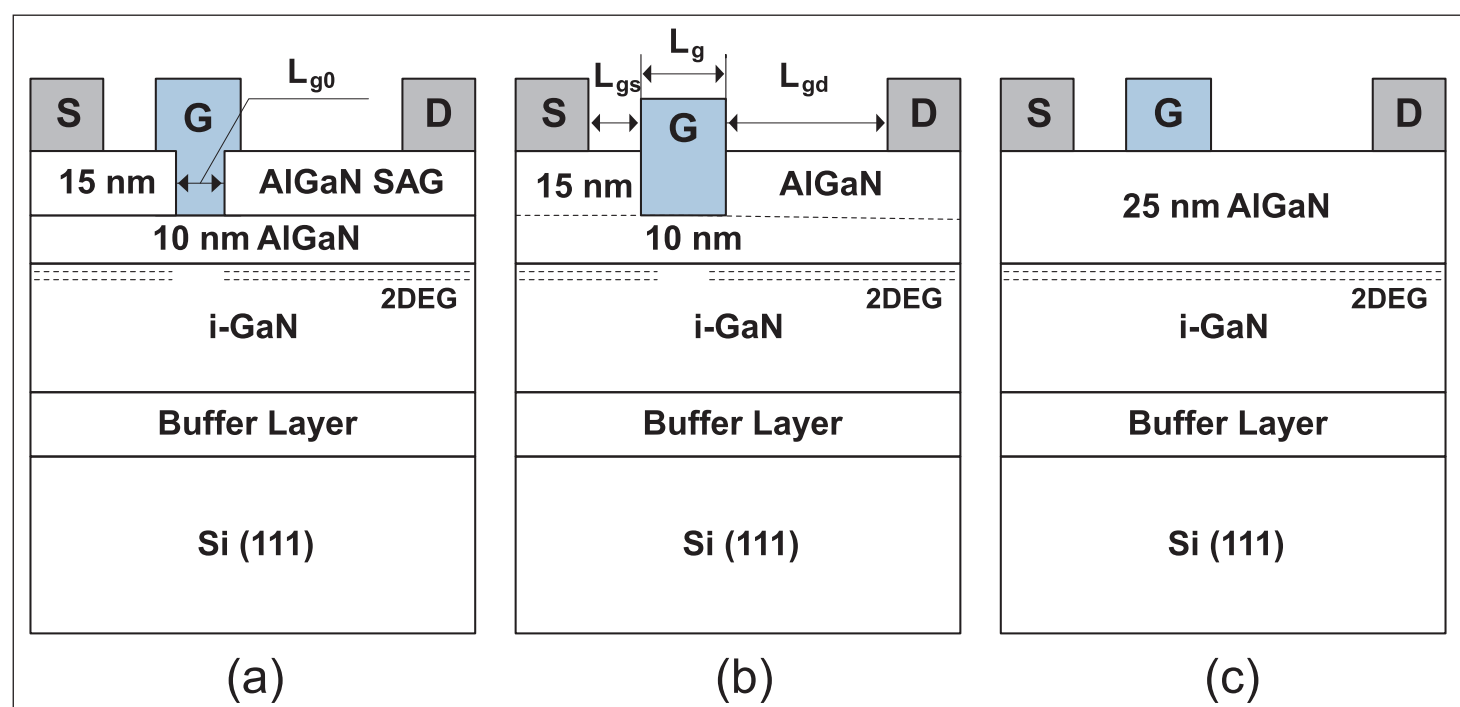


Figure 1. Schematics of SAG-HFET (a), ICP-HFET (b) and C-HFET (c).

The ICP- and SAG-HFETs demonstrated positive thresholds of 0.6V and 0.4V with maximum drain currents at 6V bias of 64mA/mm and 300mA/mm, respectively. The C-HFET had larger maximum drain current of 750mA/mm due to the higher density of carriers under the gate.

The researchers estimated the gate injection current into the channel at $+1.6 \times 10^{-4}$ mA/mm, $+1.3 \times 10^{-4}$ mA/mm and $+48.4$ mA/mm for the C-, SAG, and ICP-HFETs, respectively. The high injection for the ICP-HFET indicates that the Schottky diode gate has turned on, losing its ability to control current flow in the channel. Under positive gate voltage, the electrons from the source end up in the gate and not the drain of the ICP-HFET, resulting in the poor maximum drain current.

The extrinsic (i.e. uncorrected for source resistance effects) transconductance performance gave peak values of 150mS/mm, 135mS/mm and 64mS/mm, respectively, for the C-HFET, SAG-HFET and ICP-HFET devices. The corresponding intrinsic (corrected) transconductances were 234mS/mm, 356mS/mm and 90mS/mm.

The high intrinsic transconductance of the SAG-HFET is probably due to the recessed gate being closer to the channel, giving greater control compared with the C-HFET. The ICP-HFET suffers from the gate leakage current that kicks in before the peak is reached with the SAG-HFET (Figure 2).

Pinch-off current leakage at a negative gate potential of -5.5V and drain bias 20V was -1.6×10^{-3} mA/mm, -2.0×10^{-2} mA/mm and -2.2×10^{-3} mA/mm, for C-,

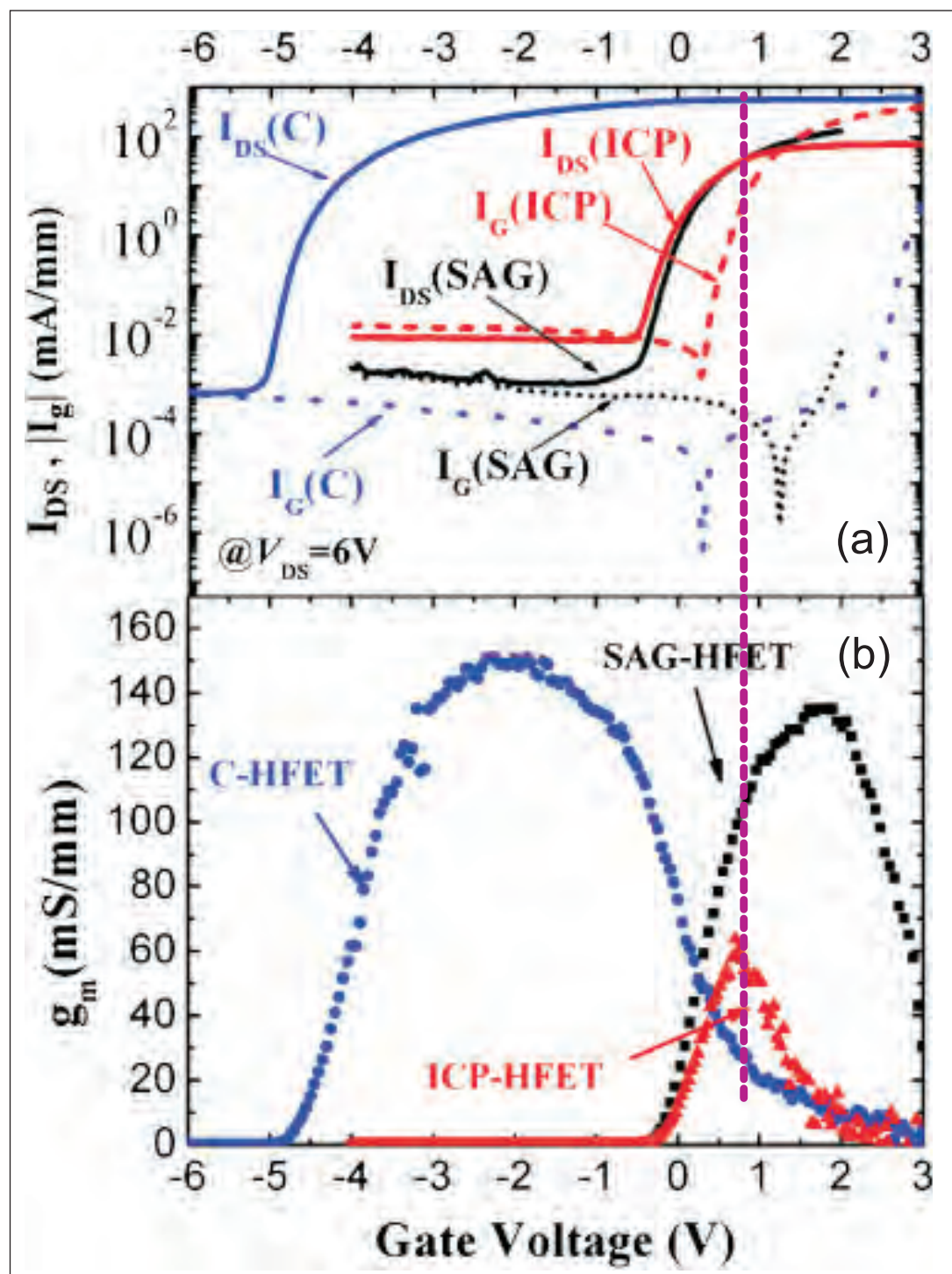


Figure 2. (a) Gate and drain currents under drain voltage of 6V, and (b) transconductance characteristics, for the three HFETs; the value for ICP-HFET showed a sudden drop when the gate voltage increased beyond 1V, corresponding to a sharp increase in gate forward current (marked with dotted line).

ICP- and SAG-HFETs, respectively. Again, the ICP-HFET showed (an order of magnitude) worse behavior.

The researchers believe that the ICP-HFET Schottky contact is degraded by the plasma etch process, where crystal damage could create defects that allow barrier tunneling effects. ■

<http://jjap.jsap.jp/link?JJAP/51/054103>

Author: Mike Cooke

Record transconductance of 1105mS/mm for GaN/InAlN MIS-HFET

UCSB has achieved maximum drain current density of 2.77A/mm in a gate-first self-aligned MIS-HFET device using N-polar nitride material.

University of California Santa Barbara (UCSB) has produced gate-first self-aligned metal-insulator-semiconductor heterostructure field-effect transistors (MIS-HFETs) based on nitride semiconductors that demonstrated record extrinsic transconductance of 1105mS/mm [Nidhi et al, IEEE Electron Device Letters, published online 26 April 2012].

The devices used N-polar nitride semiconductor material rather than the more usual Ga-polar gallium nitride (GaN) buffer devices. Also, instead of a strained aluminium gallium nitride (AlGaN) top barrier, the UCSB devices use an unstrained indium aluminium nitride (InAlN) bottom/back barrier to generate a two-dimensional electron gas (2DEG) in the GaN channel layer.

The epitaxial material (Figure 1) for the devices was grown using plasma-assisted molecular beam epitaxy (PA-MBE) on C-face 6H silicon carbide (SiC) substrates. The $\text{In}_{0.17}\text{Al}_{0.83}\text{N}$ back-barrier was lattice matched to the GaN layers. The 1nm of low-temperature GaN was designed to inhibit indium desorption in subsequent high-temperature process steps. The 2nm AlN inter-layer was aimed at reducing alloy scattering. The structure was found to give a low sheet resistance of 330 Ω /square.

A silicon nitride layer was applied as gate dielectric using metal-organic chemical vapor deposition (MOCVD). The gate metal stack consisted of tungsten/chromium/silicon dioxide/chromium. These steps constitute the 'gate-first' part of the self-aligned process.

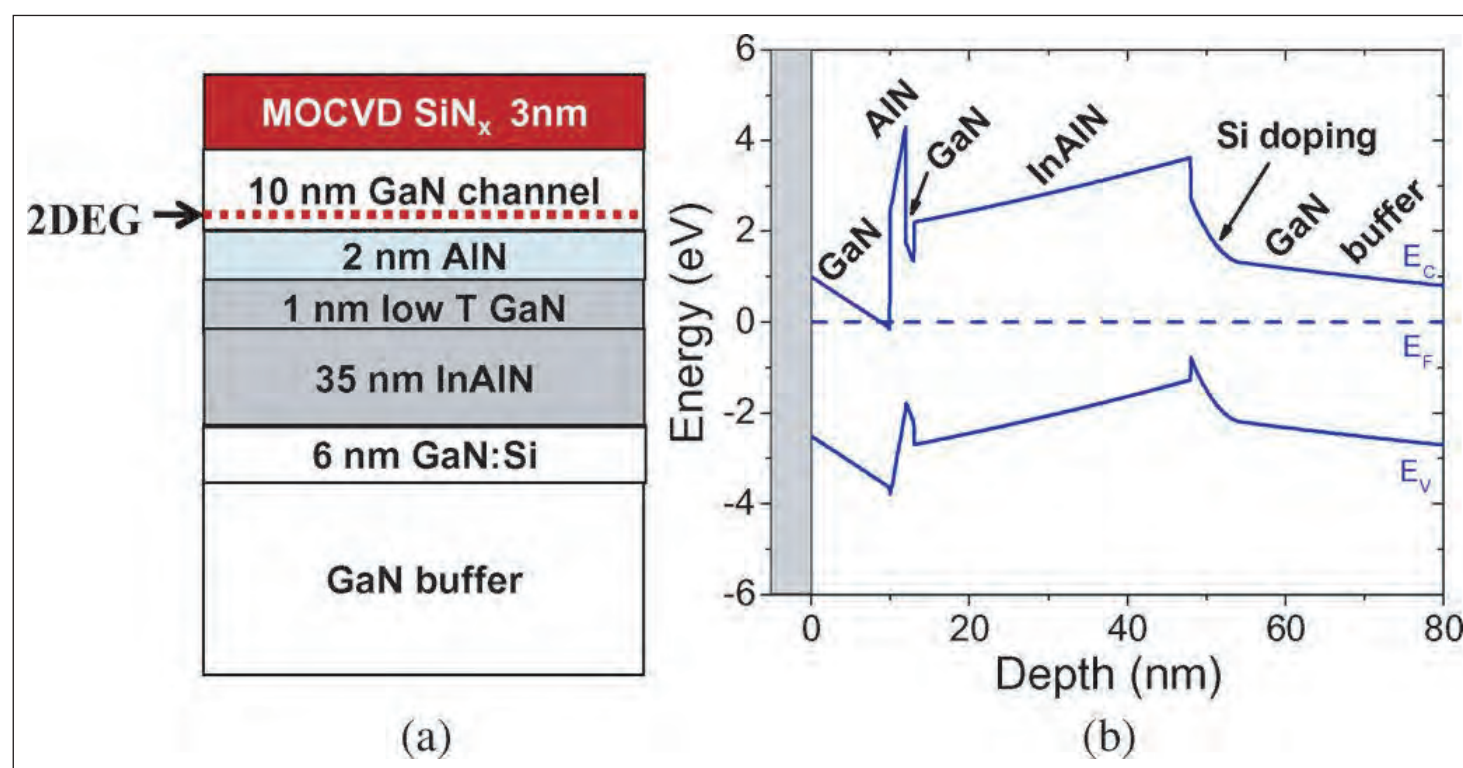


Figure 1. (a) Device epitaxial-layer structure for scaled GaN channel with an InAlN back barrier. (b) Band diagram of the device under the gate.

After gate definition, a 40nm layer of silicon nitride layer from plasma-enhanced chemical vapor deposition (PECVD) was used as spacer material around the gates to allow MBE re-growth of highly doped InGaN/InN for source/drain contact access, giving an 'ultra-low' contact resistance of $25\Omega\cdot\mu\text{m}$. The polycrystalline growth on the gate finger was etched away, followed by mesa isolation of the individual transistor. Titanium/gold non-alloyed metal layers were used as source/drain ohmic and probe contacts.

A 60nm-gate device showed a maximum drain current density of 2.77A/mm and an on-resistance of $0.29\Omega\cdot\text{mm}$. The current is described as 'state-of-the-art' for both Ga-polar and N-polar devices. The on-resistance is "the lowest value ever reported for a GaN device."

At 0V gate potential, the saturated drain current was 2.13A/mm at drain bias of 2V. For a 30nm-gate device, the saturated drain current density was 2.25A/mm . The peak extrinsic transconductances (g_m) were 1105mS/mm and 1000mS/mm for 60nm and 30nm gates, respectively. The researchers comment: "This is the highest value for extrinsic g_m reported for III-nitride

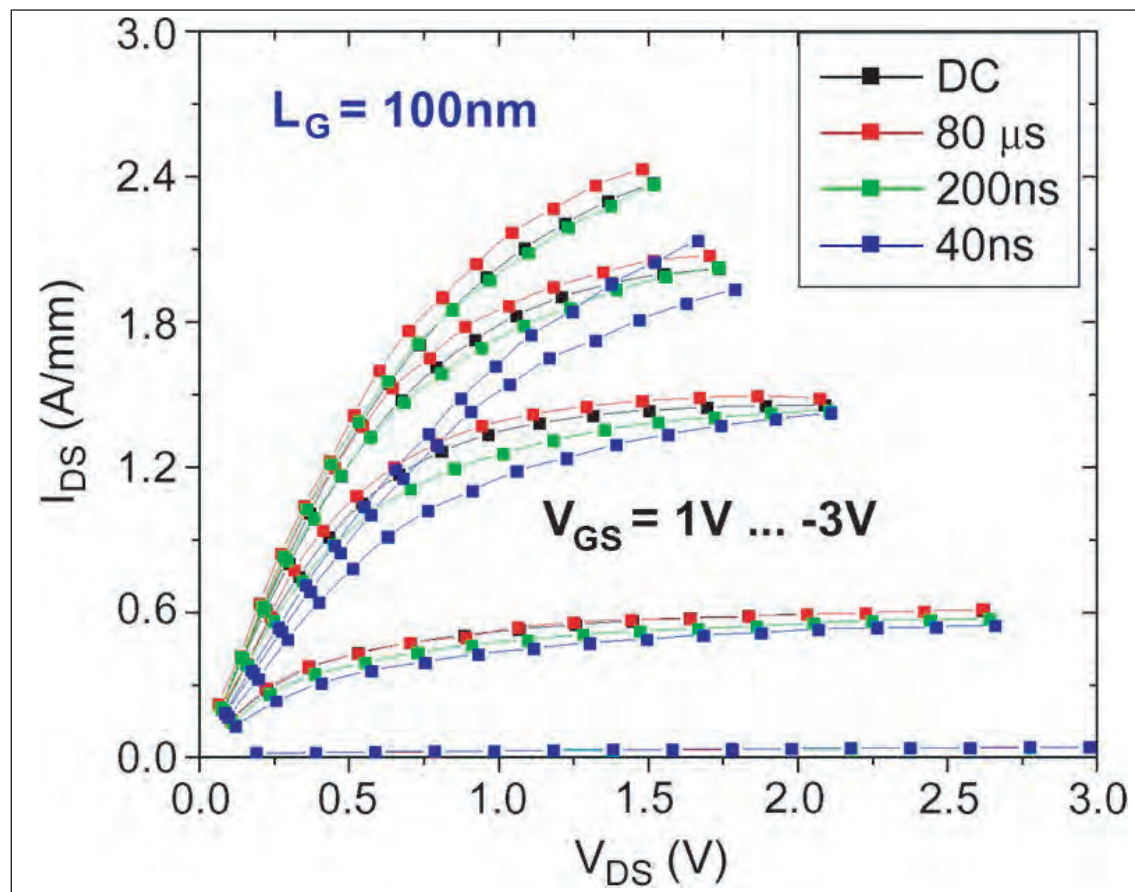


Figure 2. Pulsed current-voltage (I - V) characteristics for 100nm gate, showing significant current collapse and knee walkout for 40ns gate pulses.

A 60nm-gate device showed a maximum drain current density of 2.77A/mm and an on-resistance of $0.29\Omega\cdot\text{mm}$ "the lowest value ever reported for a GaN device."

For a 30nm-gate device, the saturated drain current density was 2.25A/mm .

The peak extrinsic transconductances were 1105mS/mm and 1000mS/mm for 60nm and 30nm gates, respectively... "This is the highest value for extrinsic g_m reported for III-nitride HEMTs on any crystal orientation."

HEMTs on any crystal orientation."

The off-state leakage was around 20mA/mm for 2V drain bias. Hard breakdown occurred at 24V drain bias.

The researchers attributed the improved device performance to "significant reduction in the device to low on-resistance and high extrinsic transconductance."

The performance was also measured up to frequencies of 67GHz. The 30nm device had a cut-off frequency (f_T) of 155GHz, but a maximum oscillation of only 20GHz (drain 3V, gate -2.5V). The poor f_{max} figure was blamed on the high resistance of the tungsten-gate.

Although the f_T is 'excellent', it does not reflect what should be expected from the transconductance value, along with the relatively low values for the parasitic components. Pulsed measurements (40nsec), however, showed significant current collapse and 'knee walkout' (Figure 2).

The researchers tentatively attribute these effects to "shallow traps in the plasma MBE-grown InAlN or the low-temperature GaN layer below the AlN interlayer."

The UCSB work was supported in part by US Navy and Defense Advanced Research Projects Agency (DARPA) funding. ■

<http://dx.doi.org/10.1109/LED.2012.2190965>

Plasma oxidation of aluminium for insulated nitride transistor gates

RWTH Aachen and Aixtron have developed a process that allows devices with subthreshold behavior near the theoretical limit.

RWTH Aachen University and Aixtron SE in Germany have developed a new technique to create aluminium oxide insulated gates for nitride semiconductor transistors [Herwig Hahn et al, Semicond. Sci. Technol., vol27, p062001, 2012]. The method consists of depositing a thin layer of aluminium that is then oxidized in oxygen plasma, creating an insulating layer of aluminium oxide (AlO_x).

Nitride transistors have excellent potential as the basis of RF power amplifiers and are also promising for use in high-power switches. However, at present, gate leakage currents limit the lifetime and performance of such devices. These currents are relatively high because up to now the best performing devices have used a gate with metal deposited directly on the nitride semiconductor material, using the rectifying Schottky barrier as insulation. This only works in the range of the Schottky barrier height.

For power devices, one tends to want enhancement-mode (e-mode) devices that are normally off when there is no gate potential, reducing power consumption and allowing fail-safe operation. Such e-mode devices should need high positive gate voltages for significant drain current to flow. However, such potentials would then be near or fall outside the Schottky barrier height.

Recently, researchers around the world have been searching for a way to incorporate an insulation layer between the gate and channel, in the same way as in metal-oxide-semiconductor field-effect transistors (MOSFETs).

The epitaxial material (Figure 1) used by RWTH/Aixtron was grown using metal-organic chemical vapor deposition (MOCVD) on 6-inch silicon (Si) <111> substrates. The material was diced into 15mm x 15mm pieces. Circular large-area diodes and transistors were used to test the gate formation process (Table 1).

The 50nm/200nm nickel/gold (Ni/Au) reference represents a standard Schottky gate structure. Sample A consisted of 3.5nm aluminium applied before further evaporation of Ni/Au gate metals of the same thickness as for the reference. Samples B, C and D were subjected to oxygen in various forms.

Cap	GaN	3nm
Barrier	Al _{0.25} Ga _{0.75} N	13nm
Mobility enhancer	AlN	1nm
Buffer	GaN	2µm
Transition	AlN/AlGaN	
Substrate	6-inch Si <111>	

Figure 1: The layer sequence of aluminium gallium nitride (AlGaN) epitaxial materials with 420Ω/square sheet resistance and sheet charge density 6.5x10¹²/cm².

The plasma oxidations were carried out in the chambers of equipment designed for inductively coupled plasma reactive ion etching (ICP-RIE). After oxidation, the samples were returned to the evaporation equipment for further metal deposition of 50nm/200nm Ni/Au.

The gates were deposited on photoresist masks that were later removed in a standard lift-off process. The 2µm gate-length transistors also had standard ohmic contacts for the source/drain access applied before gate deposition. Various 10-minute rapid ther-

Table 1. Set of Schottky reference and four samples with variation in processing of Al layer.	
Sample	Preparation
Ref.	Ni/Au gate stack
A	Al/Ni/Au evaporated at once
B	Al exposed to clean room air for 1 h
C	Al plasma-oxidized for 2 min, -20V RF bias
D	Al plasma-oxidized for 10 min, -50V RF bias

mal anneal treatments in nitrogen were explored.

The diode measurements suggested that an aluminium oxide (AlO_x) dielectric layer had formed in sample D with a capacitance of 1130 nF/cm^2 . Assuming a typical dielectric constant of 9 would give a layer thickness of 7 nm . The reverse gate leakage was 10^{-4} A/cm^2 , at least one order of magnitude smaller than that of the standard Ni/Au Schottky gate of the reference sample. Sample C also showed the presence of a dielectric, but had a higher reverse gate leakage of 0.01 A/cm^2 .

Since the other samples showed significant degradation due to the presence of interface trap states, the researchers concentrated on sample D in further anneal processing and measurements. Annealing at 600°C reduced gate leakage by an order of magnitude. In transistor structures, the same anneal process resulted in gate leakage less than 1 nA/mm , raising the prospect of on/off ratios of the order of 10^9 .

Capacitance–voltage measurements at 1 MHz show a fall in capacitance with increasing anneal temperature. The researchers comment: “With the decreasing capacitance, the formation of oxides with lower dielectric constant has to be assumed. Also, a reaction with the GaN cap layer cannot be excluded. At the moment, no reasonable explanation for this effect can be presented and, due to this, a meaningful estimation of the oxide thickness cannot be performed.”

Also, shifts in the threshold voltage were found with different anneal temperatures. Unusually the shift was in the positive direction, despite reduced capacitance that would normally be expected to give a negative trend.

For transistors (Figure 3a), another effect of increased anneal temperature is reduced subthreshold swing (steeper slope). For 600°C annealing, the swing is reduced to 80 meV/dec , close

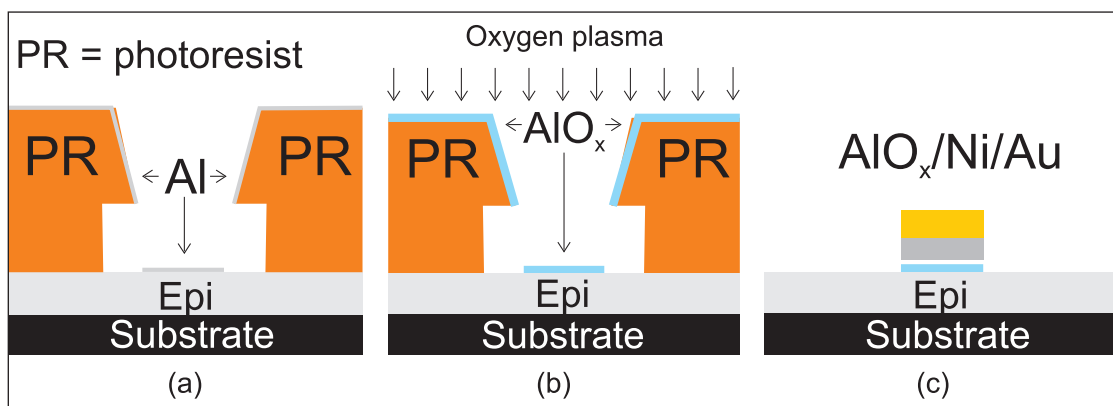


Figure 2: Process scheme for samples C and D. First, Al was evaporated (a). Second, the samples were exposed to oxygen plasma in an ICP tool (b). Third, Ni and Au were evaporated with subsequent lift-off (c).

to the room-temperature limit of 60 meV/dec . Again, the threshold increases by $+0.7\text{ V}$. The transconductance is increased from 80 mS/mm for the as-deposited sample to almost double at 140 mS/mm for 600°C annealing. The researchers see the transconductance as “quite good” for unpassivated devices with a thick AlGaN barrier and $2\mu\text{m}$ gate length.

The researchers find that the transconductance improvement is associated with the subthreshold performance, “indicating a better controllability of the channel due to a decreased amount of trap states at the insulator–semiconductor interface”, and not to reduced source resistance.

The researchers conclude: “As this process is applicable with surface passivation prior to gate deposition, it might be an elegant way to form high-performance enhancement-mode MISHFETs.” ■

<http://dx.doi.org/10.1088/0268-1242/27/6/062001>

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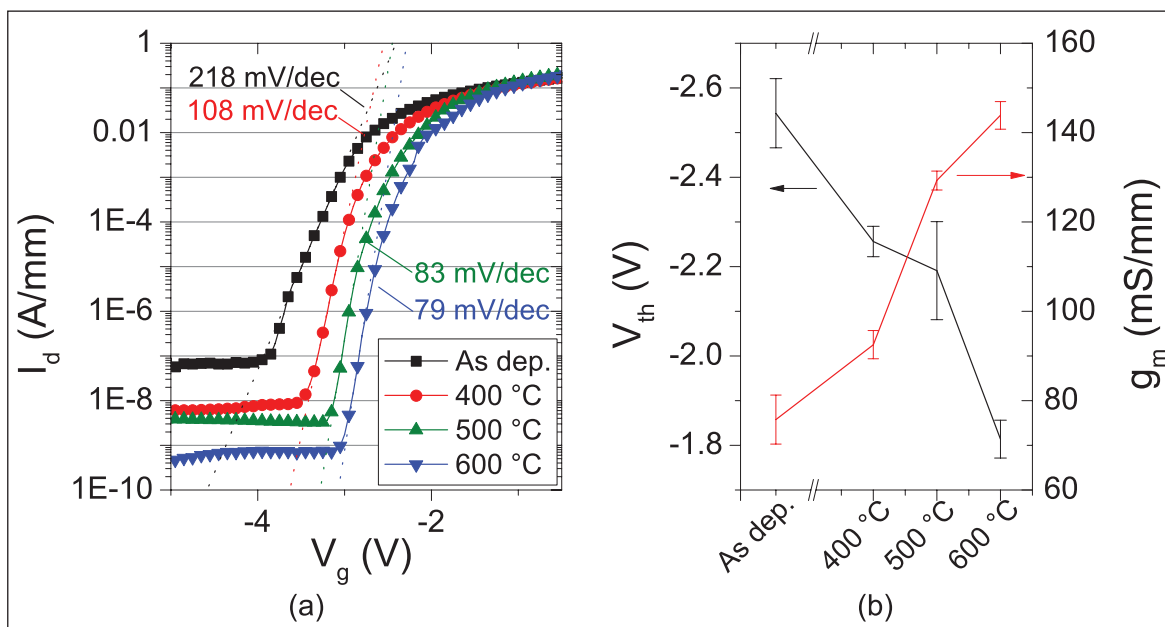


Figure 3: Semi-logarithmic transfer characteristics for 10 V drain bias (a); dependence of threshold voltage (left) and peak transconductance (right) vs annealing temperature (b).

Annealing RIE damage to improve InGaAs QWFET performance

MIT presents a novel self-aligned gate-last InGaAs quantum well MOSFET process with a view to manufacturability.

Massachusetts Institute of Technology (MIT) researchers have found that a post-etch anneal dramatically improves the performance of their self-aligned indium gallium arsenide (InGaAs) quantum-well metal-oxide-semiconductor field-effect transistors (QWFETs) [Jianqiang Lin et al, Appl. Phys. Express vol5, p064002, 2012].

It is hoped that devices with high-mobility channels such as InGaAs could lead to higher-performance logic than traditional silicon-based CMOS circuitry. However, developing manufacturable self-aligned processes involving anisotropic etching is a challenge to researchers. For InGaAs devices, a particular concern is that such anisotropic reactive-ion etching (RIE) can severely damage device performance.

The MIT devices were produced from lattice-matched epitaxial heterostructures grown by molecular beam epitaxy (MBE) wafer supplier IntelliEpi Inc on indium phosphide (InP) substrates with 400nm InAlAs buffer, 15nm InGaAs channel, 4nm InP etch stop, and 15nm n-InGaAs cap layers. The InAlAs layer was Si-doped in a thin layer at 5nm beneath the channel.

Device fabrication (Figure 1) was carried out at the

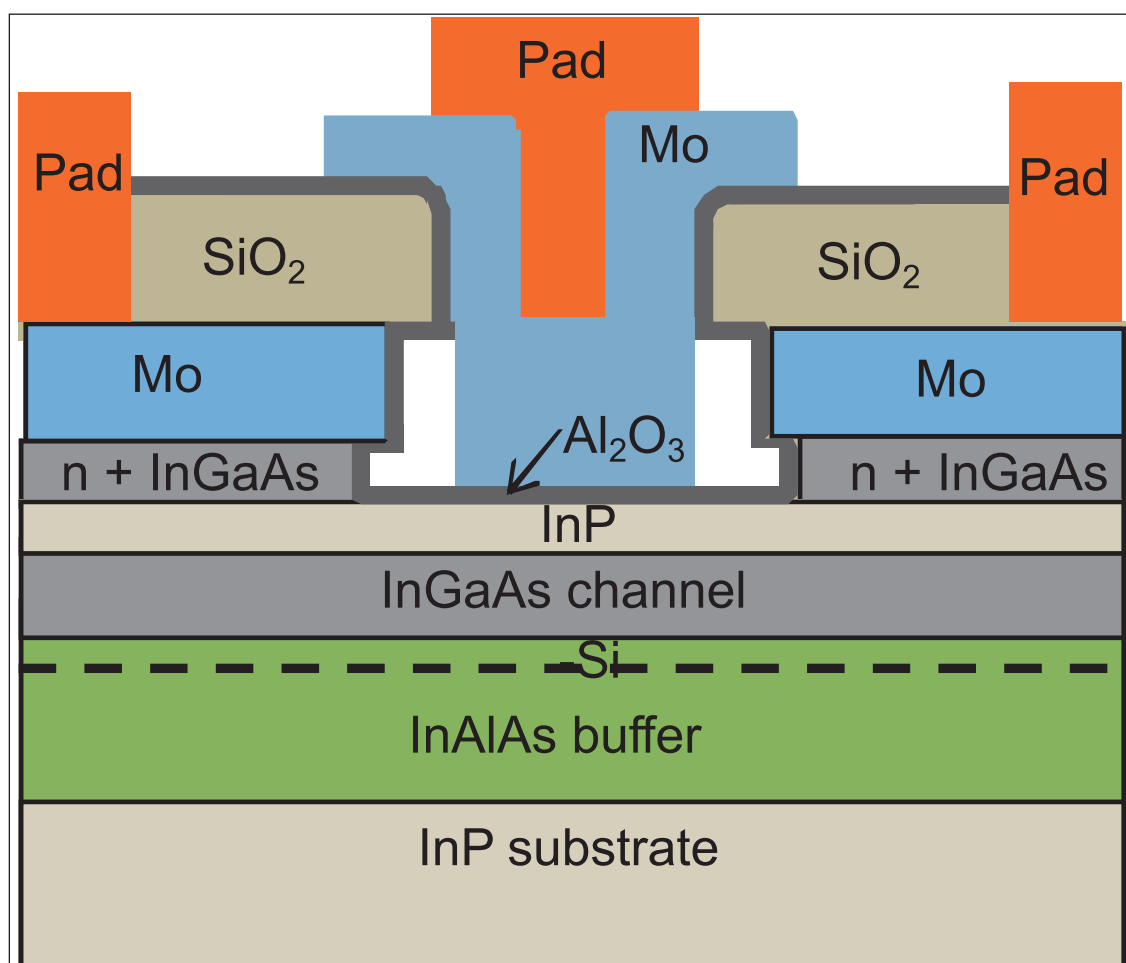


Figure 1. Cross-sectional schematic of self-aligned InGaAs QW-MOSFET. A self-aligned air spacer that is passivated by Al_2O_3 separates the S/D and gate metal. The side recess length is 100nm.

Microsystems Technology Laboratories at MIT. The first step was to evaporate 50nm molybdenum (Mo), then apply 60nm silicon dioxide (SiO_2) through plasma-enhanced chemical vapor deposition (PECVD).

The gate region was defined using photolithography and then a series of etches carried out to reach the InP etch stop layer. These RIEs were followed by a selective plasma etch designed to pull back the Mo from the edges of the SiO_2 layer. The RIE damage was repaired using a 340°C anneal in nitrogen for 15 minutes.

The InGaAs cap layer was etched under the Mo layer using a wet etch of citric acid in hydrogen peroxide.

Cleaning and thinning of the InP layer was then performed before the application of 4nm Al_2O_3 dielectric using atomic layer deposition (ALD). More Mo was then applied and etched as gate metal. The element was chosen because it is CMOS-compatible, has a suitable workfunction and, further, it can be patterned using RIE.

The RIE damage annealing produced dramatic improvements in $2\mu\text{m}$ -gate-length devices (Figure 2). The peak transconductance was increased from around $50\mu\text{S}/\mu\text{m}$ for a non-annealed device to $205\mu\text{S}/\mu\text{m}$ with annealing. The subthreshold swing was reduced from $300\text{mV}/\text{dec}$ to $95\text{mV}/\text{dec}$.

The threshold voltage of the annealed device was negative at -37mV , but was closer to the enhancement-mode region ($>0\text{V}$) needed for CMOS logic applications. Also, the gate leakage at 1V overdrive potential was low, at $1.1 \times 10^{-4}\text{A}/\text{cm}^2$. ■

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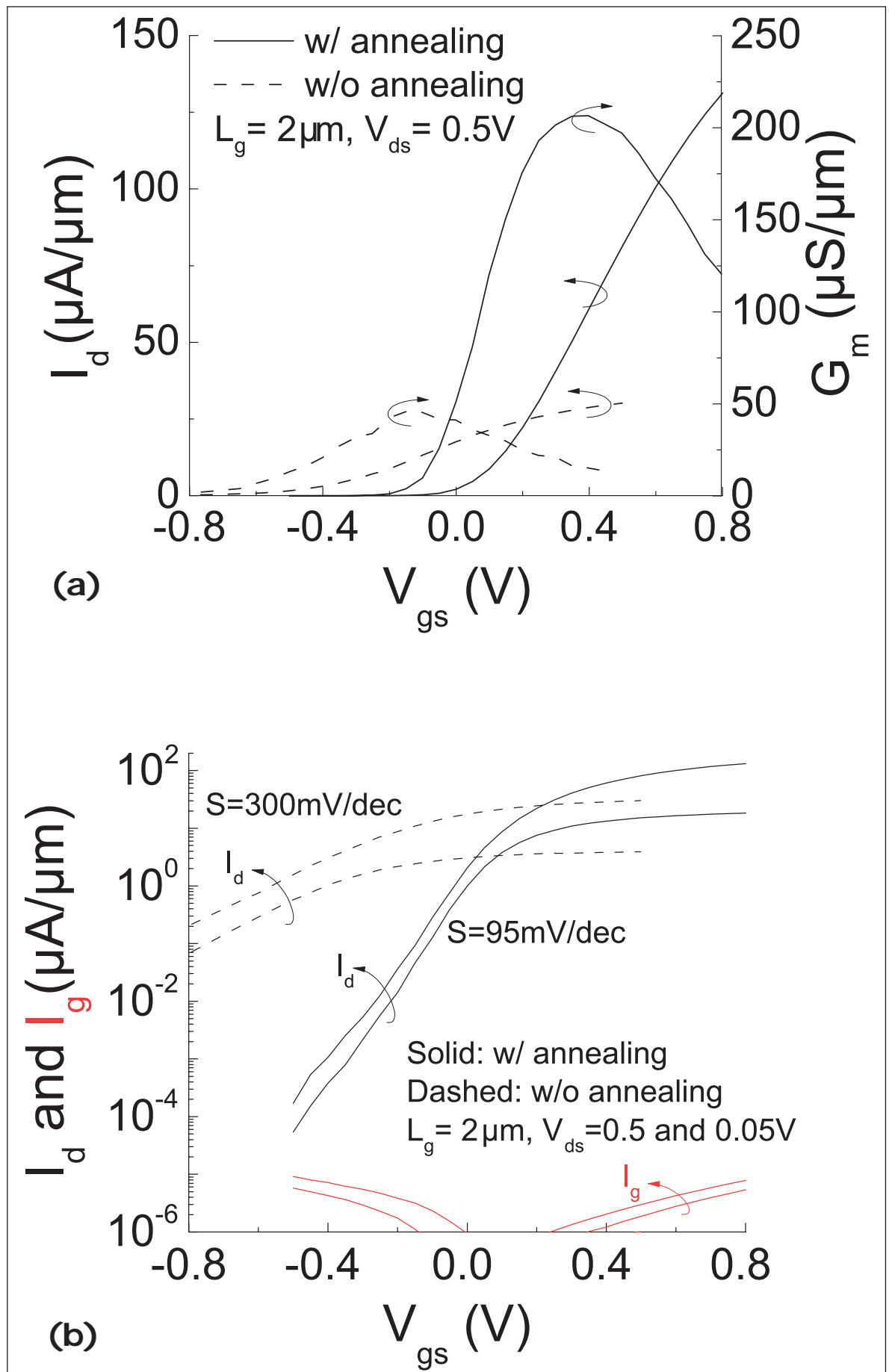


Figure 2. (a) Transfer and transconductance characteristics of QW-MOSFET with (solid) and without (dashed) RIE damage annealing. (b) Subthreshold characteristics and gate leakage current of QW-MOSFET with (solid) and without (dashed) RIE damage annealing.

Upwardly mobile III-V- and Ge-based transistors

Researchers from around the world reported progress in enhancing transistor performance through semiconductor material engineering at the 2012 IEEE Symposium on VLSI Technology in Hawaii. [Mike Cooke](#) reports.

Prospects of radical changes in mainstream semiconductor device technology in the coming years have attracted specialists in III-V semiconductors, along with those promoting the wider use of germanium. Here we look at the contributions in these directions at June's 2012 IEEE Symposium on VLSI Technology in Honolulu, Hawaii.

Scaling III-V transistors

The University of Tokyo, Japan's National Institute of Advanced Industrial Science and Technology (AIST) and Sumitomo Chemical reported the first demonstration of sub-60nm deeply scaled indium gallium arsenide (InGaAs)- and indium arsenide (InAs)-on-insulator (OI) metal-oxide semiconductor field effect transistors (MOSFETs) on silicon (Si) substrates [S. H. Kim et al, session 21.1].

Often InGaAs devices are grown on indium phosphide (InP) substrates, but for mass production these devices need to be produced on Si. The base III-V-OI structures used by Kim et al were formed by the transfer of layers grown on InP to a silicon dioxide layer on silicon.

Then devices were created using MOS interface buffer engineering and nickel-InGaAs source-drain regions to achieve a 400% increase in on-current over an InGaAs control device with the same drain-induced barrier lowering (DIBL) of 100mV/V and an off-current of 1nA/μm.

An InAs-OI device with a 55nm channel gave a small DIBL of 84mV/V and a subthreshold swing (SS) of 105mV/dec. The use of InAs allowed the researchers previously to create MOSFETs with high mobility performance values up to 3180cm²/Vs.

SEMATECH, University of Modena & Emilia, CNSE, Teledyne, and MIT also used InAs, this time to produce quantum well devices (Figure 1) with record transconductance of 1.73mS/μm, and record high frequency

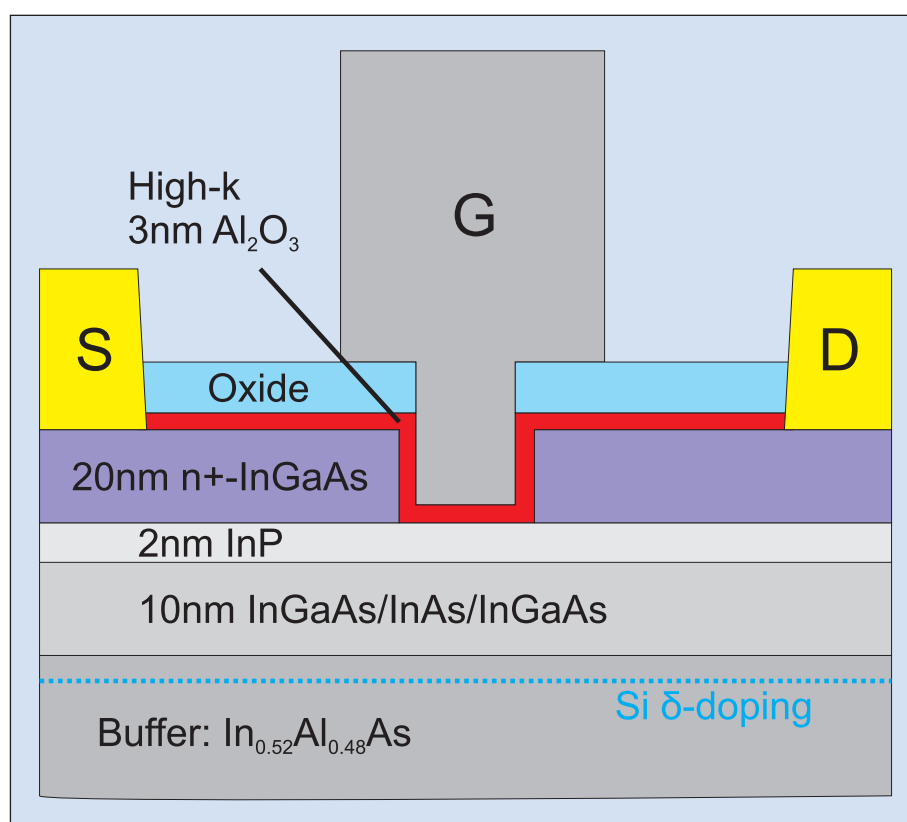


Figure 1. Schematic cross-section of quantum well device created by SEMATECH, University of Modena & Emilia, CNSE, Teledyne and MIT.

cut-off (f_T) and maximum oscillation (f_{max}) values of 245GHz and 355GHz, respectively [T.-W. Kim et al, 21.2]. The gate length was 100nm. The researchers used an aluminium oxide/indium phosphide (Al₂O₃/InP) gate stack to give a low density of interface traps that can degrade transistor performance. The researchers see III-V channels as especially promising for low-power logic applications.

Pennsylvania State University and the US Naval Research Lab used antimonide (InAsSb) quantum wells to achieve a record mobility of 6000cm²/V-s in a long-channel (20μm gate) device [A. Ali et al, 21.3]. The high-k dielectric gate insulator consisted of 1nm of Al₂O₃ and 10nm of HfO₂. A short-gate (150nm) transistor

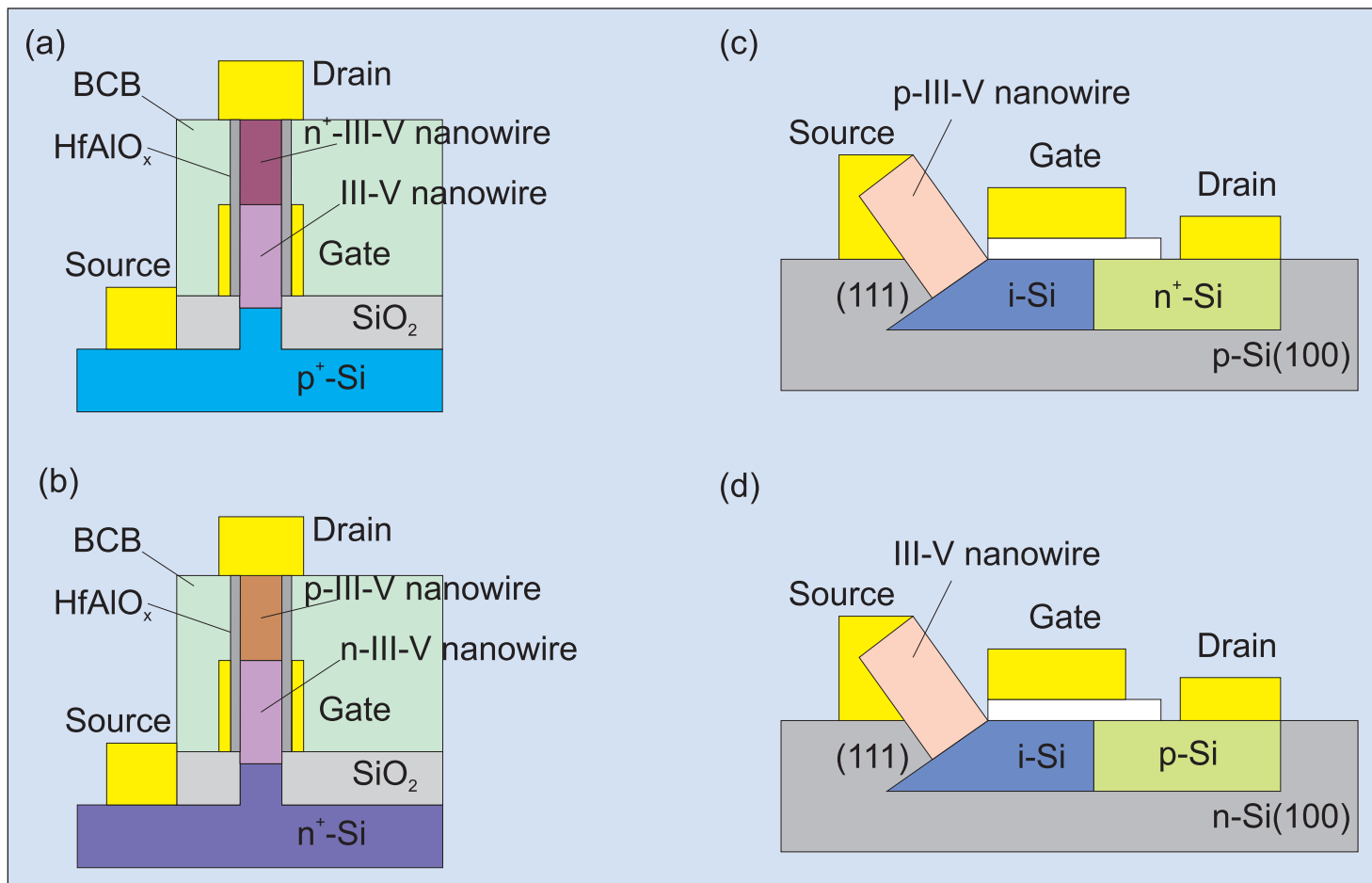


Figure 2. Schematics of Hokkaido University/JST TFETs using III-V NWs/Si heterojunctions. (a), (b) vertical surrounding-gate type TFETs on Si(111) surfaces using Si as source and III-V NWs as gate and drain region. (c), (d) planar type TFET on Si(100).

achieved an f_T of 120GHz. The 120GHz cut-off and (cut-off \times gate-length) product value of 1.8GHz- μ m are claimed to be "the highest for any III-V MOSFET" (presumably before the presentation of SEMATECH et al with $f_T \times L_G$ of 24.5GHz- μ m). The Pennsylvania State University/Naval Research Lab devices were depletion-mode/normally-on, but the researchers reported that the preferred enhancement-mode/normally-off performance had recently been demonstrated.

Stanford University, Applied Materials and US Naval Research Lab reported some preliminary theoretical and experimental explorations of InGaSb as a high-mobility channel material for both NMOS and PMOS, giving complementary MOS (CMOS) behavior, as used in mainstream integrated circuits [Z. Yuan et al, 21.5].

Electron and hole mobilities in excess of 4000cm²/V-s and 900cm²/V-s, respectively, can be achieved using InGaSb. Although performance of transistors was restricted by contact and series resistance effects, the researchers comment: "This is, to our best knowledge, the first demonstration of a high-mobility NMOS and PMOS in the same channel material with comparable I_{ON} , thereby making InGaSb an attractive channel material for realizing complementary logic in III-Vs."

Low power, steep subthreshold

Hokkaido University and Japan Science and Technology Agency (JST) – PRESTO presented InAs nanowire (NW) tunneling field-effect transistors (TFET) with subthreshold swings as low as 21mV/dec [Katsuhiro Tomioka et al, 6.3]. The formation process was similar to that reported by the same group at IEDM 2011 [Mike Cooke, Semiconductor Today, February 2012, p93], with InAs replacing InGaAs.

The nanowires consisted of vertical NWs of InAs material grown on p-Si (111) using metal-organic vapor phase epitaxy. The transistors were constructed with the deposition of a hafnium dioxide/aluminium oxide/tungsten (HfO₂/Al₂O₃/W) gate stack and etch-back to define a gate length of 200nm (Figure 2a,b). The source was given by a titanium/gold back-contact on the p-Si wafer. The drain was given by titanium/aluminium/titanium/gold deposited on the exposed tips of the NWs.

Although the initial devices had a high SS of 104mV/dec, this was improved by enlarging the drain region (decreasing contact resistance) and reducing the NW diameter (increasing heterojunction resistance and lowering defect densities). By reducing the NW diameter from 90nm to 30nm, the SS at 1V drain bias

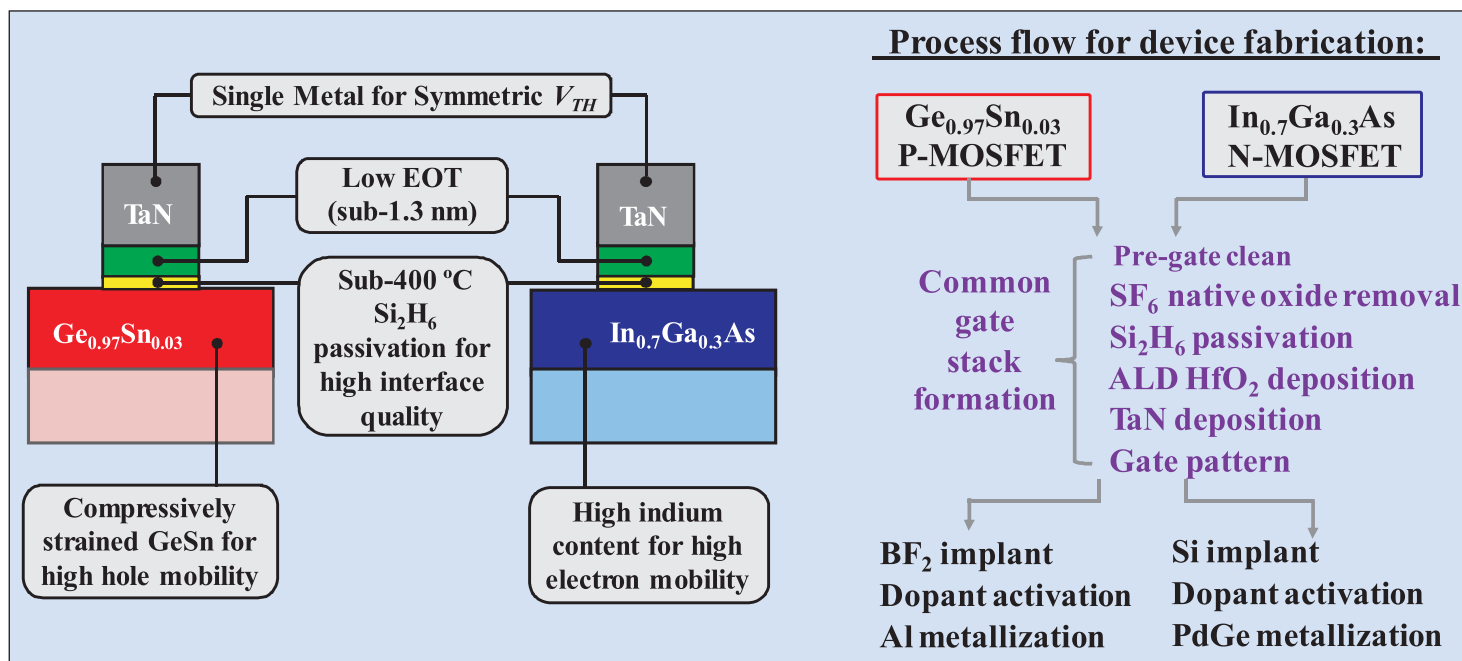


Figure 3. Left, key highlights of Singapore/China common gate stack technology for $\text{Ge}_{0.97}\text{Sn}_{0.03}$ P-MOSFET and $\text{In}_{0.7}\text{Ga}_{0.3}\text{As}$ NMOSFET. Right, process flow with Si_2H_6 passivation technique developed to achieve high interface quality, transport carrier confinement, and reduced gate leakage current.

was reduced to as low as 21mV/dec (average 25mV/dec). This beats the ~60mV/dec theoretical limit of planar CMOS at room temperature. The on-off ratio of the NWTFT best device was 10^6 .

The devices were grown on Si (111) crystal orientation rather than the Si (100) used in CMOS production. However, the researchers suggest that they could be incorporated into the mainstream by angled growth (Figures 1c, d).

Intel Corporation reviewed its III-V MOSFET and TFET research [G. Dewey et al, 6.2]. The company sees III-V devices, “especially the 3D tri-gate MOSFET and TFET” as viable options for future ultra-low-power applications. Intel also reported simulations of expected improvements from the use of TFET architectures [Uygar E. Avci et al, 21.4]. Disappointing performance in experiments on large devices was suggested as being due to geometrical factors. The modelers comment “Results suggest the III-V TFET with optimized electrostatics is a realistic candidate to outperform CMOS at low supply voltages to improve logic energy efficiency.”

Mobility enhancements

National University of Singapore reported the first demonstration of germanium telluride as a liner stressor for FinFETs [Ran Cheng et al, 11.1]. The material was converted from an amorphous to crystalline material in a thermal anneal step at 220°C, resulting in a 10% volume contraction, thus setting up compressive stress in the silicon channel. The stress increased the mobility of the channel so that the maximum drain current was increased by 69% in a device with a 30nm liner stressor

(33nm before anneal) and 106% in one with a 50nm liner stressor (55nm pre-anneal), at a fixed off-current of 10nA/ μm . The researchers also claimed that the 3nm gate length of their devices was the shortest reported to that date.

A relatively new mobility enhancement is from the use of germanium tin (GeSn) semiconductor layers. Although GeSn is normally proposed for pMOS, Stanford University, IMEC, KULeuven, and GLOBALFOUNDRIES reported the first experimental realization of GeSn nMOSFETs [S. Gupta et al, 11.2]. The researchers grew GeSn (5% Sn) layers using atmospheric-pressure chemical vapor deposition. NMOS transistors were formed gate-last with phosphorous-doped source drain regions. The gate oxide was Al_2O_3 . Devices with and without a 5nm Ge cap were produced.

The devices were found to have poor activation of the implanted P doping, even after thermal annealing, giving large source-drain parasitic resistance. Further problems include significant interface trap densities and compressive strain in the channel. These factors limit device performance compared with theoretical simulations suggesting better electrical behavior over pure Ge NMOSFETs. The Ge cap is found to offer some improvement and the researchers comment: “Further enhancements in GeSn nMOSFETs can be obtained by employing implant-free S/D technology, [and] strain engineering to introduce channel tensile strain.”

National University of Singapore, Chinese Academy of Sciences’ State Key Laboratory on Integrated Optoelectronics, and Singapore’s Institute of Materials Research and Engineering also report “the world’s first

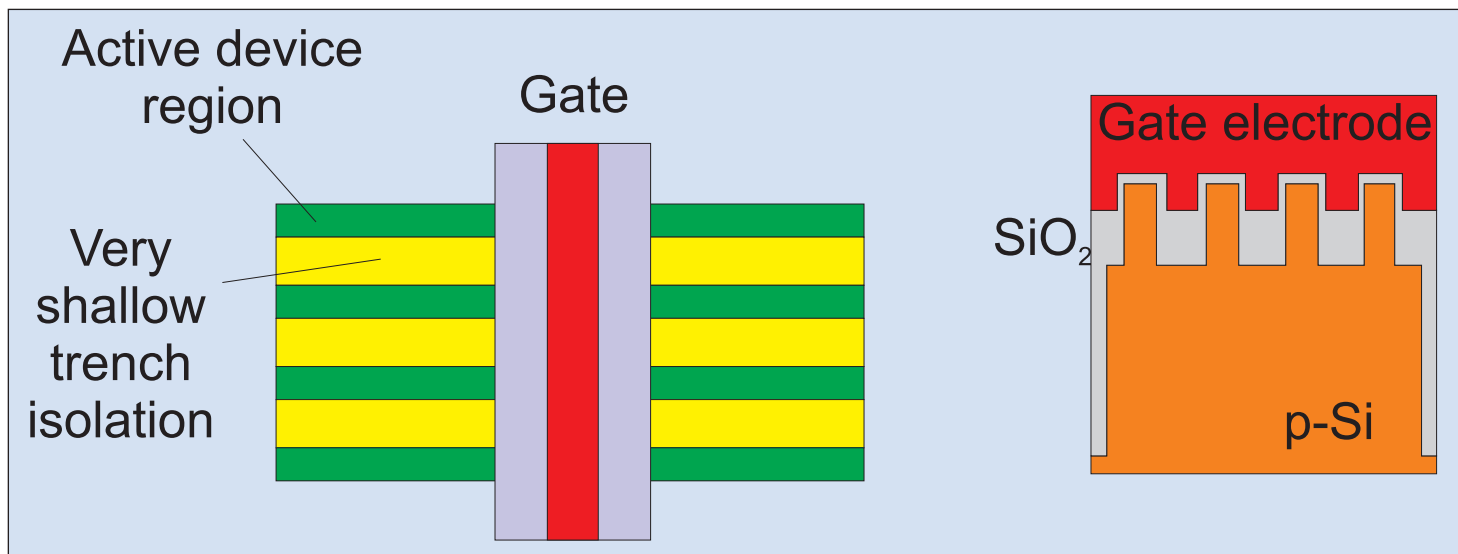


Figure 4. Plan view (left) and cross-sectional view (right) across the gate of UCB/Applied Materials/Soitec SegFET structure.

germanium-tin (GeSn) channel nMOSFETs" [Genquan Han et al, 11.3]. The 170nm p-GeSn channel was grown on Ge using molecular beam epitaxy (MBE). The Sn composition was 2.4%. The gate-last process used a native oxide (GeSnO_2) interlayer between the channel and the high-k gate dielectric of tantalum nitride/aluminum oxide. The SS was 128mV/dec. The on-off ratio was $\sim 10^4$.

The Singapore/China researchers also presented a common gate stack for high-performance GeSn PMOS and InGaAs NMOS, giving a potential CMOS solution [Xiao Gong et al, 11.4]. The equivalent oxide thickness of the HfO_2 gate dielectric was less than 1.3nm (Figure 3). The gate metal was tantalum nitride. The passivation was provided by silicon delivered through disilane (Si_2H_6) applied at relatively low temperatures of less than 400°C.

The researchers report: "Using this gate stack, the world's first GeSn short-channel device with gate length (L_g) down to 250nm was realized. Drive current of more than 1000 $\mu\text{A}/\mu\text{m}$ was achieved, with peak intrinsic transconductance of $\sim 465\mu\text{S}/\mu\text{m}$ at V_{DS} of -1.1V ."

The team was keen to find ways to implement a common surface passivation and gate stack, since such processes are preferred in manufacturing because of the reduced number of

The world's first GeSn short-channel device with gate length down to 250nm was realized. Drive current of more than 1000 $\mu\text{A}/\mu\text{m}$ was achieved, with peak intrinsic transconductance of $\sim 465\mu\text{S}/\mu\text{m}$ at V_{DS} of -1.1V ... Lower source/drain resistance combined with shorter gates will lead to improved saturation drain current performance

process steps. The channel materials with 3% Sn and higher-than-usual indium content (70%) were designed to boost mobility performance for holes and electrons, respectively.

The 250nm short-channel GeSn device had even higher Sn content of 5%, along with other factors used to improve the performance of such components: S/D extension (SDE), halo implant, spacer formation and deep S/D implant, etc. The researchers believe that lower source/drain resistance combined with shorter gates will lead to improved saturation drain current performance.

Ge-based devices

For pure Ge PMOS transistors, University of Tokyo reported record high hole mobility of 596 $\text{cm}^2/\text{V}\cdot\text{s}$ with 0.8nm equivalent oxide thickness [R. Zhang et al, 19.1]. The gate stack consisted of $\text{HfO}_2/\text{Al}_2\text{O}_3/\text{GeO}_x/\text{Ge}$. University of Tokyo has developed a plasma post-oxidation (PPO) method using an electron cyclotron resonance oxygen plasma. Previously the researchers have used the method to create aluminium oxide, but with a view to thinner equivalent oxide thickness (EOT), they have now applied it to hafnium dioxide, with aluminium oxide used as a diffusion control layer, giving better MOS interface control.

Japan's AIST and Meiji University have created Ge nanowire pMOSFETs with records for high inversion hole mobility of 855 $\text{cm}^2/\text{V}\cdot\text{s}$ and for saturation drain current at 1V bias of 731 $\mu\text{A}/\mu\text{m}$ [Keiji Ikeda et al, 19.3]. The NWs were subjected to compressive strains of up to 3.8%. Metal source/drain regions were used. Both the channel and source/drain regions were undoped, avoiding process variability arising from impurity fluctuations. The gate length for the record device was 65nm. The Ge channel was formed by a two-step condensation of SiGe-on-insulator.

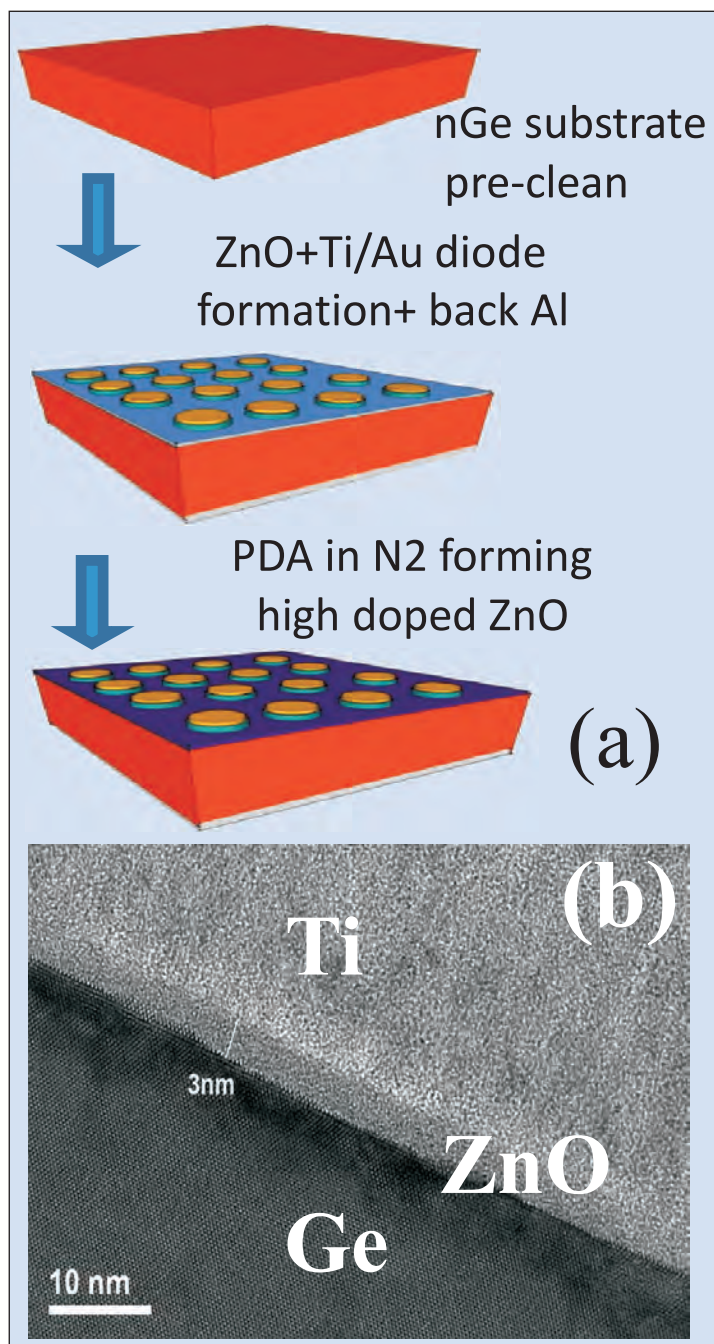


Figure 5. (a) Indian Institute of Technology Bombay/ Applied Materials process flow for making ohmic contacts on n-Ge using ZnO. (b) TEM of Ti/ZnO/Ge interface.

University of California at Berkeley, Applied Materials, and Soitec reported 30% improved on-current for SiGe channel pMOSFETs with segmented channels over planar SiGe channels [Byron Ho et al, 19.4]. Over pure Si reference devices, the on-current was increased by 70%. The off-current was 10nA/ μm layout width. The 70nm-wide Si/SiGe/Si (20nm/3nm/3nm) stripes were grown in gaps between 30nm-wide SiO_2 lines (Figure 4).

IMEC has been developing SiGe implant-free quantum well (IFQW) structures for PMOS [J. Mitard et al, 19.2]. Studies suggest that the key parameter for improving performance is mobility improvement, rather than gate-length reduction.

ZnO in advanced Si, Ge, SiC transistors

Finally, and slightly to one side, Indian Institute of Technology Bombay and Applied Materials have made simulations and experiments of the use of n-type zinc oxide as an interfacial layer between metal and n-type semiconductor [P. Paramahans et al, 9.4]. Among their aims is to create lower-resistance ohmic source-drain contacts than the present silicide (metal-silicon compound) technology.

In particular, complications in using silicides arise as the devices are scaled to smaller dimension. Further, higher-mobility transistors using germanium channels suffer from low dopant activation and Fermi-level pinning, creating a barrier at metal/n-Ge junctions.

In one experiment, a 1000x increase in current was achieved by inserting a 0.7nm layer of n-ZnO between titanium metal and n-Ge (Figure 5). Specific contact resistance values ($0.8\text{--}1.5 \times 10^{-6} \Omega\text{-cm}^2$) matching the best reported values on n-Ge have also been achieved. Increasing the doping of the n-Ge from $10^{19}/\text{cm}^3$ to $10^{20}/\text{cm}^3$ is expected to give the specific contact resistance of $10^{-8} \Omega\text{-cm}^2$ required by the International Technology Roadmap for Semiconductors (ITRS). ■

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

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Market for RF filters/duplexers, PAs and antenna switches to reach \$4.7bn in 2016

SOI antenna switches are winning market share over GaAs, says market research firm Yole Développement.

Emerging technologies are driving changes in RF architecture and will create new market opportunities, says market research firm Yole Développement in its new report 'RF filters, PAs, Antenna Switches & Tunability for Cellular Handsets'.

The radio front-end is a key part in every cell phone, from low-cost GSM handset to multi-mode multi-band LTE smartphones. This market is very fragmented in terms of architectures, however there are a few types of components that are key. Filters or duplexers, power amplifiers (PAs) and antenna switches are at the heart of every cell phone radio. "Those components represent a \$3.6bn market in 2011 already, growing at a 5.6% rate annually until 2016 [to \$4.7bn]," says Laurent Robin, activity leader at Yole. As the market becomes increasingly attractive, major technical evolutions and changes are observed in the competitive landscape for those categories of devices.

Filters and duplexers are the most dynamic market. Driven by duplexers which are growing at 10.5% annually, this market will reach \$1.7bn in 2016. Indeed, smartphones are widely using WCDMA bands and LTE is a new strong driver.

Depending on each band, SAW (surface acoustic wave) or BAW (bulk acoustic wave) developments are candidates for further growth. While Epcos and Murata dominate the SAW area, we observe a fierce competition between Avago and TriQuint in the BAW segment.

The power amplifier is another strategic component in the RF segment. This market is maturing, but Yole's analysts still see many new technologies that are impacting the market. One current trend is that converged PAs and more broadband PAs are increasingly accepted in the market. Gallium arsenide (GaAs) is still dominating the PA market by far but is poised to lose market share as complementary metal oxide semiconductor (CMOS) PAs are growing (starting at the low end of the market) and as silicon-on-insulator (SOI) technology could be used for PAs in the near future. There is hence still room for many changes in the competitive landscape dominated by Skyworks, with RFMD, TriQuint, Avago and Murata/Renesas as challengers.

Antenna switches are also becoming more mature, however Yole observes evolutions in two directions. First, the team sees an evolution towards more performance for the new LTE bands and an increasing number of throws. This is where Peregrine Semiconductor has a leading position. Second, Yole has observed massive adoption of SOI technology since 2010. All the big players are now involved with this technology, which offers a good price/performance ratio. GaAs switches are thus decreasing, although some players (such as Sony) are still releasing products with exceptional performance. At the same time new technologies are nearing production, e.g. MEMS (micro-electro-mechanical systems).

Tunability and changes in architecture

Yole's report also provides a detailed analysis on tunability, which is a new hot topic for radio front-end modules. Indeed, after years of development, antenna tuners have seen adoption in 2011. In addition to GaAs switches, ferroelectric capacitors and MEMS variable capacitors have also been integrated successfully into flagship products such as some Samsung Galaxy S2 smartphones. While there is no consensus yet on this topic, antenna tuners are now providing a significant value proposition, so Yole expects them to become the next hot market in this sector.

New types of tuners and the massive deployment of LTE by 2014 will be additional drivers of tunability. Leading the MEMS field, Wispry will be a key player to watch, while Sony and Peregrine also offer promising approaches based on alternative technologies. The acquisition of Paratek by RIM (Research In Motion) in March is also a sign that antenna tuners will become a strategic technology to be integrated into many cell-phone platforms in the near future.

All these changes at the component level (PA, ASM, filters, etc) and the rise of tunability are having a dramatic impact on the global evolution of RF component architectures. Both technical and competitive challenges and opportunities are shaping future front end modules. Similarly, the trend towards integration in various types of modules is driving changes at the individual component level. New packaging technolo-

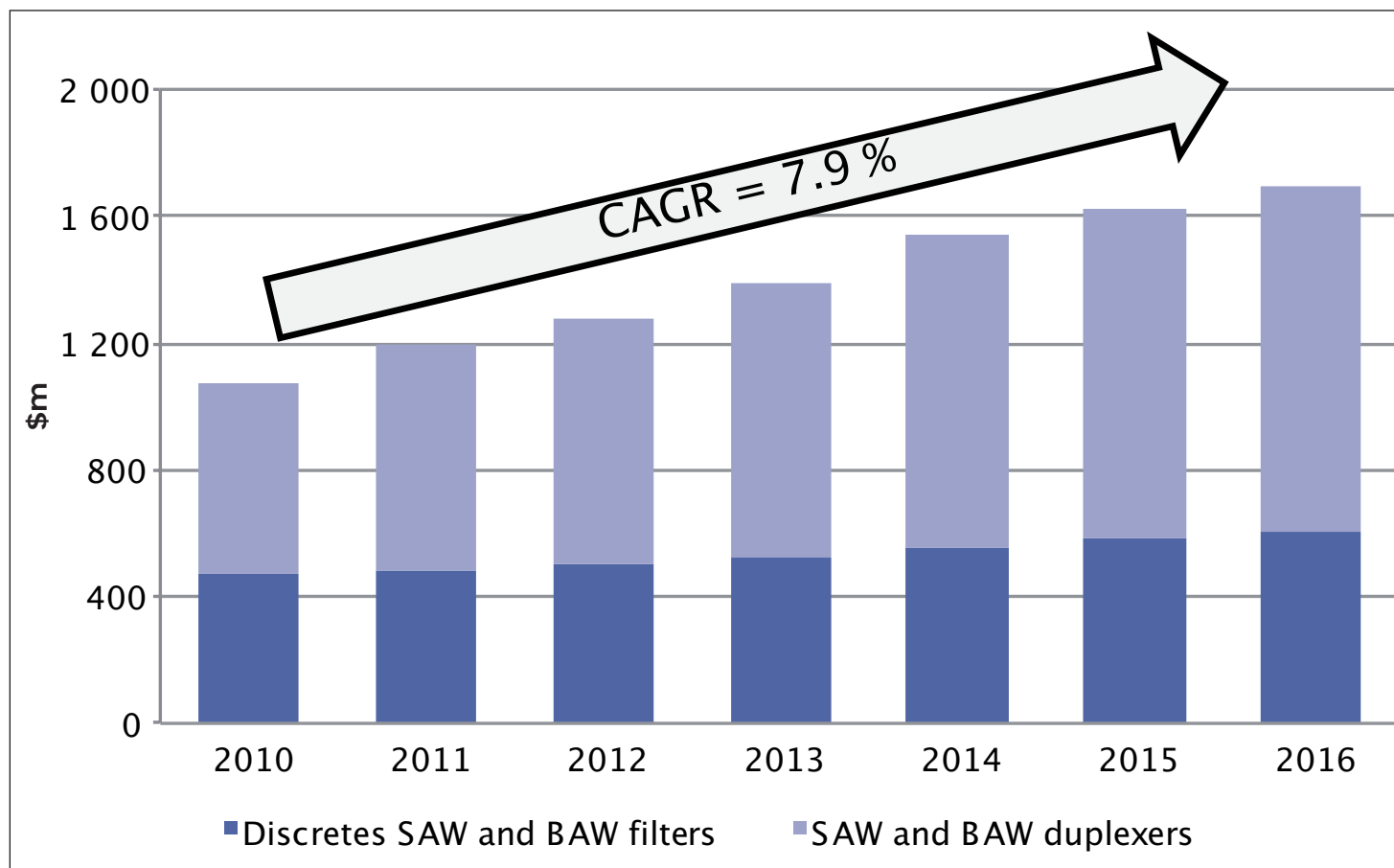


Figure 1. Market for RF filters and duplexers in RF part of mobile phones (\$m).

gies now enable compact multi-chip packages: Rx modules, PA modules, multi-duplexers, and other RF technologies. Collectively, front-end modules already comprise a \$2bn market in 2011. Growing at 12% annually, this will represent more than three times the market for standalone PAs, filters/duplexers and tuners in 2016.

Rapid evolution of technology and competitive landscape

While Yole is starting to see some level of consolidation, the competitive landscape in this RF market is changing quickly. Some firms are becoming more vertically integrated, such as Murata after its acquisition of the PA business of Renesas (which may translate into a change in the business model of the company). Currently, a limited number of companies dominates this RF segment, but generally those players are involved in a very specific market space, so significant

evolution can be expected in the near future. For instance, Skyworks leads the PA market and is a big player in switches but has no activity in filters, while Avago is a large PA vendor and dominates the BAW filter market, but is involved in neither SAW filters nor antenna switches.

The evolution of device architectures towards modules is one driver that pushes each company to be capable of handling all types of components or to set up specific partnerships. Another driver for competitive change is technical evolution, which is very rapid in this area: at the antenna switch level, players with early involvement in SOI switches (e.g. Skyworks and RF Micro Devices) are winning more market share versus players involved in GaAs (e.g. TriQuint). Such a change should also be seen with PA technology too, reckons Yole. ■

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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
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Fax: +1 716 833 2926
www.williams-adv.com

16 Assembly/packaging equipment

Ismeca Europe Semiconductor SA

Helvetie 283,
La Chaux-de-Fonds, 2301,
Switzerland
Tel: +41 329257111
Fax: +41 329257115
www.ismeca.com

Kulicke & Soffa Industries

1005 Virginia Drive,
Fort Washington, PA 19034,
USA
Tel: +1 215 784 6000
Fax: +1 215 784 6001
www.kns.com

Palomar Technologies Inc

2728 Loker Avenue West,
Carlsbad, CA 92010,
USA
Tel: +1 760 931 3600
Fax: +1 760 931 5191
www.PalomarTechnologies.com

TECDIA Inc

2700 Augustine Drive, Suite 110,
Santa Clara,
CA 95054, USA
Tel: +1 408 748 0100
Fax: +1 408 748 0111
www.tecdia.com

17 Assembly/packaging foundry

Quik-Pak

10987 Via Frontera,
San Diego, CA 92127,
USA
Tel: +1 858 674 4676
Fax: +1 858 674 4681
www.quikicpak.com

18 Chip foundry

Compound Semiconductor Technologies Ltd

Block 7, Kelvin Campus,
West of Scotland, Glasgow,
Scotland G20 0TH,
UK

Tel: +44 141 579 3000

Fax: +44 141 579 3040

www.compoundsemi.co.uk

United Monolithic Semiconductors

Route departementale 128,
BP46, Orsay, 91401,
France

Tel: +33 1 69 33 04 72

Fax: +33 169 33 02 92

www.ums-gaas.com

19 Facility equipment

MEI, LLC

3474 18th Avenue SE,
Albany, OR 97322-7014,
USA

Tel: +1 541 917 3626

Fax: +1 541 917 3623

www.marlerenterprises.net

20 Facility consumables

W.L. Gore & Associates

401 Airport Rd,
Elkton, MD 21921-4236,
USA

Tel: +1 410 392 4440

Fax: +1 410 506 8749

www.gore.com

21 Computer hardware & software

Ansoft Corp

4 Station Square, Suite 200,
Pittsburgh, PA 15219,
USA

Tel: +1 412 261 3200

Fax: +1 412 471 9427

www.ansoft.com

Crosslight Software Inc

121-3989 Henning Dr.,
Burnaby, BC, V5C 6P8,
Canada

Tel: +1 604 320 1704

Fax: +1 604 320 1734

www.crosslight.com

Semiconductor Technology Research Inc

10404 Patterson Ave., Suite 108,
Richmond, VA 23238,
USA

Tel: +1 804 740 8314

Fax: +1 804 740 3814

www.semitech.us

22 Used equipment

Class One Equipment Inc

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Tel: +1 770 808 8708

Fax: +1 770 808 8308

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Fishbone Consulting SARL

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France

Tel: + 33 (0)1 30 47 29 03

E-mail: jean-luc.ledys@neuf.fr

25 Resources

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San Jose, CA 95134, USA

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Fax: +1 408 428 9600

www.semi.org

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Defects in Semiconductors: Gordon Research Conference

University of New England, Biddeford, ME, USA

E-mail: Evan.Glaser@NRL.navy.mil

www.grc.org/programs.aspx?year=2012&program=defects

22–24 August 2012

LED Tech Korea 2012 & Optical Expo 2012

KINTEX, Seoul, Korea

E-mail: led2100@naver.com

www.korealed.org

27–30 August 2012

Compound Semiconductor Week (CSW 2012), including:

39th International Symposium on Compound Semiconductors (ISCS 2011) and 24th International Conference on Indium Phosphide and Related Materials (IPRM 2011)

Santa Barbara, CA, USA

E-mail: wmorris@housing.ucsb.edu

http://csw2012.ece.ucsb.edu

27 August — 1 September 2012

Summer School on Crystal Growth and Photovoltaic Materials

Brasov, Romania

E-mail: school2012@fpce1.fizica.unibuc.ro

http://rocam.unibuc.ro/intschool

29–31 August 2012

IEEE's 9th International Conference on Group IV Photonics (GFP 2012)

Holiday Inn on the Bay Hotel,

San Diego, CA, USA

E-mail: r.bankowski@ieee.org

www.gfp-ieee.org

2–6 September 2012

9th European Conference on Silicon Carbide & Related Materials (ECSCRM 2012)

St Petersburg, Russia

E-mail: yuri.makarov@ecscrm-2012.org

www.ecscrm-2012.org

6–9 September 2012

14th China International Optoelectronic Exposition (CIOE 2012)

Shenzhen Convention & Exhibition Center,

Shenzhen, China

E-mail: cioe@cioe.cn

www.cioe.cn

10–14 September 2012

42nd European Solid-State Device Research Conference (ESSDERC-2012) and 38th European Solid-State Circuits Conference (ESSCIRC-2012)

Bordeaux, France

E-mail: cor.claeys@imec.be

www.esscirc.org

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11–12 September 2012

Deutscher MBE-Workshop 2012

Leibniz Universität Hannover, Germany

E-mail: DMBE2012@mbe.uni-hannover.de

www.dmb2012.uni-hannover.de

18–20 September 2012

Strategies in Light Europe

M.O.C. Event Centre, Munich, Germany

E-mail: jamesh@pennwell.com

www.sileurope.com

23–27 September 2012

IEEE Photonics Conference 2012 (IPC-2012), formerly the IEEE LEOS Annual Meeting

Hyatt Regency San Francisco Airport, Burlingame, CA, USA

E-mail: m.hendrickx@ieee.org

www.ipc-ieee.org

23–28 September 2012

17th International Conference on Molecular Beam Epitaxy (MBE2012)

Nara Prefectural New Public Hall, Japan

E-mail: secretary@mbe2012.jp

<http://mbe2012.jp>

23–28 September 2012

37th International Conference on Infrared, Millimeter, and Terahertz Waves (IRMMW-THz 2012)

University of Wollongong, Australia

E-mail: daniel@rice.edu

www.irmmw-thz.org

24–26 September 2012

2012 International Semiconductor Conference Dresden-Grenoble (ISCDG)

MINATEC Campus, Grenoble, France

E-mail: iscdg2012@insight-outside.fr

<http://iscdg2012.insight-outside.fr>

24–27 September 2012

SPIE Remote Sensing 2012 and SPIE Security & Defence 2012

Edinburgh, Scotland, UK

E-mail: customerservice@spie.org

<http://spie.org/security-defence-europe.xml>

<http://spie.org/remote-sensing-europe.xml>

24–28 September 2012

27th European Photovoltaic Solar Energy Conference and Exhibition (EU PVSEC 2012)

Frankfurt, Germany

E-mail: pv.conference@wip-munich.de

www.photovoltaiic-conference.com

25–27 September 2012

LED Japan/Strategies in Light

Pacifico Yokohama, Yokohama, Japan

E-mail: jamesh@pennwell.com

www.sil-ledjapan.com

30 September – 5 October 2012

37th International Conference on Infrared, Millimeter, and Terahertz Waves (IRMMW-THz 2012)

Wollongong, Australia

www.irmmw-thz.org

7–10 October 2012

International Semiconductor Laser Conference (ISLC)

San Diego Mission Valley Marriott, CA, USA

E-mail: m.hendrickx@ieee.org

www.photonicsconferences.org

7–12 October 2012

222nd Electrochemical Society (ECS) Meeting

Hawaii Convention Center, Honolulu, Hawaii, USA

E-mail: meetings@electrochem.org

www.electrochem.org/meetings/biannual/fut_mtgs.htm

9–11 October 2012

SEMI CON Europa 2012

Messe Dresden, Germany

E-mail: eweller@semi.org

www.semiconeuropa.org

14–17 October 2012

IEEE Compound Semiconductor Integrated Circuit Symposium (CSICS 2012)

Hyatt Regency Hotel, La Jolla, CA, USA

E-mail: customer.service@ieee.org

www.csics.org

14–17 October 2012

29th North American Conference on Molecular Beam Epitaxy (NAMBE 2012)

Evergreen Marriott, Stone Mountain Park, Georgia, USA

E-mail: della@avs.org

www2.avs.org/conferences/nambe/2012

14–19 October 2012

International Conference on Nitride Semiconductors (IWN2012)

Sapporo, Japan

E-mail: secretary@iwn2012.jp

<http://iwn2012.jp>

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