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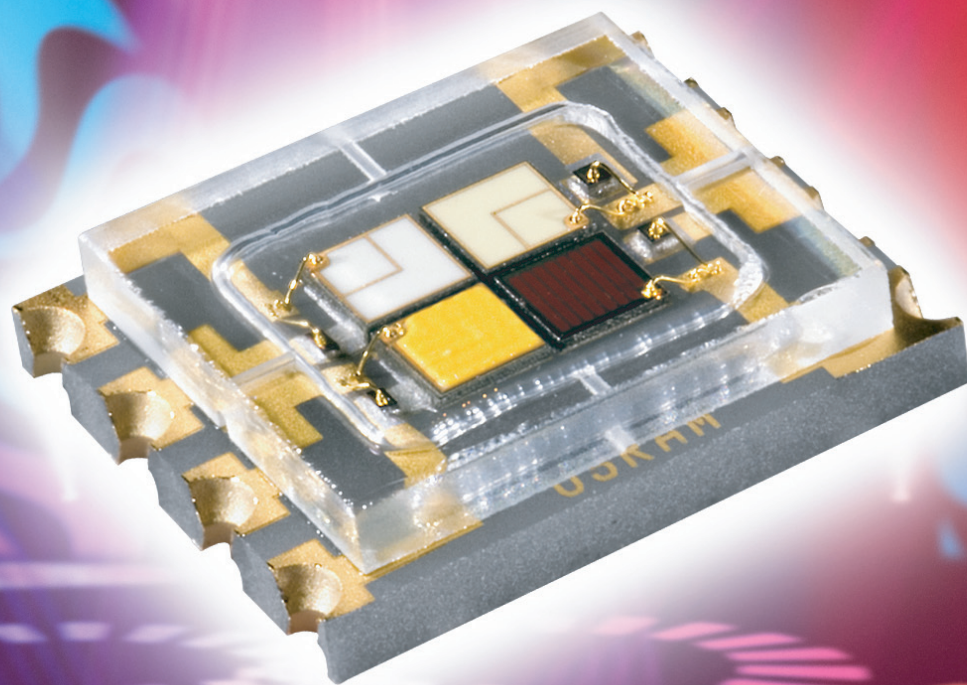
COMPOUNDS & ADVANCED SILICON

Vol. 7 • Issue 2 • March/April 2012

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Efficiency droop in nitride & phosphide LEDs

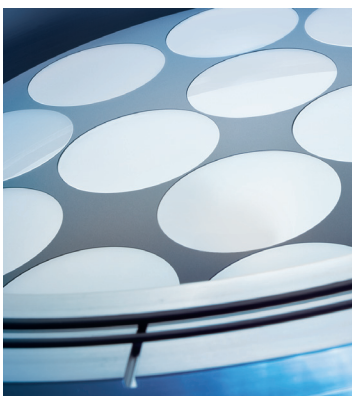
First single-crystal gallium oxide FET



Graphensic spun off • Emcore sells VCSEL range to Sumitomo
Masimo buys Spire Semiconductor • Oclaro and Opnext merge

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p10 Chong Joon Woon and TriQuint's Glen Riley opening the firm's new international HQ in Singapore.



p43 Meaglow launches nitrogen-rich InN wafers, made using low-temperature plasma-based nitrogen sources.



p81 TSMC Solar's CIGS PV module manufacturing facility enters production, with shipments due to start in April.



Cover: Osram Opto Semiconductors' new Ostar Stage LED, which has a flat glass window, providing the basis for compact spotlights with a very narrow beam and high luminance — **p56**. Also, on page **100** we examine efficiency droop in not only nitride LEDs but also phosphide LEDs at low temperature.

Overcoming current drop

On pages 100–104 of this issue, we focus on the key technical challenge for nitride-based LEDs of the droop in luminous efficiency as the drive current is raised. Experiments at low temperature have shed light on the mechanism causing droop in not only nitride blue LEDs but also phosphide red LEDs.

Also, on pages 98–99, Chinese Academy of Science researchers show how graded electron-blocking layers can not only boost light output in green nitride LEDs but also delay the onset of droop from 50mA to 150mA.

Meanwhile, further evidence is emerging of the effect on the supply chain of the delayed take-off of demand for lighting applications. After last issue reporting a 38% drop year-on-year in fourth-quarter MOCVD system revenue for Veeco (from \$240m to \$150m), on page 32 of this issue we report a 38% drop year-on-year in Q4 sales for rival Aixtron (from €224.7m to €140m), while order intake was down 86% (from €204m to €29.3m).

This tallies with HB-LED market growth slowing to just 4.3% in 2011, according to EPIC (see page 8). According to NPD DisplaySearch, in 2011 LED supply exceeded demand by 30%, causing MOCVD system utilization rates to fall to 50% (page 7). Consequently, after falling by 15% in 2011, total MOCVD system shipments for GaN LED applications are expected to fall by 48% in 2012, reckons IMS Research (page 9). This should cut LED oversupply to 19% in Q1/2012 and then 16% in Q2, says DisplaySearch. IMS expects Q1 MOCVD shipments to be about half of those in Q4/2010. However, second-half 2012 should see a recovery due to expected rapid growth in demand for general lighting in 2013. Aixtron "remains convinced that the development of a sustainable LED lighting industry will follow this temporary period of uncertainty" and is hence still increasing R&D spending while cutting operating costs.

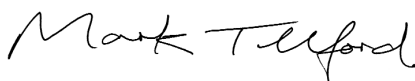
GaN microelectronics is also covered in this issue on pages 108–111, and in articles on pages 86–92. This is driving a GaN power electronics market that could exceed \$1bn by the end of this decade, if qualified for applications like electric vehicles, reckon both IMS and Yole Développement (p106–107).

On pages 84–85 we report how Sweden's Lund University has developed a self-aligned gate-last process to improve frequency performance and on-resistance in InGaAs-channel MOSFETs by avoiding the use of high temperatures and plasma etching. On pages 82–83 we cover how Japan's National Institute of Information and Communications Technology (NICT) has developed the first single-crystal gallium oxide FETs.

In the optical communications sector, recent weeks have seen long-expected consolidation, with components makers Oclaro and Opnext merging to become the second biggest supplier (page 64). Oclaro is also to transfer its final assembly & test operations in Shenzhen, China to the Malaysia facility of Singapore-based Venture Corporation (page 65). Meanwhile, after its revenue fell 28% in the December-quarter following the flooding at contract manufacturer Fabrinet in Thailand, Emcore is to sell its VCSEL-based product portfolio to Sumitomo Electric as it focuses on "tunable, coherent high-speed transmission systems and next-generation broadband architectures" (page 68). In addition, Emcore has just opened the factory of its Suncore joint venture San'an in China. Further fiber-optic communications news from OFC/NFOEC 2012 will be covered next issue.

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

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

Regular issues contain:

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

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ALWAYS ONE STEP AHEAD



HIGHER PRODUCTIVITY // With almost 30 years of experience AIXTRON stands for proven engineering power and dedicated customer support: Our equipment serves a diverse range of customers to manufacture highest LED volumes at lowest cost.

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AIXTRON started in 1983 and is today a leading provider of deposition equipment to the semiconductor industry. With our advanced solutions customers worldwide build components for electronic as well as opto-electronic applications. As pacemaker in our line of industry we are keeping always one step ahead.

AIXTRON

CIGS PV panel market to grow rapidly to \$4.4bn by 2017

Improved cost per watt vital to combat low-cost crystalline silicon

Revenues from copper indium gallium diselenide (CIGS) thin-film photovoltaic (PV) panels will reach \$4.4bn by 2017, forecasts 'CIGS Photovoltaics Markets - 2012', the latest in an ongoing series of reports on CIGS solar markets from industry analyst firm NanoMarkets.

However, while the recent announcement of a 150MW solar farm supports the notion that CIGS technology is finally ready for prime time, CIGS manufacturers will have to adopt new strategies to protect themselves from falling solar panel prices, notes NanoMarkets.

To meet the challenge of very low-cost crystalline silicon (c-Si) solar panels, CIGS will need to continue to improve on its cost per watt, reckons the firm. NanoMarkets expects CIGS to succeed in this regard through volume production and manufacturing efficiencies such as thinner absorber layers and aggressive recycling of absorber materials. CIGS can also compete with crystalline Si based on superior aesthetics and good performance in indirect light.

NanoMarkets believes that reducing the cost of encapsulation is the key to success for flexible CIGS panels, which will generate more than \$635m of the market by 2017. Current use of complex dyadic film encapsulation is proving very expensive, and the report suggests that there may be some potential for lowering costs by using overcoats of silicon nitride, silicon oxide and/or silicon oxynitride before final module encapsulation. Also, the CIGS industry will embrace low-cost advanced plastic substrates as a replacement for polyimide, forecasts the report.

The analyst firm also believes that CIGS manufacturing will take new directions resulting in higher efficiencies and lower costs. Laser annealing of the absorber layer will become more common and will enable more thermally sensitive substrates to be used. However, before this can happen, the cost of laser annealing equipment will need to be reduced.

NanoMarkets also foresees solution-based deposition as playing a

Reducing the cost of encapsulation is the key to success for flexible CIGS panels

growing role in the creation of CIGS panels based on new types of solvents. In the past, this type of approach has suffered as the result of high levels of impurities in the materials, says the firm. However, hydrazine is now proposed as a solvent system for solution-based deposition, and has shown promising results in the lab. This new approach seems likely to considerably improve CIGS efficiency, the firm concludes.

Applications sectors covered in the report include rigid panels (conventional and BIPV), flexible PV, portable PV and building-integrated PV (BIPV) glass. The report also includes in-depth analysis of the latest trends in CIGS manufacturing and the market impact. Eight-year forecasts — including revenue and volume (MW) — are broken out by application sector and by type of deposition/manufacturing. The report also discusses the strategies of key suppliers of both panels and materials.

www.nanomarkets.net

IN BRIEF

GaN electronics development expanding

As products using gallium nitride technology continue to gain acceptance in military and commercial applications, development activities at microelectronics firms are accelerating, notes the Strategy Analytics GaAs and Compound Semiconductor Technologies Service viewpoint 'Compound Semiconductor Industry Review October-December 2011: Microelectronics'.

The viewpoint from market research firm Strategy Analytics summarizes technology, product, contract, financial and employment announcements from compound semiconductor device suppliers such as RF Micro Devices, Skyworks Solutions, Fujitsu, Anadigics, Agilent, Hittite Microwave, TriQuint Semiconductor, Avago, NXP Semiconductors, Microsemi, Renesas Electronics, Freescale, Broadcom, Cree and Murata Manufacturing in fourth-quarter 2011.

"GaN-based products have demonstrated performance advantages for military systems for some time and they are finally beginning to see acceptance in commercial applications, such as CATV and wireless infrastructure," notes Eric Higham, director of the Strategy Analytics GaAs and Compound Semiconductor Technologies Service. "As these application areas broaden, the industry is responding by increasing their efforts to develop new products, processes and partnerships," he adds.

"Recent announcements indicate growing interest in GaN-on-silicon processing (to reduce cost) and higher-voltage GaN processes (which will improve power-handling performance)," says Asif Anwar, director of the Strategy Analytics Strategic Technologies Practice.

www.strategyanalytics.com

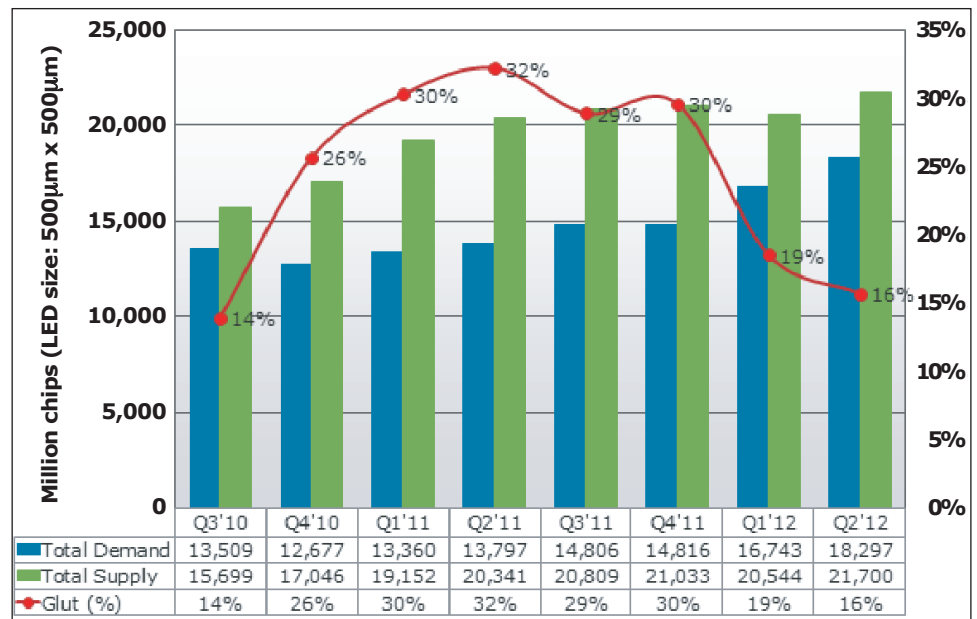
Rising demand in backlight and lighting applications to cut LED oversupply in 2012

In 2011, due to poor LED-backlit LCD TV sales and slow growth in LED lighting, LED supply exceeded demand by 30%. However, according to the 'Quarterly LED Supply/Demand Market Forecast Report' from market consulting firm NPD DisplaySearch, in 2012 this gap is closing due to recovering backlight demand and increasing demand for lighting. The glut is 19% in first-quarter 2012 and will drop to 16% in Q2/2012.

In 2010, key LED makers such as Samsung LED, LGIT (LG Innotek) and Lextar rapidly increased their metal-organic chemical vapor deposition (MOCVD) capacity, but found that they had overestimated market demand. In reaction to the oversupply, in late 2011 they began to adjust utilization rates, which have fallen to an average of 50% now.

However, two applications are forecast to drive LED demand in 2012.

First, currently LED backlights are used in all small/medium LCDs, and LED penetration in mobile PCs is nearly 100%, but penetration of LEDs in LCD monitors and LCD TVs continues to grow. So, while the number of LED packages per set is decreasing, high growth is expected for low-cost direct LED



LED supply and demand for backlight and lighting applications.

TVs. These backlights are likely to trigger renewed demand for LEDs in TVs due to the lower pricing. For example, for a 32" set, the price difference between cold-cathode fluorescent lamp (CCFL)-backlit LCD TVs and low-cost direct LED-backlit TVs is only about 5%.

Second, LED lighting will continue to grow gradually due to efficacy enhancements and cost reductions. For LED lighting products, the lumen per dollar is nearing that for

traditional light sources. Following the Japan earthquake in March 2011, LED lighting products saw sales increases in Japan due to electrical power shortages as well as a government incentive program. NPD DisplaySearch forecasts that sales in Japan will continue to rise rapidly in 2012. Other regions, such as China, the USA and Korea, are aggressively promoting LED lighting.

www.displaysearch.com

Compound semiconductor revenue growth slowing

Early announcements from compound semiconductor manufacturers Skyworks, RF Micro Devices and Freescale all point to revenue declines at the close of 2011, but bandwidth consumption and mobile handset sales are still increasing, notes the Strategy Analytics GaAs and Compound Semiconductor Technologies Service (GaAs) viewpoint 'Compound Semiconductor Industry Review January 2012: Microelectronics'.

The report from market research firm Strategy Analytics summarizes technology, product, contract, finan-

cial and employment announcements for the above firms, and others such as Fujitsu, Anadigcs, Agilent, Hittite Microwave, TriQuint Semiconductor, Avago, Soitec, Analog Devices and Microsemi for January 2012.

"Even though we are seeing revenue growth rates slow from some of the larger compound semiconductor manufacturers, this should not set off too many warning bells," believes Eric Higham, director of the Strategy Analytics GaAs and Compound Semiconductor Technologies Service. "The need for bandwidth, especially due to

ever-increasing sales of mobile handsets, will continue to power revenue growth in the compound semiconductor industry," he adds.

"Revenue is typically the highest in the third quarter as manufacturers increase production in advance of the holiday season," comments Asif Anwar, director of the Strategy Analytics Strategic Technologies Practice. "Despite the declines at the end of the year, Strategy Analytics expects 2012 revenue growth for the industry to be close to the historical average of 6%."

www.strategyanalytics.com

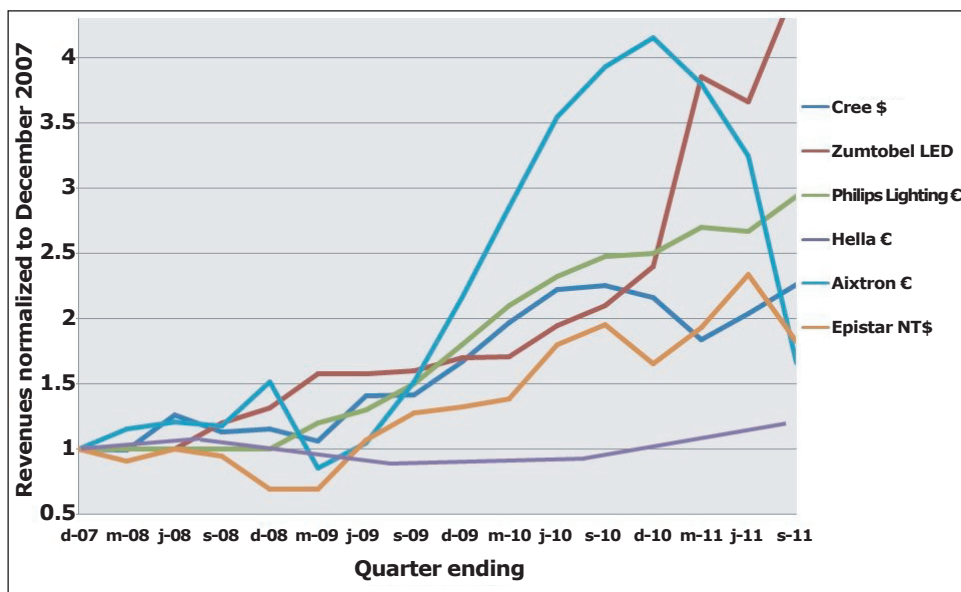
HB-LED market grew 4.3% in 2011

Fall in LED prices and usage per display counteracts growth in displays

The high-brightness LED (HB-LED) market grew 4.3% year-on-year to \$12bn in 2011, according to the report 'LEDs: The 2011 Market Review' from the European Photonics Industry Consortium (EPIC).

Demand for LED BLU (back-light unit) displays is still growing. However, fewer LEDs are needed to realise a BLU than in previous generations, so LED chip consumption is falling. The cost per LED is also falling. Together, these two factors mean that revenues attributed to LEDs per display screen are dropping rapidly. So, although production of BLUs based on LEDs should continue to rise through 2014, demand for LEDs for edge-lit BLUs has peaked and will settle at about 70% of its maximum value in 2010–2011.

EPIC has compiled its EPIC Bellwether Index of key companies, indicating the commercial development of solid-state lighting. In 2011, the Bellwether companies



Quarterly revenue (normalized to December 2007) for Bellwether Index firms.

showed widely varying fortunes. For example, lighting systems firms such as Philips and Zumtobel showed healthy growth, while chip makers like Epistar and Cree showed mixed results. In contrast, the slowing demand for the back-light-

ing market, together with the end of Chinese government subsidies for the purchase of metal-organic chemical vapor deposition systems, has led to a scaling back in demand for MOCVD system maker Aixtron.

www.epic-assoc.com

LED market slowing in 2012 after 2 years of high growth

Equipment spending forecast to decline in 2012

After two years of explosive revenue growth, the LED market appears to be slowing in 2012, notes the Strategy Analytics GaAs and Compound Semiconductor Technologies Service (GaAs) viewpoint 'Compound Semiconductor Industry Review January 2012: Optoelectronics, Materials & Equipment'.

The report from market research firm Strategy Analytics highlights that equipment spending and epitaxial substrate demand in the LED sector is forecast to decline in 2012. This validates recent announcements from equipment manufacturers (such as MOCVD reactor maker Aixtron) that substantial funding from Asian governments has been masking inherent softness in LED demand. The view-

point also summarizes technology, product, contract, financial and employment announcements in January from major optoelectronic material, device and equipment suppliers (such as Soitec, Sumitomo Electric, AXT, IQE, Oclaro, Cree, Renesas Electronics, GigOptix, Avago Technologies, JDSU, Lumileds and First Solar), categorized by material and equipment, laser, LED and compound photo-voltaic activity.

Companies are hard at work developing products that improve the performance and cost of devices in preparation for the next wave of LED adoption

"The LED industry has grown in cycles," notes Eric Higham, director of the Strategy Analytics GaAs and Compound Semiconductor Technologies Service. "The first phase involved backlighting for small consumer devices, like mobile handsets. These solutions have evolved to meet the needs of laptop, TV, electronic sign and automotive applications, and the next wave for LED adoption appears to be commercial and residential lighting," he adds.

"Companies are hard at work developing products that improve the performance and cost of devices in preparation for the next wave of LED adoption," comments Asif Anwar, director of the Strategy Analytics Strategic Technologies Practice.

www.strategyanalytics.com

GaN LED MOCVD shipments to fall 48% to 342 in 2012

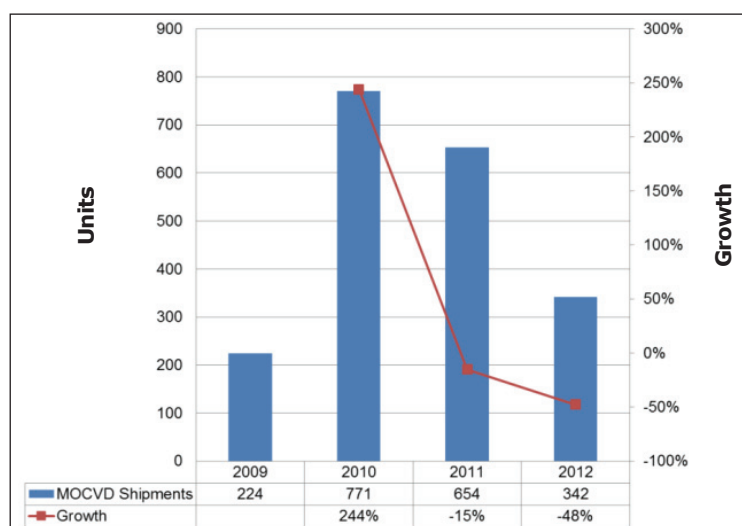
Shipments to bottom in first-half 2012 before recovery in second-half

Shipments of metal-organic chemical vapor deposition (MOCVD) reactors for gallium nitride (GaN) LED applications will fall by 48% from 654 in 2011 to 342 in 2012, forecasts IMS Research in its most recent 'Quarterly GaN LED Supply/Demand Report'.

Due to capacity needed for LED TVs, MOCVD shipments grew 244% from 224 in 2009 to 771 in 2010 (peaking in second-half 2010), the market research firm notes. Shipments fell by 15% in 2011, but they totalled a still healthy 654 as new Chinese manufacturers and Chinese-Taiwanese joint ventures entered the market, backed by government subsidies for MOCVD reactors, despite an oversupply in second-half 2010. However, with the oversupply expanding in 2011 and China's MOCVD subsidies expiring in most regions, shipments and orders have since stalled.

In addition to China's supply-side subsidies, the over-supply rose on weaker-than-expected demand due to global macroeconomic weakness, slower-than-expected growth in LED TV penetration, and the adoption of fewer LEDs per panel in many backlighting applications. In addition, LED lighting is still a relatively small market. As a result, MOCVD order intake fell sharply in second-half 2011, resulting in low expectations for MOCVD revenue in first-half 2012.

"The market peaked in Q3/10 and Q4/10 with 239 and 238 GaN reactors shipments respectively. Almost every quarter since then has been a decline," notes analyst Jamie Fox. "For 2012, we expect the first three quarters combined to be about the same as just one of those peak quarters," he adds. "Without the Chinese growth, the market would have almost completely collapsed [in 2011, China accounted for 76% of the market, reaching a peak of 92% in Q4/2011 — 2" remains the predominant wafer diameter due to



Unit shipments and year-on-year growth for MOCVD systems. research firm's customers and

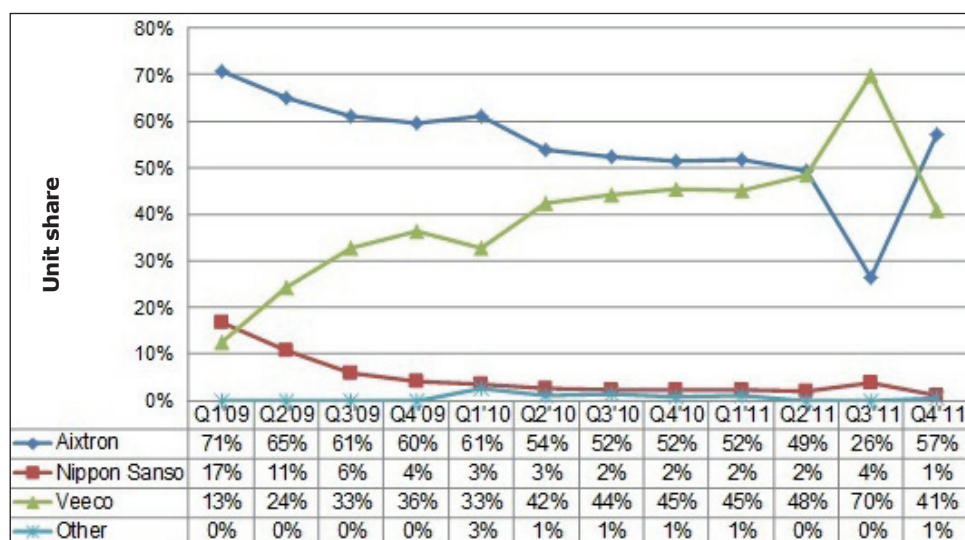
China, despite a trend to 4" and 6" globally at tier-1 manufacturers]." However, even with the severe market decline, 2012 is still forecast to be 52% higher than 2009's 224 units.

In Q4/2011, shipments actually grew sequentially, as some large orders in China materialized in the quarter, particularly for system maker Aixtron. In particular, China's Yangzhou Zhongke Semiconductor Lighting Center Co Ltd was the biggest customer in Q4/2011, while San'an Optoelectronics Co Ltd (the largest manufacturer of full-colour LEDs in China) was the biggest for full-year 2011. In terms of unit shipments Aixtron led the market in

the publically available information on the order intakes of MOCVD system makers Aixtron and Veeco clearly tell the story of a big decline expected in Q1/2012, which will see shipments of about half of Q4/2010's, reckons IMS.

The first two quarters of 2012 are therefore currently expected to experience the lowest shipment levels. However, a modest recovery should then be seen in second-half 2012 as firms begin adding capacity in response to expectations of rapid growth in demand from the general lighting market in 2013 onwards, concludes IMS.

www.ledmarketresearch.com



Market share of MOCVD system makers, showing Aixtron regaining lead in Q4.

TriQuint opens International Headquarters in Singapore

RF front-end component maker and foundry services provider TriQuint Semiconductor Inc of Hillsboro, OR, USA has officially opened TriQuint International Pte Ltd, its new International Headquarters at the Changi Business Park, close to the Changi International Airport in Singapore, which will be the focal point for most international customers, suppliers and manufacturing partners. The new office will offer dedicated resources in a wide variety of areas, ranging from customer service to supply chain management.

TriQuint has just recorded its sixth consecutive year of record revenue, driven largely by the proliferation of smartphones, tablets and the emergence of 3G/4G broadband wireless. With business outside the USA now contributing about 70% of annual revenue, customers in Asia drove a big part of this growth, while manufacturing partners in Asia assembled and tested almost all of the high-volume TriQuint-designed products sold into these applications.



Chong Joon Woon (director of the Electronics Economic Development Board of Singapore) and Glen Riley (managing director of TriQuint International Pte Ltd, Singapore) opening TriQuint's international HQ.

"With Asia's appetite for new technologies, particularly in mobile devices, and government support of the latest communications infrastructure, we believe Asia will continue to offer great opportunities for business growth," says president & CEO Ralph Quinsey. "It is with that long-term view that we further globalize our business,

in order to strengthen our relationships with international customers and drive greater efficiencies across our supply chain," he adds.

"We have solid plans to grow our share in the mobile device and network communications markets in Asia and Europe," says Glen Riley, VP & managing director, TriQuint International Pte Ltd. "Singapore is a great location to recruit and develop experienced talent, given the number of multi-national semiconductor companies already located here," he adds. "Over time we also plan to work on technology innovations and new product designs out of Singapore, through close collaboration with international customers," Riley continues.

"The headquarters is testimony to Singapore's competitiveness as a preferred location for companies to gain supply chain efficiencies," says Chong Joon Woon, director of the Electronics Economic Development Board of Singapore.

www.triquint.com

TRITIUM Duo: smallest dual-band PA for 3G and 4G smartphones

TriQuint's new TRITIUM Duo is claimed to be the smallest dual-band power amplifier duplexer (PAD) for global 3G and 4G smartphones, combining two band-specific power amplifiers (PAs) and duplexers in a single compact module (smaller than a single-band PAD), effectively replacing up to 12 discrete components.

The TRITIUM Duo family includes three products handling different pairs of bands: the TQM6M6214 (bands 1 & 4, for USA, Europe, Africa & Asia); the TQM6M6218 (bands 1 & 8, for Europe, Africa & Asia); and the TQM6M6225 (bands 2 & 5, for North America).

"We've powered the world's top smartphones with over a half billion of our single-band TRITIUM modules, and now the TRITIUM Duo is being evaluated by customers for use in next-generation smartphones,"

says president & CEO Ralph Quinsey. "Our broad technology portfolio has enabled us to integrate two commonly used bands in one small footprint," he adds. "Not only have we simplified the RF front-end for phone designers, we have also increased performance and flexibility."

The TRITIUM Duo family shares a common 6mm x 4.5mm footprint, simplifying design, speeding overall time to market, and giving the flexibility to support multi-band, multi-mode operation. Mobile device makers can capitalize on the size reductions to include more features or larger batteries in thinner, lighter form factors with all the performance needed for CDMA, 3G, and 4G networks.

TriQuint says that benefits to mobile device vendors include:

- a quad-band solution (two TRITIUM

Duos) with a footprint of ~50mm² (half that of a comparable discrete solution);

- a lower parts count, reducing the bill of materials (BOMs) and improving manufacturing & supply-chain efficiency; and

- performance optimized for each of its two bands (no switching is required after amplification — unlike configurable architectures).

TriQuint says that the dual-band TRITIUM Duo family brings a higher level of integration to its portfolio of PA-duplexer modules.

The TRITIUM Duo combines with TriQuint's QUANTUM Tx family of transmit modules to offer a complete RF front-end solution for smartphones and other mobile devices.

The TRITIUM Duo is currently sampling, with volume production planned in June.

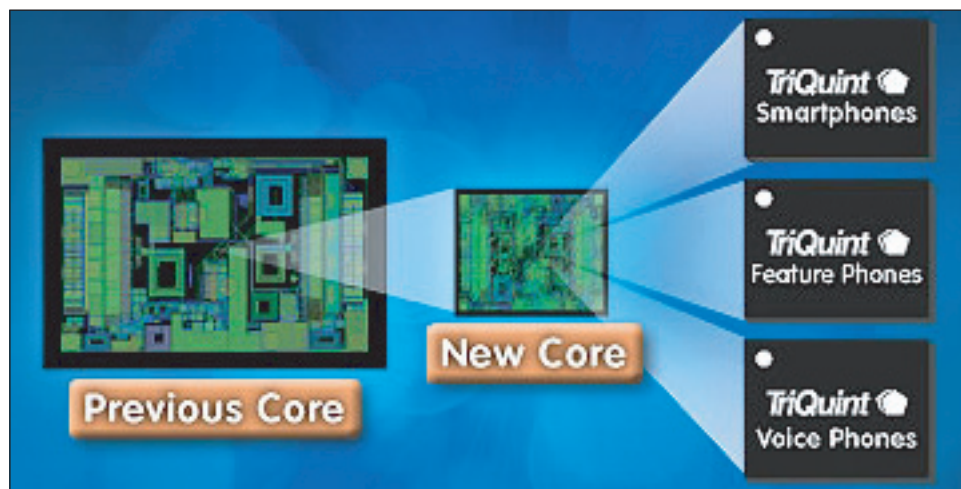
TriQuint claims smallest 3G/4G transmit modules

TriQuint Semiconductor says that it is building market momentum with two QUANTUM Tx modules that are 40% smaller than the previous generation. The transmit modules integrate the firm's new ultra-small GSM core, and enable more flexibility for smartphones, feature phones and low-cost voice-only phones.

"Design innovations have enabled cost and size breakthroughs without compromising performance," says Shane Smith, VP of global marketing for Mobile Devices.

"Our 2G QUANTUM Tx module has already made significant inroads in the GSM market. Our new 3G/4G QUANTUM Tx module pairs with our new TRITIUM Duo family of dual-band PA-duplexer modules [launched in late February] to create the industry's smallest, high-performance RF solution for global 3G/4G wireless devices," he claims.

TriQuint says that some of the world's leading mobile handset makers (including Samsung, Huawei and ZTE) have selected its new QUANTUM Tx modules. Of the firm's previous generations of QUANTUM Tx modules, to date more than 150 million units have been shipped. "We expect to ship more than 100 million QUANTUM Tx modules in the next 18 months alone, making it one of the highest volume product lines in our factory," Smith says. TriQuint increased manufacturing capacity by 40% in 2011 to support customer demand for its growing mobile device portfolio.



Core of TriQuint's latest QUANTUM Tx transmit module.

Shipping in volume since mid-2011, TriQuint's 2G (GSM) TQM6M4068 QUANTUM Tx module offers phone designers full GaAs HBT performance and a small size to enable flexible designs. At 5mm x 6mm, the TQM6M4068 is claimed to be the industry's smallest Tx module. Approved for MediaTek's chipset reference design, the product has been chosen for many new 2G phone platforms. "Close to 1.5 billion GSM-based phones will be produced this year," notes Neil Shah, an analyst with market research firm Strategy Analytics. "Virtually all 3G- and 4G-capable phones incorporate 2G access technology, and 2G remains the dominant wireless communication technology in many areas of the world," he adds.

Shipping in volume since January, the TQM6M4069 QUANTUM Tx module features the same small 5mm x 6mm footprint, making it

the smallest 3G/4G transmit module on the market, it is claimed.

TriQuint says that the new part simplifies mobile device design and showcases the firm's strength in integration, since it includes a GSM/GPRS power amplifier and WCDMA antenna switch. TriQuint also plans to expand the QUANTUM Tx module family in the months ahead with product solutions that incorporate additional switch ports to support more frequency bands.

The QUANTUM Tx transmit modules implement proprietary CuFlip technology to replace wire bonds with copper bumps, saving board real-estate and boosting system performance by eliminating noise-radiating wires. The copper bumps also dissipate heat better than traditional interconnect techniques. The QUANTUM Tx modules offer improved system efficiency and full RF transmit functionality in a compact size of just 30mm².

TriQuint powers linearized 3G/4G small-cell solution

TriQuint and Scintera have developed a design-ready solution to power 'small cell' 3G/4G/LTE base-stations that network operators see as a cost-effective capacity constraint remedy and a way to enable 4G/LTE data rates.

The new solution, the first to use a 12V power supply, combines

Scintera's SC1869 RF power amplifier linearizer with TriQuint's broadband TQP7M9103 and AP561-F. Delivering 2W (33dBm) of linear output power, the solution can support single or multiple carriers up to 20MHz (total signal bandwidth) for all major global cellular frequencies.

"This innovation simplifies RF connectivity by leveraging market-tested solutions while reducing input power. The ICs are very broadband, so two devices can be used to support all cellular frequencies," says TriQuint VP Brian P. Balut.

www.triquint.com

Anadigics launches dual-band PAD front-end modules

Anadigics Inc of Warren, NJ, USA has introduced a new family of dual-band power amplifier duplexer (PAD) modules based on the firm's third-generation High-Efficiency-at-Low-Power (HELP3E) technology.

By combining HELP3E power amplifiers with high-performance internal duplexers (with balanced Rx ports), the new PAD front-end modules deliver what is claimed to be optimal RF performance and longer battery-life, while reducing device design and assembly complexity. The modules include two separate RF paths in a compact 4.5mm by 6mm package, offering what is claimed to be the industry's smallest 3G/4G dual-band footprint and reducing PCB space requirements by up to 40%. In addition, the maximum 1mm package height supports next-generation thin form-factor phones.

Compliant with WCDMA/HSPA, HSPA+ and LTE, the new family of dual-band PAD modules uses the firm's exclusive InGaP-Plus technology to achieve optimal power-added efficiency (PAE) across low-range and mid-range output power levels (via three mode states) for use with



Anadigics' new PAD modules.

or without a DC-DC converter, and to achieve low quiescent current of 4mA. The internal design optimizes the power amplifier and duplexer match to deliver greater overall system efficiency and RF

The modules include two separate RF paths in a compact 4.5mm x 6mm package... reducing PCB space requirements by up to 40%

front-end performance, says Anadigics. The firm also claims best-in-class linearity at maximum output power. In addition, a flat gain response across all bands yields superior system performance and ease of calibration, it is claimed.

"Next-generation mobile devices are being designed to deliver an unprecedented level of features, performance, and style as consumers continue to demand greater functionality and versatility," says John van Sadlers, senior VP of RF products. "By combining industry-leading efficiency, linearity, and integration, Anadigics' PAD modules help extend battery-life, minimize space requirements, and reduce time-to-market," he adds.

Engineering samples are available now for the AWT6641 (for Bands 1 & 5), AWT6645 (for Bands 2 & 5), and AWT6648 (for Bands 1 and 8). Operating at a voltage of 3.4V, end-to-end WCDMA efficiency is 20.1% for Band 1 and 20.5% for Band 5 for the AWT6641; 20.5% for both Bands 1 and 5 for the AWT6645; and 20.1% for Band 1 and 21.2% for Band 8 for the AWT6648. Maximum output power is 24.5dBm.

HELP4 and HELP3E PAs power Galaxy Note in China and Korea

Anadigics is shipping production volumes of its ALT6705, AWT6621 and AWT6624 fourth-generation High-Efficiency-at-Low-Power (HELP4) power amplifiers and AWC6323 dual-band third-generation HELP3E power amplifiers (PAs) to Samsung Electronics for its Galaxy Note devices. The AWT6621 powers the Galaxy Note I9228 (TD-SCDMA) and the AWC6323 powers the Galaxy Note I889 (CDMA), both available in China. The ALT6705, AWT6621, and AWT6624 power the Galaxy Note SHV-E160L, available in Korea.

"The new Samsung Galaxy Note represents an advanced convergence device that merges the impressive multimedia features of

a tablet with the versatility and functionality of a smartphone," comments Michael Canonico, Anadigics' senior VP of worldwide sales. The power amplifiers help to extend battery-life in power hungry multimedia-rich devices, he adds.

Anadigics' HELP4 and HELP3E PAs use the firm's exclusive InGaP-Plus technology to achieve optimal power-added efficiency (PAE) across low-range and mid-range output power levels (with three mode states) and provide low quiescent currents of 4mA. Anadigics also claims best-in-class linearity at maximum output power.

Devices in the HELP3E family incorporate two independent PAs in a single package with a 3mm by

5mm footprint, along with internal voltage regulation and an integrated RF coupler.

HELP4 PAs allow a high level of integration in a 3mm by 3mm footprint (with internal voltage regulation and an integrated 'daisy chainable' directional RF coupler with 20dB directivity) and enable an average reduction in current consumption of 30% compared with previous-generation PAs.

In particular, the ALT6705, AWT6621, AWT6624 and AWC6323 power amplifiers deliver what is claimed to be industry-leading efficiency to extend battery life in handsets, smart phones, tablets, netbooks, and notebooks.

www.anadigics.com

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IN BRIEF

RFMD surpasses 1 billion power amplifiers shipped to China-based manufacturers

RF Micro Devices Inc of Greensboro, NC, USA says that it has shipped over 1 billion cellular power amplifiers (PAs) to handset makers headquartered in the Greater China area. The firm says that the milestone demonstrates its ongoing commitment to providing China-based customers with operational scale, technological innovation and what it claims is an industry-leading cost structure.

RFMD opened its first manufacturing facility in Beijing in 2002 in support of local China-based manufacturers and international manufacturers with operations in China. In 2007 it opened its Shanghai Design Center and a major expansion of its Beijing facility. The firm says that it now offers a complete end-to-end source for design, manufacturing, field applications engineering and sales support, with approximately 2000 employees in China supporting hundreds of customers and baseband providers.

"This considerable milestone exemplifies RFMD's long-standing commitment to our customers based in China," says president & CEO Bob Bruggeworth. "As we commemorate our tenth year of operations in Greater China, we anticipate strong growth with China-based customers, driven by continued innovation in 2G components and the industry's most innovative and most reliable RF product portfolio for the rapidly growing 3G and TD-SCDMA/TD-LTE smartphone markets," Bruggeworth adds.

www.rfmd.com

RFMD powering multiple devices for top-tier smartphone maker

RF Micro Devices says that it has been selected by a top-tier manufacturer of 3G/4G smartphones to support multiple next-generation devices, including an LTE smartphone that will feature multiple variants of its family of ultra-high-efficiency WCDMA and 4G LTE power amplifiers.

RFMD is currently supporting multiple devices for this smartphone maker with a broad range of high-performance products, including PowerSmart power platforms, ultra-high-efficiency 3G/4G power amplifiers, and multiple switch-based components.

"RFMD continues to increase our exposure to the world's leading smartphone manufacturers," says Eric Creviston, president of RFMD's Cellular Products Group. "With these wins, we expand our participation in a growing family of highly popular smartphones and bolster our position in the high-growth LTE category," he adds. "We look forward to expanding our content opportunity in future devices as new programs ramp and as new product families are introduced," Creviston says.

RFMD says that its ultra-high-efficiency 3G and 4G LTE PAs extend

battery life and reduce the thermal impact of data usage in smartphones. The product family currently covers WCDMA bands 1, 2, 3, 4, 5, and 8, and LTE bands 4, 7, 11, 13, 17, 18, 20, and 21, addressing the most common UMTS/HSPA+ and LTE frequency bands and band combinations. Additional multi-mode, multi-band (MIMB) and single-mode LTE variants will be introduced in first-half 2012.

RFMD says that it offers a broad portfolio of 3G and 4G LTE solutions in single-mode and converged architectures to ensure alignment with leading chipset providers and

Additional multi-mode, multi-band (MIMB) and single-mode LTE variants will be introduced in first-half 2012

enable worldwide network compatibility. Its 3G and 4G LTE product portfolio reduces the thermal impact of data usage in smartphones while enabling

increased battery life during data-centric applications, such as web surfing, video calls and internet radio services, the firm adds.

Front-end module launched for 915MHz ISM-band applications

RF Micro Devices has launched the RF6559 front-end module (FEM) for 915MHz AMR (automated meter reading) systems.

The FEM contains an integrated three-stage power amplifier (PA) with 42dB of gain and typical power output of 28dBm. The RF6559's integrated single-port Rx/Tx (50Ω) allows for transmit/receive (Tx/Rx) functions on a single antenna via two integrated SPDT (single-pole double-throw) switches.

The module includes Tx filtering, a built-in power detector, and a

two-stage low-noise amplifier (LNA) with bypass mode with typical gain of 32dB, all a 28-pin, 6mm x 6mm laminate package with backside ground.

Applications include wireless automated metering, wireless alarm systems, portable battery-powered equipment, smart energy, 868MHz/915MHz ISM-band applications, and single-chip RF front-end modules.

The product is available in production quantities. Pricing begins at \$2.84 each for 750 pieces.

RFMD expands PowerSmart family

At the 2012 Mobile World Congress in Barcelona, Spain (27 February to 1 March), RFMD announced the expansion of its family of PowerSmart power platforms to include multiple new 3G and 4G LTE variants. The PowerSmart power platforms are part of the technology shift to converged front ends in multi-mode, multi-band applications (e.g. smartphones, tablets and other data-centric mobile broadband devices).

The newest PowerSmart power platforms include PowerSmart 4G, a converged multimode multi-band power platform (capable of up to 12 bands of 4G LTE, 3G and 2G) that is designed specifically for 4G LTE operation and expands upon the first-generation PowerSmart power platform by adding three additional bands of 3G or 4G LTE coverage. PowerSmart 4G also includes all necessary switch and signal conditioning functionality in a compact reference design, providing smartphone makers a single scalable source for the entire front end.

RFMD's expanded PowerSmart product family also includes a new power platform optimized for emerging 3G entry (3Ge) applications and capable of multi-mode multi-band coverage of up to seven bands of

3G or 2G. Similar to PowerSmart 4G, the PowerSmart power platform for emerging 3Ge applications includes all necessary switch and signal conditioning functionality in a compact reference design.

RFMD is also expanding the PowerSmart product family to include multiple 3G and 4G discrete power amplifiers (PAs), which can be placed optionally with any PowerSmart power platform to achieve additional band or mode coverage. Architected in tandem with the RF Configurable Power Core in each PowerSmart power platform, the discrete PAs can deliver significantly improved PA efficiency at backed-off power, the firm says.

"As the world's only truly converged solution with single-die multi-mode performance, RFMD's PowerSmart is positioned to drive the cellular wide-area network (WAN) experience across a broad range of mobile devices, including tablets, notebooks, ultra-books, e-readers and next-generation in-vehicle networking," claims Eric Creviston, president of RFMD's Cellular Products Group (CPG). "We expect these new products to support multiple cellular handset and smartphone manufacturers this calendar year."

IN BRIEF

3G/4G antenna control solutions

RFMD has launched 3G/4G antenna control solutions, optimized to solve the complex RF demands of smartphones for high band-count and signal integrity in a very compact form factor.

"RFMD's antenna control solutions are securing key design activity at leading smartphone manufacturers by solving the increasingly complex challenges in multi-mode, multi-band front ends," says RFMD's Eric Creviston. "By optimizing antenna performance across modes and bands, RFMD's antenna control solutions improve call quality and extend battery life... RFMD's 3G/4G antenna control solutions will begin to achieve broad customer adoption this calendar year."

RFMD's switch and signal-conditioning product portfolio already includes antenna switch modules, switch filter modules, switch duplexer modules, RF power management components, and low-noise amplifiers. Sales for the portfolio were over \$25m in the December quarter.

RFMD adds 2nd-generation high-efficiency PAs for LTE

RFMD has expanded its ultra-high-efficiency power amplifier (PA) product portfolio to include six 4G LTE PAs. Complementing RFMD's first-generation family of ultra-high-efficiency PAs for WCDMA applications, the new PAs are claimed to deliver superior peak efficiency and current consumption in LTE mode.

RFMD's ultra-high-efficiency product family now covers WCDMA bands 1, 2, 3, 4, 5 and 8, and LTE bands 4, 7, 11, 13, 17, 18, 20 and 21, helping to accelerate the global reach of LTE in mobile devices such as smartphones and other high-performance data-centric connected devices, and enhancing data

throughput, battery life and thermal performance for mobile broadband consumer applications.

The PAs deliver peak efficiency of 42–44% in LTE mode, which is claimed to be significantly above competing product portfolios. The LTE PAs also offer high linearity at the highest power conditions, enabling bandwidths up to 20MHz and resulting in higher data transfers.

In both 3G and 4G LTE, the PAs use RFMD's RF systems expertise and RF power management to deliver what is said to be best-in-class current consumption across all power levels and in all modes and bands. Power management is expected to

be increasingly critical in 2012, says RFMD, as leading cellular solutions begin to adopt advanced power management schemes such as average power tracking (APT) and envelope tracking (ET).

"As RFMD's customers continue to push the limits on band count and form factor, this is creating an unprecedented opportunity for RFMD to solve the increasingly complex RF challenges related to battery life and thermal performance," says Cellular Products Group president Eric Creviston. "We expect strong growth and market share gains in 3G and 4G LTE as our ultra-high-efficiency product portfolio continues to expand."

IN BRIEF

PAs and FEMs for data-intensive mobile platforms

Skyworks Solutions has launched several new 3G and 4G high-efficiency front-end solutions for smartphones, tablets and wireless data modules. The 'SkyHi' solutions deliver what is claimed to be industry-leading power-added efficiency (PAE) for data-intensive mobile platforms, extending battery life, reducing the radio footprint and simplifying calibration for manufacturers.

"Today's applications and devices require improved efficiency at high power," says Thomas J. Richter, senior marketing director of front-end solutions. "Skyworks' new family of SkyHi amplifiers and front-end modules deliver close to 50% PAE and offer a path to even higher efficiency when utilized in an envelope tracking system," he adds.

The SkyHi family comprises the following front-end products:

- SKY77619 (for bands I, II, III, IV, V and VIII) — a multimode, multiband power amplifier module (PAM) that supports 2.5G/3G and 4G handsets and operates efficiently in GSM, EGPRS, EDGE, WCDMA and LTE modes;
- SKY77733 (for bands XIII/XIV) and SKY77737 (for bands XII/XVII) — fully matched surface-mount PAMs for LTE applications;
- SKY77751 and SKY77752 — dual-band PAs supporting bands I and VIII or II and V (coming in a 3mm x 4mm package and having either a single RF input or dual RF input for CDMA and WCDMA applications);
- SKY77761 — a fully matched 10-pad surface-mount PAM for WCDMA applications; and
- SKY77762, SKY77764, SKY77765 and SKY77768 — PAMs supporting band I, II, IV, V and VIII, respectively (for CDMA, WCDMA and LTE applications).

Skyworks adds antenna switch modules and LTE switch solutions

Skyworks Solutions has expanded its family of antenna switch modules (ASMs) for smartphones and tablets, offering solutions in up to 14 throw counts to meet various handset makers' layout preferences and design needs. It has also unveiled a full suite of complementary discrete LTE transmit and receive solutions spanning single-pole double-throw (SPDT) to single-pole eight-throw (SP8T) applications in a compact 2mm x 2mm footprint.

Together, the latest devices support low-cost 3G handsets, as well as high-speed packet access/LTE-enabled data-centric devices such as data cards and tablets — both of which require design flexibility, high performance and cost-effective architectures.

Skyworks' RF switch solutions are based on GaAs pHEMT and silicon technology and complement its existing GaAs and silicon power amplifiers and front-end solutions. "Our ability to support multiple platforms and architectures in various process technologies demonstrates Skyworks' technical breadth," says David Stasey, VP of analog components.

The ASMs are logic-compatible with the interface requirements of the leading 3G/4G chipset providers. In addition to integrated switch and logic, the devices all feature dual low-pass GSM harmonic filters. Designed for any combination of 2G/3G multimode cellular applications, the ASMs are:

- The SKY13404-466LF is a single-pole 10-throw ASM in a compact 2.6mm x 3.4mm QFN package designed for dual- and tri-mode, high-power band switching applications that need low insertion loss. The device features eight high-linearity ports, providing full flexibility for 2G, 3G and LTE handsets and data cards.
- The SKY13412-487LF is a single-pole 12-throw ASM in a 3.0mm x 3.8mm QFN package featuring 10

high-linearity ports providing full flexibility for 2G, 3G and LTE handsets and data cards. The device includes port-to-port RF isolation comparisons in order to optimize signal routing in an increasingly more challenging RF signal environment.

- The SKY18120-11 is a single-pole nine-throw ASM in a very compact 2.5mm x 2.5mm package, 20-pin multi-chip module. It has three high-linearity ports suitable for tri-band 3G/quad-band 2G or TD-SCDMA/2G multi-mode handsets and data cards.

Skyworks' LTE transmit/receive switches are high-linearity solutions that can handle multiple-input, multiple-output receive diversity as well as post power amplifier WCDMA/HSPA+/LTE PA transmit signal routing requirements. Using advanced switching technologies, they maintain low insertion loss and high isolation for both transmit and receive switching paths:

- The SKY1341X-485 scalable family spans single-pole four-throw to SP8T switches allowing up to eight bands of WCDMA/LTE transmit & receive. The high-linearity performance and low insertion loss suit main/diversity switching commonly used in LTE handsets, data cards and tablets that use antenna diversity solutions. The SKY13414-485LF (SP4T), SKY13415-485LF (SP5T), SKY13416-485LF (SP6T), SKY13417-485LF (SP7T) and SKY13418-485LF (SP8T) form a general-purpose input/output (GPIO) control-logic-compatible series of LTE transmit/receive switches in a 2.0mm x 2.0mm lead-frame package.
- The SKY13330-397LF is a SPDT all-symmetric-port transmit/receive switch in a 2.0mm x 2.0mm lead-frame package. Designed for post linear power amplifier single routing to frequency filtering components, it is differentiated by very low insertion loss and single-bit GPIO control.

www.skyworksinc.com

Kopin's III-V revenue grows 12% in Q4/2011 to \$17.4m Consolidation of domestic III-V activities into one facility to cut costs and fund continued R&D investment

For full-year 2011, Kopin Corp of Taunton, MA, USA has reported revenue of \$131.1m, up 8.9% on \$120.4m in 2010. Of this, revenue from III-V products rose 6.8% from \$62.2m to \$66.5m and revenue from Display products rose 11.2% from \$58.2m to \$64.7m.

Most recently, fourth quarter 2011 revenue was \$35.2m, up 6.3% on \$33.1m a year ago and as much as 19% on \$29.6m in Q3/2011.

In particular, III-V product revenue was \$17.4m, up 12% on \$15.5m in Q3 and 15% on \$15.1m a year ago, driven by strong sales of wireless handsets and growing demand for BiFET and BiHEMT structures as enabling technology for smartphone power amplifiers. "BiHEMTs deliver the high performance in the small footprints required by next-generation smartphones, and our IC customers' BiHEMT qualification and production activities increased significantly in the fourth quarter," says president & CEO Dr John C.C. Fan.

However, revenue from Displays was \$17.8m, up 26% on \$14.1m in Q3 but down 1.7% on \$18.1m a year ago, reflecting lower R&D and military display revenue (partially offset by higher revenue from consumer electronics applications).

Gross margin rose from 30.4% in 2010 to 34.6% in 2011. "During

2011, we maintained a strong financial position while investing for the future. Our 2011 gross margin dollars increased \$8m compared with 2010, which enabled us to increase internal R&D investments in our III-V, display and Golden-i technologies by \$5.1m," says Fan.

On a non-GAAP basis, operating income was \$3.5m in Q4/2011, up from \$3.1m a year ago. Full-year operating income rose from \$5.7m to \$8.2m. Q4 net income was \$2.4m, down from \$4m a year ago but up from \$0.8m in Q3.

During 2011, Kopin generated \$18.1m of cash from operating activities, allowing it to spend \$11m on buying Forth Dimension Displays (FDD) in January 2011, \$5.9m on capital expenditure and \$4.4m for the repurchase of stock. Cash and equivalents and marketable securities has consequently fallen from \$111m to \$105.4m (although Q4 saw a recovery from \$103m at the end of Q3).

"We anticipate another strong year of growing global demand for smartphones to drive a solid performance for our III-V business in 2012, and our Golden-i technology is on track for a 2012 launch," Fan said. "However, we expect Defense Department budget cuts to negatively affect our military display

revenue," he adds. Consequently, for full-year 2012, Kopin expects overall revenue to fall about 12% to \$110-120m.

"By the end of this month we anticipate the completion of a plant consolidation project we started more than a year ago," says Fan. "We have consolidated all of our domestic display manufacturing activities into one facility that allowed us to consolidate all of our domestic III-V activities into one facility and we effectively closed our other domestic III-V facility this month. Actions like these will help to generate substantial cost savings, allowing Kopin to remain financially strong and flexible so that we can continue to invest in the future growth of our business," he adds.

"In 2012 we will continue to focus on developing our BiFET and BiHEMT smartphone technologies as well as on working with our partner for the successful launch of our Golden-i technologies," notes Fan. "These investments will position us to further capitalize on our leadership position in III-V technology, as well as on our expertise in advanced display imaging systems for consumer and industrial markets to drive market share gains and longer-term growth," he believes.

www.kopin.com

TowerJazz receives Innovation Award from Skyworks

Skyworks Solutions Inc of Woburn, MA, USA has bestowed its 2011 Innovation Award on specialty foundry TowerJazz (which has fabrication plants at Tower Semiconductor Ltd in Migdal Haemek, Israel, and at its subsidiaries Jazz Semiconductor in Newport Beach, CA, USA and TowerJazz Japan Ltd). This is the first time that TowerJazz has won the award, but Skyworks previously honoured the firm with its Foundry Supplier of the Year

award for three consecutive years for providing "excellent quality, performance and solid alignment with Skyworks' supply chain requirements".

Skyworks uses a range of TowerJazz's specialty processes, including mixed-signal CMOS, RFCMOS, BiCMOS, SOI and SiGe BiCMOS, to develop products such as transmit/receive modules, power amplifier controllers, switch controllers, linear devices, and wireless LAN solutions.

"Skyworks has been a long-time customer of TowerJazz and we are extremely pleased to continue addressing their next-generation technology needs," says TowerJazz's VP sales David Postula. "This award demonstrates our commitment to partnering with our customers in helping reduce their costs through joint value-engineering projects that deliver economic benefits not only to existing but also new products."

www.towerjazz.com

Riber and Imec extend collaboration on III-V logic CMOS 300mm MBE chamber, clustered with CMOS production equipment, to be evaluated for Si devices with Ge and III-V channels

Riber S.A. of Bezons, France, which manufactures molecular beam epitaxy (MBE) systems as well as evaporation sources and effusion cells, has signed an agreement with nanoelectronics research center Imec of Leuven, Belgium to further collaborate on epitaxy process technologies for next-generation III-V CMOS devices. The agreement follows a successful collaboration on advanced channel materials for high-performance CMOS scaling, germanium and compound semiconductor (III-V) materials.

In the quest for miniaturization, technology has come to a point where CMOS scaling beyond the 45nm node cannot be achieved by simply reducing transistor dimensions. Moreover, the need for small form factors - coupled with the stringent requirement of low current leakage/low energy performance - has become critical, especially in next-generation mobile devices. Within Imec's Germanium and III-V devices program, Imec and its core partners are exploring the efficacy of high-mobility channel materials for CMOS devices for advanced nodes. Together with Riber, the bottleneck issue of gate stack passivation was tackled, resulting in effective passivation techniques for Ge and GaAs.

Riber's 200mm III-V and metal oxide MBE cluster offered the required extremely clean background and absence of any interfering gas-phase components,

enabling material and interface control on the atomic level. This resulted in the development of a passivation scheme for the MOS gate stack module. Amongst other things, it was shown that controlling the GaAs surface reconstruction followed by a H₂S passivation treatment and in-situ high-k deposition was crucial to create a well-passivated MOS structure with record low interfacial state density. Moreover, the world's first successful MOS capacitors on a new high-mobility candidate material (GeSn) were made in the 200mm MBE cluster.

In the new project, the suitability of Riber's 300mm UHV chamber (ISA300) — equipped with in-situ tools for surface analysis, and clustered with state-of-the-art 300mm silicon CMOS production equipment — will be evaluated for the production of advanced CMOS devices based on high-mobility Ge and III-V channels. The aim is threefold: (1) use Riber's UHV chamber for the study and control of surface structures; (2) bring knowledge on gate stack passivation from a 200mm research environment to a 300mm fab-compatible platform; and (3) demonstrate the technical viability of a 300mm MBE module, clustered with 'standard' 300mm Si CMOS production equipment.

"Participating in early-stage research is intrinsic to Riber's aim to strengthen our leading position in the compound semiconductor

industry," says Riber's CEO Frédéric Goutard. "MBE is considered to be most efficient technology to leverage compound semiconductors towards high-end applications with a tremendous market potential, such as mobile phones, telecom, automotive, satellite,...," he adds. "Using our ISA300 chamber in a 300mm cluster configuration will allow for higher performance in terms of devices operating at high frequencies with reduced energy consumption, etc. We are therefore convinced that this project will clearly demonstrate the attractiveness of our technology in the production of next-generations CMOS devices," Goutard continues.

"Through the collaboration with Riber, Imec can integrate the power of UHV systems into state-of-the-art semiconductors production equipment on large-diameter wafers," says Hans Lebon, VP fab operations and process step R&D at Imec. "This will allow the application of powerful in-situ surface analysis tools in CVD [chemical vapour deposition] and ALD [atomic layer deposition] equipment, which so far was not feasible due to the gas-phase environment," he adds. "Also, MBE-like UHV techniques for interface control and passivation come in reach, which will benefit the development of next-generation CMOS technologies."

www.riber.com
www.imec.be

Riber sells research system to Argentina

Riber has sold a Compact21 research system to a laboratory in Argentina.

The reactor will be set up in the Institute of Nanosciences and Nanotechnologies of Bariloche. It will enable the lab to strengthen

its development capacities for designing III-V component-based semiconductor systems.

Riber claims the Compact21 is the world's top-selling research MBE system, with the flexibility to meet the most demanding expect-

tations for applied research on compound semiconductor materials.

The firm adds that its first sale in Argentina demonstrates Riber's geographical diversification.

www.riber.com

BridgeWave using IBM's SiGe chipset technology

BridgeWave Communications of Santa Clara, CA, USA, a supplier of millimeter-wave gigabit wireless solutions for 4G network backhaul, has signed an agreement with IBM to develop technology that it says will help to close the cost gap between millimeter-wave (MMW) high-capacity backhaul solutions and traditional microwave (MW) solutions, allowing mobile operators and wireless carriers to cost-effectively deal with growing bandwidth demands.

Recent reports show that wireless data traffic (videos, audio and e-mails sent via laptops, smart phones and tablets) rose 133% in 2011. With many consumers also migrating to 4G networks, this has put a significant strain on global wireless networks, especially in dense urban cities, says BridgeWave.

As data consumption rates continue to grow, this causes a reduced range of wireless network coverage, raising investment costs for building infrastructure with access points to cover service areas. Alternative approaches, such as integrating backhaul and small-cell technology, can reduce these bandwidth bottlenecks and spotty service while increasing speeds over a larger network, the firm adds.

BridgeWave says that, using IBM's silicon germanium (SiGe) technology, the collaboration will provide the high silicon integration with gallium arsenide (GaAs)-equivalent RF performance, across the entire 71-86GHz spectrum. The devices yield ultra-low phase-noise performance, enabling the very high spectral efficiencies and system gain for millimeter-wave backhaul solutions required by next-generation 4G/LTE networks. As part of the integration process, BridgeWave will assimilate its proprietary micro-coax mQFN (micro-coax Quad-Flat No-leads) packaging technology along with the IBM-designed devices to create high-performance, integrated, low-cost millimeter-wave chipsets.

"Until now, the eco-system for millimeter-wave components was very limited compared to their microwave counterparts," says CEO Amir Makleff. "IBM's R&D efforts in the area of millimeter-wave SiGe, along with BridgeWave's proprietary mQFN micro-coax interconnect technologies, will allow us to bring cost-effective, high-performance, carrier-grade solutions to market that operators require as they build out their 4G/LTE networks," he adds.

Use of IBM's SiGe as the basis for their backhaul network solutions will provide a platform that can scale to meet exploding data growth rates, says Danny Elad, manager, Analog & Mixed Signal, IBM Research-Haifa. "Sampling results of these designs are exceeding expectations and will enable BridgeWave to start integration into products in 2012," adds Idan Bar-Sade, IBM's senior VP of engineering & product management. www.bridgewave.com

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IN BRIEF

Black Sand appoints VP worldwide sales

Black Sand Technologies has strengthened its senior management team by appointing Richard Murphy to the newly created post of VP of worldwide sales.

With over 15 years of experience in selling and marketing semiconductor solutions into the wireless terminal market, Murphy has a track record in sales and business development, particularly in the Asia-Pacific (APAC) region.

"We have recently secured \$10m in Series C funding, strengthening our balance sheet and putting us on track for the next phase in our growth," says CEO John Diehl.

"In 2010 we overcame the technical challenges of creating all-silicon power amplifiers; in 2011 we commenced commercial shipments into multiple design wins; 2012 will be the year in which the market takes off in serious volume, and Richard's appointment puts us in a strong position to make the most of that opportunity," he adds.

Murphy will take responsibility for Black Sand's sales activities on a worldwide basis. In the past he was VP of worldwide sales for 2G CMOS PA provider Axiom Microdevices, where his sales leadership and innovative sales techniques contributed directly to "unparalleled revenue, unit volume and market share achievements," Black Sand says.

Previously, Murphy ran sales, marketing and business development for semiconductor companies including Zero G Wireless (acquired by Microchip Technology Inc) and Aspendos Communications (acquired by Beceem Communications Inc). He has also held sales positions at Audience and Embedded Wireless Devices.

Murphy is a graduate of Bucknell University and Cornell University's Japanese studies program.

Black Sand adds 3G bands to BST34 CMOS PAs to enable global take up

Fabless semiconductor firm Black Sand Technologies Inc of Austin, TX, USA, which specializes in power amplifier technology for wireless applications, has extended its established BST34 series of CMOS silicon power amplifiers (PAs) with two devices that complete its range of products for use in every common global cellular frequency band. The BST3405 and BST3408, for use in Band-5 (824–849MHz) and Band-8 (880–915MHz) respectively, are drop-in replacements for the gallium arsenide components traditionally found in every 3G mobile phone, tablet and datacard.

Black Sand manufactures the BST34 series using an industry-standard CMOS semiconductor process. The firm claims that, by replacing GaAs process technology, customers can benefit from lower costs, enhanced product robustness and reliability, and an improved supply chain.

"The BST34 series is already shipping into multiple design wins with multiple customers," says CEO John Diehl. "Our technology has reached maturity and gained acceptance — this is the right time to extend our reach by leveraging our ability to offer customers solutions for all the major 3G frequency bands," he adds.

"Last year the cellular PA market grew 19% to \$3.3bn and, as the non-handset market grows, we predict it will increase to \$4bn by 2016," comments Chris Taylor, who earlier this month published data on the cellular PA market for analyst firm Strategy Analytics.

"Mobile device manufacturers are looking for an alternative to GaAs PA technology, which has a known history of supply shortages and higher cost-structure," claims Black Sand's VP marketing Jim Nohrden. "We can now offer customers a complete range of silicon PAs which,

at 28dBm output power, meet or exceed the performance of older GaAs devices, with none of their disadvantages. This high output power, offered across every major frequency band, can be used by our customers in all their mobile products — from low-end to high-end and from datacards to smartphones to tablets," he adds.

"We have a strategic supply base larger than all existing GaAs PA vendors combined and this has proved critical as the market continues to adopt 3G mobile devices, which have two to three times as many PAs as 2G phones," Nohrden continues. "Our products offer handset manufacturers better performance and a more reliable source of supply," he asserts.

The new BST3405 for 'cellular' Band-5 (824–849MHz) and BST3408 for 'GSM' Band-8 (880–915MHz) products join the existing BST3401 for the '2100' Band-1 (1920–1980MHz), BST3402 for 'PCS' Band-2 (1850–1910MHz), and BST3404 for 'AWS' Band-4 (1710–1755MHz). The devices are fully function and pin-compatible drop-in replacements for existing 3G GaAs RF PAs.

The BST34 series devices deliver up to 28dBm of linear power and are packaged in a 3mm x 3mm 10-pin form factor. The products include an integrated directional coupler with daisy-chain support, integrated overvoltage and over-temperature protection circuitry. Black Sand also offers the BST35 series products, which include the firm's TrueDelivered power detection technology, allowing mobile phones to produce up to 2dB higher total radiated power than is possible using GaAs power amplifiers, it is claimed.

The BST3401/2/4 are available and shipping now. The BST3405/8 will ship in second-quarter 2012.

www.blacksand.com

SemiSouth unveils second major expansion in 18 months

Extra \$18m accelerates availability of SiC power devices for solar, wind, traction-drive & hybrid/electric auto industries

SemiSouth Laboratories Inc of Starkville, MS, USA (which designs and manufactures silicon carbide devices for high-power, high-efficiency, harsh-environment power management and conversion applications) has announced its second major capacity expansion within 18 months.

Following a \$30m investment from Power Integrations in 2010 that allowed SemiSouth to grow from about 70 staff to 115, the new \$18m in funds from an existing investor will create over 100 new jobs over the next 18 months and help to drive continued growth of its SiC fabrication facility, with the aim of better serving customers adopting the firm's diode and power transistor products. SemiSouth claims that the adoption of its SiC technology enables ultra-efficient power conversion for solar



SemiSouth's fab in the Thad Cochran Research Park.

and wind inverters, hybrid/electric vehicles, traction-drive and other applications that benefit from high energy efficiency.

"Today's announcement is a testament to SemiSouth's success with existing customers in solar inverter and industrial power supply market segments," says president

Jeff Casady. "We are ramping with our customers' demands for our industry-leading SiC power JFET and power diode products, and this new expansion will allow us to expand our volume another 50% for these customers and new ones starting up with us," he adds.

"We have many customers in production with even more in development for our products in energy-sensitive markets such as solar inverters, server power supplies, wind inverters, and electric vehicle development," says Dieter Liesabeths, senior VP of sales & marketing.

www.semisouth.com

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Graphensic spun off from Sweden's Linköping University for graphene-on-SiC epi

Rositzta Yakimova, Mikael Syväjärvi and Tihomir Iakimov of Sweden's Linköping University have founded the spin-off Graphensic AB (part of the business incubator LEAD) as what is claimed to be the first European supplier of epitaxial graphene on silicon carbide (SiC).

The research team has worked on SiC growth processes over many years, and since the early 1990s has developed various growth methods, from epitaxy to bulk. The patent-pending method that has been developed is said to work at higher temperature than competing processes. High quality is achieved through an understanding of the activity of silicon and carbon on the surface.

During its research the team supplied material to several projects, both national and European. Professor Yakimova (team leader, and CEO of Graphensic) says this shows that there is an existing demand for the firm's material for the development of applications. A benefit of SiC is that the wide-bandgap compound semiconductor



Graphensic's graphene-on-SiC wafer.

may be conductive or semi-insulating, depending on requirements of the specific device developed by users.

The research team started working with graphitic materials in 2002, resulting in the existing High Temperature Graphene Process (HTGP) for growing epitaxial graphene on SiC, where the higher growth temperatures is said to provide better material uniformity. The first product is monolayer graphene on the silicon face of hexagonal SiC. The firm is also developing bilayer graphene. The research will continue developing new materials in the academic environment in parallel with the industrialization of graphene.

Graphensic's founders hope that the research will be further supported by the EU-funded 'Graphene Flagship' project (for which six ICT projects have been chosen to compete for funding, of which two will be selected this summer), potentially involving €1bn in support over the next 10 years. Graphensic's first customers come from the Nordic countries, France and Japan. Graphensic also targets supplying industrial groups, says Syväjärvi, who worked on the entrepreneurial steps to launch the start-up. Such firms have much greater demands and are hence useful for Graphensic to work further on its process and materials, he adds.

"We are developing a process for cubic SiC, and study the combination of this material with the graphene," says Yakimova. "There are many fascinating processes and insightful knowledge in this combinatorial materials system. We hope that these can be a part of our product portfolio in the company," she concludes.

www.graphensic.com

Infineon orders Tokyo Electron epi growth system to mass produce SiC power devices

Tokyo Electron Ltd (TEL) says that Germany's Infineon Technologies has ordered its Probus-SiC silicon carbide epitaxial film growth system for the mass production of SiC power devices.

The Probus-SiC can handle film growth on substrates up to 6 inches in diameter. It also features automatic transfer and multi-reactor functions, and has been evaluated as being suitable for improving device performance and productivity, says Tokyo Electron. The system is scheduled to be delivered this summer.

"In order to ensure the stable performance required for mass



TEL's Probus-SiC epi growth system.

production, the Probus-SiC incorporates key design and development concepts to achieve good uniformity, low defect density, reduced surface roughness, high throughput and easy operability," says Yoichi Ishikawa, general manager of TEL's New Product Development Division. "With Infineon Technologies' validation of the Probus-SiC performance and design, TEL is looking forward to the opportunity to contribute to low-cost manufacturing of high-quality SiC power devices and the further expansion of the SiC power device market," he adds.

www.tel.com

Group4Lab contracts Alfred University to develop sacrificial substrates for GaN-on-diamond technology Cordierite glass-ceramics to match thermal expansion coefficients

Group4 Labs Inc of Fremont, CA, USA, which develops and supplies 'extreme materials' that aim to improve the performance of gallium nitride (GaN)-based devices, has contracted Alfred University (AU) researchers to develop a sacrificial substrate for diamond coatings to support GaN-on-diamond technology. S.K. Sundaram and Scott Misture, who are Inamori Professors of materials science in Alfred University's Kazuo Inamori School of Engineering, will oversee the project, which aims to improve efficiencies in the lighting industry and advance the sensing and communication industries.

Misture and Sundaram will develop a substrate material for Group4 Lab's technology, which combines diamond and semiconductors to extract heat rapidly, efficiently, passively, and cost-effectively.

According to Sundaram, the micron-sized diamond coating is first applied to a sacrificial substrate. When that is removed, the diamond coating can then serve as the substrate for further processing of the semiconductor coating.

Once completed, the technology can be used in applications such as solid-state lighting, sensing, and communication industries.

Misture and Sundaram believe that cordierite glass-ceramics are most suitable as a diamond coating substrate because the two materials are well

Cordierite glass-ceramics are most suitable as a diamond coating substrate because the two materials are well matched

matched with regard to thermal expansion as well as chemical and thermal stability under the processing conditions of interest to Group4 Labs. The sacrificial substrate must also be inexpensive because it is disposed of during processing.

Previously, diamond had been deposited on substrates with different thermal expansion coefficients, resulting in 'mis-match failure and thermal cracking', says Misture. The main challenge is matching the thermal expansion coefficients of the substrate and the coating. Misture and Sundaram hope to accomplish that by manipulating the glass chemistry and controlling a specific crystal phase's crystallization.

<http://group4labs.com>
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IN BRIEF

HRL GaN transistor technology available commercially

HRL Laboratories LLC of Malibu, CA, USA (a corporate R&D lab owned by The Boeing Company and General Moto's) is now offering products in its gallium nitride (GaN) high-electron-mobility transistor (HEMT) technology to commercial customers in select markets, providing what is claimed to be significant advantages for high-data-rate wireless links, radars and active sensors.

HRL has been investing in GaN transistor development since the late 1990s, reporting the first Ka-band GaN power amplifier at the 2004 IEEE International Microwave Symposium (IMS) and the first W-band GaN power amplifier at the 2006 International Electron Devices Meeting (IEDM).

The firm says that its GaN amplifiers offer a more than five-fold improvement in E- and W-band output power compared with current state-of-the-art commercial solid-state technologies. This high power output reduces the need for power combining multiple amplifiers and minimizes the power module assembly complexity, says HRL. In addition, the intrinsic higher linearity of GaN allows the transmission of modulation schemes with higher spectral efficiency, increasing the potential data throughput for wireless links.

HRL is offering wideband 70–100GHz GaN power amplifiers as well as a family of application-specific E- and W-band power amplifiers covering the 71–76GHz, 81–86GHz and 90–96GHz bands.

The new GaN products were introduced at GOMACTech 12 in March and will also be introduced at the IEEE MTT-S International Microwave Symposium (IMS 2012) in Montreal, Canada (17–22 June).

www.hrl.com email

TriQuint launches 30W, 2.5–6GHz GaN PA with 35% PAE for wide-band communications & defense markets

In conjunction with exhibiting at the 2012 Government Microcircuit Applications and Critical Technology Conference (GOMACTech 12) in Las Vegas (19–22 March), RF front-end component maker

and foundry services provider TriQuint Semiconductor Inc of Hillsboro, OR, USA has launched a new packaged, 30W wideband GaN power amplifier with high power and efficiency for defense, communications and general test applications.

Fabricated using TriQuint's 0.25 μ m, production-released GaN on SiC process and available in a standard, surface-mount flange package, the TGA2576-FL delivers 30W of saturated output power (45.5dBm) across the 2.5–6GHz frequency range, and typically offers 35% power-added efficiency (PAE) and 26dBm of small-signal gain. Samples and evaluation fixtures are now available. The TGA2576-FL is also generally exportable.



TriQuint says that its GaN portfolio (which includes amplifiers, transistors and switches) offers the performance and dependability demanded for defense, aerospace and commercial applications, and that it provides design assistance and support built around enabling the use of new high-efficiency GaN circuits. The firm adds that interest in GaN technology continues to grow as it transitions from defense applications (that initially demonstrated its capabilities) into mainstream commercial markets (where its frequency range, power density, efficiency and device size are superior to other semiconductor technologies).

www.triquint.com

R&D reported on E/D-mode InAlN/GaN devices and GaN X-band amplifiers

At GOMACTech, researchers from TriQuint presented papers highlighting GaN advances.

Presentations detail enhancement/depletion (E/D)-mode indium aluminium nitride/gallium nitride (InAlN/GaN) devices that deliver record high-frequency performance in DARPA-funded programs.

Integrated GaN X-band amplifiers will also be explored. TriQuint's new GaN X-band paper reports how its researchers have integrated RF matching and bias circuits in a 66W high-efficiency GaN solution.

The firm also claims that its R&D programs set new standards while also enabling a wide selection of design-ready GaN products for commercial and defense applications.

TriQuint's provides a full range of field-effect transistors (FETs), monolithic microwave integrated circuits (MMICs), packaged transistors, and high-power RF switches, as well as foundry services. In addition to GaN- and GaAs-based devices, the firm also provides surface acoustic wave (SAW) and bulk acoustic wave (SAW) devices.

www.gomactech.net/2012

Keithley launches high-voltage System SourceMeter for high-power semiconductor test

Keithley Instruments Inc of Cleveland, OH, USA has launched the Model 2657A High Power System SourceMeter, which adds high voltage to the Series 2600A System SourceMeter family of high-speed, precision source measurement units. Together, the instruments allow the characterization of a broader range of power semiconductor devices and materials, says the firm.

A built-in 3000V, 180W source allows the Model 2657A to source up to five times as much power to a device under test (DUT) as the nearest competitive system, at much lower cost, it is claimed. The precision, high-speed 6½-digit measurement engine built into the Model 2657A enables femtoamp current measurement resolution to support the low-leakage requirements of next-generation devices.

The Model 2657A is optimized for high-voltage applications such as testing power semiconductor devices, including diodes, FETs and IGBTs, as well as characterizing newer materials such as GaN, SiC and other compound semiconductor materials and devices. It is also useful for characterizing high-speed transients and performing breakdown and leakage tests at up to 3000V.

Like the rest of the Series 2600A family, the Model 2657A has a flexible, four-quadrant voltage and current source/load coupled with precision meters. It combines the functionality of multiple instruments in a single full-rack enclosure — semiconductor characterization instrument, precision power supply, true current source, 6½-digit DMM, arbitrary waveform generator, voltage or current pulse generator, electronic load, and trigger controller — and is fully expandable into a multi-channel, tightly synchronized system via Keithley's TSP-Link technology. The firm claims that, unlike competitive solutions (typically limited in terms of power), the Model 2657A can source or sink up to



Model 2657A High Power System SourceMeter.

180W of DC power ($\pm 3000\text{V}@20\text{mA}$, $\pm 1500\text{V}@120\text{mA}$). The 1fA resolution also allows fast, accurate sub-picoamp measurements even when sourcing up to 3000V.

The Model 2657A provides a choice of digitizing or integrating measurement modes for characterizing both transient and steady-state behavior, including rapidly changing thermal effects. Each mode is defined by two independent analog-to-digital (A/D) converters (one for current and one for voltage) that run simultaneously to ensure accurate source readback without sacrificing test throughput. The digitizing mode's 18-bit A/D converters support 1 μs -per-point sampling, so users can capture voltage and current transients simultaneously (rather than averaging multiple readings, which is too slow to characterize transient behavior). The integrating mode, based on 22-bit A/D converters, optimizes the Model 2657A's operation for applications that demand the highest measurement accuracy and resolution. Keithley says this ensures precise measurement of the very low currents and high voltages common in next-generation devices.

Basic device characterization can be performed with no need for software installation or programming

with TSP Express (Keithley's LXI-based I-V test software utility). Users can simply connect a PC to the LXI LAN port and access TSP Express with any Java-enabled web browser. Test results can be viewed in either graphical or tabular format and then exported to a .csv file for use with spreadsheet applications. Two additional tools for creating test sequences are provided: the Test Script Builder application (for creating, modifying,

debugging, running, and managing TSP scripts) and an I-V-based LabVIEW driver (to simplify integrating the Model 2657A into LabVIEW test sequences). The Test Script Builder application has new debugging capabilities that make test program development easier and more productive.

ACS Basic Edition software is also available as an option for component characterization. The latest release offers features for characterizing high-voltage and high-current components. Measurement libraries have been updated to support both DC and pulse-mode operation of both the high-voltage Model 2657A and high-current Model 2651A. A special 'Trace Mode' provides real-time control over an instrument's voltage or current output using a simple slider.

The 2657A can be connected to other instruments in a test system with standard safe high-voltage (SHV) coaxial cable connections compatible with existing high-voltage test applications. But, for applications that depend on the instrument's low-current measurement performance, Keithley also offers special HV triaxial (guarded) connections to optimize accuracy.

Shipments of the Model 2657A will begin in May.

www.keithley.com

Solar slowdown prompts 5N Plus' \$45.6m write down and idling of panel recycling plant

Pricing lowered in revised CdTe supply agreement with First Solar

5N Plus Inc of Montreal, Canada has reported results (in US dollars) for the quarter to end-December and for the fiscal year (of just seven months, due to a change in fiscal year-end from end-May to end-December).

5N produces tellurium, cadmium, selenium, germanium, indium and antimony as well as related II-VI compounds such as CdTe, CdS and InSb as precursors for growing crystals for electronic applications, including photovoltaic, radiation detector and infrared markets. Also, in mid-April 2011, 5N acquired MCP Group SA of Tilly, Belgium, a producer and distributor of bismuth chemicals (with a 50% global market share) as well as other specialty metals (including gallium, indium, selenium and tellurium).

Hence, revenue for the quarter of \$149.4m was up 674% on \$19.3m for the quarter to end-November 2010. Revenue for the seven-month fiscal year was a record \$391.7m. The backlog of orders (expected to translate into sales over the next 12 months) was \$223.2m at the end of December. This compares with revenue of \$180m for the prior 12-month fiscal year (to end-May 2011) but a corresponding order backlog of \$263.7m (higher than the current backlog).

"We did experience a significant softening in demand for most of our products, resulting partly from a greater year-end seasonality in the markets of the recently acquired MCP Group and to a larger extent from the impact of the general downturn in the economy," says president & CEO Jacques L'Ecuyer.

Seasonality was most strongly felt in the Eco-Friendly business unit, where sales fell. Demand also softened in the Electronic Materials business unit due mainly to lower-than-anticipated sales of gallium-based products. "We also incurred significant impairment costs in this

business unit as we wrote-down our tellurium inventories by \$21.5m and wrote-off our fixed assets in Wisconsin [a solar module recycling facility]," L'Ecuyer says. "We also chose to write-off our investment in Sylarus, given the current conditions in the solar market." In January 2011, 5N Plus acquired a majority stake in Sylarus Technologies LLC of Saint George, UT, USA, which produces Ge substrates for manufacturing multi-junction photovoltaic cells.

Impairment charges totaled \$45.6m in the quarter and \$46.9m for the seven-month period, due mainly to the turmoil in the solar market and the impact on the selling price of solar-related products and the value of fixed assets used to manufacture or develop such products, says the firm. Specifically, the charges include total write-offs of fixed and intangible assets amounting to \$12.2m and total inventory write-downs of \$33.4m in the quarter and \$34.8m for the fiscal year.

Net losses for the quarter and seven-month fiscal year were \$37.2m and \$21.6m, respectively, versus net earnings of \$6.5m for the quarter to end-November 2010 and \$21.9m for the 12-month fiscal year to end-May 2011.

"Our integration of MCP activities is continuing as planned. Efforts are now largely aimed at improving overall operational efficiency and at reducing costs as we aim to right size our activities and eliminate redundancies," continues L'Ecuyer. 5N has idled its Wisconsin module recycling plant until further notice. "We have cut back on our workforce and are implementing a number of cost-reduction initiatives and expect to continue doing so for most of the 2012 fiscal year... This effort, together with a number of investments that we recently announced, should enable us to be very well positioned for future growth," he believes. During the

quarter, 5N acquired the outstanding 40% stake in its joint venture Laos Industrial Resources Co Ltd.

Also, 5N Plus has entered into a revised CdTe supply agreement with First Solar, which starts on 1 April and replaces three existing agreements between the firms. The new deal, which is evergreen in nature, is for 5N to supply substantially all of the CdTe required by First Solar in its global PV module manufacturing. Pricing has been lowered from the existing agreements in line with more competitive environments in both the solar and material-feedstock markets. Either party can terminate the new agreement by providing two-year advance notice, which in the case of First Solar will be effective only after a minimum quantity of CdTe has been purchased.

"We are pleased to have strengthened our relationship with our main customer in the solar market, First Solar, in an extremely challenging environment," says L'Ecuyer. "We expect our new supply agreement with First Solar to be in effect for a number of years and, although we have had to adjust our terms and conditions to reflect the new market dynamics, we are confident that we are now better positioned than ever to take advantage of growth opportunities in the solar market," he adds.

"Preliminary results for the current quarter suggest that sales and earnings are reverting back to more standard levels when compared to the quarter ended December 31, 2011, further highlighting the detrimental impact of the year-end seasonality," says L'Ecuyer. "We are also reducing our cash requirements and have correspondingly downsized our credit facility [from \$250m to \$200m]," he adds. "We remain a well-diversified corporation with a large number of customers, a broad range of products and a very unique skillset and asset base."

www.5nplus.com

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SAFC Hitech opens Taiwan facility to enhance HB-LED precursor capacity

Expansion boosts site's capacity for TMG, TEG and TMI, as well as ALD and CVD precursors

SAFC Hitech of St Louis, MO, USA (a business segment of SAFC within the Sigma-Aldrich Group) says it has underlined its commitment to the Asia-Pacific electronics markets by opening its new multi-million dollar facility in Kaohsiung, Taiwan in a ceremony attended by dignitaries including Kaohsiung City Mayor Miss Chiu Chen and senior executives Rakesh Sachdev (Sigma-Aldrich president & CEO), Gilles Cottier (SAFC president) and Philip Rose (SAFC Hitech president).

The 270,000ft² expansion significantly increases the site's existing capacity for the high-volume manufacturing of high-quality trimethylgallium (TMG), triethylgallium (TEG) and trimethylindium (TMI) precursors for high-brightness LED (HB-LED) applications. The site will also produce atomic layer deposition (ALD) and chemical vapour deposition (CVD) precursors for the silicon semiconductor market and offer regional transfilling capability and technical service and support.

SAFC Hitech says that the latest expansion of its global manufacturing footprint reinforces Taiwan as a strategic regional hub from which to leverage its existing proprietary knowledge and capabilities as a provider of ultra-high-purity metal-organic and silicon precursors for thin-film deposition production processes for the microelectronics and optoelectronic markets. The firm's existing Taiwan operations will transition to the new Kaohsiung facility.

"One of SAFC Hitech's key objectives is to continue to provide leading materials technology solutions to drive functional performance in end-use devices in the high-growth markets we serve — for now and in the future," said Rose at the opening. "Following the March 2010 produc-



Ribbon-cutting ceremony at SAFC Hitech's Taiwan facility.

tion expansion for TMG at our Bromborough, UK manufacturing site, this strategic investment in Taiwan will continue to strengthen our position as a leading global supplier of reliable precursors for the HB-LED market. This market is tailored to address the increased focus on improving efficiency and reducing energy costs through design and technology advances, which is driving the electronics sector to introduce more energy-conscious products and systems," he added.

"Due to the rise in demand for LEDs, and in particular HB-LEDs, we are increasingly engaged in cus-



Exterior of the facility in Kaohsiung.

tommer collaboration activities throughout the Asia-Pacific region," added Dr Geoff Irvine, SAFC Hitech's VP of marketing & business development. "With 30 years experience in supplying precursors, our focus is on developing local infrastructure and manufacturing

capacity in order to continue to offer customers a broad product range and novel delivery systems optimized for performance and cost of ownership," he added. "Our proprietary delivery systems like bubblers/ampoules and EpiFill, EpiVapor and EpiSensor are allied to strong application development and vertical integrated manufacturing."

In addition to the enhanced manufacturing capacity, SAFC Hitech's Kaohsiung site capabilities can handle and characterize highly specialized laboratory-scale chemicals and features a dedicated customer support center. The site also provides integrated inert

atmosphere transfilling stations, analytical instrumentation for the detection of ultra-low-metallic and -oxygen-containing contaminants and dedicated cylinder preparation and packaging areas. The site is ISO 9001 certified for quality, with work to acquire ISO 14001 certification for safety and environmental protocols in process.

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IQE grows revenue and profit in 2011 despite Q4 wireless inventory corrections

Rise in CapEx prepares for return to growth in Q2/2012

For 2011, epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK has reported record revenue of £75.3m, up 4% on 2010's £72.7m (or up 8% in US dollars), driven by increased sales volumes.

Revenue in first-half 2011 grew strongly by 23% in US dollars (16% in sterling). However, second-half revenue was impacted in fourth-quarter 2011 by inventory corrections at two major wireless customers. Despite this, full-year 2011 sales for wireless applications were level on 2010 at about £55.1m, although they fell from 76% of total revenue in 2010 to 73% in 2011.

Including the impact of the acquisition in 2010 of antimonide substrate maker Galaxy Compound Semiconductors Inc of Spokane, WA, USA, optoelectronics business continued to grow at a faster pace than the core wireless business, achieving year-on-year growth of more than 27% in US dollars (or 21% growth in sterling, from £15.4m in 2010 to £18.6m in 2011, rising from 21% of total revenue to 24.6%).

Electronics business fell from £2.2m in 2010 to £1.6m in 2011 (falling from 3% of revenue to 2%).

Reflecting continued strong management of costs, a beneficial product mix, and further improved operating efficiencies, gross margin has continued to improve, from 22.8% to 24.1%.

The increase in sales and the tight control of costs translated into earnings before interest, tax, depreciation and amortization (EBITDA) of £14m (up 6% on 2010's £13.1m) and an operating profit of £7.4m (up from £7.2m).

Strong conversion of operating profit into cash delivered operating cash inflow of £10.8m (up from £10.3m). However, capital expenditure rose from 2010's £5.6m to £17.4m, reflecting capacity expansion to meet anticipated sales growth. In addition, investment in new-product development rose from £3.4m to £3.7m. Hence, net debt at the end of 2011 was £3.9m (compared with net funds of £7m at the end of 2010).

"New product qualifications have progressed very well, with newly qualified products now ramping into production and other qualifications nearing completion," says president & CEO Dr Drew Nelson. "Furthermore, our capacity expansion program remains on track, which is providing customers with a high degree of confidence in IQE as a key supplier [to satisfy their increasing demand and surge requirements] as they keep their allocation of supplier shares under review," he adds.

IQE now supplies all 12 of the top RF wireless chip producers globally. The impact of any future inventory corrections as a result of temporary market share shifts is being mitigated

by further product qualifications across all wireless products and customers, the firm says. When completed, these additional qualifications should result in a highly robust and risk-averse strategy, it adds. "Inventory corrections continued into the first quarter but, as anticipated, customer forecasts now reflect a return to growth, as expected for Q2 and onwards," says Nelson.

"Our optoelectronics business has a number of near-term opportunities which have progressed well during 2011 and which could result in a number of key products ramping to volume production as early as 2013," notes Nelson. "Following the year end [in February], we announced a strategic investment [taking a 9% stake] in Solar Junction Corp of San Jose, CA, USA [which makes III-V multi-junction solar cells for concentrated photovoltaic (CPV) modules] and an exclusive long-term supply agreement, a move that will accelerate our penetration into the exciting, third-generation CPV solar market," he adds.

"The prospects for IQE's wireless markets, coupled with continuing strength across the group's other market sectors, mean that the board remains confident that IQE is well positioned to deliver strong growth in 2012 and beyond," Nelson concludes.

www.iqep.com

ON Semiconductor's president & CEO joins Veeco's board

Epitaxial deposition and process equipment maker Veeco Instruments of Plainview, NY, USA has appointed Keith Jackson to its board of directors.

Jackson is president, CEO & director of ON Semiconductor, a supplier of silicon solutions for energy-efficient electronics with 20,000 staff. He joined the firm in 2002. It has since completed nine corporate acquisitions and increased annual revenue

by over \$2bn (to about \$3.4bn).

Before joining ON Semiconductor, Jackson was executive VP & general manager, Analog, Mixed Signal and Configurable Products Groups at Fairchild Semiconductor Corp, which provides energy-efficient semiconductor solutions for power and mobile designs. From 1996–1998, he was president and a member of the board of directors of analog and

mixed-signal product maker TriTech Microelectronics Ltd in Singapore. Jackson has also served on the board of the Semiconductor Industry Association since 2008.

"Keith brings a strong technology background to Veeco's board that includes more than 30 years in the semiconductor industry," says CEO John R. Peeler.

www.veeco.com

Soitec earns new certifications for global quality, safety and environment management systems

Soitec of Bernin, France, which makes engineered substrates — including silicon-on-insulator (SOI) wafers and III-V epiwafers — as well as concentrating photovoltaic (CPV) solar systems, has earned new certifications from the International Standards Organization (ISO) and the Occupational Health and Safety Assessment Series (OHSAS).

With a customer base spanning global microelectronics and energy firms on five continents, all of Soitec's operational sites worldwide — including its semiconductor material and solar module factories in France, Germany and Singapore — now meet ISO quality and environmental requirements.

As a result of the most recent audit conducted at the end of 2011, LRQA (Lloyd's Register Quality

Assurance) has awarded:

- ISO/TS 16949 certification to Soitec's semiconductor material operations in France at its Bernin and Paris Sud facilities (both of which demonstrated full compliance on their initial audits). The Singapore factory also achieved this compliance so Soitec will now use the ISO/TS 16949 standard — which is more specific and stringent than ISO 9001 — as the basis of its world-wide quality-management system.
- ISO 9001 and ISO 14001 certification to Soitec's solar facility in Freiburg, Germany (where it manufactures its CPV systems).
- OHSAS 18001 health and safety certification to Soitec's Paris Sud facilities. Hence, all of the firm's semiconductor materials operations are now in compliance with OHSAS

18001. Soitec is now working to extend these protocols to its solar module facility in Freiburg by the end of 2012.

"Our fully integrated quality, safety, health and environmental management system is focused on ensuring the superior quality and reliability of our products as well as maintaining our best practices to deliver the highest levels of customer satisfaction," says chief operating officer Paul Boudre.

Soitec's newest manufacturing plant in San Diego, CA is currently being refitted to produce CPV modules for the US renewable-energy market. This facility aims to gain ISO 9001 and ISO 14001 certifications next year and OHSAS 18001 compliance by 2014.

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Aixtron reports loss in Q4 on revenue down 38% year-on-year

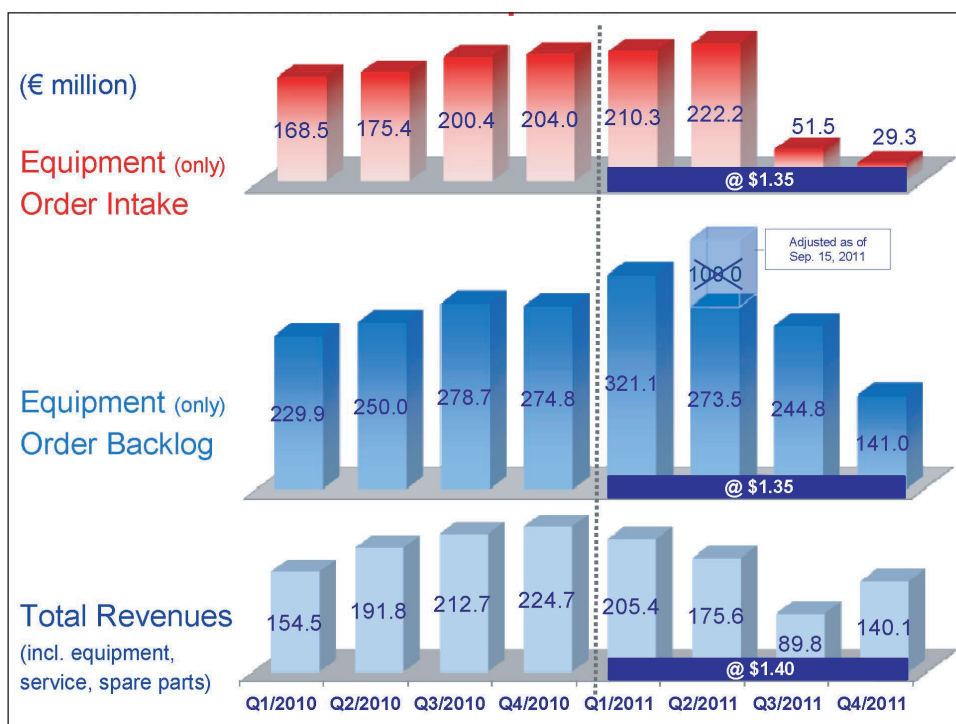
R&D investment grows as profit forecast for 2012

For full-year 2011, deposition equipment maker Aixtron SE of Herzogenrath, Germany has reported revenue of €611m. This is the firm's second best year, but down 22% on 2010's €783.8m due to market weakness in second-half 2011. After quarterly revenue fell 49% from Q2's €175.6m to Q3's €89.8m, Q4 saw a rise of 56% to €140.1m, but this was still down 38% on €224.7m a year ago.

"However we look at 2011, it was certainly an extraordinary year by any standard," says president & CEO Paul Hyland. "We were still delivering strong revenues in the first half of the year, whereas in the second half, the market environment changed dramatically, resulting in an abrupt reduction in demand for MOCVD systems [due partly to financing pressures on some Asian LED makers, including both sovereign and bank suppression of credit lines and bank loans]," he adds. Second-half revenue of €229.9m was down 40% on the first-half's €381m.

Nevertheless, Aixtron was able to quickly adapt to the deteriorating business environment during second-half 2011, and consequently still delivered reasonable profit margins for the full year. Although down from 2010's 53%, gross margin was 38%. Earnings before interest and taxes (EBIT) fell from 2010's €275.5m (an operating margin of 35% of revenue) to €112.9m (18% margin). However, in Q4 gross margin was just 8% (down from 43% in Q3 and 52% a year ago), and EBIT was -\$16.9m (-12% margin), down from \$86m (38% margin) a year ago.

Full-year net profit was €79.5m (13% of revenue), down from 2010's €192.5m (25% of revenue). However, compared to Q3's net profit of €61.6m, Q4 saw a net loss of €10.9m.



Aixtron's revenue, order intake & backlog in the last 24 months.

Compared with free cash flow of €95.9m in 2010, €36.2m was consumed in 2011. Overall, cash & cash equivalents plus cash deposits fell from €384.7m to €295.2m.

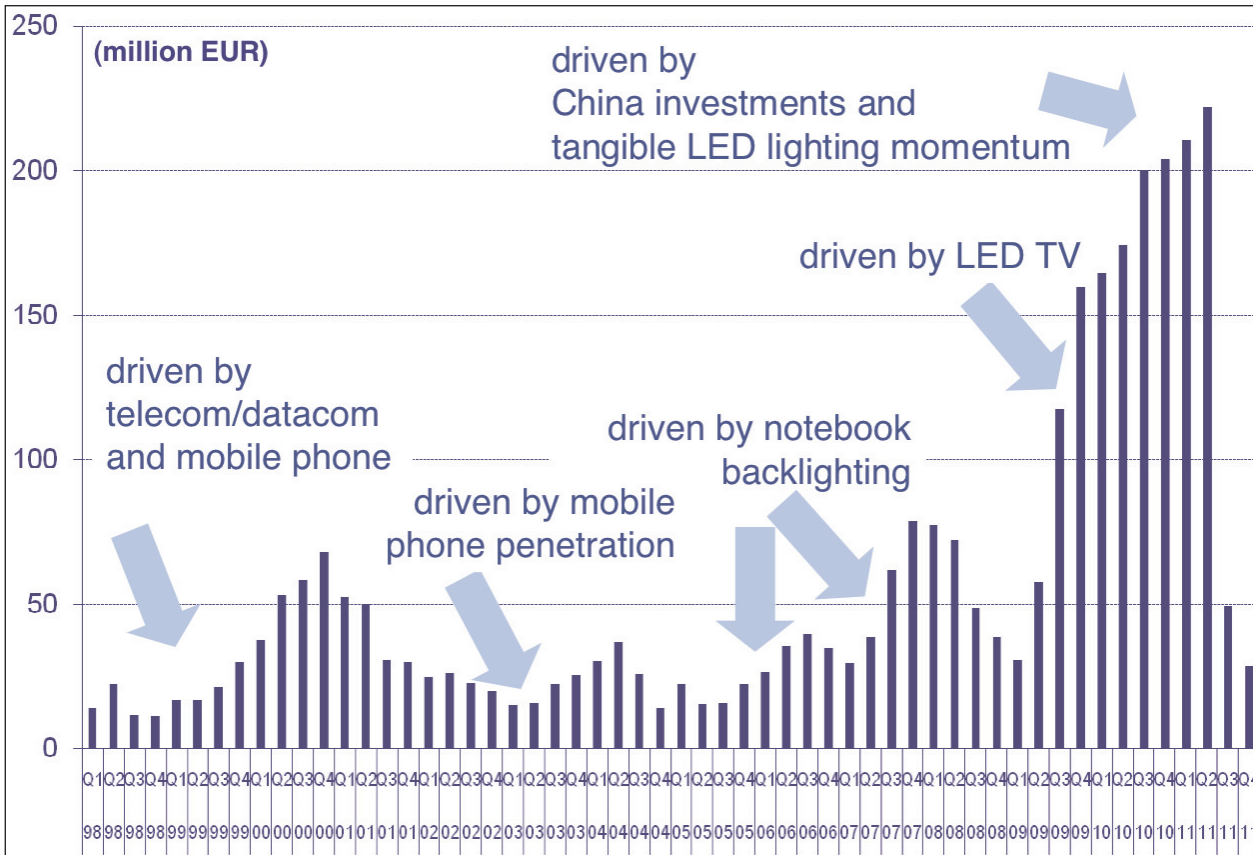
Total order intake in 2011 was €513.4m, down 31% on 2010's €748.3m. Intake slowed dramatically in second-half 2011 (by 81%, from first-half's €432.5m to just €80.9m). Specifically, after falling 77% from Q2's €222.2m to Q3's €51.5m, intake fell a further 43% in Q4 to just €29.3m (down 86% on €204m a year ago). Order backlog was €141m (down from €244.8m at the end of Q3 and almost half the €274.8m at year-end 2010). However, this includes a decision in mid-September to reduce order backlog by €100m after receiving increased requests for delivery deferrals since August.

"Our 2011 full-year result still underlines the benefit of the company's flexible business model and stable financial position, which has enabled us to effectively cope with these severe market fluctuations,

whilst maintaining our commitment to strategic investments in R&D [up by 9% from €46.1m in 2010 to €50.4m in 2011]," Hyland says.

Following an assessment of the market outlook for Aixtron's specific industry and the firm's currently limited visibility, management has concluded the likelihood of a continuation of the low level of market activity seen towards the end of 2011 into first-half 2012. In view of this and the consequent likely reduction in inventory turnover, combined with the timing of new product developments in the pipeline, management has decided to make a provision against the potential risk of unsold excess inventories of about €40m, resulting in reduced year-end total inventory of €184.6m.

"We have made the necessary adjustments to our order book and inventory and executed immediate cost-saving measures, including headcount reductions, without jeopardizing our ability to quickly respond to an uptick of demand or



"In the short term, we believe that the next substantial investment cycle will be triggered by MOCVD demand from the emerging LED lighting market," Hyland summarizes. "We continue to see very encouraging signals in the form of increasingly proactive governmental engagement and clear market preparation and positioning activities from

Aixtron's quarterly compound semiconductor orders, showing 77% and 43% drops in Q3 and Q4/11.

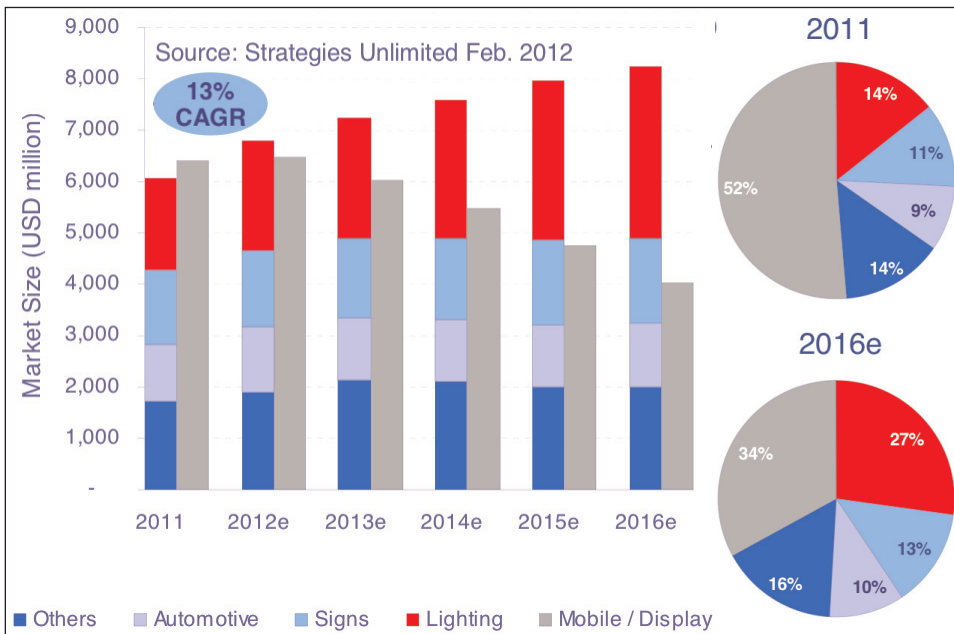
diluting our R&D focus," says Hyland. Indeed, Aixtron plans to further increase R&D spending in 2012.

Aixtron management says that, despite the current market conditions, it remains convinced that the development of a sustainable LED lighting industry will follow this temporary period of uncertainty.

"Our substantial multi-year investment program is not exclusively limited to the development of next-generation LED manufacturing tools," says Hyland. "We are also focusing on the development of new technologies for other end-markets we believe we can address with the expertise that we have," he adds.

significant industry players, specifically targeting the LED lighting opportunity," he adds. "The mid-to long-term prospects for the LED industry remain excellent, particularly in view of the increasing worldwide acceptance of the environmental and cost benefits that come with using LED technology for general lighting applications."

"With currently very limited order visibility, it is far more difficult than in previous years to provide a full year guidance," says Hyland. "However, management believes that 2012 looks set to be a transitional year between LED investment cycles with potentially lower revenues." Consequently, Aixtron expects that in 2012 it will remain EBIT profitable on the basis of a break-even model of €275m in revenue (€136.8m backlog, revalued at \$1.40/€, plus €40m in assumed spares & non-equipment revenues, plus €98m in shippable equipment orders still required) at a gross margin of 40% with operating expenditure of €110m.



Forecast decline in mobile/display applications and rise in lighting.

www.aixtron.com

IN BRIEF

Epistar receives its first CRIUS II-XL

Aixtron customer Epistar Corp of Taiwan has received its first CRIUS II-XL system (in 19x4"-wafer configuration), for mass producing ultra-high-brightness (UHB) blue and white LEDs.

The CRIUS II-XL has passed the process demonstration and acceptance test. Epistar will now further qualify the system in mass production. Epistar plans to buy more CRIUS II-XL systems when it expands production capacity. "Looking at this first tool, I can see that the CRIUS II-XL will make a huge difference to our productivity," notes Epistar's president Dr Ming-Jiunn Jou. "Thanks to its seamless process compatibility with our earlier-generation reactors, the latest CRIUS technology is set to rapidly and efficiently drive forward future capacity expansion and technology advances," he adds.

"The CRIUS II-XL design concept offers the largest productivity with best-in-class uniformities, which massively increases yield and directly translates into enhanced competitiveness for Epistar's products in an ever demanding marketplace," says Aixtron's chief operating officer Dr Bernd Schulte.

Located at the Hsinchu Science-based Industrial Park, Epistar has for over a decade been focused on developing and manufacturing UHB LED products. Using its proprietary MOCVD process technology, it continues to commercialize a full range of UHB LEDs.

Launched by Aixtron last November, the CRIUS II-XL configuration offers a reactor capacity up to 19x4" wafers (up 46% on the original CRIUS II), giving it the highest throughput and lowest cost of ownership in the LED industry, it is claimed.

www.epistar.com.tw

China's Quantum Wafer orders three more Aixtron MOCVD systems to ramp up production

Deposition equipment maker Aixtron SE of Herzogenrath, Germany says that in fourth-quarter 2011 it received an order from existing customer Quantum Wafer Inc of China for three more Aixtron metal-organic chemical vapor deposition (MOCVD) systems, all of which will be dedicated to the growth of high brightness (HB) LED wafers based on gallium nitride (GaN) materials.

Delivery is due to take place during first-quarter 2012. Aixtron's local support team will install and commission the new reactors.

Quantum Wafer is an optoelectronic materials and device manufacturer located at the heart of the

Zhujiang Delta Industry Area of China. As a manufacturer of semiconductor wafers, the firm supplies materials for making LED devices, as used in a wide range of applications such as LED TVs, mobile phones, solid-state lighting, large-screen displays, traffic lights, etc.

"We have been very impressed with the performance of the two 42x2" Aixtron G4 MOCVD systems that we purchased in 2011," says general manager Dr Shu Yuan. "We therefore wish to add more equipment from Aixtron, as we implement the next step in our strategic plans."

www.quantumwafer.com

China's Aucksun Opto orders five reactors for HB-LED production

In first-quarter 2012 new customer Huaian Aucksun Optoelectronics Technology Ltd of China ordered five multi-wafer Aixtron MOCVD systems — two AIX 2600G3 IC reactors (both in 49x2"-wafer configuration) and three AIX2800G4 reactors (each in 60x2"-wafer configuration) for delivery in second-quarter 2012. One of Aixtron's local support teams will install and commission the reactors in Aucksun Opto's cleanrooms in Huaian, China, or the growth of materials for high-brightness (HB) LEDs.

"We are familiar with the very high quality of service and equipment we can expect to receive from Aixtron, and their MOCVD systems will provide the perfect solution for the development and production of wafer materials for HB-LEDs," says Aucksun Opto's general manager Kai Chen. "Aixtron has a strong presence in China and their local service team will play a key role in assisting our internal efforts as we ramp up production," he adds. "We



Aucksun's general manager Kai Chen and Aixtron's VP sales Dr Bastian Marheineke.

shall be returning to Aixtron in the future to help us with our plans for the production of HB-LEDs based on gallium nitride materials."

Aucksun Opto is a subsidiary of Jiangsu Aucksun Co Ltd, formerly known as Jiangsu Aucksun Metal Co Ltd. Its current clients are mainly information technology (IT) manufacturing companies, and it operates its businesses predominantly in the Yangtze River Delta and the Pearl River Delta, China.

www.aixtron.com

Aixtron Training and Demonstration Center opens at SINANO in Suzhou

MOCVD technology center to support China's global LED aims

To mark the opening of its new training and demonstration center at SINANO — the Suzhou Institute for Nanotechnology and Nanobionics, deposition equipment maker Aixtron SE of Herzogenrath, Germany has held a ceremony in the city of Suzhou, China, attended by a representative of the National Development and Reform Commission (NDRC), the German Consul General in China, many of Aixtron's key customers, and numerous partners from leading universities and research institutes from across Greater China.

At the Suzhou Industrial Park (SIP) in the Yangtze River Delta — which Aixtron describes as one of China's most influential business locations — future Chinese MOCVD experts will be trained in the latest semiconductor technology and manufacturing processes. The Aixtron center will be able to draw upon the collaborative synergies between industrial and institutional research and will also offer a high quality of training, says Aixtron.

"In order to achieve China's aim of global LED leadership, LED products made in China need to be able to take the lead in lighting quality, efficiency and cost-effectiveness. This cooperative arrangement will make a significant contribution toward achieving these goals," says a spokesperson for SINANO. "One of the new facility's main priorities will be to provide Chinese customers with the depth of process knowledge they need in order to optimize their devices," they add.

"China is now playing a significant global role in the emergence of the LED lighting market through the extensive national and regional encouragement of LED applications," said Aixtron's president & CEO Paul Hyland at the ceremony. "At the new center, we will be able

to proactively support our customers' technology developments by utilizing the very latest Aixtron technologies and by providing the highest-quality training, not only in the field of LEDs but also in other nanotechnology areas, including GaN-on-Si," he adds. The cooperative agreement with SINANO will facilitate the full process and characterization of LEDs, the technical properties of which are essential to lighting product quality, says the firm.

The training courses offered will use Aixtron's latest-generation CRIUS II-XL and AIX G5 HT MOCVD systems and will be held in a production cleanroom environment, laboratories, and classroom training facilities that occupy a total area of 350m². "We will focus on the most critical factors in the manufacturing process, which will enable operators of MOCVD facilities to achieve better system utilization times and higher yields, thereby reducing their operating costs — our focus will be on operational efficiency, maintenance routines, process optimization and fab management," says Dr Nicolas Muesgens, director of the Aixtron Training and Demonstration Center. "In Suzhou, we will offer intensive, science-based, hands-on training courses to small groups, led by Aixtron's highly qualified and experienced engineers," he adds.

Aixtron says that, as well as its focus on best-practice commercial considerations, the new training center will also pay special attention to operational health and safety issues and to the protection of the environment, by adhering to and promoting German, international and Chinese product-safety and waste-management standards.

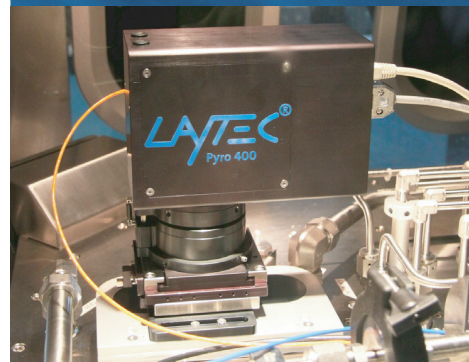
Applications to attend a training course can be submitted online at:

www.aixtron.com/Service/Training

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University of Texas at Austin demonstrates high-quality wafer-scale graphene using Aixtron system

Researchers at the University of Texas at Austin, USA have demonstrated high-quality wafer-scale deposition of graphene on evaporated copper films for the first time, using their recently acquired cold-wall vertical BM (Black Magic) Pro reactor from deposition equipment maker Aixtron SE of Herzogenrath, Germany (Li Tao et al, 'Synthesis of High Quality Monolayer Graphene at Reduced Temperature on Hydrogen-Enriched Evaporated Copper (111) Films', ACS Nano (2012), DOI: 10.1021/nn205068n).

"Most research and synthesis of graphene to date has been on copper foil, and while good-quality films can be achieved using such a method, we have succeeded in depositing monolayer graphene chemical with negligible defects onto evaporated copper films on the wafer-scale," says professor Deji Akinwande, who led the research

together with professor Rod Ruoff's team at the Microelectronics Research Center at UT Austin.

"A pre-annealing process is used at first to create a hydrogen-rich polycrystalline copper film of <111> preferential orientation, followed by the decomposition of pure methane for the growth of high-quality grapheme. The growth proceeds without the need for hydrogen gas during the growth phase, and occurs at a lower processing temperature than on copper foil," he adds.

"This work creates a pathway for wafer-scale synthesis of graphene with negligible defects, which is an essential requirement for heterogeneous graphene/Si VLSI applications and industrial adoption of grapheme," says Akinwande.


"Indeed, the BM Pro is a high-performance, flexible platform with unique chemical vapor deposition (CVD) processing capabilities," he

adds. "This allowed us to conduct our research effectively and achieve these growth results in a short time with outstanding uniformity on the wafer-scale."

The experimental work was carried out at the National Nanotechnology Infrastructure Network (NNIN) and Texas Materials Institute (TMI) facilities at The University of Texas at Austin and is supported in part by the Nanoelectronic Research Initiative (NRI-SWAN Center), and the Office of Naval Research. Established in 1983, the Microelectronics Research Center is equipped with semiconductor fabrication equipment housed in 12,000ft² of Class 100 and Class 1000 clean-room space, with 15,000ft² of characterization laboratories. The center has 15 faculty and 120 graduate students.


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Lake Shore launches cryogen-free probe stations

Lake Shore Cryotronics Inc of Westerville OH, USA, which makes scientific sensors, instruments and systems for precise measurement and control, has launched the new Model CRX-VF and Model CRX-EM-HF cryogen-free probe stations.

The two new platforms add vertical and horizontal field to Lake Shore's growing family of closed-cycle refrigerator (CCR) probe stations. The new CCR probe stations suit non-destructive measurement of the electrical, magneto-transport, electro-optical, parametric, high-Z, DC, RF and microwave properties of materials and test devices. Nanoscale electronics, quantum wires and dots, spintronic (TMR, GMR) devices, and semiconductors are typical materials measured.

Lake Shore says that the new probe stations are simple to operate, and that they control temperature efficiently using two-stage CCR cooling engines that cut ongoing usage costs by eliminating the



challenges of sourcing and handling liquid cryogens. Cooling automation allows one-switch startup and unattended cool-down. The CCR probe stations provide full temperature instrumentation for accurate temperature measurement, stable control and optimized warm up for sample exchange, translating to research productivity. Depending on probe station and configuration,

temperature ranges span from 8K to 500K, providing good temperature stability (10–20mK). The Model CRX-VF and CRX-EM-HF provide field strengths of 2.5T and 0.6T, respectively. Sample-stage vibration is limited to less than 1 μ m throughout the full-scale temperature range so as not to affect measurement performance.

The new cryogen-free models expand Lake Shore's overall line of probe stations to nine models. "With the increasing costs of liquid helium, and the growing difficulty in obtaining it, we see more customers deciding to invest in cryogen-free measurement systems," says Rob Ellis, VP of strategic planning. "Our globally installed base of CCR probes stations is growing rapidly." CCR probe stations also simplify processes and reduce scheduling conflicts related to operating with cryogenics (staff trained in cryogen transfers and monitoring of cryogen are no longer needed).

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Owens Design delivers customized automated film frame handlers to semiconductor and LED customers

Owens Design Inc of Fremont, CA, USA, a design and manufacturing service provider for semiconductor, solar and data storage capital equipment, says that it has delivered multiple customized film frame automated handling solutions to customers in the semiconductor and LED industries.

Owens Design says that the large variety of film frames and film frame cassettes has created a need for customizable solutions for various process tool applications. By working with customers in a collaborative design and build approach, the firm has developed an automated film frame handling solution that can easily be customized to address non-standard form factors.

Until recently, the loading and unloading of film frames into a process tool has been mostly a manual operation. However, semiconductor manufacturers now need to automate the process to address the timing needs of back-end-of-line (BEOL) inspection and test applications. At the same time, LED makers need an automated solu-

tion to enable greater volume production to support the increasing demand for LEDs in a variety of markets, says the firm.

"LED usage is becoming widespread in an ever-growing number of applications, including aviation and automotive lighting, household appliances, remote controls for electronic systems and traffic signals," says president John Apgar. "The LED market, however, is extremely price-sensitive, so LED manufacturers are looking for ways to increase productivity, while lowering manufacturing costs," he adds. "Our customizable automated film frame handler solution provides a low-risk approach to meeting both these needs."

Owens Design says that it offers semiconductor, solar and LED capital equipment manufacturers a proven methodology to reduce tool development costs, minimize technical risk, and speed their time to market. By working closely with an established design and manufacturing firm, a capital equipment company can focus its internal efforts on its core technology, it claims. In turn,

the design and manufacturing services company can focus on integrating this new core technology into a system-level platform that has been optimized to meet the equipment manufacturer's performance specifications.

"Developing an easily customizable handling solution for our customers required expertise in film frame extraction, alignment and transport, expertise that Owens Design has developed over many years of successfully delivering a wide range of automation solutions to our customers," says Jack Yao, director of business development. "Our collaborative design and manufacturing approach has a proven record of delivering the kind of low-risk, low-cost, and rapid time-to-market solutions our customers have come to rely on," he adds. "Automating film frame handling with a customized solution helps our customers leverage existing tool sets and enter new markets, while also enabling their customers to reduce manufacturing costs and increase volume production."

www.owensdesign.com

Palomar's 3800 Die Bonder supporting LED development in China

Exhibiting together with Hybond and Asia Science and Technology (AST) at SEMICON China 2012 in Shanghai (20–22 March), microelectronics and optoelectronic packaging system maker Palomar Technologies Inc of Carlsbad, CA, USA (a former subsidiary of Hughes Aircraft) will have a 3800 Die Bonder and manual Hybond equipment on-site to give demonstrations.

"By 2015, China intends its manufacturing standards to be globally viable for the volume production market," said Palomar Technologies' Asia director PH Chan recently regarding how LEDs relate to China's 12th five-year plan. "By

that time, China's LED industry is estimated to reach \$75bn," he adds. "The 3800 Die Bonder is capable of ultra-high precision and high-reliability eutectic and epoxy die attach processes. This robust system is in production with several major players in the Asia-based LED market today," Chan continues. "The 3800 Die Bonder embodies great versatility to accommodate multiple processes on a single 710in² work envelope as well as tremendous flexibility to remain vigilant for the future of component packaging," he claims.

Palomar also offers several complementary bonder systems: the

6500 Die Bonder is an ultra-high placement accuracy pick-and-place machine (which also has a wafer-level packaging configuration), and the 8000 Wire Bonder is a large-area, high-reliability wire bonder and ball bumper with deep access capabilities. Augmenting these are Palomar Technologies Customer Services (Field Service support, Process Development Consulting and bonder training courses) and Palomar Technologies Assembly Services (which offer customers the unique ability to prototype and develop critical processes and materials with an OEM).

www.palomartechnologies.com

Linde LienHwa China to supply ammonia to Kaistar

Gases and engineering firm The Linde Group of Munich, Germany says that its joint venture Linde LienHwa (LLH) China with Taiwan's LienHwa MiTAC Group has strengthened its commitment to LED manufacturing via an exclusive supply agreement to deliver bulk gases and high-purity ammonia (NH₃) to the new production facility in Xiamen of Kaistar.

Kaistar is a joint venture of Epistar Corp of Hsinchu Science-based Industrial Park (Taiwan's largest LED chipmaker) and China Electronics Corp (CEC), a state-owned conglomerate under the direct administration of central government (spun off from the former Ministry of Electronics Industry in 1989, and the largest state-owned IT company in China, with over 70,000 staff).

Specialist high-purity gases are crucial for manufacturing LEDs and, in particular, ultra-high-purity ammonia is used to ensure quality, since oxygen-containing molecules such as moisture — even in trace quantities — can significantly reduce light output.

Kaistar's new facility will be constructed near to Linde's ultra-high-purity ammonia plant in Xiamen (opened in 2010) to meet demand from the fast-growing Chinese LED industry. Using technology for purification, packaging and analytical methodology, the facility is the first operating plant in China to produce ultra-high-purity ammonia.

The Chinese LED market will reach \$6.9bn in 2012 and up to \$11.1bn by 2015 — equivalent to a five-year compound annual growth rate (CAGR) of 17.7% — estimates iSuppli. This rapid growth is reinforced by lucrative incentives and funding led by the Chinese government and subsidies provided by local governments to stimulate the country's LED manufacturing industry.

The first subsidy policy on LED general lighting applications is jointly conceived by the China NDRC (National Development and Reform Commission) and the Ministry of Treasury, totalling RMB8bn, and is planned for launch in 2012. The policy to stimulate the end-market is expected to further expedite the penetration of LEDs in general lighting, creating domestic demand for the vast capacity of LED supply built in the past two years.

Linde says that its ammonia plant guarantees security of supply to Kaistar's new facility and to other LED makers' facilities as the growth of the local LED industry continues. The plant, which has an initial capacity of 500 tonnes per year, produces ultra-high-purity ammonia at the 7N (99.99999%) level.

To help reduce the cost of manufacturing and to ensure consistently stable high purity, Kaistar will use Linde's new SpectraPure high-flow ammonia delivery system, which provides the very high flow rates

and cost-effective logistics required for high-volume manufacturing in today's large fabs, with integral purification helping to improve process consistency and ensuring the highest available purity supply to Kaistar's facility, Linde says.

The agreement between LLH China and Kaistar is an extension of Linde's existing relationship with LienHwa MiTAC Group, i.e. the joint venture Linde LienHwa (LLH) Taiwan (which is already one of Epistar's biggest suppliers of high-purity gases).

"Kaistar will become one of the world's leading LED total solution providers, making this exclusive agreement our most significant gas supply contract in the LED sector to date," believes Andrew Lau, president & general manager of LLH China.

"As LED chip manufacturers look to adopt more advanced, cost-effective and energy-efficient manufacturing processes, the demand for Linde's leading gas solutions will continue to grow. We are confident that our ammonia supply capabilities in Xiamen are able to meet a wide range of LED customer needs," he adds.

"With the fast development of the global LED industry, our new facility in Xiamen enables us to capitalize on the huge growth potential of this space in China, especially in the close partnership with Taiwan business," says Kaistar's deputy general manager Ren Liu.

www.linde-gas.com/electronics

Rite Track acquires Rudolph's CV inspection product line

Semiconductor equipment and services supplier Rite Track Inc of West Chester, OH, USA has signed a licensing agreement for the CV wafer carrier inspection product line of Rudolph Technologies Inc of Flanders, NJ, which makes defect inspection, process control metrology and data analysis systems and software for microelectronics and solar manufacturing.

The deal includes intellectual property, assets and inventory for the

CV9800 and CV9812 wafer carrier inspection products, designed to help avoid costly production transfer issues. Rite Track plans to provide global parts and service support for existing products once the transfer is complete, as well as new, updated versions of the CV product line in the near future. Rudolph is contacting existing customers with a formal letter providing information to effect the smooth transfer of support. Rite Track will also announce an

official support start date once transfer plans are formalized.

The CV product line fills an industry void for affordable wafer cassette inspection equipment, reckons Rite Track's president & CEO Tim Hayden. "Customers can expect the same award-winning, global parts and technical support Rite Track offers on its existing products, thus extending the CV Series product life for many years to come," he adds.

www.rudolphtech.com

Twin Creeks launches system for producing ultra-thin silicon, germanium, GaN, SiC and sapphire wafers

Twin Creeks Technologies of San Jose, CA, USA, which provides equipment for making thin crystalline wafers for solar and semiconductor manufacturers, has launched Hyperion, a wafer production system that can dramatically reduce the cost of solar modules and semiconductor devices by cutting the amount of silicon and other substrate materials used by up to 90%, it is reckoned.

The key to Hyperion is thinness. Taking advantage of Proton Induced Exfoliation (PIE) technology, Hyperion generates monocrystalline wafers that are less than a tenth of the thickness of conventional wafers. With thin wafers, manufacturers can profitably produce solar cells and other devices well below the current best-in-class cost structure, it is claimed. Twin Creeks estimates that Hyperion will allow manufacturers to produce solar cells for under 40 cents a watt in commercial-scale volume production facilities, with prices declining over time.

Hyperion 3, the third-generation wafer production system designed and built by Twin Creeks, is its first commercial offering, available for shipment now.

"The thickness of wafers today is based on wafer slicing capabilities and the handling requirements for device processing," says CEO Dr Siva Sivaram. "In reality, only the very top layer of a substrate plays an active role in generating energy or transmitting signals - the rest is wasted," he adds. "By eliminating excess material, we will help solar manufacturers produce modules that compete with grid power and open up new markets for chip makers."

With PIE, Hyperion effectively uses atoms as a scalpel, Twin Creeks says. Hyperion embeds a uniform layer of high-energy protons (hydrogen ions) into monocrystalline wafers to a depth



Twin Creeks' Hyperion 3 system.

of up to 20 μ m. When heated, this new layer expands, cleaving the top surface from the donor wafer to form an ultra-thin wafer that is otherwise identical to the original. This is then further processed into solar modules or semiconductors. Creating wafers with PIE also eliminates the kerf (wasted silicon) in solar manufacturing.

Hyperion is compatible with a wide variety of monocrystalline wafers — including germanium (used in making concentrated PV solar modules), gallium nitride, sapphire and silicon carbide (for LEDs and power electronics). Twin Creeks initially concentrated on helping manufacturers of crystalline silicon solar cells because of the urgent need to cut the cost of solar power. The lessons learned will further allow manufacturers to employ Hyperion for other applications, such as CMOS sensors.

By reducing the amount of silicon required in solar modules by 90%, Hyperion makes the entire silicon wafer value chain more efficient and lowers the capital needs of users, claims Twin Creeks, since manufacturers do not need as many saws, furnaces and crystal pullers to make the same amount of wafers.

The firm claims that Hyperion also improves the monocrystalline silicon value proposition in other ways. As well as being much lighter

than conventional solar cells, cells produced with Hyperion wafers are also bendable, allowing manufacturers to consider flexible packaging and encapsulants for modules instead of glass.

Additional layers of photovoltaic material can be added to wafers as well: Twin Creeks has produced hetero-junction solar cells

(combining crystalline and amorphous silicon) in its development center. Over time, the combination of lower cost and lighter packaging will allow Twin Creeks customers to expand into other markets such as building-integrated photovoltaics (BIPV) and consumer electronics.

In keeping with providing a true manufacturing solution, Twin Creeks has developed intellectual property for creating and handling ultra-thin wafers as well as producing finished solar cells. This IP can be licensed to Twin Creeks' customers.

Founded in 2008, Twin Creeks is backed by venture capital firms as well as loans and grants from the Mississippi Development Authority. As well as having R&D facilities in San Jose and Boston, the company - in collaboration with the state of Mississippi - has built a commercial-scale demonstration plant in Senatobia, MS, where Twin Creeks and its customers can fine-tune processes for generating ultra-thin solar modules and wafers with Hyperion. The plant is capable of producing 25MW of solar cells per year and will be expanded to 100MW. The firm has obtained UL and TUV certification for hetero-junction technology-based panels made there. In addition, the firm aims to build facilities in Malaysia through a joint venture.

www.twincreekstechnologies.com

SiGen launches second-generation production equipment for thin kerf-free wafering

Proton-beam-induced wafering for solar, HB-LED and packaging/3D structures using Si, GaAs, Ge, SiC, GaN and sapphire

Wafering tool supplier Silicon Genesis Corp (SiGen) of San Jose, CA, USA, which was founded in 1997 to provide engineered substrate process technology for the semiconductor, display, optoelectronics and solar markets, has finalized the specifications of its second-generation production system.

As well as being used for fabricating thin-silicon solar wafers, SiGen's core proton-beam-induced wafering technology is capable of supplying materials to other applications such as high-brightness (HB)-LEDs and packaging/3D structures using silicon, gallium arsenide (GaAs), germanium, silicon carbide (SiC), gallium nitride (GaN) and sapphire. The firm claims that the key advantage is minimizing the cost of high-performance materials while maintaining their effectiveness in demanding end-applications.

SiGen says that the system design is a result of over six years of development, prototype testing and solar cell material evaluation with numerous equipment and solar cell partners. The new GenII PolyMax system follows what are claimed to be industry firsts, including making free-standing 20 μ m, 50 μ m, 85 μ m, 120 μ m and 150 μ m of 125mm and 156mm industry-standard square kerf-free monocrystalline silicon solar-cell wafers (resulting in what was claimed to be the first true monocrystalline c-Si kerf-free wafering for the PV industry).

SiGen claims that the PolyMax high-volume manufacturing system brings the industry a step closer to replacing wire saw processes with lower-cost waste-free wafering. A strength of the system is its ability to produce wafers thinner than is achievable with wire saw technology, allowing the production of cells with higher conversion efficiencies and lower cost.



A free-standing 20 μ m-thick silicon wafer, showing its flexibility.

"The solar industry's severe pricing pressure further strengthens the proton-beam-induced wafering approach," believes president & CEO Francois Henley. "We first introduced our beam-induced cleaving technology at the 2008 PVSEC [Photovoltaic Science and Engineering Conference] with 50 μ m-thick wafers made using a prototype 2MeV high-energy proton implanter," he adds. "The benefit of using our technology will significantly cut the cost of making high-efficiency solar cells, allowing the PV industry to reach unsubsidized grid parity years ahead of expectations," he believes. "These thin and ultra-thin solar wafers have been well characterized and tested, both by our partners and independent third-party laboratories."

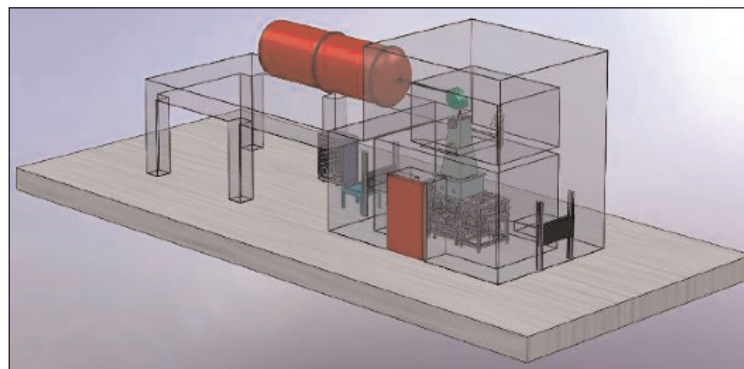


Diagram showing the design of SiGen's GenII PolyMax proton implanter system.

Henley reckons that recent announcements from other thin-silicon technology providers confirm the need for new approaches and processes that can cut costs in making high-efficiency silicon absorbers. "We evaluated the Ampulse hot-wire CVD technology while it was still at NREL [National Renewable Energy Laboratory] in 2006 in combination with a SiGen layer-transferred single-crystal silicon layer. We opted for our direct high-energy beam-induced cleave approach instead. The approach has merit if the company can indeed make high-quality films using their novel textured backing technology," Henley notes.

"We are also closely following recent announcements by Twin Creeks Technologies of a process similar to our beam-induced wafering, except it is reportedly limited to bonded (non-free-standing) 20 μ m films. As the pioneers of beam-induced wafering, and assuming it is not utilizing any of our technology embodied in our 100+ US patent portfolio which we are monitoring, SiGen is happy to see another company recognizing the importance of thin crystalline silicon for its capability to dramatically reduce the cost of solar cells," he adds. "The fact that Twin Creeks Technologies was founded by a

venture capital firm shortly after it evaluated SiGen's beam-induced wafering business plan and technology, including our prototype 2MeV implanter, is of concern."

www.sigen.com

OCI starts shipping sapphire grown in GT's ASF furnaces

GT Advanced Technologies Inc of Merrimack, NH, USA (a provider of polysilicon production technology as well as sapphire and silicon crystalline growth systems and materials for the solar, LED and other specialty markets) has says that South Korea-based OCI Company Ltd, its long-time PV and now also sapphire equipment customer, has begun production of sapphire boules and cores in its new manufacturing facility.

OCI has completed the initial installation of GT's ASF Advanced Sapphire Furnaces, which were bought in January 2011. In a ceremony on 2 March to dedicate its new sapphire production facility, OCI said that it has begun shipping 6-inch sapphire cores as well as 2-inch and 4-inch products to manufacturers in Taiwan and Korea. OCI's new plant has an annual production capacity of 4 million millimeters of sapphire.

A recent article in The Korean Times reported that, with technical help from GT's service installation team, OCI had started exporting various-sized sapphire cores to its customers, adding that GT's ASF furnaces, which use the heat exchanger method (HEM) growth process, incorporate a cost-effective sapphire crystallization methodology for high-yield production.

"Starting up a new sapphire production facility takes tremendous planning and coordination to



GT's ASF sapphire growth furnace uses the heat exchanger method (HEM) for producing boules and cores suitable for the LED industry.

ensure a successful launch," says Cheryl Diuguid, GT VP & general manager of its Sapphire Equipment and Materials Group. "I am proud of the effort of our serv-

OCI and GT have previously partnered for a number of years in the PV industry, where OCI has grown to become one of that industry's main polysilicon producers



GT's sapphire boules and wafers.

ice and installation team who worked closely with OCI's production and engineering team throughout the entire process to deliver a state-of-the-art sapphire production facility that is now producing high-quality material," she adds.

GT says that OCI's ability to produce LED-grade sapphire at diameters up to 6-inches will help to position them as a major sapphire producer in the region. Their entrance into the LED industry using GT's ASF sapphire growth technology expands the relationship between the two firms. OCI and GT have previously partnered for a number of years in the PV industry, where OCI has grown to become one of that industry's main polysilicon producers.

www.gtat.com
www.oci.co.kr/eng

GT completes \$75m accelerated share repurchase program

GT Advanced Technologies has completed its accelerated share repurchase (ASR) program of \$75m of its common stock.

On 18 November, GT entered into an agreement with UBS AG, London Branch to effect an accelerated repurchase of \$75m of its common stock, as part of its \$100m share repurchase authorization announced on 16 November.

GT paid \$75m to UBS and received

7,822,686 shares of its common stock on 23 November. UBS delivered an additional 900,000 shares on 5 March followed by another 715,593 shares on 8 March, bringing the total number received under the ASR to 9,438,279. The effective per-share repurchase price was \$7.95, based on the volume-weighted average share price of GT's common stock, minus a discount, during the ASR period.

All of the shares involved in the ASR were cancelled and retired upon receipt by GT. As of 9 March, and subsequent to each of the foregoing transfers, GT had about 118.3 million shares outstanding. The firm now expects that the fully diluted share count for fiscal fourth quarter 2012 (to end-March) will be about 121 million and the fully diluted share count for full-year fiscal 2012 will be about 126 million.

Meaglow launches nitrogen-rich indium nitride wafers

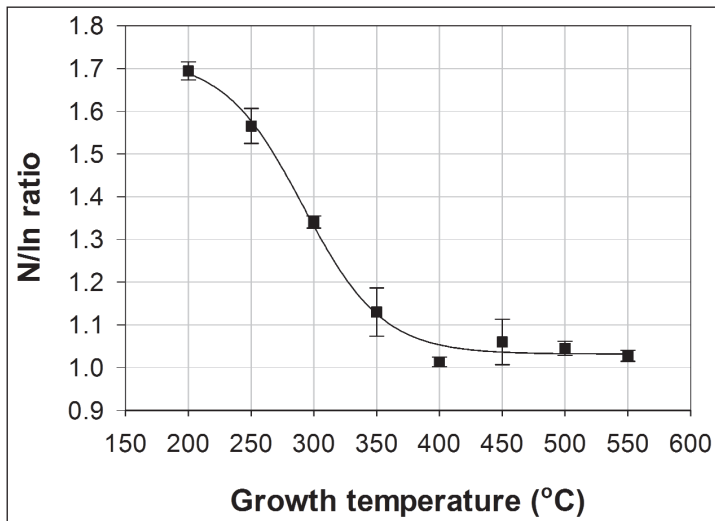
Low-temperature plasma-based nitrogen sources allow greater than 30% of excess nitrogen

Meaglow Ltd of Thunder Bay, Ontario, Canada — a privately held firm that produces a range of epitaxy equipment (migration-enhanced afterglow) and MBE and MOCVD accessories, as well as providing specialized thin films to research institutes and industry — has announced what it claims is a breakthrough in understanding indium nitride.

When alloyed with gallium nitride (GaN), indium nitride (InN) forms the light-emitting component that powers the US\$10bn LED industry. In its own right InN is being developed as an advanced material for solar cells, high-speed transistor devices and other applications. However, there are still many things that are not properly understood about InN.

For instance, based on theory it had long been assumed that it was impossible to produce nitrogen-rich InN, so it was a surprise a few years ago when samples made at low temperatures were measured with greater than 30% excess nitrogen present. Many researchers did not believe the measurements, says Meaglow, but they were subsequently repeated by many groups. Theory didn't agree with experiment. How the excess nitrogen could occur remained largely unexplained until Meaglow's chief scientist Dr K. Scott Butcher in January published an explanation (Applied Physics Letters 101 (2012) 011913).

"Basically, the excess nitrogen is seen when forming the material at relatively low temperatures using plasma-based nitrogen sources. These plasma sources provide the extra potential energy needed for nitrogen-rich material to form," says Butcher. "To a greater or lesser extent, excess nitrogen species are probably present in most InN samples, as plasma techniques are commonly used," he



Nitrogen-to-indium ratio determined by the stoichiometry measurement technique HIERDA (heavy ion elastic recoil detection analysis) for material grown by a remote plasma-enhanced chemical vapor deposition (RPECVD).



Reactir for Meaglow's CVD-based migration-enhanced afterglow deposition process.



Meaglow's indium nitride wafers.

adds. "It may take some years for the research community to come to terms with this, but nitrogen-rich InN is a reality, and now it's a reality we understand."

Nitrogen-rich InN may also be important from another perspective. InN is plagued by a surface current problem which is limiting its development. However, the excess nitrogen species, previously ignored, may hold the key to solving this problem. Butcher notes that these species are fairly mobile and migrate to sample surfaces. "They seem to fit the bill as a culprit for this phenomena."

Meaglow says that it is now launching a range of nitrogen-rich InN wafers for sale exclusively on its website in order to further research and industry collaboration, so that all parties can obtain a stronger understanding of InN, and so that the material can realize its full potential.

www.meaglow.com

Rubicon's revenue falls 42% in Q4/2011 after LED makers delay transition to 6" sapphire

Demand to return in late Q2 once excess inventory is digested

Rubicon Technology Inc of Bensenville, IL, USA, which makes monocrystalline sapphire substrates and products for the LED, RFIC, semiconductor and optical industries, says that its full-year revenue rose from \$77.4m in 2010 to \$134m in 2011. However, in fourth-quarter 2011 revenue was \$19.4m, slightly below the guidance range (given in November) of \$20–23m, and down 34% on \$29.5m a year ago and down 42% on \$33.6m in Q3/2011. "Demand was limited, for both sapphire wafers and cores, because of excess inventory in the LED supply chain," notes president & CEO Raja Parvez.

In early February, Rubicon signed a new agreement (worth \$20m) for 6" polished wafers with its key customer [which accounts for 60% of total revenue] that outlines a base level of shipments from June through December (the previous agreement expired in December). However, due to the challenging market conditions, in Q4 Rubicon reduced the volumes and pricing requirements under the customer's previous contract. It also provided accommodations to some other key customers of its 2–4" cores, and consequently wrote off \$1.7m of accounts receivable in Q4. "We have worked very closely with our major customers to help them through this challenging period and to ensure that our relationships remain strong and mutually beneficial," Parvez comments.

Impacted by the reductions in pricing (with the average selling price of its 6" wafers down 30% in Q4) as well as lower capacity utilization for the firm's fabrication and polishing operations (with utilization of the wafer polishing facility in Malaysia just 20%), gross margin has fallen from 48% in Q3 to just 12.1% (well below the guidance range of low- to mid-30%).

Net income has fallen from \$15.4m (\$0.64 per diluted share) a year ago and \$8.2m (\$0.35 per diluted share) in Q3 to just \$861,000 (\$0.04 per diluted share, below the expected \$0.07–0.10). However, this includes income of \$1.7m from a reduction in the full-year tax rate to 30.3%. Excluding that shows an underlying operating loss of \$0.7m. During the quarter, cash and short-term investments fell further, from \$72.6m to \$55m.

"We are seeing signs of improvement in the LED market in the first quarter," notes Parvez.

"Orders for 2–4" cores have begun to recover somewhat but, given that it is early in the recovery, prices remain low," he adds. "LED customers have substantial inventory of 6" polished wafers, and we expect few orders from that market segment in the quarter." In the silicon-on-sapphire (SoS) market, demand for large-diameter wafers continues to grow, but this is a smaller market.

For first-quarter 2012, Rubicon expects total revenue to fall further, to \$8–12m. Together with further reduced utilization in fabrication and polishing operations, it expects a loss of \$0.10–0.14 per share.

"We are increasing our vertical integration by deploying our internally developed raw material processing capability, which we expect will decrease our raw material costs by at least 20% when fully imple-

mented," notes Parvez. "We are relocating much of our slicing and polishing capacity in Illinois to our new facility in Malaysia, which will be our primary finishing location as the market improves and will provide state-of-the-art capability in a low-cost environment," he adds.

"We expect capacity utilization among the LED chip makers to continue to improve throughout the first half of this year," Parvez says. "Looking beyond the first half of 2012, the outlook for sapphire substrates is for very strong growth, as LEDs gain momentum in the general lighting market, where LED penetration presently is only in the single digits, and as LED penetration into the auto market continues and the backlighting market strengthens," he adds.

"We have continued to maintain high utilization of our crystal growth facilities throughout this slowdown because we are confident that demand will be strong in the second half of 2012 [boosted by the \$20m renewed contract for with its main customer for 6" polished wafers]," says Parvez. "The LED industry's largest potential market, general lighting, is in its infancy, and the more established markets for LEDs such as consumer electronics and the automotive industry have plenty of growth opportunities as well," he believes.

"The use of large-diameter sapphire substrates is expected to grow significantly in the coming years as LED chip manufacturers continue to look for ways to drive greater efficiency throughout the supply chain," Parvez continues. "Rubicon continues to be the market leader in terms of capability and cost, and we are well positioned for the market rebound... As pricing and utilization improve, we will gradually move back to our targeted gross margin of over 40%," he believes.

www.rubicon-es2.com

We are seeing signs of improvement in the LED market. Orders for 2–4" cores have begun to recover... Customers have substantial inventory of 6" polished wafers, and we expect few orders from that market segment in the quarter

AZZURRO's advisory board gains veterans Haitz and Platzoeder

AZZURRO Semiconductors AG of Magdeburg, Germany, which makes gallium nitride (GaN) epitaxial wafers based on large-area silicon substrates, says that its advisory board has gained two new members: former Agilent Technologies chief technology officer Dr Roland Haitz and former Siemens and Infineon executive Dr Karl Platzoeder.

Extending the advisory board with technical experts in LEDs and power semiconductors is a move to boost corporate competence in these markets, says CEO Erwin Wolf. AZZURRO will gain a deeper understanding of market requirements, and will map these to R&D development roadmaps, he adds.

Roland Haitz is the former CTO of the Semiconductors Product Group at Agilent Technologies, a parent firm of LED maker Lumileds. AZZURRO says that, as it is using its patented GaN-on-Si technology for large-diameter wafers to drive down the cost of LEDs, it is proud to have the expert on board who coined 'Haitz' Law' ('Moore's Law' for optoelectronics). In his role on the advisory board, Haitz will apply technical and strategic experience of more than 40 years in the optoelectronics industry to strengthen AZZURRO's delivery of its technology.

After studying physics in Germany, Haitz joined the Shockley Transistor Research Laboratory in Palo Alto, CA. For his work with William Shockley, he received his PhD from the Technical University of Munich in 1963. After five years at Texas Instruments' Physics Research Laboratory of he joined Hewlett-Packard as R&D Manager for optoelectronic technology and component products. While at HP/Agilent, the opto business grew from under \$1m in 1969 to over \$1.5bn at his retirement in 2002. He also co-founded the Optoelectronics Industry Development Association (OIDA) and wrote a seminal paper in solid-state lighting, says AZZURRO.

Karl Platzoeder has 35 years' experience in power semiconductors at Siemens and Infineon, spanning engineering responsibilities (including productization) to president and general manager of the power semiconductor division. He was one of the major contributors that made Infineon/Siemens the top company in the power semiconductor field, says AZZURRO.

After studying physics at Munich University, Platzoeder began his professional career at Siemens as an R&D engineer in the Power Semiconductor Division. Later he was promoted to head of engineering and production, when his department focused on high-performance diodes and thyristors for industrial applications. In 1982 Platzoeder gained business responsibility for Discrete & GaAs Semiconductors at Siemens and drove the low-cost mass production as well as the development of chips for high-frequency applications.

In 1992 Platzoeder became president & general manager of the newly founded Discrete & Power Semiconductor Division, consolidating activities in this area at Siemens. He focussed on the rapidly growing markets for power MOS semiconductors in automotive and industrial applications. From 1997 to 2006 Platzoeder was responsible at Infineon for worldwide backend production and engineering.

Having pioneered the growth of GaN-on-Si substrates using metal-organic vapor phase epitaxial (MOVPE), AZZURRO is supplying epiwafers worldwide for LED and high-voltage applications. The firm claims that its unique capability to grow very thick (8 μ m) high-quality GaN on large-area silicon substrates (currently 150mm) enables cost breakthroughs for high-brightness LEDs and power semiconductors by making GaN-on-Si ready for standard silicon process lines.

www.azzurro-semiconductors.com

IN BRIEF

AZZURRO appoints Sumitomo Taiwan as local distributor

AZZURRO has appointed Sumitomo Corp Taiwan Ltd as its sole distributor partner in Taiwan.

AZZURRO says that, capitalizing on its customer traction, it has stepped up its customer support by opening its Regional Office Asia in Taipei, Taiwan in August and is now expanding its support.

The firm adds that acceptance of its products in the power semiconductor and LED markets continues to rise. As the production ramp up is currently underway, it is important to have a smooth supply chain and be very reactive to customer and logistic market requirements, the firm continues.

AZZURRO aims to become a global player in GaN markets. Accordingly, establishing an agile support structure for its Asian business partners through its own local facility in Taiwan (with direct access to all design and engineering as well as corporate functions in Germany) was of great importance, says AZZURRO. This bridge function is intended to ensure smooth implementation at customers, with product roadmap support, technical product optimization, adaptation to technical customer requirements, and effective communication of the latest market trends and suitable AZZURRO products.

"The agreement will considerably contribute to establish AZZURRO further in the pivotal Asian markets, where Taiwan is in the spearhead position," says Erwin Ysewijn, VP marketing & sales. "We see Sumitomo as a well established player in the market, close to customers... and able to fulfil regional business requirements. This agreement will ensure that our customers will receive optimum care and service," he adds.

www.sumitomocorp.com.tw

IN BRIEF

Sapphire crystal, core & wafer cost-simulation tool

Due to its specific growth technologies — Kyropulos, Czochralski (Cz) growth, EFG (edge-defined film-fed growth) etc — and linked wafering steps (drilling, beveling, sawing, CMP etc), the cost of sapphire crystals and subsequent cores and epitaxy-ready wafers can be difficult to estimate, says market analyst firm Yole Développement. This is why a specific and very flexible tool is required for cost optimization, the firm reckons.

Yole has therefore launched what it claims is a unique cost-simulation tool, Sapphire CoSim+, to enable evaluation and optimization of the manufacturing cost of sapphire crystals, cores and epi-ready wafers.

The Excel-based tool allows the user to:

- simulate a complete sapphire manufacturing unit (alumina raw material, crystal growth, drilling, sawing etc) with four pre-loaded growth techniques (Kyropulos, CZ on-axis, CZ off-axis and EFG) and any boule weight, EFG ribbon size or wafer diameter;
- evaluate the cost of manufacturing using your own inputs or using the pre-defined parameters included in the tool;
- run a simulation for a variety of different conditions (region, process type, business model...);
- save an unlimited number of process flows, equipment types and materials/chemicals, and simulate of up to five simultaneous scenarios, allowing the user to compare results such as yield improvement, change of growth technology, manufacturing location impact on cost, etc.

The tool comes with complete equipment, chemicals & materials databases.

www.i-micronews.com

MoCu composite wafer substrate to prevent cracks in LED chips

PLANSEE High Performance Materials of Reutte, Austria has developed MoCu R670, a molybdenum-copper composite material for semiconductor wafer substrates which has high thermal conductivity to ensure optimized heat dissipation in LED chips. The new material has the same coefficient of thermal expansion as sapphire, and hence reduces defects in the semiconductor structure that can occur during the hot bonding process. Mo-Cu R670 therefore helps to ensure the reliable production of LED chips and increases the efficiency of the light source, claims the firm.

In the most commonly used process for the production of blue-spectrum chips (including white LEDs), gallium nitride (GaN)-based semiconductor layers are grown on sapphire (Al_2O_3) substrate using epitaxial growth methods such as MOCVD. A metallic wafer, intended for the dissipation of heat, is then bonded to the semiconductor layers at high temperatures using various joining technologies. However, stresses caused by different coefficients of thermal expansion can lead to cracks in the semiconductor layers. To prevent these defects, the metal wafer substrate ideally has the same coefficient of thermal expansion (CTE) as sapphire.

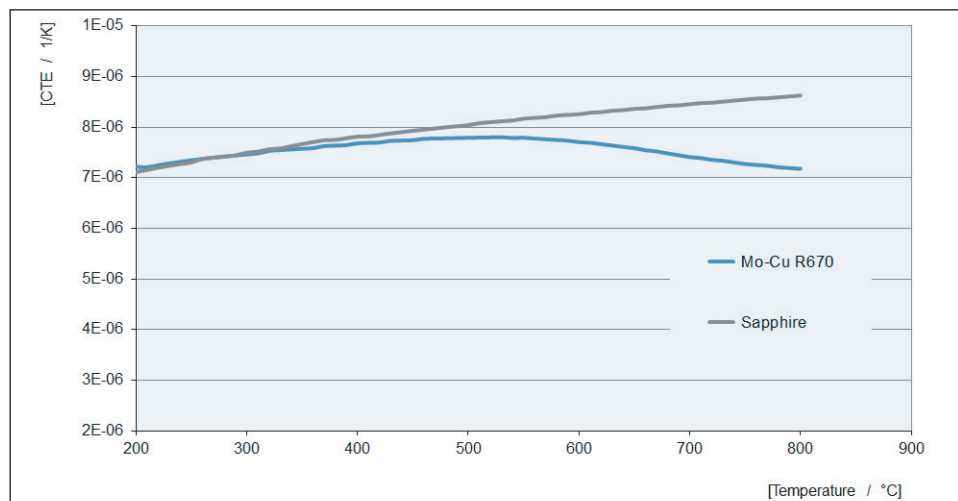
Molybdenum is commonly used

for such wafer substrates, since it offers good thermal conductivity and is very heat-resistant. However, molybdenum has a lower coefficient of thermal expansion than sapphire. PLANSEE hence developed wafer substrates made from the molybdenum-copper composite material R670 especially for sapphire-based and high-temperature-bonded LED chips. R670 has a thermal conductivity of 170W/mK and, with 6.7ppm/K, the same CTE as sapphire.

PLANSEE can supply Mo-Cu wafer substrates with coatings made from nickel-gold, ruthenium, chromium, silver and other interface materials, which protect the wafer substrate against corrosion and optimize its surface properties for the subsequent bonding process.

As a manufacturer of refractory metals and composite materials, PLANSEE supplies metallic wafer substrates for heat dissipation as well as other components for the production of LED chips and packages. These include furnace components and molybdenum and tungsten crucibles for sapphire single-crystal growth, components for MOCVD/MBE reactors, evaporation boats and coils for metallic mirror or barrier layers, and base plates for improved thermal management of high-power LEDs.

www.plansee.com



Coefficient of thermal expansion vs temperature for Mo-Cu R670 and sapphire.

Kyma cuts energy usage by 68% in cleanroom and 35% overall after grant from NC Green Business Fund

Kyma Technologies Inc of Raleigh, NC, USA, which provides crystalline GaN, AlN and AlGaIn materials and related products and services, has announced energy-saving measures completed in 2011, including North Carolina's largest geothermal HVAC system for cleanroom air handling.

After being awarded over \$400,000 in April 2011 by the North Carolina Green Business Fund, Kyma contracted TriMech Inc of Mebane, NC to install a 30 ton HVAC system and a 20 ton industrial chiller, and Danco Electrical Contractors Inc of Youngsville, NC to install energy-efficient lighting. Kyma also installed a facility-wide data acquisition system for energy usage analysis and optimization. It estimates that the energy needed to run the facilities for its cleanroom has been cut by 68% and that the firm's overall energy usage has been cut by 35%.

The data acquisition system also allows continued analysis of other energy-consuming systems to identify further possible savings.

The HVAC unit controls all the air handling for Kyma's class 10,000 (ISO 7) cleanroom, and maintains stringent temperature and humidity requirements (with 25 air changes per hour). The geothermal unit is one of the largest in North Carolina and the only one that uses 100% outside air. Addison provided the custom HVAC unit, which is uniquely designed for parameters outside the normal design space. Kyma is continuing to work with TriMech and Addison engineers to monitor and optimize operation.

"We are breaking new ground in showing that this type of system works and is very energy-efficient," comments TriMech's president Paul Penland.

"This project has helped us to significantly lower our costs while simultaneously lowering our impact on the environment," says Dr Heather Splawn, Kyma's chief operating officer & director of business development (who led the project). "We now have a much better understanding of our energy usage," she adds. "We are very thankful for the vision of the North Carolina Board of Science and Technology and those state legislators who support the NC Green Business Fund."

The fund provides grants to help North Carolina's small businesses develop commercial innovations and applications in the biofuel and green building industries, and attract and leverage private sector investment and entrepreneurial growth in eco technologies and renewable energy products and businesses.

www.kymatech.com



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IN BRIEF

SETi receives certification to International Aerospace quality standard AS9100

Ultraviolet LED maker Sensor Electronic Technology Inc (SETi) of Columbia, SC, USA says it has received certification and is operating in full compliance with the International Aerospace quality standard AS9100:2009, Rev. C through the not-for-profit public health and environmental organization NSF International Strategic Registrations (NSF-ISR) of Ann Arbor, MI.

AS9100 is an enhancement to the ISO9001 certification which SETi received in December 2009, and adds additional requirements necessary to address aviation, space and defense industries. This quality management system (QMS) includes additional focus on the design and development functions of the business as well as a more sophisticated product quality control system, and provides the essentials of an effective traceability program from development through product sourcing.

"Achieving AS9100 certification is a true testament to our core values of continuous quality improvement and exceeding our customer's expectations both in private and public sectors," says president & CEO Dr Remis Gaska.

SETi has developed what is reckoned to be the broadest range of UV LEDs on the market (with continuous spectral coverage from 240nm to 355nm) and has extensive experience in developing specialized UV LED solutions for defense and space industries: in 2007 SETi was announced as a DARPA/SBIR success story and in 2010 its UV LEDs were space qualified.

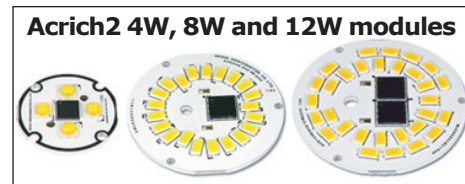
www.s-et.com

Seoul Semiconductor receives UL recognition for Acrich2 modules

South Korean LED maker Seoul Semiconductor Co Ltd says that two of its Acrich2 AC-powered LED modules have been recognized under the Component Recognition Program of UL (Underwriters Laboratories).

The modules, which operate directly from AC line voltages, contain newly developed high-voltage LEDs that use Seoul Semiconductor's patented Acrich technology as well as a capacitor-free power-conditioning integrated circuit. The firm says that UL recognition will help customers using the Acrich2 to more easily obtain UL listing of their replacement lamps and luminaries. The products also have the cUL Recognition Mark for Canada.

The modules were investigated using the requirements contained in the Standard for Light Emitting Diode (LED) Equipment for Use in Lighting Products, UL 8750, First Edition, dated 1 November 2011. The two modules — the 8W SMJEA3011220 and the 12W



SMJEA3012220 (which produce 500lm and 800lm (minimum), respectively, at an operating voltage of 120V_{rms} — are designed for replacement lamps and other similar applications.

"The Acrich2 modules permit quick time to market for our customers making luminaries and replacement lamps," claims Brian Wilcox, VP of Seoul Semiconductor, North America. "UL recognition speeds the certification process and helps eliminate some of the potential listing delays," he adds.

Seoul Semiconductor has recently launched several individual products in the Acrich2 family, available to customers through Seoul Semiconductor's direct sales force and distributors.

www.seoulsemicon.com/en

Luminus achieves environmental and health/safety certifications

Luminus Devices Inc of Billerica, MA, USA, which manufactures PhlatLight (photonic lattice) LEDs for illumination applications, has announced two certifications for its Massachusetts facilities. ISO 14001:2004 recognizes the firm's ability to meet rigorous international criteria in the management of environmental and sustainability processes. OHSAS 18001:2007 is awarded to companies meeting occupational health and safety management system specifications. The firm is also ISO 9001:2008 certified for quality management processes and has recently been accredited to the ISO 17025:2005 laboratory standard.

"These new certifications, integ-

rated into our quality management systems, demonstrate with clarity to customers that they will receive superior, innovative products made by people from a company dedicated to global professional standards as well as the environment," says president & CEO Keith T.S. Ward. Luminus currently holds more than 144 patents and patents pending for 'big chip' LEDs.

The firm also announced recently that 100% of the electricity at its manufacturing facility in Woburn, MA is being purchased with Renewable Energy Certificates (RECs). Luminus says that the RECs will help avoid the emission of 946 metric tons of CO₂ in 2012.

www.luminus.com

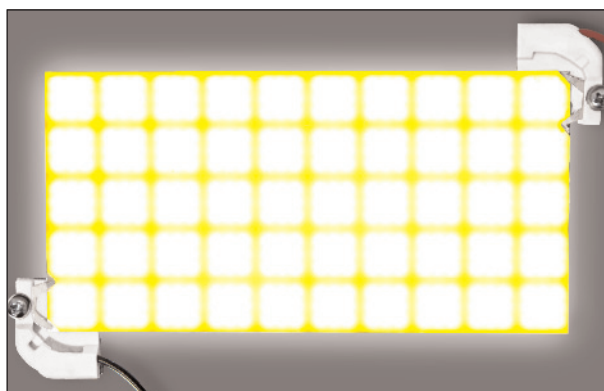
Optogan launches chip-on-board LED lighting module delivering up to 50,000lm from single component

European LED chip and luminaire maker Optogan says that its new high-power 'X10' chip-on-board (COB) LED lighting module is based on the vision of scalability and lean processing, offering a modular approach for luminaire designs from 1100lm to 55,000lm.

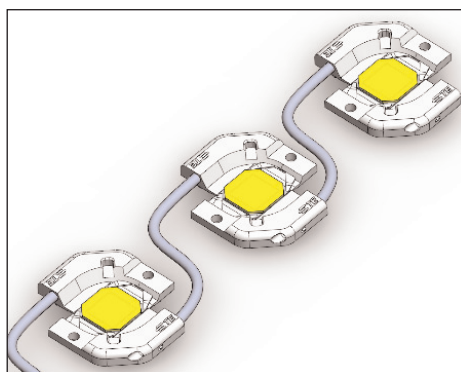
The X10 is a ceramic-based COB-block, consisting of 50 segments, which can be easily divided into LED elements of smaller sizes and power. Each of them can be used in separate light fittings. The smallest segment of the X10 consists of a 1cm² ceramic board and consumes 10W (1A, 10V), with efficacy levels already exceeding 100lm/W.

The ceramic base and product material selection is based on long-life performance. The COB was designed for direct mounting on heat sinks, offering a smaller footprint than conventional solutions. Also, as an X10 system-specific accessory, a universal connector (providing both electrical and mechanical interfaces for assembly and optics) is available.

Due to the various sizes and forms of the elements, the modules can



Maximum power: 500W X10 COB.



Modularity: linear configuration.

be used in LED-retrofits, downlights, and industrial and street lighting up to flood and stage lights. The new technology also ful-

fills smart binning and lean in-house production capabilities, says Optogan.

Optogan says that its multinational engineering team has achieved the objective of developing a unified COB module portfolio for simplified application, handling, increased performance and lifetime at a universal level.

"X10 represents Optogan's new flagship, offering

modular solutions, economical and simple to use, for that additional degree of freedom in lighting design," says Markus Zeiler, general manager global sales & marketing at Optogan GmbH in Germany. "Coupled with state-of-the-art module efficiency over 100lm/W, the X10 provides our clients the maximum possible variety in steps of 10W reaching up to 500W."

The X10 was launched at the end of February at Embedded World 2012 in Nuremberg, Germany. Pre-series production is currently ramping up.

www.optogan.com

Luminus' R&D and Testing laboratory accredited for testing LEDs to LM-80 standard

Luminus Devices Inc of Billerica, MA, USA, which manufactures PhlatLight (photonic lattice) LEDs for illumination applications, says that its Boston-area R&D and Testing Laboratory has been accredited to conduct testing on LEDs to the LM-80 standard (the approved method for measuring LED light sources). The accreditation to ISO/IEC 17025:2005 is awarded by the National Voluntary Laboratory Accreditation Program (NVLAP), and the standard is endorsed by the US Department of Energy (DOE) and the Illumination Engineering Society (IES).

The National Institute of Standards and Technology (NIST) administers the NVLAP, accrediting public and private laboratories based on evaluation of their technical qualifications and competence to carry out specific calibrations or tests.

"The rapid growth of LED technology has resulted in increased customer interest and the need for accurate measurements to industry standards in LED quality and performance," says Arvind Baliga Ph.D., VP of engineering at Luminus. "This accreditation will cut our product development time, and

assure our growing customer base that Luminus' 'big chip' LEDs will deliver the promised light and color performance to specifications over a long period of time," he adds. "The reports generated by our LM-80 testing are also critical if customers wish to seek an Energy Star certificate."

Luminus says that its 'big chip' LEDs enable major global brands that manufacture products for general lighting, signs and displays, projectors, entertainment lighting, portable lighting, medical devices and UV curing.

www.luminus.com

IN BRIEF

LED phosphor maker Intematix receives \$16.2m in funding for growth capital

Materials developer Intematix Corp of Fremont, CA, USA, which makes customizable, patented phosphors and remote phosphor components for LED lighting, has received \$16.2m in funding from current investors Draper Fisher Jurvetson and Crosslink Capital as well as a new financial investor. Intematix has now received \$63m total in funding since it was founded.

The firm plans to use the latest round of investment to continue tackling challenges for the LED industry through facility expansion, working capital and the development of its phosphor products and ChromaLit remote phosphor products.

"This investment further enables Intematix to continue its growth trajectory as it addresses the light quality needs required by the general lighting and display markets," says the firm's chief financial officer Maurice Carson.

While lighting LEDs have grown in efficiency they have faced challenges in color quality and thermal management in small form factors, says Intematix. The firm says that its phosphors enable white light comparable to conventional sources, and ChromaLit remote phosphor systems have shown more efficient cooling, leading to compact light bulb solutions.

"Intematix is a key provider of the light quality needed for general adoption of LEDs in lighting," comments board member Alain Harrus, a partner at Crosslink Capital.

www.intematix.com

Sheffield University LED spin-off Seren Photonics raises £1.8m

Funding to speed transfer of HB-LED technology to global manufacturing partners

UK-based university IP commercialization company Fusion IP plc says that Seren Photonics Ltd (which was spun off from the University of Sheffield in February 2010) has raised £1.8m in equity funding from investors including I2BF Global Ventures (£1,100,000), Fusion IP plc (£300,000) and IP Group plc (£400,000).

The funding will enable Seren to speed the transfer of its LED technology to manufacturing partners around the globe. The first of these exploitation agreements was recently announced with an India-based manufacturer. "We are already in discussion with HB-LED manufacturers in China about the possibility of licensing or creating a joint venture manufacturing facility," says Seren's CEO Dr Carl Griffiths. "We will continue to look for other potential partners outside of these territories."

Specifically, the funding will be used to purchase key capital equipment for high-brightness (HB) LED pilot-scale development and to create a specialist engineering team for the transfer of Seren's processes to its commercial manufacturing partners. Post funding, Fusion will have a 40.2% undiluted shareholding in Seren (compared with its initial holding of 60%).

Seren says that its new processing technique, developed by professor Tao Wang from the University of Sheffield, has been shown in tests to greatly increase the HB-LED efficiency and to significantly reduce heat generation under normal running conditions. Demonstrations of the patent pending technology have resulted in a significant increase of the light output compared to untreated devices, so that either much brighter LED lamps can be manufactured or the power consumption of LED lamps can be

reduced.

Seren's technology is targeted at fast-growing white light HB LED markets (including domestic, architectural and street lighting). "This market is currently worth an estimated \$7bn in 2011 and is set to grow to \$20bn by 2014," says chairman Dr Godfrey Ainsworth. "HB LEDs are set to replace incandescent lamps as governments around the world bring in legislation banning the manufacture and sale of incandescents and concerns increase about the poor light quality and environmental contamination fears from compact fluorescents. The rate of adoption will accelerate as the brightness of HB LEDs increases and the cost of manufacture reduces," he adds.


"We believe LEDs will play a large role in reducing energy intensity for a range of municipal and industrial users, and that Seren is well-positioned to help drive that growth due to the double impact of its technology on both brightness and reduction of heat loss," says David Wasserstein, partner and director of investments at I2BF. "We are also pleased to be supporting a UK university spin out at this time, which has been ably supported by our co-investors Fusion IP PLC," he adds.

"We remain confident that Seren can make a significant contribution to enabling the use of LEDs in a variety of different energy-efficient applications where there is a continuous need to reduce power consumption and improve product performance," says Fusion IP's operations director Peter Grant. "With this funding in place we look forward to the company securing further deals for the use of its technology internationally."

www.serenphotonics.co.uk

www.fusionip.co.uk

www.i2bf.com



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Chevron and Bridgelux team on street-light initiative California cities Livermore and Dublin upgrade street-lights in demonstration projects

LED chip and lighting array maker Bridgelux Inc of Livermore, CA, USA and San Francisco-based sustainable energy project developer Chevron Energy Solutions (the energy services division of Chevron USA Inc) have allied to promote LED lighting technologies, with the aim of enabling cities to reduce utility bills and maintenance costs.

Under the program, Chevron Energy Solutions will upgrade streetlights with LED technology, often at no upfront cost to cities. The LED street-lights require 50% less power and far less maintenance than ordinary streetlights, allowing cities the opportunity to finance the installation with the savings. The LED street-lights also offer better quality of light, improving visibility and increasing safety and security.

Livermore and Dublin, two Northern California cities in Alameda County, are participating in demonstrating the LED technology and have upgraded several of their street-lights with the Bridgelux technology.

Street-lights typically account for 10–40% of a municipality's energy costs. According to the Clinton Global Climate Initiative, the energy used by street-lights



Bridgelux LED Street Light module.

amounts to the third largest use of power by local governments. Many cities in America could see reductions of up to 40% (or as much as \$17m in annual energy costs) just by converting their existing conventional street-lights to Bridgelux's LEDs, it is reckoned.

"All cities are facing a similar fiscal dilemma: they need to upgrade their infrastructure, but lack the capital to move forward," says Chevron Energy Solutions' president Jim Davis. "Through this new initiative, we can help cities modernize their infrastructure by financing projects through energy savings. These LED street-lights are making a dramatic difference, but they are just the start of what we can do to help cities save on their energy costs," he adds.

"We think this could be a success-

ful financing model for many of our infrastructural improvement projects," comments Dublin's mayor Tim Sbranti.

The heart of the street-light is an LED lighting module designed to be installed or upgraded quickly and easily into the existing street-light head. Designed by Bridgelux, the module contains the light source and other components most subject to rapid evolution. Bridgelux says that, as the technology advances in energy efficiency and capabilities, it is anticipated that modules could be simply swapped out without having to replace a city's physical infrastructure.

The module also allows cities the potential of upgrading street-lights in the future to incorporate sensing and networking capabilities, giving city managers tools to control their lights and monitor traffic or remote locations (which is impossible with conventional street-lights).

"LEDs and solid-state lighting represent more than just a technical advance," says Bridgelux's CEO Bill Watkins. "They will usher in new business models and capabilities for running our homes, businesses and cities."

www.bridgelux.com

www.chevronenergy.com

LED arrays used by Borden to illuminate San Francisco's Presidio

Fixture maker Borden Lighting of San Leandro, CA, USA says that the Presidio of San Francisco has installed LED walkway lighting to enhance the safety and energy efficiency of the national park.

Using LED arrays made by Bridgelux (which claims to be the only vertically integrated manufacturer of LED solid-state light sources specifically for the lighting industry), Borden Lighting designed a unique indirect post-top walkway luminaire. Additional installations are planned.

The Borden luminaire was developed to conform to 'dark sky' lighting design concepts that effectively illuminate the pathway while preventing glare and light pollution. The original lighting design plan called for the use of metal halide (MH) luminaires, not for LED-based lighting. Borden decided to use Bridgelux's 1200 lumen ES LED arrays not only for their greater energy efficiency but also because the arrays offered much higher quality of light and

long life in a small source size.

"We used a warm 3000K white light to create a soft, welcoming appearance," says David Malman, project lighting designer from Architectural Lighting Design. "The combination of the dark-sky luminaire design and the LED technology resulted in a beautiful addition to the landscape lighting while preserving the natural nighttime setting appropriate for a national park," he adds.

www.bordenlighting.com

Bridgelux brings Micro SM4 LED to market

Bridgelux Inc of Livermore, CA, USA has announced commercial availability of the new Micro SM4 surface-mount LED (which was announced last October), which features its latest advances in epitaxial gallium nitride layer growth, LED chip design and automated packaging technologies and is targeted at cutting the cost and improving the performance of lighting in commercial buildings.

As a multiple die emitter, the Micro SM4 reduces the component count, cost, complexity and size of diffuse or directional lamps (the popular ceiling fixtures seen in modern office buildings and retail establishments).

The Micro SM4 consumes only 4.2W but emits as much light as a 20–40W incandescent or 20–35W halogen B10-style bulb and will last thousands of hours longer. It can deliver 330–500 lumens in both warm white (2700K and 3000K) and cool white (5600K) color tem-



Bridgelux's new Micro SM4 SMT LED.

peratures. Minimum 80 and 90 CRI (color rendering index) options, with 3-step MacAdam Ellipse color selections, will be offered for warm-white products.

The Micro SM4 also delivers high flux density in a smaller footprint, giving designers, architects and lamp manufacturers greater freedom in creating and illuminating interior spaces, Bridgelux says.

"We've developed products with Bridgelux LED arrays over the last

couple of years," comments Raimund Koehler, general manager of lighting product maker MeLiTec GmbH of Ense-Höingen, Germany. "The smaller form factor delivering high-quality light and excellent color over angle performance gave us the edge for our new directional lamp applications," he says of the Micro SM4. "The continuing innovation that we see from Bridgelux is driving LED light source technology in the directions MeLiTec needs to cost-effectively develop the next generation of high-quality, energy-efficient retrofit lamps required for market conversion to solid-state lighting."

The new smaller-footprint, surface-mountable emitter requires fewer components for applications typically using discrete LEDs, says Bridgelux. The 20–40W replacement market segment constitutes a \$1bn opportunity in the \$100bn market for lighting, it is reckoned.

www.bridgelux.com

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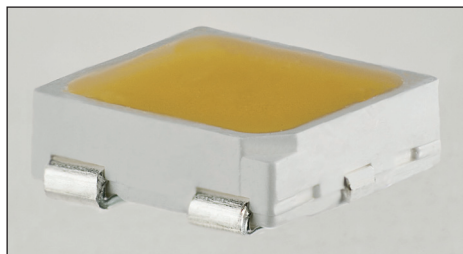
The Business of Science®

Cree expands XLamp ML family of mid-power lighting-class LEDs to optimize and simplify luminaire designs

Cree Inc of Durham, NC, USA has launched mid-power XLamp ML-C and ML-E LEDs, bringing increased versatility and flexibility to a wide spectrum of lighting applications.

Designed to accelerate the adoption of LED lighting, the expanded XLamp ML family now offers red, green and blue color options, high-voltage and three different price-performance options in the proven and reliable ML package. The ML LED high-voltage options can enable the use of more efficient, smaller drivers to reduce cost for applications such as LED replacement lamps.

Cree says that ML LEDs deliver the flexibility and optimization needed to quickly design a portfolio of products for multiple lighting applications, including architectural, hospitality, emergency vehicle, decorative lighting, and linear fluorescent LED replacements. With a shared 3.5mm x 3.45mm footprint, users can quickly and easily expand



An LED in Cree's XLamp ML family.

or update their product portfolio by leveraging a common ML package, the firm adds.

"Using products from Cree's ML LED family gives us great flexibility," comments Michael Pena, president of Blue Ridge Lighting Solutions LLC of Cary, NC. "From a full white color temperature spectrum and different power ratings to the offer of color LEDs, the family of ML products gives us the capacity to offer our customers a full range of lighting options," he adds.

"Providing the broadest portfolio of LED components is essential to

accelerate LED adoption," says Mike Watson, Cree's senior marketing director, LED components.

"Cree's expanded family of optimized ML LEDs further extends the options for our customers to support a wide array of lighting applications without sacrificing lighting-class performance."

The ML-C LED delivers luminous flux up to 37 lumens in cool white (5000K) and up to 31 lumens in warm white (3000K), both at a drive current of 100mA. The series versions of XLamp ML-C and ML-E white LEDs have typical voltages of 6.4V and 9.6V, respectively, at 50mA. The entire family of XLamp ML white LEDs provides 6000 hours of LM-80 data available now, which can speed up the ENERGY STAR qualification process. The XLamp ML white family is also available in minimum 80, 85 and 90 CRI (color rendering index) options.

www.cree.com/versatile

Soraa uses GaN-on-GaN for first 40W-halogen-equivalent LED MR16 lamp for outdoor and enclosed fixtures

Soraa Inc of Fremont, CA, USA,, which is developing solid-state lighting technology built on 'GaN on GaN' (gallium nitride on gallium nitride) substrates, has launched its Outdoor LED MR16 lamp, which matches the performance of a 40W halogen MR16, says the firm. Soraa claims that the new MR16 lamp is the first in its class appropriate for use in outdoor and enclosed fixtures.

The lamp is designed and tested specifically to operate in challenging environments (in fully enclosed, recessed or confined, non-ventilated track fixtures). Designed to replace standard 40W MR16 halogen lamps, the new product exceeds the performance of halogen lamps, while saving 75% of the energy, says the firm. It is available with correlated color temperatures (CCTs) of

2700K and 3000K, and provides halogen-equivalent brightness and light quality without needing a mechanical fan.

Soraa says that its proprietary GaN-on-GaN technology plays a key role in the performance of the Outdoor LED MR16. Its GaN crystal is up to 1000 times purer than the GaN on sapphire or GaN on SiC substrates used by other LED lighting technologies, it is claimed. This technology enables the Outdoor LED MR16 to overcome common ventilation and thermal design barriers while still producing a reliable, high-performing, natural light.

"We proved that GaN-on-GaN is the future of LED lighting with Soraa's Premium and Essential MR16 products," says CEO Eric Kim. "Now, with the launch of the Soraa

Outdoor LED MR16, we're proving GaN-on-GaN's ability to overcome critical barriers and open new frontiers in LED lighting," he adds.

Like the entire family of Soraa's LED MR16 lamps, the OUTDOOR LED MR16 lamp's crystal structure delivers a bright, highly focused, controlled beam with the ability to produce a high color rendering index (CRI) and center beam candle-power to match a standard halogen lamp, says the firm.

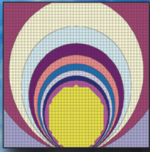
"I've compared my outdoor lighting projects using a competitor LED replacement lamp and a traditional halogen lamp, and I want all my lighting projects to look the way they do when lit with Soraa's Outdoor LED MR16," comments landscape lighting designer Jan Moyer.

www.soraa.com



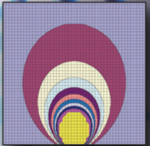
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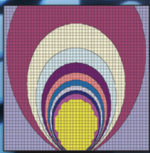
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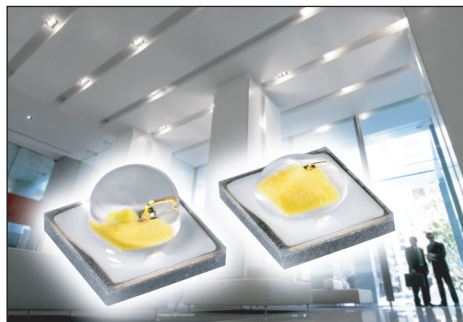


Temescal

Osram SSL efficiency & flux temperature stability boosted

Osram Opto Semiconductors GmbH of Regensburg, Germany says that its new generation of high-power Osram SSL LEDs has improved performance, with efficiency increased by about 25%. Also, the luminous flux at elevated temperatures has been stabilized, making it possible to retain almost constant luminous efficacy despite high operating temperatures. Thanks to this optimization, the luminaire design is significantly simplified.

Osram Opto says the new generation of Osram SSL LEDs presents a particularly temperature-stable light source. It provides a luminous flux of typically 98lm in warm white (3000K), with an operating current of 350mA at a junction temperature of 85°C in the chip. Typical luminous efficacy of 96lm/W makes it one of the most efficient 1mm²-chip LEDs currently on the market, the firm claims. The combination of higher luminous flux and reduced forward voltage of 3.1V equates to an efficiency increase of about 25% compared with the previous generation. Osram Opto says that this makes



New Osram SSL LEDs generate high output with a long lifetime on a small surface, even at high temperatures.

luminaire development easier for lighting manufacturers: a smaller number of LEDs can attain the same luminous flux, as well as the same efficiency, as before.

The firm says that the latest developments in chip technology, converters, and package are the key to this optimization of the Osram SSL's performance. The higher temperature stability of the luminous flux, even when operating under 'hot' operating conditions, greatly simplifies thermal management. "This efficiency enhancement not only implies a reduction of the

initial costs incurred by our customers, it also makes the development of luminaire solutions so much easier," says marketing manager Martin Wittmann.

The new Osram SSL LEDs are available in 'warm white' color (3000K) with a color rendering index (CRI) of 80 (minimum), suitable for interior lighting (type EC) such as in downlights, as well as in 'cold white' (5000K) with a CRI of 70 (typical) for use in exterior lighting (type PC). As with the previous products in the Osram SSL-range, the new products are also available in the small size of 3mm x 3mm and offer two different lenses. Due to the reflectivity of the package, light that is irradiated to the side or to the back is reflected and can be used again. "This LED generation, which combines the converter and reflective package, ensures the best possible light color homogeneity over angle," claims Wittmann.

Osram Opto adds that the Osram SSL LED product portfolio is continually being expanded with the addition of further colour temperatures.

Ostar Stage's flat glass window & AR coating yield smaller spotlights

With their much flatter profile, Osram's new Ostar Stage LEDs (which has a flat glass window) provide the basis for compact spotlights with a very narrow beam and high luminance. The LEDs are suited to moveable stage lights (moving heads), which provide powerful light beams for rock concerts and other lighting displays.

Instead of the usual lens, Ostar Stage LEDs have a flat glass cover with an anti-reflective coating, giving a flatter profile just 1.23mm high (a quarter of the usual height). Spotlights can therefore be made much more compact.

The LED's beam angle is 120°, but the glass cover is optimized for injecting the light into lens systems. Its etendue (the emission angle/area ratio of the emitting light sur-

face to the projected light surface) — in conjunction with customer optics — enables a very narrow beam of light ($\pm 9^\circ$) to be produced (smaller by a factor of two than for spotlights based on plastic-encapsulated LEDs). This optimum bundling of the light increases the luminance of the spotlight also by a factor of two.

The new light sources are based on Ostar SMT platform and contain four different chips in red, green, blue and white, so they can produce virtually any color. All four chips are manufactured using efficient thin-film technology so that almost all the light produced internally is emitted at the top and more light can be focused in the customer optics system, says Osram. The individual chips can be operated at

up to 2A in pulsed mode, and up to 1A in continuous mode. This gives maximum output of 146lm in red (625nm), 234lm in green (527nm), 1.3W in blue (455nm) and 286lm in white, with a correlated color temperature of 6500K. The overall brightness of an LED at a typical output of 10W can be up to 700lm.

The LED has a footprint of just 5.9mm x 4.8mm. Thermal resistance is very low (3.1K/W) and heat removal is no problem at all. In constant use the LEDs will last for more than 50,000 hours (typical), giving the moving heads a very long life.

The LEDs can be used in spotlights of any size, from small stage spots to large moving heads.

www.osram-os.com

Tokyo Institute of Technology installs EVG wafer cleaning system for optical IC R&D

EV Group (EVG) of St Florian, Austria, a supplier of wafer bonding and lithography equipment for the MEMS (micro-electro-mechanical system), nanotechnology and semiconductor markets, has shipped an EVG301 semi-automated single-wafer cleaning system to Tokyo Institute of Technology (Tokyo Tech). The EVG301 has already been installed at Tokyo Tech's Arai-Nishiyama Lab, and is being used in the R&D of advanced optical communication ICs, specifically to remove particles from the surfaces of pre-bonded III-V compound semiconductor and silicon-on-insulator (SOI) wafers that are used in the production of optical ICs.

As network traffic continues to rise dramatically, the need for higher levels of integration in optical communication ICs — including the use of optical routers and wave division multiplexing (WDM) transceivers — is needed to keep transmission rates of each channel at manageable levels, says EVG. In response, Tokyo Tech's Arai-Nishiyama lab initiated work to develop compound semiconductor-based optical transceiver components on silicon, enabling higher levels of circuit integration. The EVG301 megasonic wafer cleaning system was accepted and installed by Tokyo Tech to help accelerate this project.

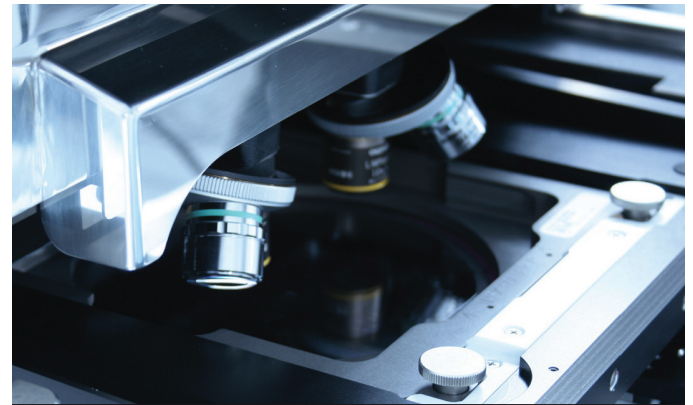
"When you build optical circuits on a silicon platform, creating high-quality luminescent components is essential, and improving wafer bond quality plays an important role in making this happen," says Dr Nobuhiko Nishiyama, associate professor at Arai-Nishiyama Lab. "The existence of even very small particles creates voids on the wafer bonding interface, and such voids prohibit the normal performance of luminescent components," he adds. "The EVG301 megasonic wafer cleaning system by EV Group completely removes such particles and enables perfect bonding results."

Since today's electronics industry is built on high-speed/high-integration silicon devices, the integration of optical circuits on silicon not only improves network speed but also increases the functionality of IC devices, including membrane photonic integrated circuits (PICs). Effective stacking of III-Vs such as indium phosphide (InP) and gallium indium arsenide phosphide (GaInAsP) to create high-performance optical ICs on silicon is essential to enabling such higher integration and functionality, says EVG. Wafer cleaning technology removes voids caused by particles during the wafer bonding process.

"The EVG301 is widely used in research organizations as the de facto standard for wafer cleaning for various wafer bonding processes — and it is offered as a standard component to EVG's leading-edge, fully integrated wafer bonding systems," notes Yuichi Otsuka, representative director of EV Group Japan KK.

www.EVGroup.com

www.pe.titech.ac.jp/AraiLab



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EV Group launches second-generation EVG®620HBL Mask Alignment System for LED Manufacturing



www.EVGroup.com



Spire Semiconductor sold for \$8.5m to Masimo Optoelectronic technology to aid custom component development for non-invasive blood monitoring

Spire Corp of Bedford, MA, USA, which provides solar photovoltaic manufacturing equipment and systems as well as biomedical processing services, has sold its foundry services business Spire Semiconductor LLC of Hudson, NH, to Masimo Semiconductor Inc, a newly formed subsidiary of Masimo Corp of Irvine, CA, which was founded in 1989 and provides non-invasive monitoring technologies for patient care.

The selling price was \$8.5m: \$8m plus the assumption of \$500,000 in liabilities, with the cash portion being reduced by retained cash and liabilities assumed by Masimo in excess of \$500,000. Spire hence received about \$7.2m in cash and Masimo assumed about \$1.2m in liabilities. Of the purchase price, about 10% of the cash portion was deposited into an indemnity escrow account for 15 months.

"With the divestiture of our semiconductor business to Masimo, Spire has strengthened its financial

position and can now more aggressively pursue opportunities in its solar and biomedical businesses," says Spire Corp chairman & CEO Roger G. Little.

"For the past several years, Masimo has been one of our largest customers and is an ideal strategic buyer for the business," Little believes. "Spire Semiconductor has developed a superior intellectual property portfolio and advanced optoelectronic technology that is well suited for Masimo's groundbreaking non-invasive patient monitoring technologies... Masimo can now leverage Spire Semiconductor's strengths for an even greater impact," he adds.

The semiconductor business specializes in wafer epitaxy, foundry services and device fabrication for biomedical, telecoms, consumer products and other markets. It will continue to develop custom optoelectronic components, concentrator photovoltaic (CPV) cells, photocathodes, PIN diodes, avalanche photodiodes (APDs),

laser power converters, thermo photovoltaics and laser diodes, says Masimo.

"We have been extremely impressed with their technology and the service they have provided to us as a customer," says Masimo's CEO & chairman Joe Kiani. "We plan to continue building on the proprietary technology base established by Spire Semiconductor," he adds. "Further advancements in non-invasive blood constituent monitoring technologies are unlikely using off-the-shelf optoelectronic components... The acquisition will permit us to focus the operation on Masimo's custom component requirements and accelerate technology advancements in our non-invasive blood monitoring products," Kiani comments. "Masimo Semiconductor will usher in a new era of technologic advancements for Masimo and ultimately our customers and patients."

www.masimo.com

www.spirecorp.com

Daylight launches widely tunable 3.2µm laser for measuring mixed hydrocarbons

At PITTCON 2012 in Orlando, FL, Daylight Solutions Inc of San Diego, CA, which makes mid-infrared molecular detection and imaging systems based on its quantum cascade laser (QCL) technology, launched the TLS-41032 external-cavity laser, which offers over 200cm⁻¹ of tunability with wavelength coverage in the 3.25µm (3080cm⁻¹) region of the mid-IR spectrum. Users will be able to embed the laser into a range of sensor products targeted at industrial monitoring, process control, process analytical technology (PAT), environmental and safety applications.

The laser will provide increased performance in spectral brightness, tuning range and power at this critical wavelength. The center wavelength matches the fundamental C-H stretching vibrational mode, allowing it to be used to measure most hydrocarbons. The broad tuning range inherent in external-cavity technology enables the analysis of multi-component samples where blended absorption features or broad backgrounds can produce ambiguous results when using distributed feedback (DFB) devices with limited tuning ranges.

"This product introduction will enable new instruments in the

petrochemical and environmental industries to detect and discriminate a wide range of molecules based on their unique spectral signatures at these wavelengths," says senior director of commercial products Dr Bob Shine.

"Adding new wavelengths and increased laser performance targeted at key industrial applications is part of Daylight Solutions' core strategy to bring mid-infrared solutions to a range of commercial markets," notes the company's CEO & chief technology officer Dr Tim Day.

www.daylightsolutions.com

www.pittcon.org

Ferdinand-Braun-Institut awarded Transfer Prize

At the Laser Optics Berlin trade fair, a team from Berlin-based Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik (FBH) was awarded the €50,000 Transfer Prize Wissens-Werte 2012, which is assigned by friends of the Technology Foundation Berlin (TSB).

This is FBH's second Transfer Prize, after its first in 2004 for the development of distributed feedback (DFB) high-power laser diodes (transferred industrially in collaboration with FBH spin-off eagleyard Photonics).

With the latest prize, six FBH scientists were honored for the sustainable transfer of high-power diode lasers for materials processing applications, on which FBH cooperates with Jenoptik Group subsidiary Jenoptik Diode Lab GmbH (spun off from FBH in 2002). "It [the award] manifests and acknowledges the long-term and extraordinarily fruitful collaboration with industrial partners like Jenoptik", says awardee Dr Götz Erbert. "This cooperation is the basis for various developments in this application field helping us to ensure international technology leadership within the market for such laser systems".

Led by Erbert, the FBH team is developing a novel generation of diode lasers for powerful laser systems used for materials processing. These consist of single diode lasers, each delivering typical output of about 10W. To enhance performance, simply increasing the output power is insufficient. The key tasks are to further increase efficiency (improve the effectiveness of transforming electrical into optical power) and to optimize the beam quality of the single diode lasers in the systems. Based on novel designs, the team has now developed diode lasers that have already achieved an efficiency of 63% at an output power of 12W. The team reckons that 15–20W should be achievable while maintaining the efficiency and beam quality. Such diode lasers hence set the stage for purely diode-laser-based systems for materials processing in the future.

To quickly transfer research results into an industrial environment, FBH is working with industrial partners. Long-term collaboration with Jenoptik, particularly in diode lasers for materials processing, yielded Jenoptik Diode Lab GmbH, which conducts semiconductor fabrication at its Adlershof campus in Berlin and continues to use the research

results from FBH for its diode lasers. The cooperation is enabling continuous improvements in performance and is the basis for a wide variety of new developments, says FBH. Due to customer demand, Jenoptik Diode Lab is expanding its production capacity, more than doubling its staffing.

www.fbh-berlin.com



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Luxtera's silicon photonics IP to be developed by ST for high-volume 300mm fab

Integration of optical transceivers to deliver photonic-enabled system-on-chip ICs for large-scale systems

An agreement has been announced to bring the IP and silicon photonics expertise of fabless semiconductor firm Luxtera Inc of Carlsbad, CA, USA to a dedicated production process to be developed by Geneva-based STMicroelectronics at its 300mm wafer fabrication plant in Crolles, France, enabling the firms to provide low-cost, high-volume silicon photonics components and systems.

According to Luxtera, silicon photonics is a key enabler of future very high-speed computing and communications applications (such as optical networking, CPU interconnect, and data storage) as they scale to multi-terabit connectivity. The technology allows high-speed optical communications devices to be built using proven, low-cost silicon manufacturing technology, rather than more expensive compound semiconductor materials containing gallium or indium.

"This will bring silicon photonics into the mainstream of important technologies such as optical networking, ultra-fast computer

processors and other applications via the commercial volume availability of a best-in-class silicon photonics IP platform," says Flavio Benetti, general manager of mixed process division at ST.

The collaboration grants ST the rights to use Luxtera's silicon photonics technology, which will be implemented in the new ST photonics process and its future generations. ST will provide Luxtera with a reliable, scalable and cost-effective supply chain, allowing it to satisfy its growing market in terms of volume and quality requirements. The firms aim to jointly enable silicon photonics to become a cost-effective mainstream technology.

"Luxtera has found a broad market opportunity for silicon photonics that requires an expanded supply chain and continued technology advancement," says president & CEO Greg Young. "We can now offer our customers a high-volume, capable source of supply and an aggressive long-term photonic process technology roadmap," he

adds. "This will advance our base technology and enable the integration of optical transceivers with SoCs from advanced CMOS nodes to deliver photonic-enabled SoCs for large-scale systems. In turn, ST can now offer customers the world's leading optical IP as the two companies expand the silicon photonics ecosystem."

The 300mm silicon photonics platform developed by ST will offer the following benefits:

- performance scalability of low-cost transceivers for data rates of 100Gb, 400Gb and upwards;
- ultra-high-density interconnects with the lowest power consumption;
- interoperability, with support for 1310nm, 1490nm and 1550nm wavelengths.

The optimized silicon photonics process will be developed at ST's Crolles technology center, where its other major CMOS R&D programs (including analog BiCMOS technologies) are running.

www.st.com

www.luxtera.com

Luxtera ships millionth silicon CMOS photonics-enabled 10Gbit

In late February, Luxtera said it had shipped its 1 millionth 10Gbit channel, validating the growing demand for silicon photonics in mission-critical data centers and computer clusters, as well as reinforcing the firm's ability to meet high-performance computing (HPC) needs on a larger scale. Luxtera says it further signifies the emergence of silicon photonics as the next generation of interconnects, with 10 Petabits of transceiver bandwidth shipped.

Founded in 2001, Luxtera claims to be the only provider of silicon photonics shipping in significant commercial volume. It says that

the technology continues to be a driving force that supports growing bandwidth demands of equipment in HPC, next-generation data centers and cloud computing, offering a reliable, low-cost yet high-performance solution compared with existing technologies such as vertical-cavity surface-emitting lasers (VCSELs). Also, adds Luxtera, silicon photonics continues to be the focus of many research labs and universities, most notably IBM and Intel, and has recently provided the enabling building block in the race to build computers on an exascale (10^{18} byte) level.

"Silicon CMOS photonics can no longer be characterized as the technology of the future, it appears it is ready to be front and center as the technology of today," says Brad Smith, analyst at LightCounting.com, which focuses on high-speed interconnect market research. "This milestone was achieved in a market that is cost sensitive, and the competing solution was often a VCSEL-based cable," he adds.

"Shipping 10 Petabits of silicon CMOS photonics links is the culmination of a vision that the founders and investors of Luxtera dreamed of almost 11 years ago," says VP of marketing Chris Bergey.

Luxtera raises \$21.7m in VC funding; board gains ex-Broadcom executive

Fabless silicon CMOS photonics firm Luxtera of Carlsbad, CA, USA has closed a \$21.7m C-round of growth capital financing to support design-win opportunities and market adoption of silicon CMOS photonics.

Participants include existing investors NEA (New Enterprise Associates), August Capital, Sevin Rosen Funds, and Lux Capital, as well as new investor Tokyo Electron, plus personal investment from someone described as "an industry titan".

Joining Luxtera's board of directors is Martin Colombatto, who was most recently CEO & president of San Diego-based ultra-wide-band (UWB)/wireless USB firm Staccato Communications. But previously Colombatto was VP & general manager of Broadcom's Networking business unit, where he established and managed a business that generated more than \$400m in revenue over a four year period, and led the acquisition of five firms that were

integrated into the business. Colombatto is also currently involved with several semiconductor start-ups.

Silicon CMOS photonics has transitioned from the exotic research labs of Intel and IBM to become a mainstream technology, says Luxtera's president & CEO Greg Young

"Silicon CMOS photonics has transitioned from the exotic research labs of Intel and IBM to become a mainstream technology," says Luxtera's president & CEO Greg Young. "With over 1 million 10Gb channels shipped and numerous opportunities to ship tens of millions of units, we have established ourselves as the leader in this important field."

www.luxtera.com

Former Broadcom executives added to aid focus on high-volume optical applications

In February, Luxtera added three new executives to its management team: VP of engineering Joseph Balardeta; VP of sales Ron Horan; and VP of marketing Chris Bergey.

Most recently a founder of Uplay LLC (acquired by Callaway Golf), Balardeta has previously held engineering management roles at Broadcom. He was also VP of engineering at Applied Micro Circuits Corp (AMCC).

Bergey also joins from Broadcom, where he was most recently VP of the Mobile and Wireless Group and, during nine years with the firm, gained experience with starting and managing product lines and marketing organizations. Previously, Bergey worked for Multilink Technology Corp and Advanced Micro Devices (AMD).

Horan was most recently senior

director and global account manager for Broadcom. Previously, he managed the platform engineering team at AMD. Prior to that, he was a senior design engineer with Compaq Computer's workstation team, where he was awarded 16 patents.

"We are now rapidly approaching the inflection point where silicon photonics will often be the only viable solution to support the cost, size, density and reliability required by leading manufacturers of switches and servers," comments Bergey.

"I have personally worked with Joseph, Chris and Ron and I am confident they will make significant contributions towards the opportunity we see ahead in the optical applications market," says president & CEO Greg Young.

Luxtera process open to OpSIS community

Luxtera has teamed with the new foundry Optoelectronic Systems Integration in Silicon (OpSIS). Its silicon photonics device design library and process is now open to the OpSIS community, sharing the cost of fabricating complex chip-scale systems across many projects (which can now have direct access to Luxtera's complete technology platform and library of optical device elements that work with a volume 200mm CMOS process).

Luxtera also supports a standard tool-flow based on EDA tools, supporting electronic-photonic co-design. The process design kit (PDK) has been production proven in subsystem- and system-level optoelectronic transceiver architectures. The PDK is covered by over 115 issued and pending patents.

"It provides the opportunity to leverage the significant investment and maturation of the world's first production-proven CMOS photonics design flow," says professor Michael Hochberg, director of OpSIS. "This will significantly accelerate the growth of the silicon photonics ecosystem," he believes. "This process will offer both academic and industrial users a chance to leverage a full electronics PDK as well as yield models for the key photonic components in order to accurately predict the performance and yield of complex systems-on-a-chip," Hochberg continues. "Historically, much of the innovation has been centered on process development. We're now moving into an era where silicon photonics can enable a great deal of innovation at the system and architectural level."

"Luxtera continues to focus its design resources on delivering products to high-volume applications," says CEO Greg Young. "There is significantly more market opportunity than Luxtera can service directly. With OpSIS, smaller projects are now granted access to Luxtera's silicon photonics library."

<http://depts.washington.edu/uwopsis>

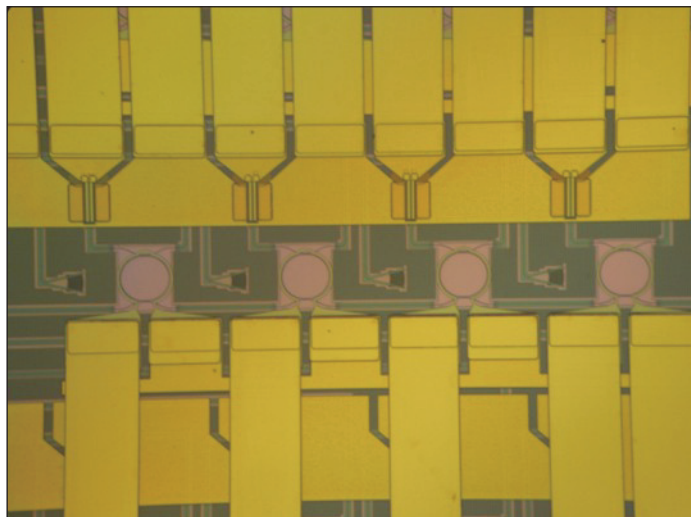
EU's BOOM project on SOI photonic integration completed

Silicon-on-insulator photonic ICs combined with InGaAs photodetectors

Nanoelectronics research center Imec of Leuven, Belgium and its partners have completed 'BOOM', a project funded by the European Union (EU) and coordinated by the National Technical University of Athens (NTUA). By systematically advancing silicon-on-insulator (SOI) photonic integration technology, compact, cost-effective and power-efficient components have been developed that enable photonic Tb/s capacity systems for current- and new-generation high-speed broadband core networks, says Imec. As part of the project, Imec realized an optical label extractor consisting of a high-resolution demultiplexer integrated with highly efficient photodetectors.

BOOM focused on the development of a photonic routing platform relying on hybrid SOI integrated photonic ICs to implement all the routing functionalities. These included label detection (Imec), control signal generation (Heinrich-Hertz-Institute HHI and IHP – Innovations for High-Performance Microelectronics), wavelength conversion (NTUA, Technische Universiteit Eindhoven TU/e, and Technische Universität Berlin) and wavelength routing (LioniX BV of Enschede, The Netherlands and AMO GmbH of Aachen, Germany). Finally, a routing machine with an aggregate capacity of >160Gb/s was built by NTUA and Telecom Italia Lab.

Imec says that, this way, the project has answered the growing demand for bandwidth-hungry Internet applications, which stresses the available capacity and performance of current optical core networks. Power efficiency, physical size and equipment cost are key issues in these networks and are increasingly more difficult to keep



Four-channel label extractor with four high-finesse ring resonators integrated with InGaAs photodetectors.

within acceptable limits, it notes. Electronic carrier routing systems consume and dissipate large amounts of electrical power and heat respectively. By incorporating photonics technologies deeper into these routers, their performance can be improved and power consumption decreased, Imec reckons.

Imec's work within the project focused on the optical label detector. In the proposed routing architecture the optical data packets are labeled with a wavelength code, which has to be extracted from the packet and sent to the routing unit.

The label extractor consists of an optical demultiplexer with very high resolution (12.5GHz) fabricated on Imec's silicon photonics platform and integrated with high-efficiency indium gallium arsenide (InGaAs)

photodetectors.

Reaching the required resolution turned out to be very challenging and required an in-depth study of silicon micro-ring resonators, says Imec. The required specifications could be reached using single ring resonator based filters. The ring resonators have integrated resistors which allow fine tuning of the wavelength

channels (bottom electrodes) through the thermo-optic effect. They are connected to evanescently coupled InGaAs photodetectors using the heterogeneous integration technology developed by INTEC (Imec's associated laboratory at Ghent University). The detectors had an efficiency of close to 1A/W and were operating at the specified speed of 1GB/s (up to 5GB/s). Finally the device was packaged in collaboration with Fraunhofer IZM group in Berlin, Germany. The device is now ready for operation in a system test-bed.

The results obtained by Imec in the project, and in particular the exhaustive study on the micro-ring resonators, are not only relevant for realizing the optical label extractor. They also form a key input for the Imec optical interconnect program, which requires high-performance demultiplexers for increasing the bandwidth in optical chip-to-chip links. Further, they can be used in optical sensors and non-linear devices, says Imec.

www.ict-boom.eu

www.imec.com

BOOM focused on the development of a photonic routing platform relying on hybrid SOI integrated photonic ICs to implement all the routing

CEA-Leti and III-V lab demonstrate fully integrated silicon photonics transmitter

Hybrid III-V/Si tunable laser, modulator and passive waveguides fabricated on SOI wafers

Micro/nanotechnology R&D center CEA-Leti of Grenoble, France and III-V Lab (a joint venture between Paris-based Alcatel-Lucent Bell Labs France, Thales Research and Technology, and CEA-Leti, which joined III-V Lab in March 2011 to contribute silicon integration capabilities) have demonstrated what is claimed to be the first tunable laser transmitter integrated on silicon, representing "a key milestone towards fully integrated transceivers".

The transmitter incorporates a hybrid III-V/Si laser (fabricated by direct bonding) that exhibits 9nm wavelength tunability together with a silicon Mach-Zehnder modulator with a high extinction ratio (up to 10dB), leading to what is claimed to be excellent bit-error-rate performance at 10Gb/s. The results were obtained in the framework of the European-funded project HELIOS (pHotonics ELectronics functional Integration on CMOS), with the contributions of Ghent University-IMEC for the design of the laser and the UK's University of Surrey for the design of the modulator.

CEA-Leti and III-V Lab have also demonstrated single-wavelength tunable lasers, with a threshold current of 21mA at 20°C, 45nm tuning range, and a side-mode suppression ratio larger than 40dB over the tuning range.

The results were overviewed at the Optical Fiber Communication conference (OFC 2012) in Los Angeles (4-8 March), where CEA-Leti also exhibited.

CEA-Leti and III-V Lab claim that the development represents a significant breakthrough in silicon photonics by integrating on the same chip complex devices such as

a fully integrated transmitter working above 10Gb/s or a tunable single-wavelength laser.

Silicon photonics has the promise of bringing the large-scale manufacturing of CMOS silicon to photonic devices that are currently still expensive due to a lack of ubiquitous technology. A big obstacle to silicon photonics is the lack of optical sources on silicon. "We can overcome this problem by bonding III-V material — necessary for active light sources — onto a silicon wafer and then co-processing the two," says Martin Zirngibl, Bell Labs Physical Technologies Research leader. "Traditional CMOS processing is still used in the process, while at the same time we now can integrate active light sources directly onto silicon," he adds.

Based on the heterogeneous integration process developed by CEA-Leti and III-V Lab, III-V materials such as indium phosphide (InP) can be integrated onto silicon wafers. The fabrication process starts on 200mm silicon-on-insulator (SOI) wafers, where the silicon waveguides and modulators are fabricated on CEA-Leti's 200mm CMOS pilot line.

"The ability to integrate a tunable laser, a modulator and passive waveguides on silicon paves the way for further developments on integrated transceivers that can address several application needs in metropolitan and access networks, servers, data centers, high-performance computers as well as optical interconnects at rack-level and board-level," says Laurent Fulbert, photonics program manager at CEA-Leti France.

www.3-5lab.fr

www.leti.fr

www.helios-project.eu

Distributor Heilind now stocking FCI's MergeOptics products

Heilind Electronics Inc of Wilmington, MA, USA, the largest distributor of interconnect products in North America, says that it is now stocking the MergeOptics products of FCI of Versailles, France, a manufacturer of high-density connectors and interconnect systems. FCI MergeOptics integrates optical components with high-frequency electrical circuits into one compact module.

MergeOptics' portfolio features products that integrate vertical-cavity surface-emitting laser (VCSEL)-based optical components and high-performance photodiodes with high-frequency electrical circuits in compact modules and cable assemblies that are compliant with industry-standard optical and electrical interfaces, operating at speeds of 10Gb/s or higher.

The products are designed for use in datacoms, telecoms, lasers, modulators and photodiode applications in the optical communications industry as well as in the fiber and Ethernet markets. Applications include 10 Gigabit Ethernet (10GbE) datacom and storage-area networks (SAN/NAS) based on the IEEE802.3ae and Fibre Channel 10GFC Rev. 4.0 standards, as well as data centers and high-performance computing applications requiring short to moderate transmission lengths.

MergeOptics delivers what are described as efficient and flexible network management solutions that include X2, XFP, SFP+, QSFP and CXPO form factors and that meet the InfiniBand Trade Association (IBTA), Fibre Channel, 10G Ethernet and IEE 802.3 specifications.

www.mergeoptics.com

www.fciconnect.com

www.heilind.com/products/fci

Oclaro and Opnext agree to merge

Complementary products and customers expand growth prospects

Optical communications and laser component, module and subsystem makers Oclaro Inc of San Jose, CA, USA and Opnext Inc of Fremont, CA, USA have entered into a definitive agreement to merge in an all-stock transaction (valued at \$179m at current share prices). Opnext shareholders will receive 0.42 shares of Oclaro common stock for every share of Opnext common stock they own.

Oclaro's chairman & CEO Alain Couder will also be chairman & CEO of the combined firm. Opnext's chairman & CEO Harry Bosco will join its board of directors. Opnext shareholders will own about 42% of the company and Oclaro 58% (giving it six out of the 10 board seats).

The merger brings together more than 30 years of combined telecom and datacom optical technology development, enabling the fourth (Oclaro) and fifth (Opnext) largest suppliers of optical components and subsystems to leapfrog JDSU to form the second largest (with 2011 revenues of \$417.2m and \$327.5m, respectively, adding to \$745m), behind Finisar. The companies says that the broad product portfolio, technology innovation, engineering resources, cost structure and strategic customer relationships of the combined firm are expected to expand growth opportunities and create long-term shareholder value.

Data-intensive applications such as video and cloud computing, and the proliferation of mobile devices, are driving the need for increased performance and bandwidth throughout the core optical networks at the heart of the world's Internet traffic, say the firms. These trends are also forcing enterprises and data centers to upgrade and deploy new data communications infrastructures.

As a result, traditionally separate telecom and datacom networks are converging, leveraging optical net-

working technologies from firms such as Opnext and Oclaro. It is reckoned that the combined company will be well positioned to capitalize on these trends to become the biggest supplier to the core optical networks, with a leadership position in the fastest-growing 40G and 100G segment, which is forecasted to increase at a compound annual growth rate (CAGR) of 42% through 2015. The broader product line resulting from the merger is expected to strengthen the combined firm's position as a key supplier to existing and new customers.

"Our respective customers want to work with fewer, more strategic suppliers who can deliver the breadth of technologies they need," says Couder. "The companies'

complementary and vertically integrated product portfolios, scale, and heritage of technology innovation will put the merged company in that valued strategic partner and leadership role," he reckons. "By doing so, and at the same time saving significant costs, we also expect to generate substantially more long-term value for shareholders than either company could deliver alone," he adds.

Our respective customers want to work with fewer, more strategic suppliers who can deliver the breadth of technologies they need. The companies' complementary and vertically integrated product portfolios, scale, and heritage of technology innovation will put the merged company in that valued strategic partner and leadership role

As well as the telecom and datacom markets, there is a large and growing opportunity for laser diodes in a range of high-growth industrial and consumer markets, the firms note. The combined firm will be the largest supplier of laser diodes for industrial and consumer applications and, with a substantial portfolio of products and technologies, will be well positioned to accelerate innovation and inroads into these high-volume markets, it is reckoned.

The combined heritage of Oclaro (formerly Bookham) and Opnext (formerly the Fiber Optic Components business unit of Japan's Hitachi Ltd, until September 2000) stems from some of the leading optical technology developers over more than 30 years, via mergers and acquisitions involving Nortel, Alcatel, Marconi, Corning and Avianex.

"Opnext and Oclaro share a rich history bringing to market some of the industry's most advanced optical technology innovations over more than three decades," says Bosco, who reckons that the merger will create a unique opportunity for customers, shareholders and employees of the merged firm to leverage this legacy of technology to lead the optical components and modules market and to achieve critical mass in the industrial and consumer laser diode segments.

Subject to customary closing conditions (including approval by the shareholders of both firms and the receipt of regulatory approvals in the USA), the transaction is expected to close within 3–6 months.

The combined firm is expected to achieve positive non-GAAP operating income in the first full quarter after the close of the merger, and annualized cost synergies of \$35–45m within 18 months. Restructuring and system integration costs should total \$20–30m.

www.oclaro.com

www.opnext.com

Oclaro's Shenzhen assembly & test operations to transition to Venture Malaysia over three years

Shenzhen building to be sold to third party and leased back

Optical communications and laser component, module and subsystem maker Oclaro Inc of San Jose, CA, USA has closed a definitive agreement to transfer its final assembly & test operations in Shenzhen, China to the Malaysia facility of Singapore-based Venture Corporation Ltd (a global provider of technology services, products and solutions with more than 12,000 staff) in a phased and gradual transfer of products over the next three years.

During the three-year transition period, Oclaro will retain control of the facility and staff will remain employed by the firm. Several of Venture's operational personnel will relocate to Shenzhen to provide support to Oclaro, oversee the transfer, and ensure that products transitioned to Venture's Malaysia facility are fully qualified by customers before the products are phased out of the Shenzhen plant.

Over the transition period, the outsourcing is expected to free up in excess of \$35m net of transition and employee retention costs. The two companies have also signed a five-year supply agreement.

The announcement is "a significant milestone in Oclaro's strategy to adopt an outsourced back-end manufacturing model, focus on our core competencies and position the company to scale," says chairman & CEO Alain Couder. "A key factor in choosing our contract manufacturing partner was to ensure we would be able to control and manage a smooth transition for our customers. Our agreement with Venture is expected to provide this seamless transition, while strengthening our balance sheet, and providing a financing source to fuel continued innovation," he adds. "Complementing our existing outsourced manufacturing relationship with Fabrinet,

this move further simplifies our manufacturing model, enabling us to create a world-class supply-chain management capability, and will offer our customers greater responsiveness and flexibility."

Venture is a strategic partner for global companies, providing a fully integrated range of original design manufacturing, electronics manufacturing services and e-fulfilment services. It has been engaged in manufacturing optical products since 1992 and is a preferred partner to global firms in for datacoms, telecoms and adjacent applications. Expertise covers low-level through final system assembly across technologies including fixed- and tunable-wavelength devices, transceivers and transponders. Venture says that, with complementary engineering capabilities, operational synergy, real-time infrastructure interfaces and faster time-to-market, it can effectively manage the value chain for electronics companies.

"We will aim to deliver a seamless product transition," says Venture's chairman & CEO Wong Ngit Liong. "We see great opportunity to share our expertise with the Oclaro product development team to drive product quality and supply chain efficiency, as well as enhance our Center of Excellence for optical communications," he adds.

Beyond the transition, Oclaro intends to maintain a long-term customer support, new-product introduction and R&D presence close to customers and the significant talent pool in Shenzhen.

Oclaro plans to sell its Shenzhen building to a third party and lease it back. Any potential proceeds would be incremental to the net cash proceeds of the Venture agreement.

www.venture.com.sg

www.oclaro.com

IN BRIEF

Opnext's QSFP+ 40GBASE-LR4 transceiver enters volume production

Opnext has announced the production release of its QSFP+ 40GBASE-LR4 transceiver. The firm says that, as industry leaders start to outgrow the reach and efficiency of current-generation 40GbE pluggables, the QSFP+ 40GBASE-LR4 transceiver offers the latest technology to those keen to scale up.

"QSFP+ is emerging as the standard for 40GbE," says Rich Zoccolillo, president of Opnext's pluggables business unit. "Adding the QSFP+ 40GBASE-LR4 product offering to our portfolio enables substantially higher port density and significantly lower power consumption," he claims. "With the QSFP+ 40GBASE-LR4 transceiver, Opnext is introducing a low-cost integration and packaging technology for multiple long-reach DFB lasers—all inside a module no larger than a pack of gum."

As OEMs are approaching the limits of current 40GbE technology in their data-center and enterprise applications, Opnext claims that its QSFP+ 40GBASE-LR4 transceiver can offer up to 100 times the reach of current QSFP+ SR4 solutions while improving on industry metrics compared to the CFP form factor: power consumption is reduced by more than 50% and almost 80% less face-plate surface area is occupied.

The evolution of laser integration technology allows for higher-density TOSA packages. Combined with the maturation of the 40GbE supply chain, these packages enable more compact, better-performing, and more affordable 40GbE solutions, the firm claims.

www.opnext.com

IN BRIEF

NeoPhotonics launches multicast switch for 'CDC' ROADMs in 100G coherent networks

NeoPhotonics Corp of San Jose, CA — a vertically integrated designer and manufacturer of photonic integrated circuit (PIC)-based modules and subsystems — has made available samples of its Multicast Switch for next-generation ROADM applications.

The Multicast Switch is designed in a dual 8x16 configuration, offering 16 drop and add ports and up to 8 directions. NeoPhotonics says that the capabilities of its PIC platform also enable support for architectures requiring 8x12 or 8x24 configurations as well as offering the option of integrated power monitoring for each port.

The Multicast Switch is intended to build on current ROADM technology to enable next-generation 'colorless, directionless and contentionless' (CDC) networks. For example, in a CDC network, it can be coupled with a wavelength-selective switch (WSS), which together are designed to direct any wavelength to any port (colorless), accept input wavelength channels from multiple directions (directionless), and be able to drop two identical wavelengths from different directions through the same switch (contentionless). This switching flexibility is intended to improve the efficiency and flexibility of telecom networks while reducing overall deployment costs.

"It can play a critical role in enabling more flexible and efficient ROADM systems," says CEO Tim Jenks. The Multicast Switch integrates over 200 optical elements, and is enabled by the firm's experience of developing and producing increasingly complex PICs, he adds.

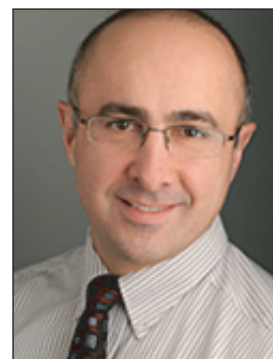
www.neophotonics.com

Fabrinet to manufacture OneChip's PIC-based PON transceivers InP-based photonic integrated circuit firm hires VP of global manufacturing operations

Privately held firm OneChip Photonics Inc of Ottawa, Canada, which develops and manufactures optical transceivers based on monolithic photonic integrated circuits (PICs) fabricated in indium phosphide (InP) for access networks and other mass-market broadband applications, has named Dan Meerovich its VP of global manufacturing operations. The firm has also reached an agreement with Thailand-based contract manufacturer Fabrinet Ltd to make its PIC-based passive optical network (PON) transceivers, which are targeted at helping system providers and carriers deploy Fiber-to-the-x (FTTx) more cost-effectively and at meeting consumer and business demand for high-bandwidth voice, data and video services.

Meerovich is responsible for building OneChip's volume manufacturing capabilities and ensuring cost-effective and efficient operations across its supply chain. "Dan has a wealth of optical communications industry experience and a successful track record of growing and streamlining operations, while exceeding sales and profit targets," says CEO Jim Hjartarson. "He will play a key role in the introduction and volume manufacture of our unique optical transceiver product line," he adds.

Before joining OneChip, Meerovich was VP of operations at wavelength-selective switch (WSS) maker Xtellus Inc of Denville, NJ, USA (acquired by Oclaro Inc in 2009). One year after the acquisition, he was instrumental in increasing revenue by 50% while increasing labor efficiency by 70%.



Dan Meerovich,
OneChip's new VP of
global manufacturing
operations.

He also expanded R&D and manufacturing capabilities in Korea and Thailand.

Previously, Meerovich was VP of manufacturing operations at Multiplex Inc, where he

established and managed a manufacturing subsidiary in China. He also held senior-level operations positions at Asip Inc/Apogee Photonics Inc, JDS Uniphase and Tyco/Laser Diode Inc.

According to Meerovich, OneChip has selected Fabrinet as its contract manufacturer because of Fabrinet's strong global footprint and its ability to get the manufacturing line up and running quickly. "Fabrinet has extensive experience manufacturing optical components and systems and will help OneChip meet the high demand for our integrated optical transceivers," he says.

As a vertically integrated manufacturer with more than 1 million square feet of space at its facilities in Thailand, China and the USA, Fabrinet will provide manufacturing services at its Pinehurst campus in Thailand including optical component attachment for OneChip's bi-directional optical sub assemblies (BOSAs) and final integration and testing of its fully packaged optical transceivers. "We look forward to helping OneChip bring its breakthrough solutions to market globally," says Fabrinet's senior director of business development Greg Reny.

www.onechipphotonics.com

GigOptix reports record revenue after 37% growth in 2011 Further growth of 30% expected in 2012

For full-year 2011, GigOptix Inc of San Jose, CA, USA (a fabless supplier of semiconductor and optical components including modulator and laser drivers and transimpedance amplifier ICs based on III-V materials) has reported revenue of \$32.3m, up 20% on 2010's \$26.9m. However, excluding Government contract revenue of \$3.8m in 2010 (14% of total revenue) and just \$628,000 in 2011 (2% of total revenue), product revenue has grown by as much as 37% from \$23.1m in 2010 to \$31.6m in 2011.

For fourth-quarter 2011, revenue was \$8.6m, up 3% on \$8.4m in Q3 (all product revenue) and 6% on \$8.1m a year ago (or up 31% on product revenue of \$6.6m a year ago, excluding the \$1.5m of Government contract revenue, which comprised 19% of total revenue). This represents a ninth quarter of sequential product revenue growth.

"The fourth quarter marked the close to a strong 2011 where GigOptix made substantial progress

at growing revenue both organically and overall and in stabilizing our balance sheet," says chairman & CEO Dr Avi Katz.

On a non-GAAP basis, net loss has been cut from \$712,000 in Q3 to \$414,000, although this compares with net income of \$588,000 a year ago. For full-year 2011, net loss was \$2.5m, up from \$498,000 in 2010.

Full-year adjusted EBITDA (earnings before interest, taxes, depreciation and amortization) was down from \$2.5m in 2010 to \$279,000. However, although down from \$1.3m a year ago, quarterly adjusted EBITDA has continued to recover, from \$289,000 in Q3 to \$346,000 in Q4. During 2011, cash and investments rose from just \$4.5m to \$16.2m.

"On the product development front, we made significant progress with our 40G and 100G products and are now addressing cutting-edge telecom and datacom market opportunities with many new products released to qualification and

production in 2011," says Katz. "We also continue to move downstream into larger-volume markets, from telecom to datacom, last-mile wireless capabilities and consumer electronics with our latest SiGe drivers and TIA production releases, and with our CMOS devices and electro-optics interface designs that we are planning to bring to the market this year," he adds.

"We are experiencing strong demand for our optical products, and are currently bringing to market next-generation products such as our 100G TFPS modulators, and ramping production of our 40G and 100G drivers and TIAs," continues Katz. "As an example, we have just booked an order from a tier-1 telecom lead OEM for \$2.8m for our latest 100G coherent driver for long-distance communication applications, all to be delivered during the first six months of 2012," he adds. For full-year 2012, GigOptix expects revenue growth of about 30% over 2011.

Sanmina-SCI design partnership expanded for 100G modulator

GigOptix has expanded its partnership with contract manufacturer Sanmina-SCI Corp. Specifically, Sanmina-SCI has designed the optical packaging and is industrializing GigOptix's LX8240 next-generation 100G coherent TFPS (Thin Film Silicon on Polymer) optical modulator.

"GigOptix's new 100G modulators are based on their proprietary TFPS technology that has never been produced before, and requires an unprecedented level of precision and accuracy," says David Dutkowsky, executive VP of Sanmina-SCI's Communications Networks Division. "Because of our significant investments in the optical space in the past decade, we have the design, industrialization, test and custom manufacturing expertise to commercialize these revolutionary products."

GigOptix says that, based on its proprietary TFPS technology, the LX8240's ultra-small form factor, low insertion loss, and low power consumption suit use in metro, long-haul and ultra-long-haul optical transport applications. The modulator leverages the firm's proprietary TFPS technology to provide low power consumption in what is claimed to be the smallest-footprint modulator on the market.

"We started working with Sanmina-SCI on our 40G technology and when we saw their design capabilities, and the level of engineering collaboration given to GigOptix, we were convinced they could help us bring our 100G technology to market in an efficient matter that would help us gain traction when engineering slots began to open," says Dr Raluca Dinu, general man-

ager & VP of optics at GigOptix. "They have become an extension of our own design team," he adds.

Sanmina-SCI's Optical and Microelectronics Division designs, industrializes, tests and manufactures complex optical and RF components and products. With facilities in the Americas and China, the division's global footprint can be customized to provide a secure supply chain that protects companies from component availability disruptions.

GigOptix and Sanmina-SCI showcased their optical solutions at the Optical Fiber Communication Conference and Exhibition/National Fiber Optic Engineers Conference (OFC/NFOEC 2012) in Los Angeles in March.

www.sanmina-sci.com
www.gigoptix.com

Emcore sells VCSEL-based product lines to Sumitomo Electric for \$17m

Firm to focus on telecom and broadband fiber-optics products

Emcore Corp of Albuquerque, NM, USA, which makes components, subsystems and systems for the fiber-optic and solar power markets, has entered into a definitive agreement to sell certain assets and to transfer certain obligations of its vertical-cavity surface-emitting laser (VCSEL)-based product lines in exchange for \$17m in cash (subject to closing adjustments) to optical and wireless communications product maker Sumitomo Electric Device Innovations USA Inc of San Jose, CA (SEDU, a subsidiary of Japan's Sumitomo Electric Inc).

The assets to be sold include fixed assets, inventory and intellectual property for the VCSEL-based product lines of Emcore's fiber-optics business unit, including VCSEL and photodiode components, parallel-optical transceiver modules, and active optical cables (AOCs).

Emcore will retain its telecom and broadband fiber-optics products, which include its tunable lasers, tunable XFPs, cable TV modules and transmitters, FTTx transceivers, indium phosphide (InP)-based lasers, photodiodes, and modulators, video transport and specialty photonics products.

Emcore says that selling the VCSEL product line allows it to focus its fiber-optics product portfolio in areas of strong product differentiation. In fiscal 2011, the VCSEL-based product lines contributed about 5% of Emcore's overall revenue.

The sale is also expected to simplify Emcore's operating structure, reduce fixed costs, and improve market focus. The firm says that its core competencies in compound semiconductor-based products and performance capabilities remain the cornerstones of its Fiber Optics business, addressing high-speed fiber-optic transmission for tele-



Emcore Connects Cable's AOC (active optical cable) product, available for 40Gbps and 52Gbps four-channel QDR and FDR data rates.

com, broadband and military & defense applications.

"The decision to sell the VCSEL-based product lines is strategic and market driven," says Emcore's CEO Dr Hong Hou. "Our product and technology portfolio is strongly aligned to support current and future requirements in tunable, coherent high-speed transmission systems and next-generation broadband architectures," he adds.

"The proceeds from the transaction significantly improve our balance sheet and the sale is expected to reduce the time to reaching profitability," Hou notes.

"Along with the improved operating model, the transaction will benefit our customers as we focus our investment in telecom, broadband and specialty photonics products to remain industry

Our product and technology portfolio is strongly aligned to support current and future requirements in tunable, coherent high-speed transmission systems and next-generation broadband architectures

leaders in those respective product lines in our fiber-optic business segment," he concludes.

SEDU says that the VCSEL is the preferred light source for data transmission in short-distance links, interconnects for the data center and local networks (LANs, SANs, etc). The VCSEL-based module products are designed to enable next-generation data interconnect capabilities that service the demands of providers and OEMs. Applications include rack-to-rack, ganged serial links, logic-logic data links, board-to-board and shelf-to-shelf configurations. The portfolio will also offer solutions for 10GbE, 40GbE, 100GbE parallel-optic modules and AOCs. Future developments will target consumer and automotive markets as well.

"SEDU is committed to developing the products necessary to meet the requirements of high-bandwidth, high-speed optical networks," comments SEDU's president & CEO John Wyatt. "By acquiring Emcore's next-generation VCSELs and parallel-optics products and technology, we will continue to advance high-performance computing applications."

SEDU plans to continue the VCSEL fab operations in Albuquerque and consolidate Emcore's Enterprise engineering team currently in Newark, CA to SEDU's nearby operations in San Jose. On or prior to the closing, SEDU will enter into several ancillary agreements with Emcore, including service agreements to ensure a smooth business transition.

The deal is expected to close shortly after securing regulatory approval by the Committee on Foreign Investment in the United States (CFIUS).

www.emcore.com

www.sei-device.com

Emcore's quarterly revenue falls 28% due to Thai flood

Fiber Optics recovery to drive rebound in March quarter

For fiscal first-quarter 2012 (to end-December 2011), Emcore of Albuquerque, NM, USA, which makes components, subsystems and systems for the fiber-optic and solar power markets, has reported revenue of \$37.5m, down 28% on \$52.1m both last quarter and a year ago.

Of total revenue, 51% came from the Photovoltaics segment (up from 41% last quarter). However, \$19.1m is still down 7% on \$20.3m a year ago and 10% on last quarter's \$21.2m.

Fiber Optics fell from 59% of total revenue to 49%: \$18.4m is down 40% on both last quarter (\$30.9m) and a year ago (\$31.8m). In October, flooding in Thailand caused main contract manufacturer Fabrinet Co Ltd to suspend operations at its facility (which supports half of Emcore's Fiber Optics revenue). Most of Emcore's process and test equipment (and inventory) was submerged, impacting its ability to meet demand for three major product lines: telecom products such as integrated tunable laser assemblies (ITLAs) and tunable XFP modules; cable TV lasers, components and transmitters; and legacy products.

Despite this, thanks to the firm's original tunable XFP manufacturing line in the San Francisco Bay Area, Emcore shipped \$1m from this product for the first time, after qualifying three more telecom customers (boosting design-wins to 10). Revenue for unaffected product lines – e.g. video transport and specialty photonics, fiber-to-the-home (FTTH) and active optical cable (AOC) products — grew 25% sequentially. In particular, Emcore shipped over 15,000 AOCs in its second quarter of product release, including the first commercial shipment of its 12x10Gb/s CXP AOC.

Due to the flood, gross margin fell further, from 24.3% a year ago and 19.2% last quarter to just 9.3%. PV margin of 22.7% is down from 33.3% a year ago but up from 21% last quarter (as manufacturing yield has been improving while new CPV

products ramp up, and the more profitable Space Photovoltaics business remains the vast majority of the solar product mix). However, Fiber Optics gross margin has fallen further, from 18.4% a year ago and 18% last quarter to -4.8%.

Lower Fiber Optics revenue due to the flood led to higher manufacturing overhead as a percentage of revenue. Manufacturing of some fiber optics-related components was moved to Emcore-owned facilities, involving higher labor costs etc. Instead of rebuilding all flood-damaged manufacturing lines, Emcore will realign its fiber-optics portfolio and focus on areas with technology differentiation and growth. Management identified \$0.9m of inventory on order related to manufacturing lines for legacy products that were destroyed by the flood and will not be replaced. Also, there was \$1.5m of additional expenses for excess and obsolete inventory. Together with other stock compensation charges, these cut gross margin by over 15 percentage points for the Fiber Optics segment, which otherwise would have been almost +10% rather than -4.8%.

Total flood-related loss was \$5.7m (\$3.9m for destroyed inventory and \$1.8m for damaged equipment). However, the firm also claimed damages and received proceeds of \$5m under its insurance policy relating to business interruption.

Otherwise, operating expenses were cut by \$1.9m from last quarter to \$14.5m, due mainly to cost-reductions put in place after the flood, including temporary salary reductions and rotating furloughs.

A loss of \$1m was recorded from the Suncore concentrated photovoltaic (CPV) component and system joint venture with San'an Optoelectronics in Xiamen, China.

Emcore's net loss was \$14.2m, level with last quarter but up on \$3.6m a year ago. Net cash provided by operating activities totaled \$20.8m, but this was due mainly to an rise in customer deposits of \$9.7m and a reduction in accounts receivable of \$9.4m. During the quarter, cash, cash equivalents, and restricted cash rose from \$16.1m to \$23.8m.

As of end-December, Photovoltaics order backlog was \$51.7m, up 19% on \$43.5m last quarter, aided by a large order from Suncore for terrestrial CPV cells. Since Emcore is reviewing its manufacturing capacity and customer commitments for the Fiber Optics business, it is not disclosing backlog for this segment (reporting will resume after manufacturing infrastructure is rebuilt).

"We have developed and implemented a solid plan to rebuild the impacted production lines at another location associated with our contractor manufacturer in Thailand as well as at our own manufacturing facility in China," says Emcore. "We expect the rebuild of our CATV production line [including the high-volume tunable XFP line] to be completed by the end of March 2012 and the rebuild of our telecom-related production line to be completed before the end of May. We are working closely with our customers on our manufacturing recovery plan to be aligned with their needs."

Due mainly to the partial recovery of Fiber Optics production capacity, for fiscal Q2/2012 (to end-March) Emcore expects revenue to rise to \$38-40m. Also, revenue from the tunable XFP product line should more than double to about \$2m (internal capacity in the Bay Area is about \$3m per quarter).

"Going into the June quarter, that's where you should start to see more of a ramp up in our Fiber Optics revenues at that point going forward, as we start to have our other lines up and running [at pre-flood levels by the end of the quarter]," notes chief financial officer Mark B. Weinswig.

Revenue from the tunable XFP product line should more than double to \$2m

Emcore-San'an joint venture Suncore opens factory

Suncore Photovoltaics Technology Co Ltd has completed its Phase-I construction and started production of concentrating photovoltaic (CPV) modules at its facility in the High-Tech Development Zone of Huainan City, Anhui Province, China (marked officially by a grand opening ceremony on 21 February).

Suncore was founded in July 2010 as a joint venture owned 40% by Emcore Corp of Albuquerque, NM, USA (which makes components, subsystems and systems for the fiber-optic and solar power markets) and 60% by San'an Optoelectronics Co Ltd of Xiamen, China (which designs and manufactures products including full-wavelength-range high-brightness LED chips and wafers, solar cells, and PIN photodiodes). The JV is targeted at the development, manufacture and distribution of CPV receivers, modules and systems for terrestrial solar power applications.

The JV broke ground to start construction of the new facility in Huainan in February 2011, as the first phase of its three-phase con-



Suncore's CPV system.

struction and business growth plan. With Phase I having now been completed, Suncore has an annual production capacity of 200MW CPV modules using a highly automated production line.

Suncore has begun production against its 50MW purchase order for an installation in Golmud, China (which, once completed, will be the world's largest CPV installation).

"Given the current macroeconomic environment for photovoltaics, we believe China is emerging as the most promising market for CPV solar power in the world," says Emcore's chief operating officer Christopher Larocca.

"Suncore's initial 50MW purchase

order is a testament to the demand for CPV in China, and we firmly believe that Suncore's cost model will allow Suncore to aggressively compete in the photovoltaic market there and around the world.

Emcore is very proud to be supplying the highest-efficiency terrestrial solar cells currently in production for this milestone project," he adds.

"With the strong support from San'an, Emcore, and the local regional government, Suncore completed the facility construction and commenced production at its new state-of-the-art manufacturing facility in one year," says Suncore's president & CEO Dr Charlie Wang. "Suncore has also made tremendous progress developing solar projects in China," he adds.

"Through close collaboration with our business partners, Suncore is well positioned to be the dominant CPV supplier in China for commercial and power utility applications," he reckons.

www.suncorepv.com

www.Sanan-e.com

www.emcore.com

Emcore enhances features of tunable XFP transceiver to provide flexibility to next-generation optical networks

Emcore has announced an enhanced feature set for its full-band tunable 10Gbps form-factor pluggable (TXFP) transceiver, including 40nm full-band support, a transmitter variable optical attenuator (VOA) and flexi-grid compliance. Based on Emcore's patented ClearLight fourth-generation external-cavity laser (ECL) platform, the TXFP transceiver is claimed to deliver the highest-quality optical signal, wavelength accuracy and transmission performance, along with best-in-class side-mode suppression ratio (SMSR).

Emcore says that its TXFP enables users to dramatically reduce size, power consumption, and operating expenses by replacing both legacy 300-pin tunable transponders and

fixed-wavelength DWDM XFP transceivers. Now with an expanded feature set, users have greater flexibility to empower the next-generation of optical networks, says the firm. The TXFP supports a full band of 40nm (100 x 50GHz channels), making it the most widely tunable transceiver on the market, it is claimed. In addition, it addresses the new International Telecommunications Union (ITU) flexi-grid standard, allowing users to tune onto any frequency grid and address any off-grid frequency.

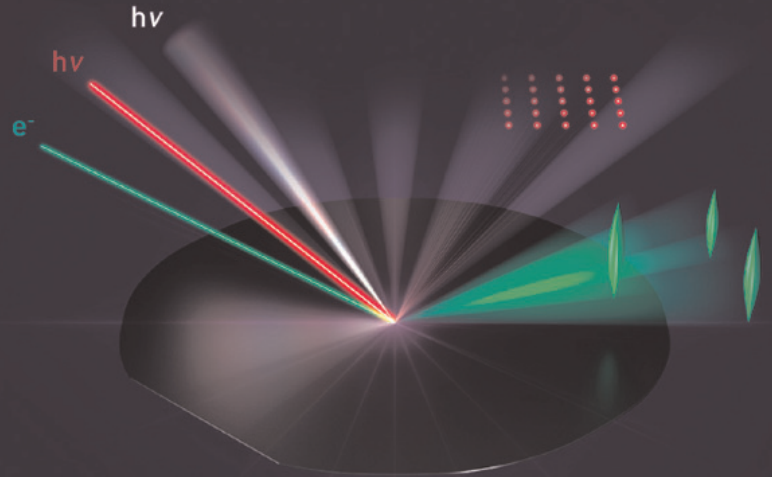
Emcore also plans to include an optional transmitter VOA that allows users to remove external attenuators, again increasing density while reducing overall system cost and complexity.

"The Emcore TXFP represents the leading-edge in metro and long-haul DWDM network flexibility by delivering the highest level of performance and tuning capability in the smallest available form-factor," claims Jaime Reloj, VP of business development. "By leveraging our ECL technology and in-house semiconductor manufacturing, we are able to offer our customers performance and features that no one else in the industry can match," he adds. "Customers are using the unique features of the Emcore TXFP — such as flexi-grid tuning and highest-available SMSR — to enable more flexible and cost-effective optical network architectures."

http://emcore.com/fiber_optics



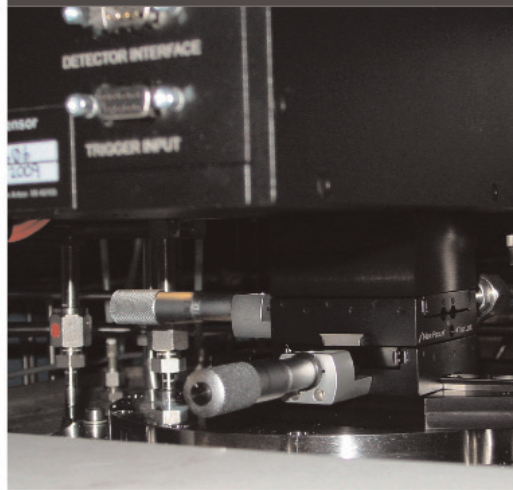
Control Your Process! Real-Time Process Monitoring for MOCVD, MBE, Sputtering, and Thin-Film PV Deposition



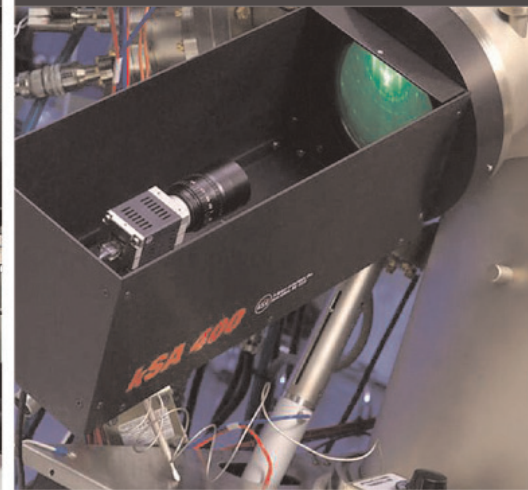
kSA BandiT Wafer Temperature



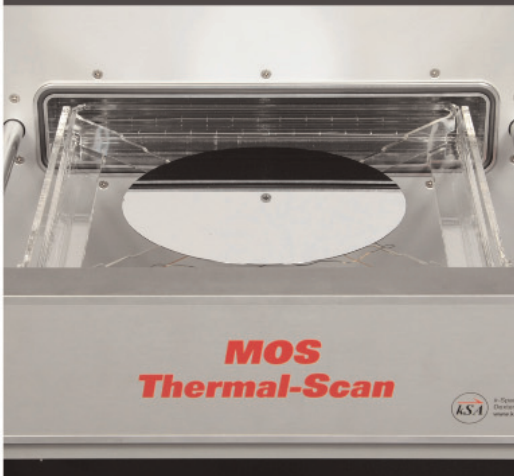
kSA MOS and kSA Mini-MOS
Thin-Film Stress



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



Soitec finalizes acquisition of Soitec Solar GmbH

Technology alliance with Fraunhofer ISE continuing with development of Smart Cell

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), has finalized its acquisition of 100% of Soitec Solar GmbH, which was spun off from the Fraunhofer Institute for Solar Energy Systems (ISE) of Freiburg, Germany in 2005 as Concentrix Solar GmbH. Soitec exercised its rights over the remaining shares of Soitec Solar in compliance with the terms of its acquisition agreement signed in December 2009.

Soitec says that the announcement validates its strategy in the solar power plant market, and confirms its trust in Soitec Solar's founders and teams, as well in its partners, who are fully associated with the firm's first successes in this new activity.

As part of their collaboration over the past two years in the context of

a technical alliance concerning the development of solar cells and CPV systems, Soitec and the Fraunhofer ISE are developing a new generation of photovoltaic cells. The new 'Smart Cell' is based on Soitec technologies that should enable CPV system efficiencies to be increased significantly beyond current capabilities, it is reckoned.

"Soitec Solar GmbH enables us to apply our materials engineering expertise to the development of high-performance photovoltaic systems at a competitive cost,"

says Soitec's president & CEO André-Jacques Auberton-Hervé. "Moreover, the synergies that we have in this field with our partners including Fraunhofer ISE and CEA-Leti are contributing to the rapid deployment of our innovations. These partnerships illustrate the advantages of public-private research collaboration to promote innovations as rapidly as possible by industrializing them," he adds.

"We are very satisfied with the strategic and technical opportunities resulting from our alliance with Soitec, especially thanks to the pooled competencies and technologies of our teams," says Concentrix Solar GmbH's CEO & founder Hansjoerg Lerchenmueller. "Soitec's ability to industrialize a disruptive technology and produce cost-competitive CPV systems has led to accelerated growth in our solar activities on an international scale," he concludes.

Soitec Solar GmbH enables us to apply our materials engineering expertise to the development of high-performance photovoltaic systems at a competitive cost

Soitec hires Dow Corning's Solar Division founder as executive VP of Solar Energy Division

Soitec has appointed Gaetan Borgers to as executive VP of its Solar Energy Division. With more than 20 years' experience in the industry with Dow Corning (including more than 10 years in charge of solar programs), Borgers joins Soitec to oversee the international expansion of its concentrator photovoltaic (CPV) activities.

Soitec says that CPV technology is currently the most efficient method of generating solar energy for the industrial solar power plant market in sunny regions of the world. To tap into that market potential, Borgers will be in charge of developing solar power plant projects in various target countries and overseeing Soitec's ramp up of production capacity to achieve the electricity price required by the



Gaetan Borgers. market. In addition, he will direct the development of related products and technologies, in particular the further development of the Smart Cell technology, which should enable CPV systems to achieve 40% efficiency.

"With the ramping up of our solar energy market activity, Soitec will benefit from new competencies that will bolster our international leadership strategy," says president & CEO André-Jacques Auberton-Hervé.

Prior to joining Soitec, Borgers

established Dow Corning's Solar Division in 2001. He then managed the sales, marketing and technical support activities until 2011, from the USA initially and then Japan. He oversaw the opening of a new manufacturing plant in Brazil and coordinated the development of partnerships with prominent technology institutes such as Germany's Fraunhofer Institute for Solar Energy Systems (ISE). Before that, he held various management posts with Dow Corning in production, purchasing, quality and customer service. Borgers also has a master's degree in chemical process engineering and an MBA from Université Catholique de Louvain in Belgium.

www.soitec.com

Australia's Silex selects IQE as epi partner

III-V cells to be developed on low-cost, large-area Ge-on-Si substrates

Epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK has been selected as a key concentrated photovoltaic (CPV) wafer supplier by Australian CPV firm Silex Systems Ltd as part of a \$2m program to develop high-efficiency multi-junction solar cells on low-cost large-area silicon substrates.

Silex received a \$2m grant from the Australian Solar Institute (ASI, which was founded by the government in 2009) to support its development of solar cell technology, which has the potential to reduce CPV energy production costs by 20%, it is reckoned.

Conducted by Silex's subsidiary Solar Systems, the program aims to develop, fabricate and test novel next-generation multi-junction solar cells used in the evolving utility-scale CPV solar power industry.

The key differentiator is the development of a new virtual 'germanium' wafer-based substrate where a thin

layer of Ge is deposited on a silicon wafer. This should reduce the cost and potentially improve the efficiency of multi-junction cells in CPV applications. The new substrates and resultant CPV cell structures will be fully characterized and analysed in the lab and then tested in the field in on-sun equipment.

Solar Systems will supplement the \$2m grant by providing about \$3m in project funding, with \$2m of in-kind support and \$1m in cash contributions over the three-year project.

Project partner and Silex subsidiary Translucent Inc of Palo Alto, CA, USA, which provides rare-earth-oxide (REO) engineered silicon substrates for low-cost epitaxy, will supply large-area silicon substrate technology for the project, allowing commercialization to be fast tracked.

"Silex Systems' selection of IQE as a partner for this program clearly demonstrates that we are recognized

as a key global player in CPV wafer products for advanced, high-efficiency solar energy generation," claims IQE's CPV technology director Dr Andrew Johnson. "This program builds on our advanced capabilities in germanium-on-silicon for CPV applications that we launched in 2010 and complements the range of CPV technologies in which we are active."

Other key CPV program partners include Boeing-owned solar cell maker Spectrolab Inc of Sylmar, CA, USA and solar cell maker Emcore of Albuquerque, NM, USA for multi-junction cell production facilities.

The partnerships will allow volume production of solar cells, which will be incorporated into Solar Systems' dense array system to characterize the performance of the new CPV modules at the Bridgewater Test Facility in central Victoria, Australia.

www.iqep.com

www.silex.com.au

Southwest to commercialize dense array CPV module with help of MaxQ's cold-plate liquid cooling

To drive commercialization of its concentrating photovoltaic (CPV) solar power technology, Southwest Solar Technologies Inc of Phoenix, AZ, USA has signed a joint development agreement with MaxQ Power Conversion LLC, an affiliate of MaxQ Technology LLC of Tempe, AZ (which provides solutions for the power electronics industry).

Southwest Solar's CPV module combines currently available high-efficiency multi-junction solar cells with what are reckoned to be innovative approaches in concentrator optics, power electronics, and efficient manufacturing. The design incorporates a unique solar flux management capability that enables non-uniform light intensity to be used, enabling use with either dish or heliostat collectors designed for concentrated solar power (CSP).

The two firms will cooperate to develop and manufacture Southwest Solar's patent-pending dense array CPV module, which packs numerous multi-junction photovoltaic cells into a compact, high-concentration solar power generation module where a solar concentration ratio of 1200 times is achieved. Extremely high energy flows from this concentration can cause heating that can reduce solar cell performance. The thermal intensity is managed via a closed-loop liquid cooling system in the form of MaxQ's cold-plate technology (currently used in high-power electronic conversion in the electric vehicle and inverter industries).

Unique internal fin construction and manufacturing methods provide efficient cooling for the solar cells. The cold plates are manufactured using the friction stir welding (FSW)

process and a patent-pending design that allows MaxQ to incorporate unique structures with high thermal performance, low pressure drops and very high reliability. Minimal material is used to achieve light weight at low cost.

Southwest says the CPV development is part of its integrated development plan centered on its solar dish concentrator (the largest commercial solar dish in North America). The firm previously announced successful proof-of-concept testing of its integrated Dish concentrator and air-based open-cycle turbine to produce electricity. The firm's product development and testing are conducted at its headquarters and operations facility at Southwest Solar Research Park.

www.swsolartech.com

www.maxqtechnology.com

First Solar's revenue falls 34% in fourth-quarter 2011, limiting full-year growth to 8%

2012 growth forecast cut from 37.5% to 30%

For full-year 2011, 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, has reported net sales of \$2.76bn, up about 8% on 2010's \$2.56bn.

First Solar had previously cut its guidance for 2011 sales several times, from \$3.7–3.9bn (given in December 2010) to \$3.7–3.8bn (in late February) then \$3.6–3.7bn (in August), \$3.0–3.3bn (at the end of October), and finally \$2.8–2.9bn (in mid-December).

On a non-GAAP basis, net income has fallen from \$695m (\$8.04 per fully diluted share) in 2010 to \$523.6m (\$6.01 per fully diluted share).

Most recently, for fourth-quarter 2011, net sales were \$660m, up 8% on \$610m a year ago but down 34% on \$1006m in Q3/2011, due mainly to the timing of revenue recognition in the systems business and lower volume for module-only sales. Net income was \$110m (\$1.26 per fully diluted share), down from \$196.5m (\$2.25 per diluted share) in Q3 and \$163.1m (\$1.88 per fully diluted share)

a year ago. During the quarter, cash and marketable securities fell from \$795m to \$788m.

"First Solar's performance in the quarter was impacted by an aggressive competitive environment, an uncertain regulatory environment, warranty-related charges, and restructuring costs incurred to help position our business for the future," says chairman & interim CEO Mike Ahearn.

"Despite these headwinds, we continue to make strides reducing manufacturing costs, increasing module efficiency, and successfully building out our captive project pipeline," he adds. "These improvements, combined with our recent restructuring and strategic repositioning, enhance our competitive position in a very challenging environment."

First Solar set record solar energy conversion efficiencies for CdTe-based solar cell and module of 17.3% and 13.4%, respectively, as certified by US Department of Energy's National Renewable Energy Labs (NREL). (This January, First Solar raised its record module efficiency record further, to 14.4%, using commercial-scale equipment and materials.) Compared with

fourth-quarter 2010, the firm also increased its average module efficiency by 0.6 percentage points to 12.2%, and reduced its average module manufacturing cost by \$0.02 per watt to \$0.73 per watt.

As well as announcing or completing the sale of four of the world's largest solar projects under construction (Agua Caliente, Desert Sunlight, Antelope Valley Solar Ranch One, and Topaz), and this January energizing the first 30MW block of the Agua Caliente project, during 2011 First Solar added about 650MW AC of new projects to its project pipeline (which grew to 2.7GW AC). Cumulative production surpassed 5GW (enough to provide electricity for about 2.5 million homes and displace 3.3 million metric tons of CO₂ annually).

Nevertheless, First Solar has lowered its 2012 net sales guidance (given in mid-December) from \$3.7–4bn (up 37.5% on 2011) to \$3.5–3.8bn (up 30% on 2011). It has also cut its guidance for operating cash flow from \$0.9–1.1bn to \$0.8–\$0.9bn. However, the firm has reiterated its guidance for earnings per fully diluted share of \$3.75–4.25 (excluding any impairment and restructuring charges).

New chief commercial officer to speed entry into emerging markets

First Solar has hired James Hughes as chief commercial officer.

In this newly created role designed to accelerate First Solar's entry into emerging markets, Hughes will have comprehensive leadership responsibility for global business development and sales; project development; engineering, procurement and construction (EPC); product management; and international public affairs and communications.

Reporting to Hughes will be Jim Brown, executive VP of global

business development; Maja Wesels, executive VP of global public affairs; Jim Lamon, senior VP of EPC and operations & maintenance; Tom Kuster, VP of product management & customer service; and Ted Meyer, VP of global corporate communications.

"Jim is extraordinarily prepared to help First Solar open new markets and reach revenue goals," believes chairman & interim CEO Mike Ahearn. "We will benefit greatly from his diverse and extensive global and operational

experience in the energy sector."

Most recently, Hughes was CEO & director of AEI, which owned and operated power distribution, power generation, natural gas transportation and services, and natural gas distribution businesses in emerging markets worldwide. Previously, he was president & chief operating officer for Prisma Energy (which was formed out of former Enron interests in international electric and natural gas utilities).

www.firstsolar.com

First Solar to build 26MW Avra Valley PV project for NRG CdTe modules to be mounted on First Solar's single-axis trackers

Power generation firm NRG Energy Inc of Princeton, NJ, USA has contracted First Solar Inc of Tempe, AZ, USA to construct its 26MW (AC) Avra Valley solar project near Tucson, AZ. Electricity from Avra Valley will be sold to Tucson Electric Power under a 20-year power purchase agreement.

The project will use modules mounted on First Solar's single-axis tracker systems, which rotate the

modules to follow the sun throughout the day. The tracker system extends the peak energy production period, providing more electricity in the afternoon, when energy demand is greatest.

"NRG and First Solar have built a very strong working relationship, starting with our first 21MW project in Blythe, California, to our most recently completed 20MW Roadrunner solar generating station in

New Mexico," says James Kelly, director of development for subsidiary NRG Solar LLC. "We look forward to working with First Solar on the Avra Valley project that, when completed, will help Arizona meet its renewable energy goals."

Project construction (which will create an estimated 200 jobs) is expected to begin in March and be completed by the end of 2012.

www.nrgenergy.com

NextEra completes acquisition of 40MW Ontario solar projects

NextEra Energy Resources LLC (the competitive-energy subsidiary of NextEra Energy Inc of Juno Beach, FL, USA, and the largest generator in North America of renewable energy from the wind and sun) has completed its acquisition of two solar photovoltaic projects totaling 40MW (AC) in Ontario, Canada from First Solar.

Located in St. Clair, the projects were designed, developed and constructed by First Solar, and began commercial operation in February. The two projects are owned and operated by subsidiaries of NextEra Energy Resources' Canadian subsidiary

NextEra Energy Canada ULC, and provide enough power to serve about 6440 homes. Each year the solar generation is expected to help avoid nearly 45,000 tons of carbon dioxide emission (equivalent to removing nearly 8600 cars from the road every year for the life of the projects). The power is being sold to the Ontario Power Authority via long-term contracts under its Renewable Energy Standard Offer Program (RESOP).

"This acquisition is consistent with our strategy to add fully contracted renewable assets to our portfolio," says NextEra Energy Resources' senior VP of develop-

ment Mike O'Sullivan. "Solar power will help promote a clean-energy economy in Ontario and reduce its dependence on fossil fuels," he adds.

"The completion of the St. Clair projects helps Ontario meet its economic and renewable energy goals," comments Peter Carrie, First Solar's VP for business development, Canada. "The projects employed 800 construction workers, including local First Nations workers, and are the first large-scale solar facilities permitted under the Province's Renewable Energy Approval process."

www.NextEraEnergyResources.com

First Solar announces 20MW Maryland Solar Farm project

First Solar Inc of Tempe, AZ, USA has announced its 100% stake in Maryland Solar Farm, a 20MW (AC) photovoltaic (PV) solar power project in Hagerstown, MD.

The project is expected to start construction in second-quarter 2012 and be completed in fourth-quarter 2012 (providing 125 construction jobs).

Using First Solar's cadmium telluride (CdTe) modules and with a contract to sell electricity and renewable energy credits to FirstEnergy Solutions, the project will generate

enough renewable energy to power about 2700 average Maryland homes, displacing about 23,000 metric tons of CO₂ annually (equivalent to taking 4400 cars off the road each year).

"First Solar is pleased to continue its work in Maryland to help the state meet its renewable energy goals," comments Frank De Rosa, senior VP for business development — the Americas.

www.firstsolar.com

14 March 2012

David dbrady@firstsolar.com

BW EUROPE to be distributor in Italy

First Solar has appointed BW EUROPE S.p.A. of Rome, Italy to sell its solar modules in Italy.

BW EUROPE not only distributes solar module sales in Italy but also provides building-integrated photovoltaics (BIPV) and PV systems integration.

"BW EUROPE is a strong distribution partner for First Solar in Italy thanks to its experience with thin-film PV and its reputation for serving aesthetically demanding customers," comments Alfredo di Stefano, Italy account manager for First Solar.

www.bweurope.eu

IN BRIEF

DOE grants \$300,000 for CdTe PV research

Building on his funded work of last year (when he attracted more than \$1m in grants for photovoltaics research), Sylvain Marsillac, associate professor of electrical and computer engineering at Old Dominion University (ODU) in Virginia, recently received a \$300,000 grant from the US Department of Energy (DOE).

The new grant, awarded through the DOE's Foundational Program to Advance Cell Efficiency (F-PACE), involves research being performed on improving the efficiency of solar cells made from cadmium telluride (CdTe).

The material is deposited in thin-film form using high-vacuum deposition. Marsillac says that the latest DOE-funded research will develop ways to enhance the CdTe back-contacts by specifically looking at new materials based on chalcopyrite and delafossite structures. "Better connection means better voltage, which means better efficiency for the PV cells," he adds.

Marsillac is partnering on the grant with two long-time alternative energy colleagues. One is at the University of Illinois (the lead institution on the grant). The other is at the University of Toledo (his previous institution, where Marsillac and his colleagues attracted more than \$20m in funding for PV research).

Marsillac says that each of the three researchers involved in the latest grant has a different sub-speciality in PV research. Marsillac's involves fabrication of the solar cells themselves (which he will be able to do more effectively at ODU in the soon-to-be-completed PV cleanroom being rebuilt in Kaufman Hall, home of the Batten College of Engineering and Technology).

www.odu.edu

Abound to accelerate production of 12.5–13%-efficient CdTe PV modules by end-2012**Suspension of 10.5%-efficient module production leads to 180 lay-offs**

Cadmium telluride (CdTe) thin-film photovoltaic (PV) module maker Abound Solar of Loveland, CO, USA says that it will cease production of its first-generation solar module in a strategic decision to accelerate the manufacturing process and equipment changes needed for the production launch of its next-generation high-efficiency module.

Compared with 10.5% for Abound's current product, its new 'AB2' module has energy conversion efficiency of 12.5% (and output of 85W), as verified by the US Department of Energy's National Renewable Energy Laboratory (NREL). Several-hundred AB2 modules were produced in early January on commercial production equipment.

The suspension of first-generation module production will result in the temporary reduction of about 180 permanent jobs from the firm's Colorado facilities. The firm determined that continuing production of its current modules was not favorable to accelerating development of its next-generation, higher-efficiency product. "Given current market conditions, Abound decided that now was the right time to make this change," it adds.

"We will continue to support all customers and partners using our current-generation product, and will continue to honor all warranties and our industry-leading, escrow-funded recycling program," says Abound. "We will be working with our customers and channel partners to install field trials of our new product and specify it into future solar projects."

After manufacturing equipment has been modified and performance tested, Abound expects to produce batches of modules this summer for customer field trials,

and to re-scale mass production in 6–9 months, resuming mass production with a 12.5–13% efficient module by the end of 2012.

"While this is a difficult move with regards to temporarily reducing our workforce, we know that accelerating the introduction of our next-generation module will bring significant benefits to our customers and allow us to create even more jobs in the future," says president & CEO Craig Witsoe. "Current market conditions are challenging for all US solar manufacturers, but the long-term winners will be manufacturers of the lowest-cost-per-watt, most reliable systems," he adds. "By focusing our resources to accelerate scale-up of our next-generation high-efficiency technology, we will sustainably lower total system costs for our customers, increase our own profitability, and grow US jobs and energy security."

In late 2010, Abound was approved for a loan guarantee of up to \$400m under the Department of Energy's Loan Guarantee Program. Abound says that it has been working closely with the DOE,

The long-term winners will be manufacturers of the lowest-cost-per-watt, most reliable systems

which has led to the release of about \$70m in loans under the guarantee, and that the DOE continues to be supportive of Abound.

The firm adds that it still has long-term plans for a manufacturing plant in Tipton, IN, once production of its next-generation modules begins. It anticipates having an update on a Tipton facility build-out in mid-2013.

www.abound.com

PVthin association formed for chalcogenide-based firms

The international, not-for-profit coalition PVthin has been formed in Brussels to represent firms active in the thin-film photovoltaic (PV) solar industry supply chain manufacturing and marketing products based on chalcogenide compounds, i.e. sulfides, selenides and tellurides (rather than oxides or amorphous silicon) such as cadmium telluride (CdTe) and copper indium gallium diselenide (CIGS).

Founding members include CdTe solar cell makers Abound Solar, Arendi, Calyxo, First Solar (the world's biggest thin-film PV firm) and GE Energy (which makes CIGS PV panels, but said last October that it is switching to CdTe at a new 400MW plant being constructed in Aurora, CO). Another member is materials maker 5N Plus, which supplies not only CdTe but also cadmium sulfide (CdS, a starter material for making CIGS). Any firm from the chalcogenide thin-film PV value chain may become a member, says PVthin.

PVthin's aim is to strengthen global energy security and to help create sustainable energy infrastructures by promoting the social, economic and environmental benefits of thin-film solar photovoltaic technologies. Thin-film PV technologies now make up about 18% of global PV sales (up from "almost nothing" a decade ago), it is reckoned.

"PVthin was created to champion the role of thin-film PV and communicate the unique technological, environmental and socio-economic aspects of this cost-effective and environmentally friendly solar technology," says PVthin's president Andreas Wade, who is director of sustainable development at First Solar and also chair of the EPIA's working group on sustainable development. "PVthin complements the excellent work of umbrella associations such as EPIA (European Photovoltaic Industry Association) in Europe, SEIA (Solar Energy Industries Association) in the USA,

and BSW in Germany and does not seek to create a rival organisation."

Compared with conventional silicon PV, thin-film PV can make more efficient use of raw materials and energy and results in both lower costs and smaller carbon footprints. Also, the new association notes that the technology lends itself to relatively simple mechanical and chemical recycling, enabling the recovery of valuable raw materials when modules need to be replaced — often at no additional cost. PVthin aims to strongly promote efficient and energy-saving production, raw material use and PV recycling and recovery programs and technologies, in cooperation with other organizations supporting this objective. Commercial-scale recycling operations are already capable of recovering up to 95% of the semiconductor material and up to 90% of the glass for use in new solar panels and other glass products.

www.pvthin.org

Calyxo reaches CdTe PV module efficiency of 13.4%

Calyxo GmbH of Bitterfeld/Wolfen-Thalheim, Germany (founded by Q-Cells SE in 2005) says that its cadmium telluride (CdTe)-based thin-film photovoltaic module has reached an output of 88.7W at an efficiency of 13.4% (measured on aperture area), as confirmed by testing body SGS Germany.

With the production of the 13.4%-efficient module, development of the next generation of modules is already underway. Calyxo's standard module is 60cm x 120cm, but the firm's patented atmospheric continuous manufacturing process can produce modules as wide as 120cm with any length desired, yielding greater flexibility and lower costs.

Calyxo has also boosted the efficiency of its existing CX3-series production module to an average of 11.9% (based on aperture area).

"The Calyxo development team rapidly reached another milestone



Bauer (left) and Holzapfel (right)

on its efficiency roadmap, aiming for even higher efficiencies in the near future," says chief technology officer Michael Bauer. "High module efficiencies, in combination with our low-cost atmospheric deposition technology, are decisive factors for cost-competitive solar energy," he believes.

At its plant in Bitterfeld/Wolfen-Thalheim (Saxony-Anhalt's 'Solar Valley'), which has been in commercial production since 2009, Calyxo has over 150 staff operating a production line with annual capacity of 25MWp of modules. Based on the latest efficiency results, technology provider Solar Fields LLC of Toledo, OH, USA (Calyxo's owner since it split from Q-Cells in February 2011) has decided to provide more funding to the firm, specifically investing in a second production line with a capacity of about 120MWp (to start production in 2012).

"With the financial contribution of our long-term shareholder Solar Fields, we will reduce our costs by the end of this year to less than €0.60 per Wp, which corresponds to a cost reduction of nearly 30% from the recent level," says CEO Florian Holzapfel.

www.calyxo.com

SoloPower sets record 13.4% aperture efficiency for flexible CIGS solar panels

Up from 11.2% via new processes on roll-to-roll production line

SoloPower Inc of San Jose, CA, USA says its next-generation thin-film copper indium gallium diselenide (CIGS) solar panel has achieved an aperture area efficiency of 13.4% — claimed to be a record for flexible CIGS-based modules — as measured by the US National Renewable Energy Laboratory (NREL).

“The cells were made in SoloPower’s San Jose manufacturing facility, so we know we have the systems in place to deliver

high-efficiency, lightweight, flexible modules to our customers around the globe,” says CEO Tim Harris.

The firm produces CIGS-based photovoltaic cells which are then packaged into modules that, it is claimed, require less balance-of-system hardware and are easier to install than traditional solar panels.

“SoloPower’s achievement of an aperture efficiency of 13.4% for our flexible CIGS modules is a result of efficiency improvement projects that

have been in place during the past two years,” says chief technology officer Dr Mustafa Pinarbasi. “We were the first company to certify flexible CIGS modules to UL 1703 and IEC standards (61646 & 61730) in 2010,” he adds. “We have improved the efficiency from 11.2% to 13.4% with new processes implemented in our roll-to-roll [electro-deposition] production line and have a strong pipeline of improvements yet to come this year.”

Engineers & technicians sought for 400MW-capacity HQ in Oregon

SoloPower is seeking engineers and technicians for its high volume manufacturing headquarters in Portland, OR, which will begin commercial production this year. The facilities should ultimately have a capacity of 400MW and employ 450 people, strengthening its ability to provide modules for

its growing global customer base.

The private-sector job growth “would not have been possible without the visionary support we’ve received from the State of Oregon, the Oregon Department of Energy and the City of Portland, as well as the US Department of Energy [via a \$197m loan guarantee received

last August],” says CEO Tim Harris. “A big reason SoloPower chose to build our new manufacturing facility in Oregon was because of the highly skilled work force, and we look forward to drawing on that local talent as our facility comes online,” he adds.

www.solopower.com

SoloPower names General Wesley K. Clark to board

Retired US General Wesley K. Clark, former NATO Supreme Allied Commander, Europe and a former US Presidential candidate, has joined SoloPower’s board as an independent director. On 19 March, Clark also provided the keynote address at PV America 2012 West in San Jose, relating world events to the role of solar energy, energy scarcity and growing environmental challenges.

“His insights, guidance and perspective will be a valuable addition to our company as we work to make solar energy a major power source for the world’s commercial and industrial buildings,” says CEO Tim Harris. “As a global leader and alternative energy champion, General Clark is a perfect fit for our dedicated board, which provides critical leadership, advice and support to the SoloPower team,” he adds.

“I look for energy solutions that help to address the energy and environmental challenges we face as a global community, which is what SoloPower’s lightweight, flexible PV panels do by maximizing efficiency while keeping total installed costs low,” says Clark.

“With growth capital in place and strong demand from the USA, Japan, South Korea and Italy, among other countries, I hope to help support SoloPower’s continued global expansion,” he adds.

Clark joins SoloPower’s board following the announcement last week that its next-generation panel has achieved an aperture-area efficiency of 13.4%, claimed to be a record for flexible CIGS-based modules. The firm is also in the midst of constructing and hiring for its high-volume manufacturing facility in Portland, OR, which will

begin commercial production later this year and are ultimately expected to have an annual capacity of 400MW, employing 450 staff.

In 38 years of service in the US Army, Clark rose to the rank of four-star general as NATO’s Supreme Allied Commander, Europe. Since retiring from the military in 2000, he has worked as an investment banker, alternative energy leader, author, cable network TV military analyst and businessman. In September 2003, he ran as a Democratic candidate for President of the United States. He returned to the private sector in February 2004.

Clark has chaired several public and private firms. He was also a member of the Clinton Global Initiative’s Energy & Climate Change Advisory Board and ACORE’s Advisory Board.

www.solopower.com

Solar Frontier sets record thin-film CIS efficiency of 17.8% 30cm x 30cm submodule aperture-area efficiency exceeds 17.2% record

In joint research with Japan's New Energy and Industrial Technology Development Organization (NEDO), Tokyo-based Solar Frontier (a subsidiary of Japanese energy business Showa Shell Sekiyu K.K.) has achieved record efficiency for thin-film copper indium selenium (CIS) photovoltaic technology

The aperture-area efficiency of 17.8% (for a 30cm x 30cm CIS submodule) surpasses the previous record of 17.2%, also set by Solar Frontier (in March 2011).

The new record was accomplished at Atsugi Research Center (ARC), Solar Frontier's dedicated research laboratory in Japan, which is described as the cornerstone of the firm's integrated research and production framework.

The company says that, after a series of deals and production milestones unveiled in the past few months, the latest efficiency record

underlines its fundamental capability in R&D, with a focus on practical commercial applications.

"This efficiency is on a fully integrated submodule, which our laboratory produces with processes very similar to what is in place in our factories at commercial production scale," notes chief technology officer Satoru Kuriyagawa. "Even higher efficiencies can be achieved by using a device with a very small surface area, but the reason we prefer to focus on the submodule level is that the path to commercial production is more practical... We are on track to achieve the higher module efficiencies we are targeting in our commercial production efficiency roadmap," he adds.

ARC's achievements include pioneering work in the zinc oxide buffer compound that eliminates the need for cadmium, says senior VP Atsuhiko Hirano. "The work

done here is the foundation on which our products are able to achieve more kilowatt hours under actual operating conditions, meeting the needs of residential, commercial and utility customers worldwide," he adds.

Solar Frontier's CIS modules are manufactured at its Kunitomi plant, which started full commercial operations last year. The technical advances made at ARC are applied to mass production through Solar Frontier's integrated research and production framework, which includes a pilot plant equipped with the machines on which the gigawatt-scale Kunitomi plant's machinery is based.

The Kunitomi plant recently produced a champion module with aperture efficiency of 14.5% (13.38% module efficiency), achieving a 164W rating.

www.solar-frontier.com

Solar Frontier and Belectric form PV CISTems joint venture

Germany-based Belectric — the world's largest solar engineering, procurement & construction (EPC) firm — and Solar Frontier (the largest manufacturer of CIS thin-film PV modules) have formed the joint venture PV CISTems GmbH in Gruenwald near Munich, Germany to develop, build and sell both ground- and roof-mounted power plants. By combining Belectric's EPC and project development experience with Solar Frontier's panel expertise, PV CISTems aims to offer worldwide turnkey solutions for solar power generation.

PV CISTems is the first operating company to result from a global framework agreement to establish a deeper working relationship between Belectric and Solar Frontier as the two strive to continue providing affordable and grid-stabilizing solar energy via lower systems and maintenance costs.

PV CISTems will operate in Germany, but future PV CISTems operating companies in other countries are expected to be established in response to local market needs and in accordance with local regulations.

Belectric and Solar Frontier are building on and accelerating the model of development and deployment created by the two firms in previous projects. "Our successful projects with Solar Frontier, ranging from ground-mounted power plants in Bessan, France, and Wildflecken, Germany, to the world's largest PV system on a car park at the new Saudi Aramco headquarters, Saudi Arabia, have convinced Belectric to take this next step," says Belectric's chief scientific officer Martin Zembsch. "The new company will strengthen our approach to new projects with respect to total power generation solutions while accelerating our competitive response and delivery capa-

bility," adds CEO Bernhard Beck.

The new JV also benefits from synergies in market coverage, reckons Solar Frontier Europe's managing director Wolfgang Lange, who also Belectric cites entrepreneurial spirit.

"With more than 700MW installed since 2010, from residential to utility scale, in a wide range of climates, configurations, and technologies, Belectric's confidence in Solar Frontier confirms the strong performance of our CIS modules within energy solutions," says Solar Frontier director, senior VP, Atsuhiko Hirano.

The JV's management board will have equal representation from both parent firms, consisting of Bernhard Beck, Martin Zembsch, Atsuhiko Hirano and Wolfgang Lange. The formation of the JV is subject to cartel approval.

www.Belectric.com

MiaSolé raises a further \$55m from VC investors

Funding to allow manufacturing and efficiency improvement while firm seeks strategic partner

MiaSolé of Santa Clara, CA, USA, which was founded in 2001 to make copper indium gallium diselenide (CIGS) thin-film photovoltaic panels, has raised \$55m in funding from existing investors, which include VantagePoint Capital Partners, Kleiner Perkins Caufield & Byers, Bessemer Venture Partners, Firelake Capital Management and Passport Capital.

"This funding comes at a time when the company has begun production of 14% modules with the industry's lowest capex per watt, which is now under 50 cents [better than that of cadmium telluride thin-film panel maker First Solar as well as crystalline silicon panel makers]," claims CEO John Carrington (formerly executive VP of global marketing & business development at First Solar until last November). MiaSolé has increased its panel efficiency by more than 30% from 2011 to 2012. "MiaSolé's ability to deliver 14% in production with demonstrated capability to achieve 17% [from a champion cell, announced in early February] further emphasizes the progress we are continuously making against our roadmap," adds Carrington.

During 2011, MiaSolé's scaled up the annual production capacity of its existing factory from 50MW to 150MW. To date, the firm has installed more than 55MW of modules in projects across North America, Europe and Asia. "This additional investment will allow us to take the company to the next level, and we are focused on aggressively building the commercial side of our business with both our traditional glass-on-glass and flexible products," he adds. "We are now focused on commercial performance: our investors have responded to that." MiaSolé says that its unique technology is also being applied to a high-efficiency flexible

This additional investment will allow us to take the company to the next level, and we are focused on aggressively building the commercial side of our business with both our traditional glass-on-glass and flexible products

rolled roof-top product that will address the fast-growing commercial and residential markets.

"MiaSolé is entering into an important time in its history," says Stephan Dolezalek, managing director at Vantage Point Capital Partners. "It has the right strategy, the right technology and the right team to deliver a new benchmark in solar for cost, performance and capital efficiency, with the enormous benefit of being able to compete in both the traditional glass and flexible panel markets," he adds.

MiaSolé has raised about \$400–500m in venture capital funding since 2004. While the latest \$55m funding will allow it to keep improving its technology and executing on its efficiency roadmap to cut cost per Watt (as well as selling and shipping its existing manufacturing capacity), the firm is said to need \$100–300m to scale up its production and expand sales globally. Last December Carrington hence declared the aim to seek one or more strategic partners that would fund MiaSolé's further expansion of production as well as marketing and sales.

www.miasole.com

CIGS PV firm MiaSolé appoints director sales & marketing EMEA

MiaSolé of Santa Clara, CA, USA has appointed Michael Povlin as director sales & marketing EMEA (Europe, the Middle East & Africa). The firm says that the appointment emphasizes its continued strategy to expand its business globally and to execute on strategic, international partnerships.

Povlin has extensive knowledge of the solar and technology industries, with more than 20 years of international management experience at high-tech companies.

He also has proven experience in market development and sales strategies in Germany and throughout EMEA, having previously been director of sales and marketing EMEA at cadmium telluride PV firm Abound Solar. Prior to joining Abound, he held management positions at Integrated Device Technology, Tensilicia and Intel.

"MiaSolé's 14% efficiency solar panels are the best thin-film solution for European free-field and rooftop applications, and Michael's appoint-

ment underscores our commitment to the European market," claims Rich Hossfeld, VP of sales & business development. "Michael's experience will be integral in further driving the growth of our company as well as enhancing the value and service we offer our customers."

In February, MiaSolé said it had achieved 14% efficiency for its thin-film PV panels in production, representing a year-on-year rise in efficiency of over 30%.

www.MiaSole.com

TSMC Solar receives UL, IEC and ISO 9001 certifications Silicon foundry's subsidiary enters production, for shipments in April

TSMC Solar Ltd, which was founded in May 2009 as a subsidiary of the world's biggest silicon wafer foundry Taiwan Semiconductor Manufacturing Co Inc (TSMC), has received certification from both Underwriters Laboratories (UL) and the International Electrotechnical Commission (IEC) for a wide range of its TS CIGS (copper indium gallium diselenide) series photovoltaic (PV) modules. Modules with nominal power of up to 130W are now listed on the California Energy Commission's (CEC) list of compliant PV modules.

"UL and IEC product certifications open the majority of the world's solar markets to TSMC Solar products," says TSMC Solar's president Ying-Chen Chao. "We are also making rapid progress in acquiring the individual market and special-purpose certifications required to compete in solar markets worldwide," he adds.



TSMC Solar's manufacturing facility in Taichung.

TS CIGS series modules entered production earlier in March at TSMC Solar's highly automated manufacturing facility in Taichung. Demonstrating its commitment to best practices in quality and manufacturing, the firm has received ISO 9001 quality management system certification. Customer shipments are due to begin in April.

The milestones have been achieved less than four months after completing tool move-in. "TSMC Solar is pleased to have third-party verification of its ability to leverage its parent company's quarter-century heritage of delivering technology innovation, quality and manufacturing excellence," comments Chao.

www.tsmc-solar.com

Stion's PV modules from new Mississippi factory receive UL and IEC certifications Commercial shipments to start in March

Stion Corp of San Jose, CA, USA, which makes nanostructure-based CIGSSe (copper indium gallium sulphur-diselenide) thin-film photovoltaic panels, has received both Underwriters' Laboratories (UL) and International Electrotechnical Commissions (IEC) certifications to ship modules produced at its factory in Hattiesburg, MS.

Stion modules with nominal power of up to 140W are now available, with commercial shipments from the factory due to start later this month, less than one year after starting its construction. The first phase of the 500MW factory has 100MW of annual production capacity (equivalent to about 25,000 residential solar electric systems).

The firm says that its modules have a robust, simple monolithic

circuit design, and are manufactured using proven industry-standard production tools. They are specifically designed for use in all major market segments (residential, commercial, government/municipal and utility). The modules have a convenient 65cm x 165cm form factor that enables streamlined installation, it is claimed. The PTC/STC ratio (a measure of the module's field performance versus standard test conditions) is higher than those for 95% of the products listed for use by the California Solar Initiative, the firm adds.

Stion will continue expansion of both its Hattiesburg factory and its San Jose headquarters. As part of its \$130m funding round last December, Stion is establishing a Stion Korea subsidiary with strate-

gic partner AVACO of Daegu, Korea (which makes vacuum-based thin-film coating equipment for flat-panel display manufacturing) to build a factory that will help to serve the Asian and European markets.

"Early in 2011, the Mississippi Development Authority was pleased to work with Stion officials to announce the company's new manufacturing location in Hattiesburg, Mississippi, and it has been gratifying to see how quickly production has gotten under way at the plant," says Jim Barksdale, interim executive director of the Mississippi Development Authority.

Stion's modules were exhibited at the PV America 2012 West show in San Jose, CA (19-21 March).

www.stion.com

NICT demonstrates first gallium oxide transistors

High breakdown voltage and low switching loss combine with low-cost melt-grown substrate for power devices.

In collaboration with power conversion and magnetic product maker Tamura Co Ltd and optoelectronics engineering firm Koha Co Ltd, Japan's National Institute of Information and Communications Technology (NICT) has developed and tested what it claims are the first single-crystal gallium oxide (Ga_2O_3) field-effect transistors (Higashiwaki et al, Applied Physics Letters vol. 100 (2012), 013504).

NICT says that Ga_2O_3 is a promising semiconductor material for high-breakdown and low-loss power devices because of its excellent material properties (such as a wide energy bandgap), which can reduce the cost and energy consumption of mass-produced devices.

Wide-bandgap semiconductors such as silicon carbide (SiC) and gallium nitride (GaN) can be used in high-breakdown and low-loss power devices. Figure 1(a) shows the prospects for Ga_2O_3 compared with these semiconductors, as estimated from their material properties. Figure 1(b) shows power device performance, which is determined by a trade-off between the two parameters breakdown voltage and on-resistance (hence the straight lines show the ideal performance limits of the materials). It can be seen that Ga_2O_3 (toward the bottom-right corner of the graph) has better characteristics as a power device material than not only silicon but also SiC and GaN.

The researchers therefore expect that Ga_2O_3 power devices will initially have high-breakdown and high-power applications. Then, as Ga_2O_3 devices become more common, applications should broaden to those of SiC and GaN due to easy and low-cost substrate production.

A feature of single-crystal Ga_2O_3 substrates is that they can be fabricated with the melt-grown method, unlike other wide-bandgap semiconductors such as SiC, GaN and diamond. Figure 2 shows a photograph of a 2" square single-crystal $\beta\text{-Ga}_2\text{O}_3$ substrate fabricated from melt. The melt-grown method is a low-energy-consumption, low-cost way to make large wafers because it does not need a high-temperature and/or high-pressure environment and its material efficiency is high. The method is especially suitable for mass production.

However, despite the material's high potential, R&D on Ga_2O_3 electrical devices has lagged. The researchers therefore fabricated a Ga_2O_3 metal-semiconductor field-effect transistor (MESFET) by using newly developed technologies for making single-crystal substrates, epitaxial thin-film growth, and processing techniques to fabricate devices (a circular MESFET with a gate length of $4\mu\text{m}$ and source-drain spacing of $20\mu\text{m}$). The key development is that, as a channel layer, they grew a high-quality Sn-doped n-type Ga_2O_3 thin film on a semi-insulating single-crystal

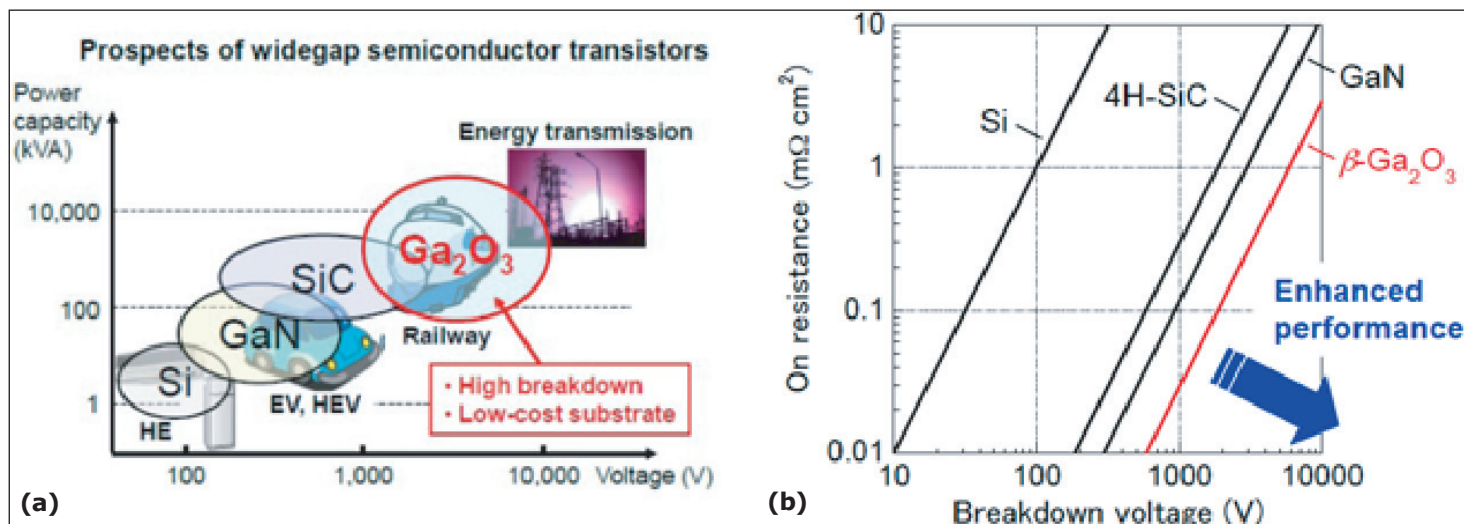


Figure 1: (a) Near-term applications of transistors. (b) On-resistance versus breakdown voltage of representative semiconductors and Ga_2O_3 for power devices.

β -Ga₂O₃ (010) substrate by molecular-beam epitaxy (MBE). Figures 3(a) and (b) show a cross-sectional schematic and a micrograph of a fabricated Ga₂O₃ MESFET.

The output characteristics in Figure 4(a) show an ideal transistor action, represented by the drain current modulation due to the gate voltage (V_{GS}) swing. A complete drain current pinch-off characteristic was also obtained for $V_{GS} < -20V$, and the three-terminal off-state breakdown voltage was over 250V (very high, says the researchers, considering that the device has a simple FET structure without any measures to increase the breakdown voltage). A low drain leakage current of 3 μ A (several μ A/mm) in the off-state led to a high on/off drain current ratio of about 10,000.

Such device characteristics — at the early stage of development — indicate the great potential of Ga₂O₃-based electrical devices for future power-device applications, say the researchers, leading to a big reduction in power loss during switching operation and making them suit practical power devices.

The work was partially supported by 'The research and development project for innovation technique of energy conservation' of Japan's New Energy and Industrial Technology Development Organization (NEDO). ■

www.nict.go.jp

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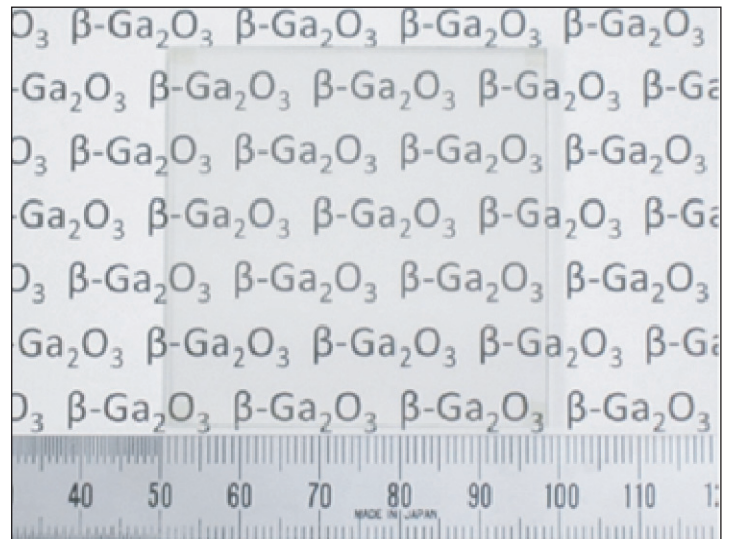


Figure 2: Two-inch square single-crystal β -Ga₂O₃ substrate fabricated by melt-grown method.

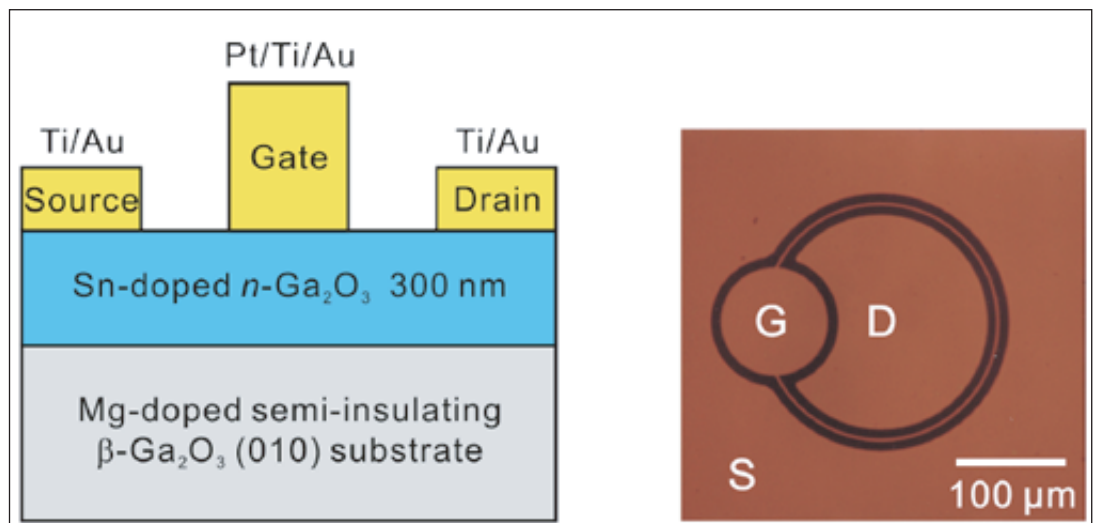


Figure 3: (a) Cross-sectional schematic; (b) optical microscope image of Ga₂O₃ MESFET.

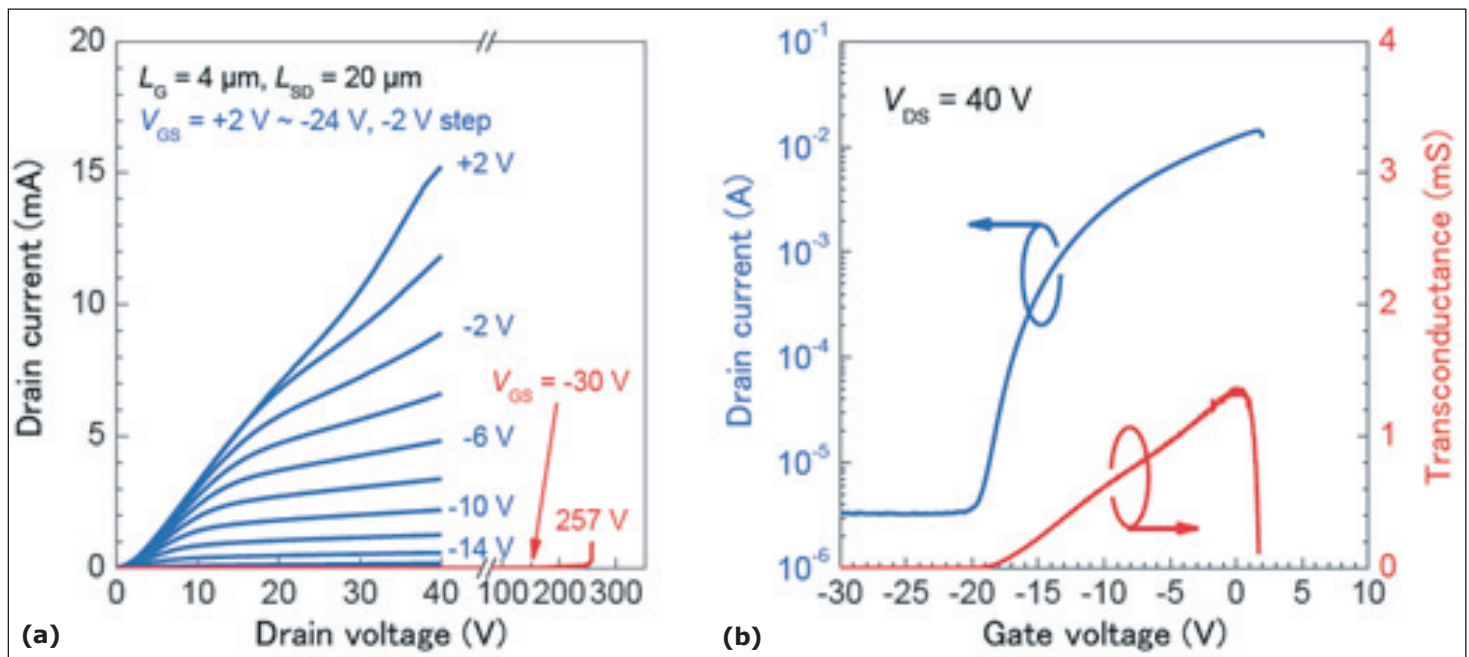


Fig. 4: (a) Output and (b) transfer characteristics of Ga₂O₃ MESFET.

Avoiding high temperatures and plasma improves InGaAs MOSFET performance

Self-aligned gate-last process allows a maximum oscillation frequency of 292GHz and a record low on-resistance of 199 Ω - μ m, reports Sweden's Lund University.

Lund University in Sweden has been developing a low-impact self-aligned process to create metal-oxide semiconductor field-effect transistors (MOSFETs) with high-quality indium gallium arsenide (InGaAs) channels [Mikael Egard et al, IEEE Electron Device Letters, published online 10 February 2012].

InGaAs channels have been proposed as a means towards smaller, better-performing electronic circuits because the material allows faster transport of electrons. However, there are a number of obstacles at present to even meeting the performance of traditional silicon-based devices.

InGaAs MOSFET development is hampered by low quality of the interface with the gate oxide insulator and high access resistance to the source-drain contacts.

The Lund researchers improved the interface quality by using a low-temperature process and wet etching. Compound semiconductors are often etched using faster plasma 'dry' etches that can leave rough surfaces and degrade interface quality.

The access resistance was improved through a self-aligned process involving metal-organic chemical vapor deposition (MOCVD) to create source-drain regions without the usual heterostructure barriers to the channel.

The process began by depositing 190nm/5nm/1nm indium aluminum arsenide (InAlAs) buffer/back barrier/spacer and 10nm indium gallium arsenide (InGaAs) channel structures on indium phosphide (100)-oriented substrates using molecular beam epitaxy (MBE) — see Figure 1.

Dummy gates of a 'silicon dioxide-like' material were formed as a hard mask using electron-beam lithography and hydrogen silsesquioxane (HSQ) resist. The mask was used to allow selective growth of 30nm InGaAs and 90nm InP source-drain layers in an MOCVD deposition process.

The dummy gates were removed in a buffer oxide etch process, leaving the InGaAs channel surface open for the foot of the gate stack to be deposited.

The insulating layers of 0.5nm aluminum oxide (Al_2O_3) and 6.5nm hafnium dioxide (HfO_2) were applied using atomic layer deposition (ALD). The precursors for the aluminum, hafnium and oxygen were trimethyl aluminum (TMA), tetrakis dimethyl amino hafnium (TDMAHf), and water (H_2O), respectively.

The gate metal consisted of 10nm palladium (Pd) and 290nm gold (Au). A T-gate structure was added to this by first removing oxide material outside the gate region with a buffered oxide etch, and then selectively etching the InP support layer in hydrochloric acid.

The source/drain contacts were formed using thermal evaporation of titanium, palladium and gold (Ti/Pd/Au). The access resistance of the contacts was estimated to be 156 Ω - μ m.

At a drain bias of 1V, the current at 1.8V gate potential for a 55nm gate-length device was 2.0mA/mm and the on resistance was a record low of 199 Ω - μ m. The peak extrinsic transconductance at 0.5V gate potential was 1.9mS/ μ m. At the lower drain bias of 0.5V, the peak transconductance was 1.5mS/ μ m and the threshold voltage was -0.3V. Short-channel effects and impact ionization effects resulted in a rather large subthreshold swing value of 187mV/dec.

A 140nm-gate device even showed a marginal 'enhancement' behavior with a barely positive threshold voltage of +0.06V at a drain bias of 0.5V. The subthreshold swing was 100mV/dec; the on-off current ratio was 2.4×10^3 ; the peak extrinsic transconductance was 1.05mS/ μ m; the on-resistance was 265 Ω - μ m; and the drain-induced barrier lowering was 110mV/V. At the lower drain bias of 0.05V, the subthreshold swing was as low as 79mV/dec. The theoretical minimum for planar devices is 60mV/dec at room temperature.

Capacitance-voltage measurements indicated an interface trap density of $4\text{-}8 \times 10^{12}/\text{eV}\cdot\text{cm}^2$ in the upper part of the energy bandgap. These results, compared with MOS capacitor/diode measurements, indicate that

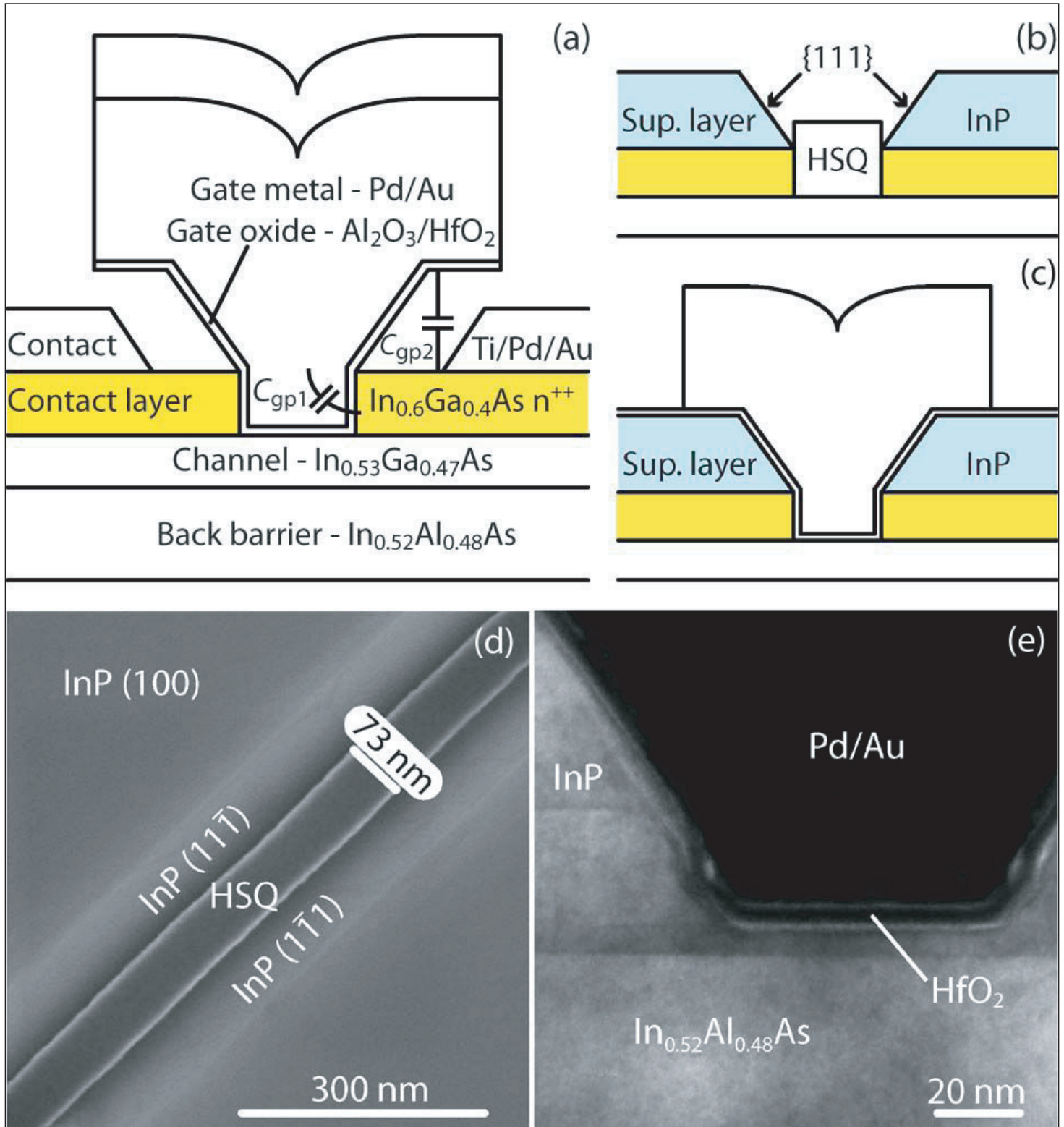


Figure 1. Schematic cross section of (a) the completed device, (b) after MOCVD regrowth, and (c) after deposition of gate metal. (d) Shows a top-view SEM image corresponding to Fig. 1(b), and (e) shows a cross-sectional TEM image corresponding to Fig. 1(c).

the processing required to produce the gate does not add a significant amount of traps.

Radio-frequency measurements on the 55nm device gave a peak cut-off frequency (f_T) of 244GHz and a peak maximum oscillation (f_{max}) of 292GHz at 1V drain bias. The intrinsic transconductance at 0.5V gate potential was 3.0mS/ μ m.

The paper also describes a small-signal model that accounts for the frequency response of gate oxide border traps and impact ionization phenomena found in the narrow-bandgap FETs. ■

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Author: Mike Cooke

Tri-gate applied to make normally-off nitride semiconductor transistors

MIT has increased on/off current ratios to eight orders of magnitude, while cutting sub-threshold slope to 86mV/dec in MISFET transistors.

Massachusetts Institute of Technology (MIT) has applied tri-gate technology to create new normally-off nitride semiconductor transistors, increasing on/off current ratios to eight orders of magnitude and reducing the sub-threshold slope to 86mV/dec on average [Bin Lu et al, IEEE Electron Device Letters, published online 27 January 2012].

The work was partially funded by the Office of Naval Research (ONR) Young Investigator Program and by the US Department of Energy's Advanced Research Projects Agency Energy (ARPA-E) Agile Delivery of Electrical Power Technology (ADEPT) project (<http://arpa-e.energy.gov/ProgramsProjects/ADEPT.aspx>).

Tri-gate structures, which wrap around the channel, have been used in next-generation development of silicon CMOS circuitry to increase electrostatic control of channel currents and to reduce short-channel effects such as increases in sub-threshold slope and drain-induced barrier lowering.

As applied to nitride semiconductor transistors, the MIT tri-gate device enables normally-off behavior. Conventional nitride semiconductor high-electron-mobility transistors (HEMTs) operate with the current 'on' at zero gate potential (normally-on or depletion-mode behavior).

For applications such as power electronics, one needs normally-off (enhancement-mode) behavior for widespread adoption in circuits that need fail-safe operation. Also, normally-off transistor circuits generally consume less power.

Other techniques have been used with varying success to increase the threshold voltage into the normally-off region, such as plasma treatment to shift the band structure of the channel region under the gate and recessing of the gate to bring it nearer to the channel. However these methods tend to degrade the on- and off-current performance. High-voltage-break-down performance is also a key requirement for power electronics that is not adequately met by existing normally-off nitride transistors.

The epitaxial material (Figure 1) was grown on silicon using metal-organic chemical vapor deposition (MOCVD).

Cap	GaN	2nm
Barrier	$\text{Al}_{0.26}\text{Ga}_{0.74}\text{N}$	18nm
Channel	GaN	1.2 μm
Buffer	AlN/GaN	3.3 μm
Substrate	Si	

Figure 1. Epitaxial layer structure.

Device fabrication began with mesa isolation and ohmic contact deposition (Ti/Al/Ni/Au). A trench structure was defined using lithography.

The pattern was defined by a Lloyd's mirror setup where light is reflected from glass at a small angle, creating a second, virtual source. Combination of the direct and reflected light results in interference fringes, in this case on the photoresist.

The trenches were then etched out using a silicon dioxide mask, giving 660nm depressions at 300nm intervals (Figure 2). The depth of the sidewalls was 250nm and the width of the top channel was 90nm. A normally-off section of channel was then defined by etching 30nm into a 120nm-long section (recessing). The gate dielectric 9nm SiO_2 and 7nm of Al_2O_3 was applied using atomic layer deposition (ALD) after annealing and cleaning/surface treatment steps.

The nickel/gold metal gate was 2 μm long. Further annealing at 500°C in nitrogen was carried out to improve the gate dielectric quality. Reference devices with planar structures with the same dielectric and some with gate recessing were also produced.

Averaged over 16 tri-gate devices, the threshold voltage was +0.80V. The drain leakage at 5V bias was 0.3mA/mm at +0.8V gate potential and 1 μA /mm at +0.54V. The sub-threshold slope was 86mV/dec at 1V drain bias. The sub-threshold behavior suggested a SiO_2/GaN interface trap density of 0.6–1.2 $\times 10^{12}/\text{cm}^2\text{-eV}$. The slope for the planar comparison device was

113mV/dec. The on/off ratio for the tri-gate device was more than eight orders of magnitude (\sim factor of 100 million).

One effect of using the $\text{SiO}_2/\text{Al}_2\text{O}_3$ dielectric combination is to reduce gate leakage to 0.1nA/mm at +7V gate bias. The typical gate dielectric breakdown voltage was 8V.

The maximum current density decreased with source-drain distance. At a distance of $8.5\mu\text{m}$, the maximum current density was 530mA/mm at drain bias 10V and gate potential +7V. The tri-gate device had an on-resistance (R_{on}) of $13.8\Omega\text{-mm}$, compared with the slightly lower value of $12.1\Omega\text{-mm}$ of the planar device. The researchers comment: "Further improvement of the R_{on} is expected by scaling the device channel dimensions and reducing the access-resistance."

The tri-gate also had improved short-channel performance in terms of drain-induced barrier lowering and constant sub-threshold current and slope, compared with longer-gate-length planar devices (Figure 3). A recessed-gate planar MISFET was not completely off at 0V gate potential, giving a drain current of $28\mu\text{A}/\text{mm}$ at 1V drain bias. The tri-gate device reduced the 0V gate potential 1V drain current to less than 0.5nA/mm.

"The positive shift of the threshold voltage is possibly due to the lateral channel depletion from the sidewalls in the tri-gate structure," the researchers write.

The $0.6\mu\text{A}/\text{mm}$ breakdown voltage for 0V gate was as high as 565V (gate-drain distance $10\mu\text{m}$). The breakdown is described as being 'hard' (i.e. permanent), occurring in the gate dielectric.

The researchers comment: "The breakdown voltage of 565V at $0.6\mu\text{A}/\text{mm}$ with $V_{\text{gs}} = 0\text{V}$ is an important improvement with respect to other normally-off GaN devices in the literature, typically measured at a much higher drain leakage current level of $0.11\text{mA}/\text{mm}$."

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The author Mike Cooke is a freelance technology journalist who has worked in the semiconductor and advanced technology sectors since 1997.

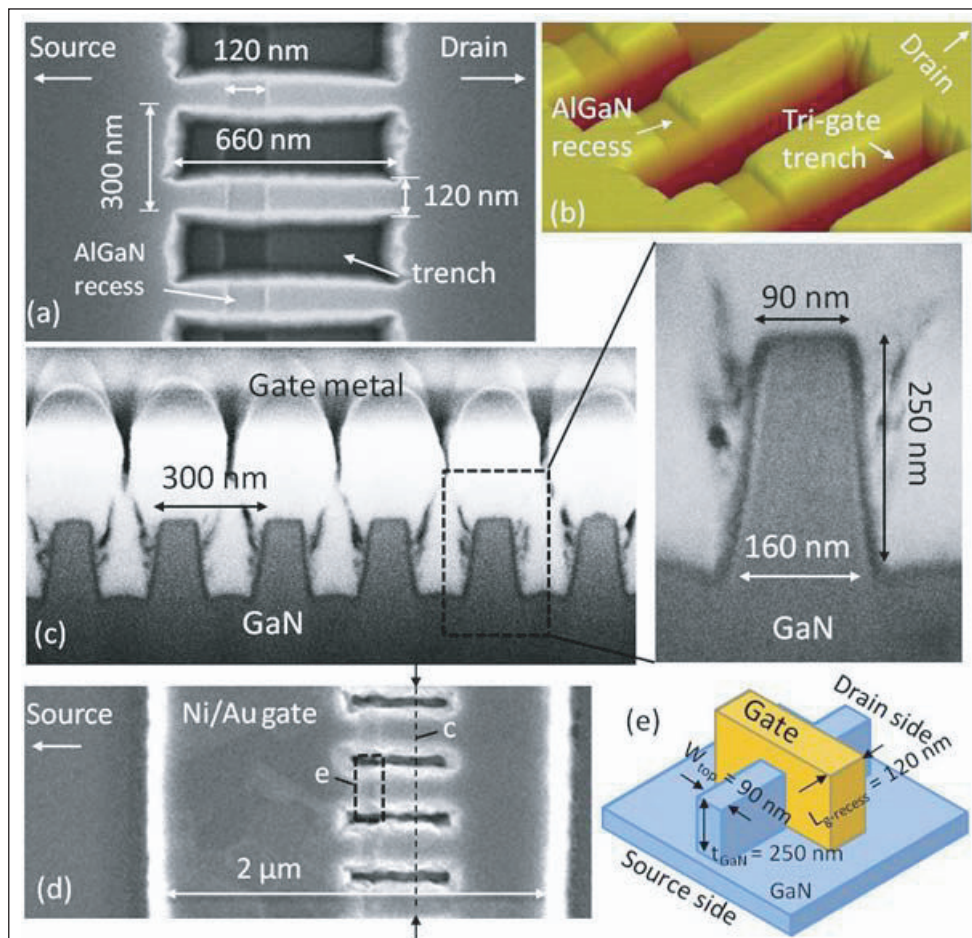


Figure 2. (a) Top-view scanning-electron-microscope (SEM) image of recessed tri-gate structure before deposition of gate electrode; (b) atomic force microscope image of structure in (a); (c) cross-section SEM of tri-gate structure from cutline in (d); (d) top-view SEM of tri-gate normally-off GaN MISFET after deposition of a $2\mu\text{m}$ -long gate electrode; (e) Normally-off channel region in the square-dashed-line area in (d).

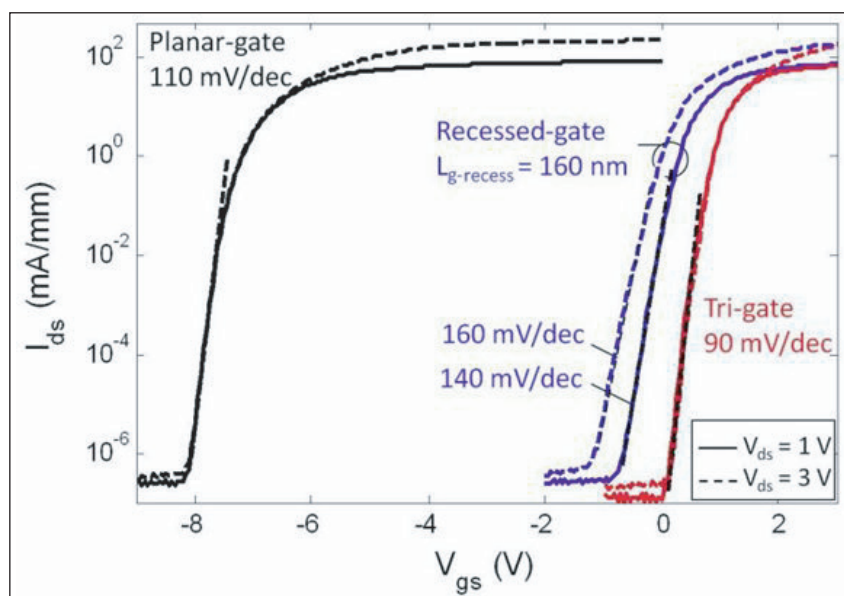


Figure 3. $I_{\text{ds}}-V_{\text{gs}}$ characteristics of the tri-gate normally-off MISFET compared with the standard planar-gate transistor and the planar-recessed gate MISFETs with recessed-gate length of 160nm. All the devices have the same dimensions with $L_{\text{gd}} = 8\mu\text{m}$ and are biased at $V_{\text{ds}} = 1\text{V}$ and 3V .

Flattening transconductance profiles in nitride HEMTs

Ohio State University uses a graded AlGa_N layer to create nitride HEMTs with a quasi-three-dimensional electron gas channel.

Ohio State University (OSU) researchers have achieved nitride transistors with a flat transconductance profile over a range of gate potentials by using polarization effects [Pil Sung Park et al, Appl. Phys. Lett., vol100, p063507, 2012]. Such transconductance profiles are needed for amplifiers to achieve high linearity and gain simultaneously.

Nitride high-electron-mobility transistors (HEMTs) can achieve high power density and efficiency.

Usually in such devices, the transconductance peaks over a very small range of gate potentials, giving a low bandwidth for amplification. These devices use the polarization contrast between gallium nitride and alloys such as aluminum gallium nitride (AlGa_N) or indium aluminum nitride (InAlN) to create an extremely thin conducting layer or 'two-dimensional electron gas' (2DEG) near the interface.

The OSU device uses an AlGa_N layer with a composition that is linearly graded between GaN and Al_{0.15}Ga_{0.85}N, followed by a high-Al-content barrier. This expands the thickness of the conducting layer to 5–6nm, giving a quasi-three-dimensional electron gas profile.

The researchers produced two epitaxial structures (Figure 1), grown using plasma-assisted molecular beam epitaxy (PAMBE) on silicon-face 4H-silicon carbide (SiC) substrates. The silicon-doping of the top layer was designed to improve access in the source-drain regions with low-resistance ohmic contact with a typical titanium/aluminum/nickel/gold alloy stack. The difference between the structures is the inclusion of a 5nm linearly graded composition AlGa_N layer for the new device, as opposed to the abrupt junction of the conventional HEMT.

Isolation mesas and gate recessing were created using inductively coupled plasma etch. The gate

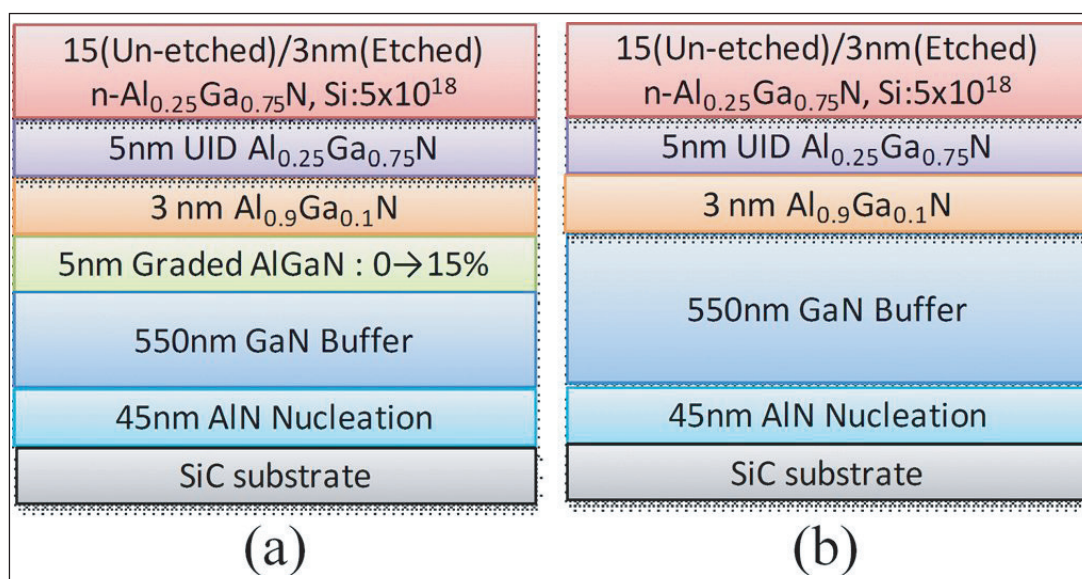


Figure 1. Epitaxial structure of the (a) graded-channel HEMT and (b) conventional HEMT.

consisted of a nickel/gold/nickel Schottky contact. The device width was 150 μ m (2x75 μ m). The gate length was 1.5 μ m. The source-gate and drain-gate distances were 1 μ m and 1.5 μ m, respectively.

Hall and transmission line model (TLM) measurements suggest a relatively low mobility (Table 1) compared with the more than 1000cm²/V-s of conventional HEMT structures. This was not expected to impact the transconductance profile in the saturation region. Using an AlN cap, rather than Al_{0.9}Ga_{0.1}N, could improve the mobility in both structures, the researchers believe.

The pinch-off voltage of the graded-channel HEMT (3.2V) was somewhat more negative than for the conventional device (2.6V), due to the thicker, deeper channel in the former case. The maximum drain currents were 970mA/mm and 720mA/mm for the graded and conventional devices, respectively.

The transconductance for the graded device averaged to 159mS/mm over gate potentials ranging from 2.2V to +3.5V (Figure 2a). The important feature is that, rather than just peaking in transconductance, the graded device profile is approximately flat. The conventional device shows a normal peaking behavior at 159mS/mm. The peak for the graded device was somewhat higher, at 168mS/mm.

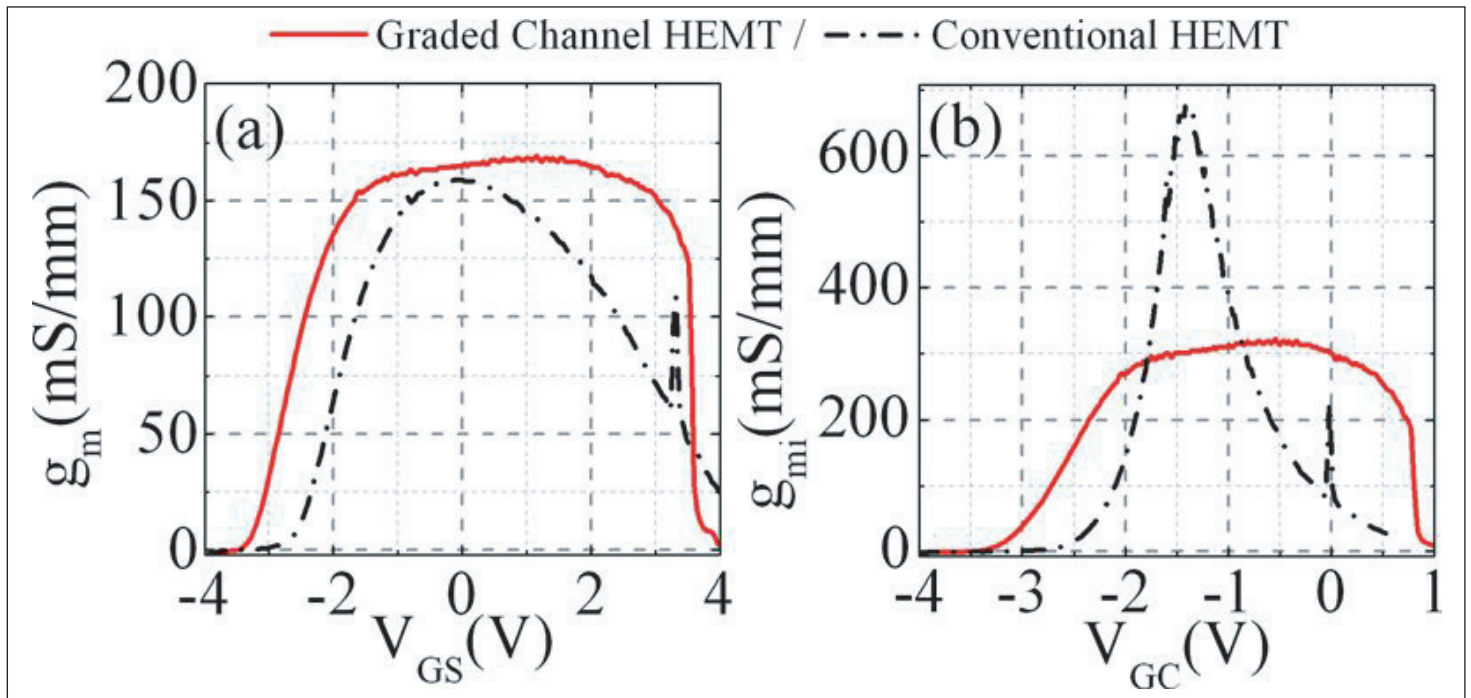


Figure 2. Extrinsic (a) and intrinsic (b) transconductances (g_m/g_{mi}) vs gate potential (V_{gs}/V_{gc}) for graded-channel and conventional HEMTs at drain bias of 10V.

The researchers also took account of the relatively high source access resistances of 3Ω and 4.8Ω for the graded and conventional devices, respectively, to estimate the intrinsic transconductance (Figure 2b). These increased the peak values to 318mS/mm for the graded device and 674mS/mm for the conventional HEMT.

The researchers comment: "The flat transconductance profile will improve the overall linearity and gain curves of large-signal microwave amplifiers based on these graded-channel devices. In addition to the obvious impact this graded channel design has on linearity,

there may be other significant advantages from the nanoscale control of electron density in the channel."

For example, reducing the electron density can increase velocities. The graded structure could be used to tune electron density while maintaining channel thicknesses that are suitable for high-frequency performance.

The US Office of Naval Research (ONR) and Air Force Research Laboratory (AFRL) provided financial support for the work. ■

<http://link.aip.org/link/doi/10.1063/1.3685483>

Author: Mike Cooke

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Doubling breakdown voltage with double heterostructure

China's Xidian University shows how an AlGaN/GaN/AlGaN HEMT can also reduce off-state leakage by factor of 100.

Researchers in China have been using double-heterostructure (DH) nitride semiconductor layers to increase breakdown voltages and reduce off-state leakage of high-electron-mobility transistors (HEMT) [Ma Juncai et al, J. Semicond., 33, p014002, 2012]. Xidian University has been developing the aluminum gallium nitride (AlGaN) barrier devices with a view to higher-voltage and power applications.

DH-HEMT and conventional single-heterostructure (SH-HEMT) materials (Figure 1) were grown on 4H-polytype silicon carbide (SiC) substrates using low-pressure metal-organic chemical vapor deposition (MOCVD). Simulations using one-dimensional Schrödinger–Poisson coupled equations suggest that the two-dimensional electron gas (2DEG) is more confined

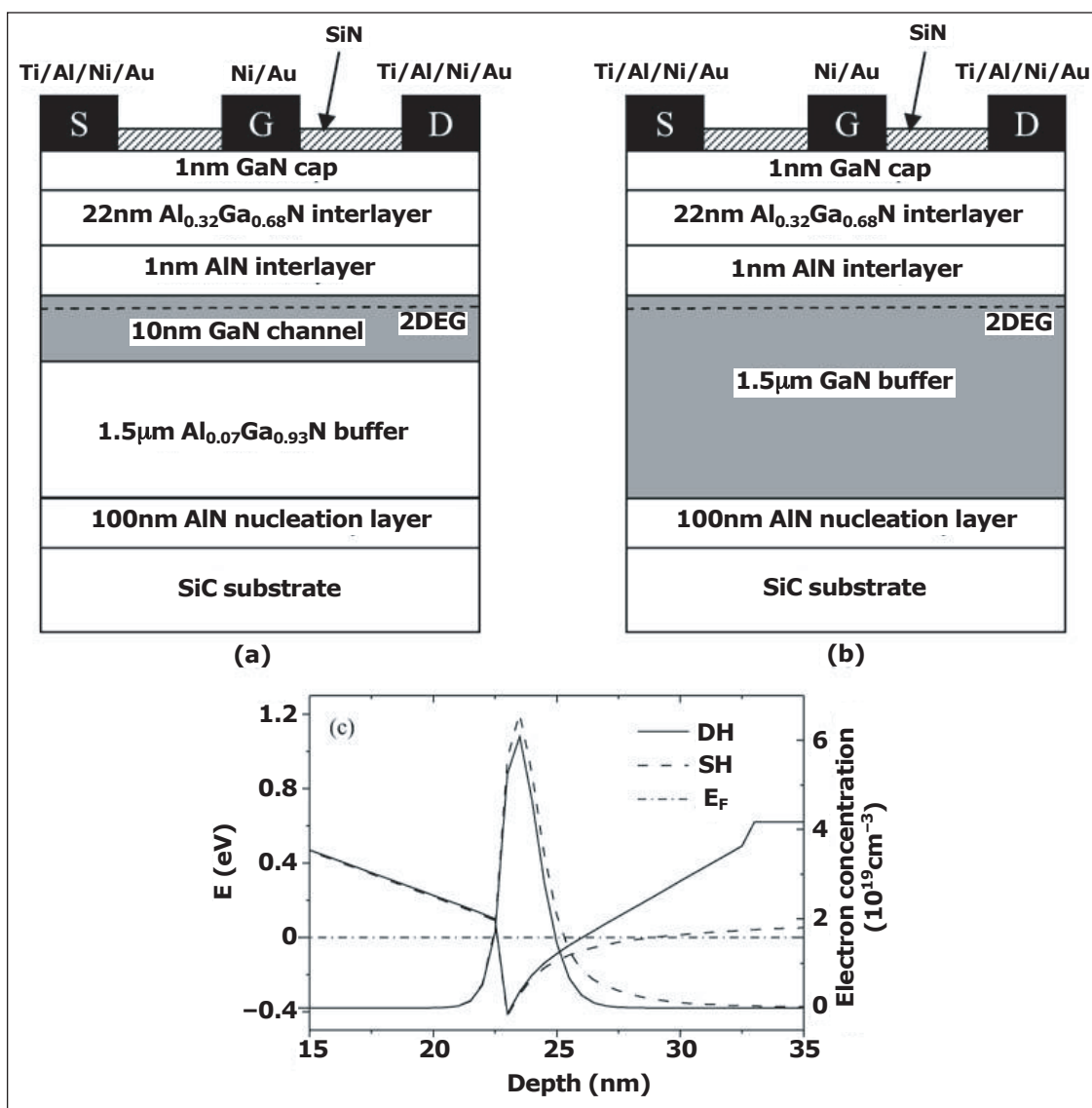


Figure 1. Schematic cross sections of (a) AlGaN/GaN/AlGaN DH and (b) AlGaN/GaN SH and (c) the calculated conduction band diagrams and electron distributions of the DH and SH.

Table 1. Characteristics of SH-HEMT and DH-HEMT.

Characteristic	SH-HEMT	DH-HEMT
Maximum drain current density	1230mA/mm	940mA/mm
Peak transconductance	240mS/mm	220mS/mm
Threshold voltage	-4.4V	-3.0V
Buffer leakage at 10V drain and -6V gate potentials	7.4x10 ⁻⁴ mA/mm	1.3x10 ⁻⁶ mA/mm
Off-state breakdown drain bias at -8V gate potential	~50V	~100V

in the DH-HEMT case due to the increased barrier height of the AlGaIn buffer.

Constructing devices from the epitaxial material consisted of mesa isolation with a plasma etch, deposition and annealing of titanium/aluminum/nickel/gold stacks for the ohmic source-drain contacts, lithography and deposition of nickel/gold for the Schottky gate, and passivation with silicon nitride.

The gate length was $0.5\mu\text{m}$ and the width $100\mu\text{m}$. The gate-drain and gate-source distances were both $1\mu\text{m}$.

Hall measurements before transistor processing were made to assess the mobility and carrier concentration of the two material structures. The DH-sample had a 2DEG mobility of $1713\text{cm}^2/\text{V}\cdot\text{s}$ and electron concentration of $8.48 \times 10^{12}/\text{cm}^2$. The SH-sample figures were $1605\text{cm}^2/\text{V}\cdot\text{s}$ and $1.07 \times 10^{13}/\text{cm}^2$, respectively. These characteristics combine to give a DH sheet resistance of $372\Omega/\text{sq}$ and an SH value of $309\Omega/\text{sq}$.

The researchers comment: "The lower carrier density and higher 2DEG mobility in the DH-HEMT are mainly attributed to the raised conduction band of the AlGaIn back-barrier layer, which enables an enhanced 2DEG confinement and thus a deeper and narrower channel, which is consistent with the calculated conduction band diagram and electron distribution."

Due to the lower conductivity of the channel in the DH-HEMT the maximum drain current and peak transconductance were reduced compared with the SH-HEMT (Table 1). However, the buffer leakage in the off state was reduced by a factor of more than a hundred (i.e. two orders of magnitude). In addition, the off-state breakdown voltage (Figure 2) was approximately doubled.

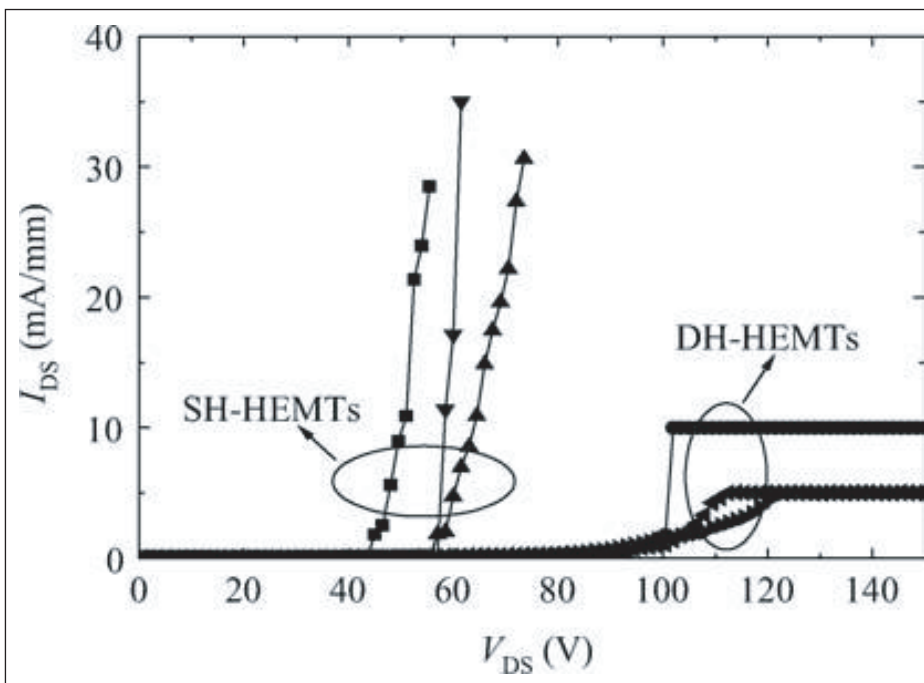


Figure 2. Off-state breakdown of conventional AlGaIn/GaN SH-HEMTs and AlGaIn/GaN/AlGaIn DH-HEMTs at a gate voltage of -8V .

The researchers comment: "The increased back-barrier height of the AlGaIn buffer layer suppresses the spillover of the 2DEG into the buffer layer and postpones the punch-through of the buffer layer, thus reducing the subthreshold drain leakage current and increasing the breakdown voltage remarkably."

Performance at 4GHz was also measured for the DH-HEMT with large signals in a Maury load-pull system. The maximum power-added efficiency (PAE) was 62.3% with a power density of $7.37\text{W}/\text{mm}$ at a drain bias of 35V. The maximum output power density was $7.78\text{W}/\text{mm}$. A linear gain of 23dB was also demonstrated.

Further improvements are expected from optimized growth conditions to reduce crystal defects in the AlGaIn buffer layer. ■

<http://iopscience.iop.org/1674-4926/33/1/014002>

Author: Mike Cooke

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Nitride HEMT with p-GaN back-barrier and recessing

Korean researchers use a p-type GaN back-barrier in a recessed-gate HEMT to achieve low buffer leakage and high thresholds up to +2.9V.

Researchers in Korea have used p-type gallium nitride (p-GaN) as a back-barrier for recessed-gate high-electron-mobility transistors (HEMTs) [Dong-Seok Kim et al, Jpn. J. Appl. Phys., vol51, p034101, 2012]. The combination of back-barrier and recessing created low buffer leakage and high thresholds up to +2.9V. Nitride HEMTs tend to have negative thresholds, giving normally-on behavior.

The researchers from Kyungpook National University and Electronics and Telecommunications Research Institute aim to develop technology for power-switching applications.

The epitaxial material was grown on (0001) sapphire using metal-organic chemical vapor deposition (MOCVD). The magnesium-doped p-GaN back-barrier was 0.2 μ m thick. Activation of this layer was performed in-situ by raising the temperature to 800°C. This resulted in a hole concentration of $2 \times 10^{17}/\text{cm}^2$ and hole mobility of $10 \text{cm}^2/\text{V-s}$.

The further layers consisted of a 250nm undoped GaN channel, a 1nm AlN interlayer, and a 25nm AlGaIn (25% Al) top barrier. This arrangement created a

two-dimensional electron gas (2DEG) with mobility and density of $275 \text{cm}^2/\text{V-s}$ and $5.48 \times 10^{12}/\text{cm}^2$, respectively. A comparison structure without the p-GaN back-barrier achieved 2DEG mobility and density of $1430 \text{cm}^2/\text{V-s}$ and $1.03 \times 10^{13}/\text{cm}^2$.

The thickness of the undoped GaN channel was optimized based on calculations using the depletion model and measurements showing that out-diffusion of Mg from the back barrier occurred to a depth of 100nm. The researchers comment: "If the thickness of the undoped-GaN channel layer is less than 250nm, the current level becomes too low because electrons cannot be sufficiently supplied from the source into the channel owing to the depletion of the 2DEG channel. If the thickness is greater than 250nm, on the other hand, the buffer leakage current will increase, which is undesirable for power-switching applications."

The epitaxial material was further processed into recessed-gate MOSHFET devices (Figure 1). Mesa and recess etching were performed using a mixed gas plasma of boron tetrachloride and chlorine. Two recess depths were studied: 20nm and 50nm. These resulted

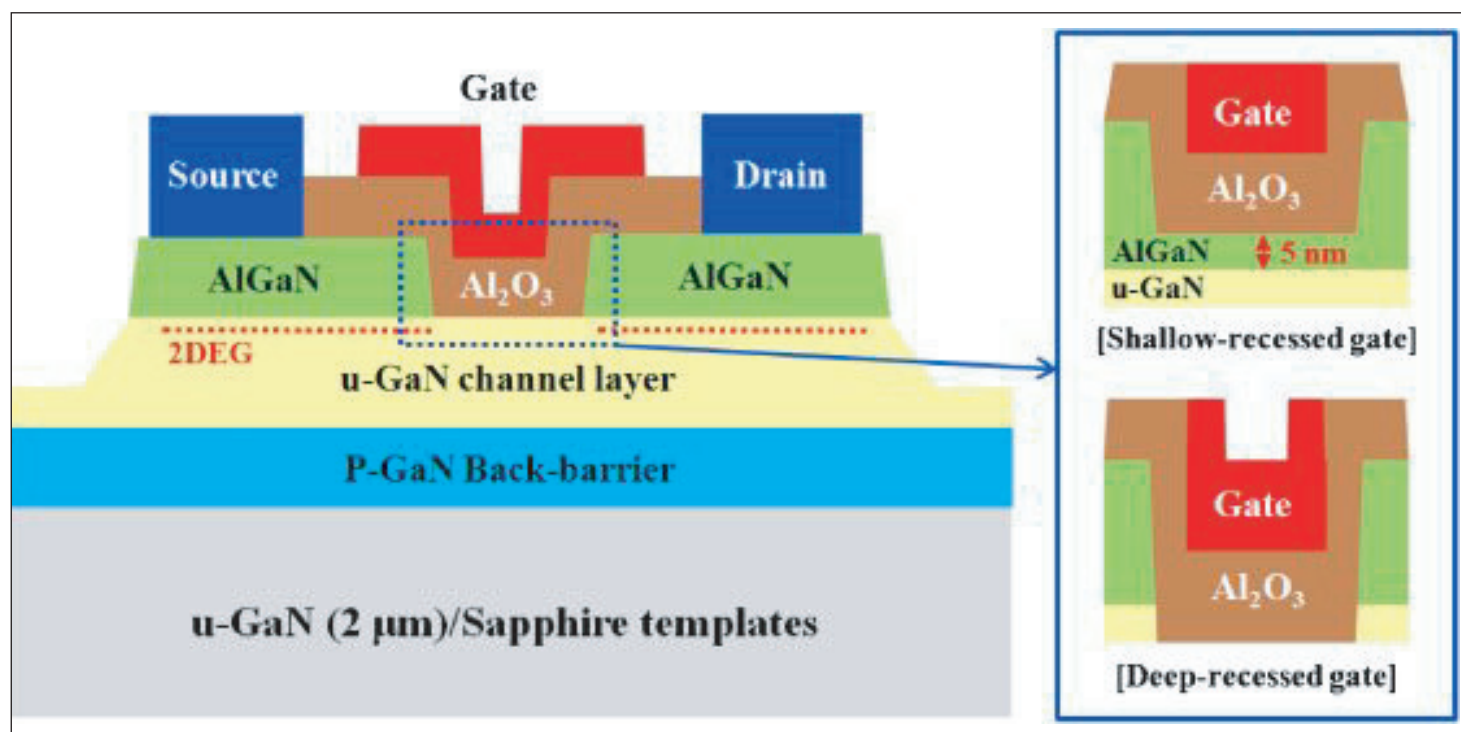


Figure 1. Schematic of fabricated shallow- and deep-recessed GaN MOSHFETs with p-GaN back-barrier.

in devices with 5nm of the AlGaN barrier left in the first case, and no barrier with further etching into the channel of 25nm in the second case.

The 35nm aluminum oxide (Al_2O_3) gate dielectric layer was deposited using plasma-enhanced atomic layer deposition. Windows were wet etched into the dielectric to allow access to the source/drain regions. The oxide was then annealed at 800°C for 20 minutes in nitrogen.

The source/drain metals consisted of titanium/aluminum/nickel/gold annealed at 750°C for 30 seconds in nitrogen. The gate metal combination was nickel/gold. The gate length and width were 0.25 μm and 42 μm , respectively.

One expected effect of the back-barrier is reduced buffer leakage. Measurements between two isolated electrodes suggest that the buffer leakage is reduced by three orders of magnitude (a factor of 1000) for the heterostructure with p-GaN back barrier. The back-barrier also reduced current collapse under pulsed operation to 8.9%, compared with 48% for the device without back-barrier.

The different gate recess depths affected the threshold voltage. The shallow recess resulted in a threshold of +0.8V, while the deeper recess gave a value as high as +2.9V. Such high thresholds are needed to avoid switching error and ensure safe normally-off operation.

The disadvantage of deep recessing is a lower maximum drain current and transconductance of 90mA/mm and 30mS/mm, respectively, at drain bias of 6V, compared with 255mA/mm and 52mS/mm for the shallow recessed device.

The researchers blame decreased channel electron mobility and degraded gate oxide interface quality due to the prolonged recess etch. The field-effect mobility was estimated at 25 $\text{cm}^2/\text{V}\cdot\text{s}$ for shallow recessing and 9 $\text{cm}^2/\text{V}\cdot\text{s}$ for deep recessing. The interface trap densities were 4.72 $\times 10^{12}/\text{eV}\cdot\text{cm}^2$ and 7.03 $\times 10^{12}/\text{eV}\cdot\text{cm}^2$, respectively. This reduced interface quality also impacted on/off current ratios (Figure 2).

Despite the degraded performance, the researchers see increased threshold as "one of the most important issues in GaN power-switching applications". They add: "The device performance can be improved by applying a post-surface treatment to recover the damage and smooth the surface."

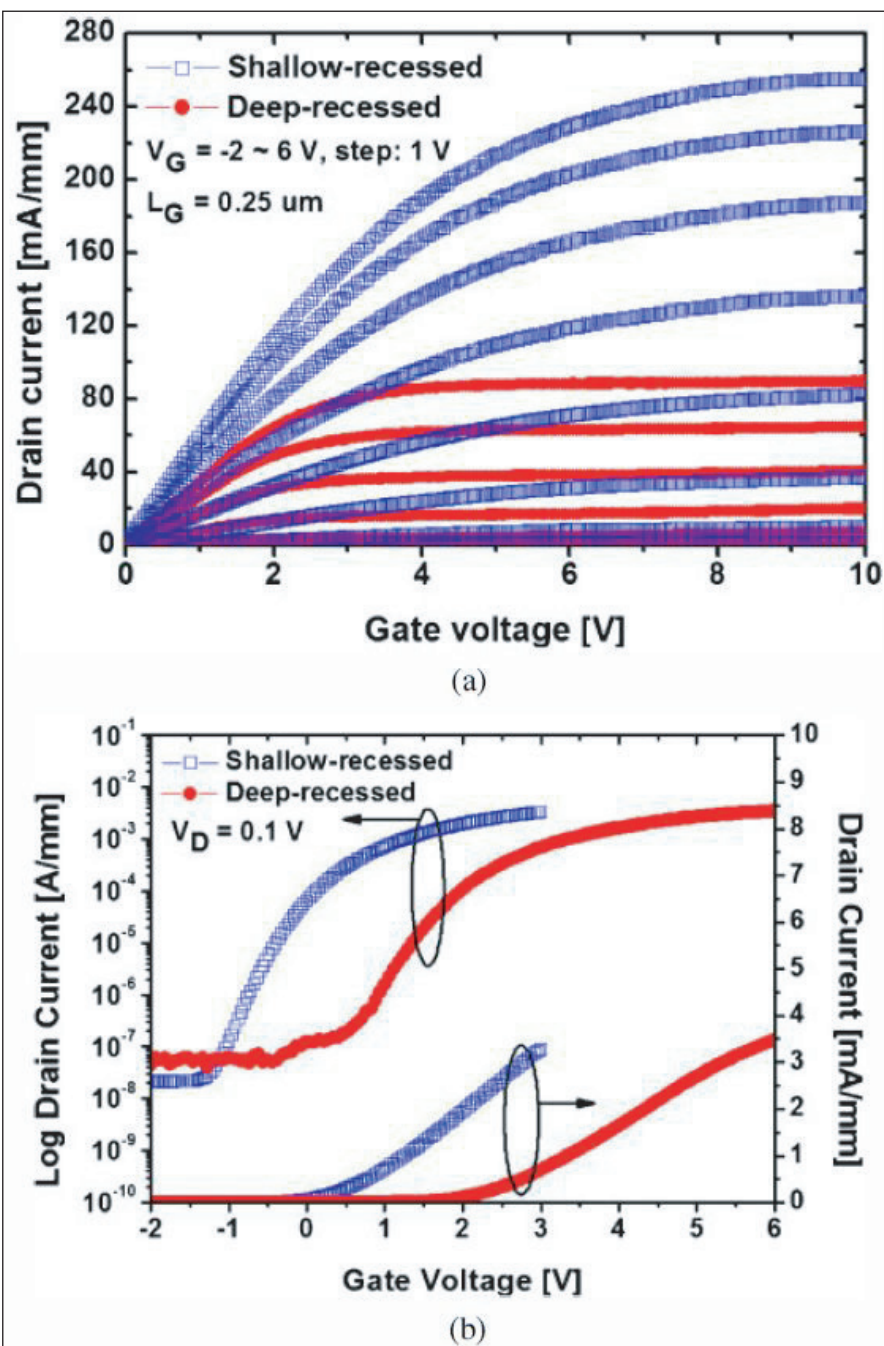


Figure 2. (a) DC characteristic and (b) linear and logarithmic transfer I-V characteristics in the linear region at drain bias of 0.1V for shallow- and deep-recessed devices.

The off-state breakdown for 1mA/mm leakage at 0V gate potential was around 70V with a gate-drain spacing of 3 μm . The researchers comment: "We believe that this low breakdown voltage may be attributed to the oxide breakdown caused by the strong electric field at the drain edge of the gate electrode for such a small gate-to-drain spacing, rather than normal drain breakdown due to impact ionization. The breakdown voltage can be increased by simply increasing the gate-to-drain distance or by adopting appropriate device designs, such as a field plate or a double recess process." ■

<http://jjap.jsap.jp/link?JJAP/51/034101/>

Author: Mike Cooke

Longer-wavelength lasing in gallium antimonide heterostructure diodes

TU Munich reports room-temperature operation of type-I quantum well GaInAsSb laser at 3.7 μm for possible detection of pollutant gases.

Researchers at Germany's Technische Universität München have made room-temperature type-I quantum well (QW) gallium antimonide (GaSb) lasers with the longest emission wavelength yet reported [Kristijonas Vizbaras and Markus-Christian Amann, *Semicond. Sci. Technol.*, vol27, p032001, 2012].

The wavelength of 3.7 μm falls within the 2–4 μm window that is of interest for the detection of methane, carbon dioxide, sulfur dioxide, ozone, etc. Detection of these gases is important for industrial and environmental monitoring. Tunable semiconductor lasers could result in compact low-cost systems.

Type-I QW structures are preferred where the wells confine both electrons and holes, since this increases overlap of the two types of carrier and hence radiative recombination. Conventional GaSb QWs tend to become type-II for energy bandgaps that would allow wavelengths longer than 3 μm . Type-II means that the well for electrons is separated from the well for holes, reducing radiative recombination.

To overcome this problem, quinary alloys of the five elements aluminum gallium indium arsenic antimony (AlGaInAsSb) have been developed to allow the extension of type-I wells to longer wavelength. TU München's Markus-Christian Amann was involved in the first report in 2005 of such use of the AlGaInAsSb system

for making room-temperature lasers with emission wavelengths of 3.26 μm .

The laser material for the new 3.7 μm device (Figure 1) with five type-I QWs was grown on gallium antimonide (GaSb) substrates in a Varian molecular beam epitaxy (MBE) reactor using solid sources for the group III (Al/Ga/In) metals and valved cracker cells for the arsenic (As) and antimony (Sb). The n- and p-type

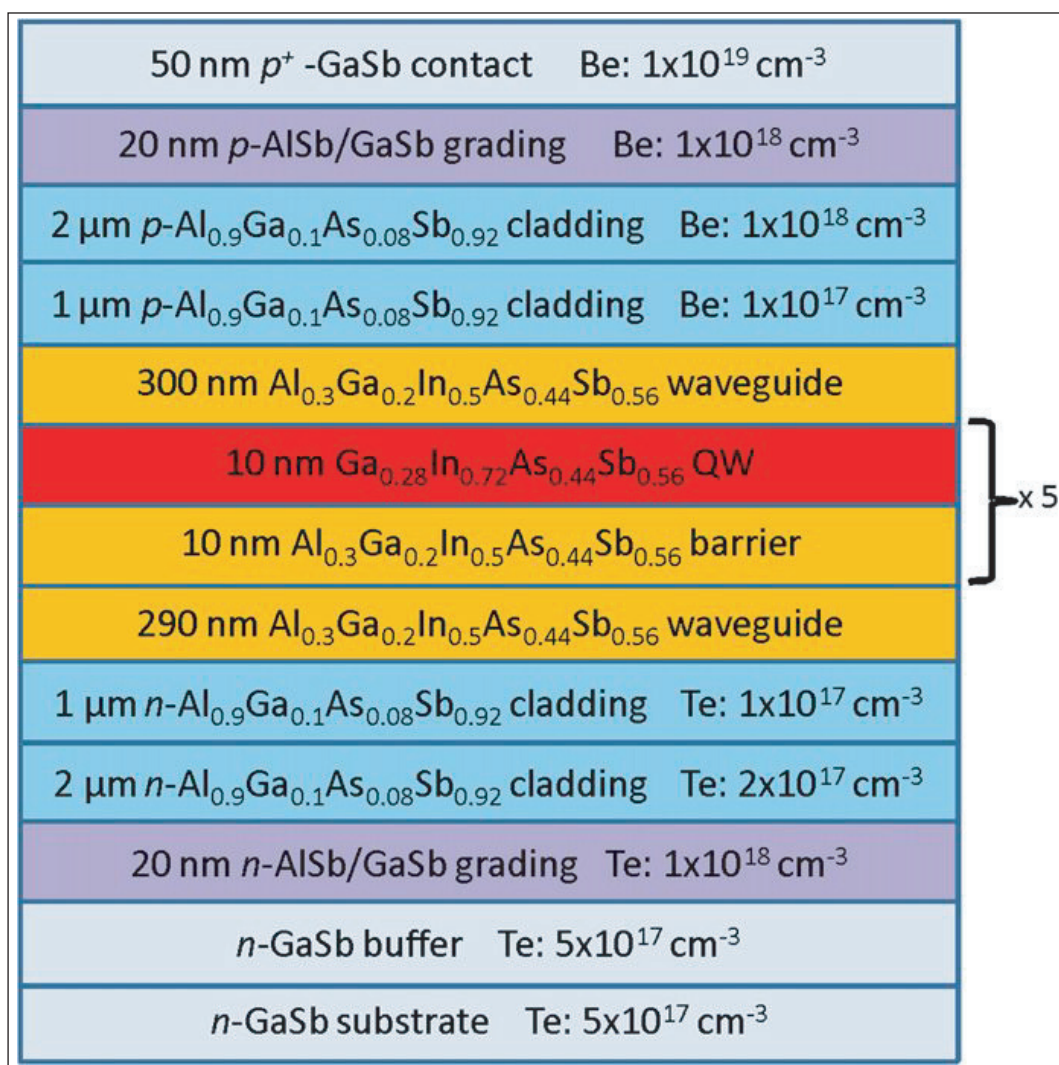


Figure 1. Schematic epitaxial layer structure of the investigated devices, emitting at 3.73 μm .

dopants were tellurium (Te) and beryllium (Be), respectively.

The growth temperatures varied (according to layer) between 550°C for oxide removal, through 505°C for the lower and upper layers, and down to 450°C for the layers between and including the waveguides.

Material characterization indicated good material quality with no relaxation of strain. X-ray diffraction measurement indicated ~0.2% compressive strain in the waveguide layers. The strain is attributed to lack of control of As/Sb ratios during the growth steps involving both group-V materials.

The epitaxial material was processed into standard Fabry–Perot ridge-waveguide lasers with stripe widths in the range 22–30µm. The ridge was defined by wet etching down to the upper waveguide layer. The etched mesas were passivated with 240nm of sputtered silicon dioxide and contact windows were then opened in this layer using plasma etching.

The top metal contact consisted of titanium/platinum/gold. The backside of the wafer was thinned to 120µm using chemical mechanical polishing (CMP) and a back Ti/Pt/Au contact was applied.

The laser structures were cleaved into bars of different lengths (1–2.5mm). The mirror facets were ‘as-cleaved’, i.e. there was no further mirror processing such as the application of reflective coating. The bars were mounted epi-side up on copper heatsinks.

The devices were designed to emit at 3.73µm wavelength. The threshold current densities were in the range 1–3.5kA/cm² at 20°C. The extrapolation to infinite cavity length was 676A/cm², or 135A/cm² per quantum well. Carrier broadening effects from diffusion outside the laser stripes were corrected for in these results. Without correcting for carrier broadening, the threshold current density for a device with a 2.4mm x 30µm ridge was 1.38kA/cm² at a heatsink temperature of 20°C.

The thresholds were around 20% lower than the researchers’ previous results with 3.6µm laser diodes. The characteristic temperature of the threshold (Figure 2) was also higher than in the previous work, at 38K below 20°C and 16K above below 20°C. A higher characteristic temperature makes for more constant operation over a range of temperatures. The maximum

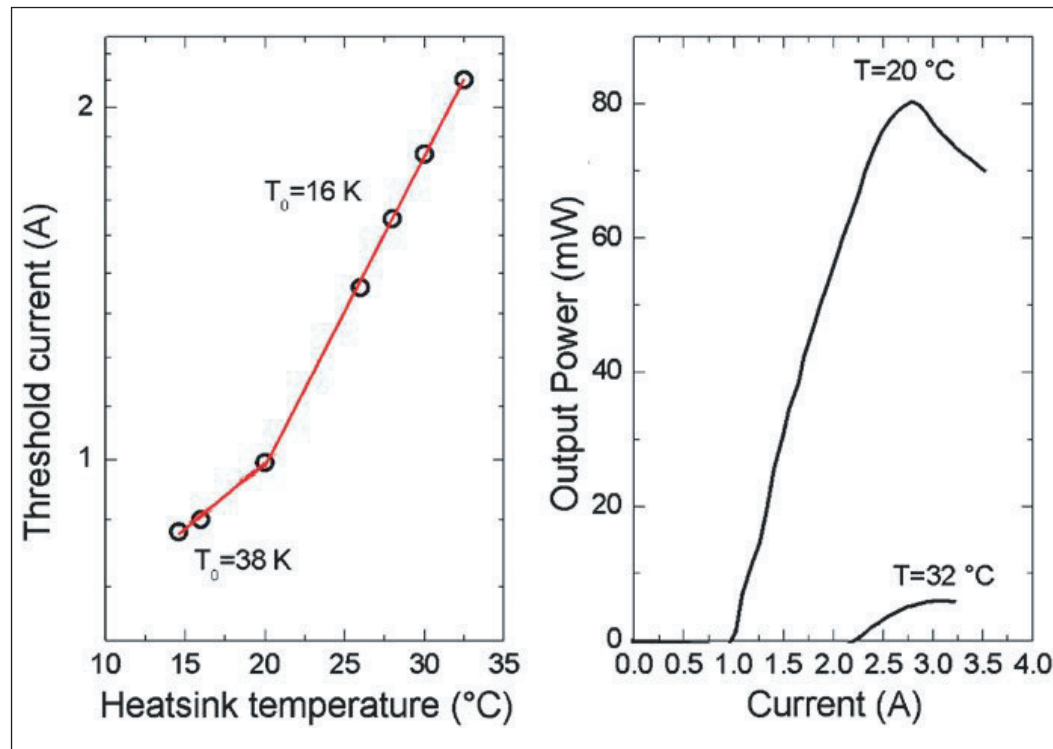


Figure 2. (a) Threshold current as function of heatsink temperature for 2.4mm-long devices with 30µm-wide ridges. Hollow circles are measurement points and red lines are exponential fits. (b) Pulsed power versus current (P–I) characteristics of the same laser at different temperatures.

operating temperature of 32°C was also higher than for the earlier device.

The researchers attribute the improved performance to “considerably higher strain in the active region (1.46% compared to 1.05%), which leads to increased differential gain and lower transparency currents, thus counteracting the higher non-radiative losses”.

The change in characteristic temperature at 20°C is attributed to the onset of a non-radiative mechanism that is not yet completely understood. Two possibilities are hole leakage and Auger recombination.

At <http://link.aip.org/link/doi/10.1063/1.3646552> a recent theory suggests that Auger electron-hole recombination to an excited electron can be enhanced in systems with large conduction band offsets relative to the bandgap. The 3.7µm laser has an offset/bandgap ratio of 0.8, which is greater than the 0.5 needed for the suggested Auger enhancement, making it a candidate for such enhancement. Also, a further effect of higher temperatures is to shrink the bandgap, increasing the relevant ratio.

The two latest devices from Technische Universität München with wavelengths of 3.6µm and 3.7µm fall within the important water absorption-free window between 3.5µm and 4.5µm. This window could be important for the atmospheric detection of methane, ozone, and the silicon dioxide industrial pollutant. ■

<http://iopscience.iop.org/0268-1242/27/3/032001>

Author: Mike Cooke

Nitride nanocolumn LEDs emitting in infrared

Japan's Sophia University shows how nitride nanocolumns with a high-indium-concentration active region enable 1.46 μm emission.

Sophia University in Japan has produced 1.46 μm infrared light-emitting diodes (LEDs) based on indium gallium nitride (InGaN) semiconductors [Katsumi Kishino et al, Appl. Phys. Express, vol5, p031001, 2012]. This was achieved by growing the nitride material in nanocolumns to allow the growth of a high-indium-concentration (~87%) active region and using a low indium concentration (~30%) for the hole-injection layer.

The new device approach not only brings optical communications within reach, it also raises the prospect of higher energy conversion efficiency nitride-based solar cells that can harvest a wider range of wavelengths.

Normally, InGaN LEDs are restricted to wavelengths shorter than green (570–520nm). This is because it is difficult to grow high-quality InGaN with the larger concentrations of indium needed to narrow the bandgap into the longer-wavelength ranges. In theory, the highest concentration (InN) should be able to emit at 1.95 μm .

One reason for the difficulty in growing high-quality InGaN is that the InN and GaN materials do not mix well. Growing their alloy tends to result in clumping of high-concentration and low-concentration regions, somewhat like oil in water.

In addition to the difficulty in growing uniform-composition InGaN, a new factor appears at indium concentrations greater than 49%. In such material, a thin n-type 'inversion layer' appears at the surface, making it difficult to achieve p-type conductivity through the normal route of magnesium (Mg) doping.

The Sophia University researchers created a triangular array of n-GaN nanocolumns using selective-area growth

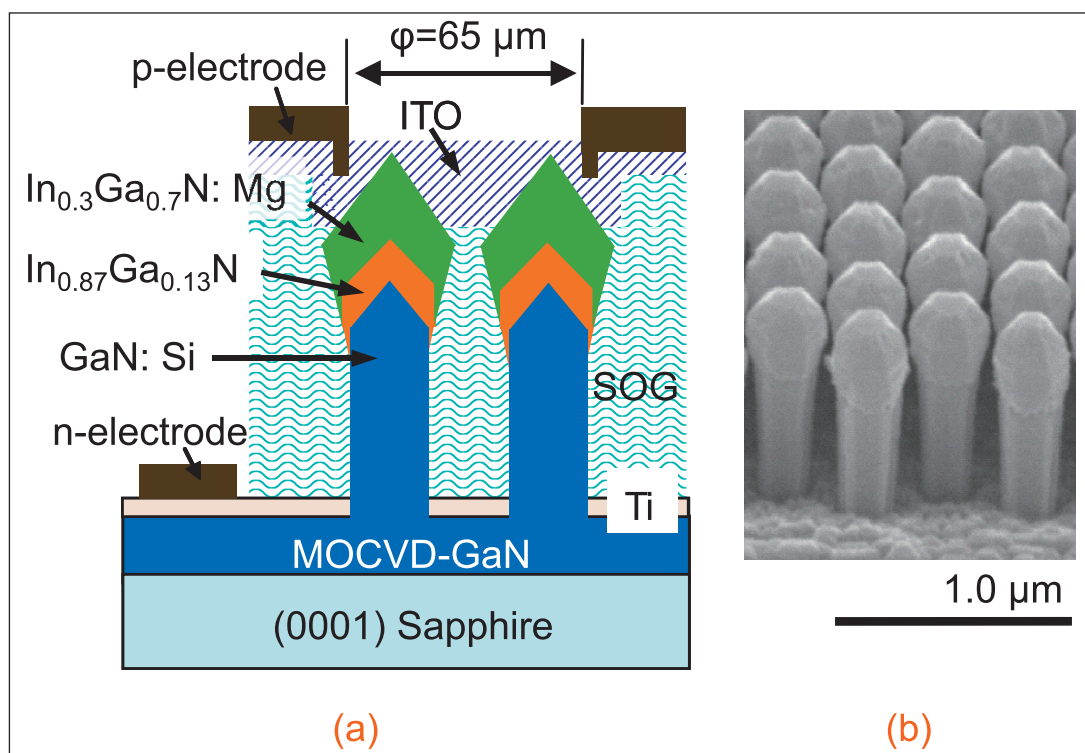


Figure 1. (a) Cross-sectional schematic structure of near-infrared nanocolumn LED, and (b) scanning electron micrograph (SEM) bird's-eye-view of LED crystal (sample B) taken at 55° angle from normal.

(SAG) through a titanium mask in a radio-frequency molecular beam epitaxy (rf-MBE) process. The nanocolumn diameter was 325nm and the period of the triangular lattice was 350nm.

The nanocolumns were capped with 80nm InGaN active layers and 300nm p-InGaN cladding (Figure 1). The tops of the nanocolumns had a match-head appearance, with reduced spacing between the heads of less than 20nm.

The p-InGaN layer had reduced indium content of 30% to avoid the problem of electron accumulation in an inversion layer at the surface that occurs in high-indium-content layers.

The full structure was about 1050nm high. The substrate/template consisted of GaN grown by metal-organic chemical vapor deposition (MOCVD) on sapphire.

Electrical contact was made with the tops of the nanocolumns with indium tin oxide (ITO) transparent

conductor. The n-side contact was titanium/aluminum/titanium/gold.

The DC electrical performance varied with the magnesium (Mg) doping concentration of the p-InGaN layer, with only the highest-doped sample showing clear rectification behavior. Increasing the Mg beam pressure also resulted in rougher surface quality. The turn-on voltage for the highest-doped device was 1V. At 1mA (30A/cm²), the voltage was 3.5V.

Electroluminescence was measured using a filter to cut wavelengths shorter than 960nm. The peak emission of the device is in the near-infrared, at 1.46 μ m (Figure 2). The

full-width at half-maximum (FWHM) was 157meV (\sim 0.27 μ m). The emission intensity increased linearly with injection current between 1.46mA and 17.8mA.

The emission wavelength leads the researchers to estimate the indium content of the active layer at 86%. The slight difference with the composition, as determined by transmission electron micrographic analysis, is attributed to compositional deviation

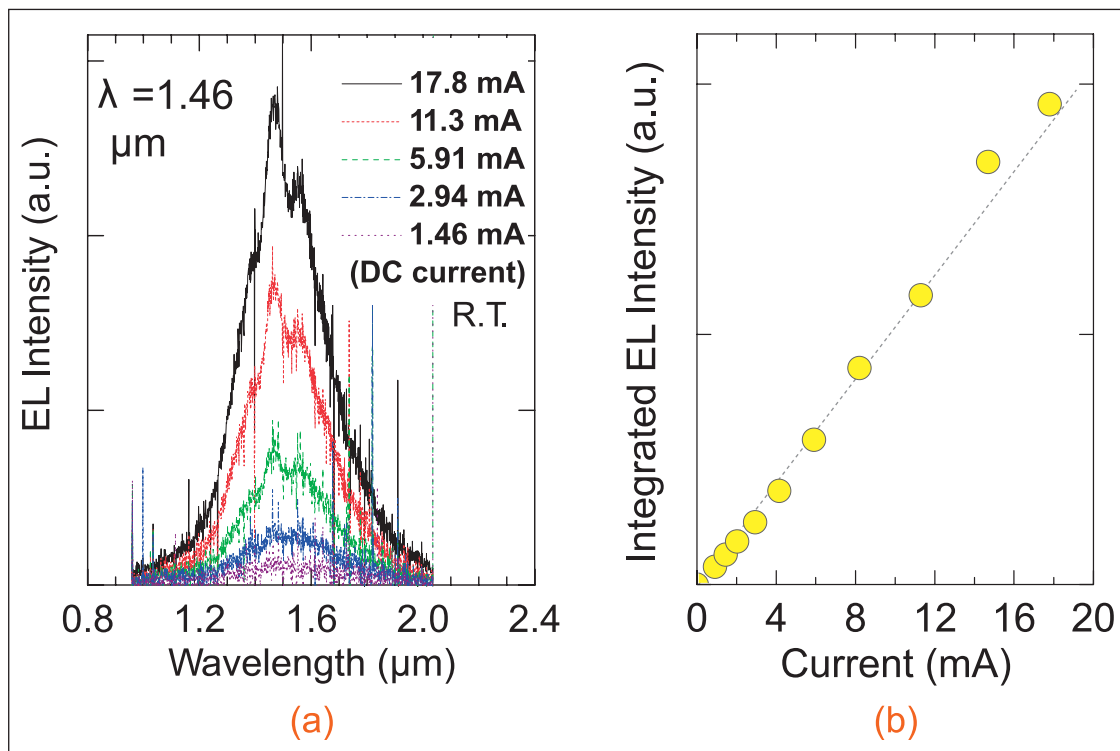


Figure 2. (a) Electroluminescence (EL) spectra of GaN-based nanocolumn LED with In-rich In_{0.86}Ga_{0.14}N active layer under DC current injection from 1.46mA to 17.8mA, and (b) integrated EL intensity vs current.

between samples and/or ambiguity in the bowing parameter.

The researchers conclude: "We consider that this experimental finding is a step forward in the development of III-V-nitride-based infrared electrically driven emitters (e.g. LEDs and laser diodes) and photodetectors". ■

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Green LEDs benefit from graded blocking

Chinese Academy of Science researchers use graded electron-blocking layers to enhance nitride green LED light output by 415% at 350mA.

Researchers in China have applied graded electron-blocking layers (GEBLs) to increase the light output powers of green light-emitting diodes (LEDs) by up to 415% at a drive current of 350mA [Ning Zhang et al, Appl. Phys. Lett., vol100, p053504, 2012]. The onset of efficiency droop was also delayed to 150mA, compared with 50mA for a conventional device.

Conventional electron-blocking layers (CEBLs) of aluminum gallium nitride (AlGaN) are often used in nitride semiconductor LEDs to avoid electrons overshooting the active light-emitting layers.

Electrons that overshoot the active region reduce the light emission efficiency by reducing hole injection into the active region.

However, AlGaN blocking layers introduce their own problems. One problem is that, while the electrons are blocked as desired, holes are also blocked to some extent. Another is that the lattice mismatch between AlGaN and the indium gallium nitride (InGaN) quantum wells and GaN barriers introduces large levels of strain.

Nitride semiconductors are highly piezoelectric, which means that strains produce large polarization fields that, in turn, set up electric fields in the active region. These electric fields tend to make it more difficult for electrons and holes to recombine and produce light (the quantum-confined Stark effect, or QCSE).

Last year, Taiwan researchers used GEBLs to improve the performance of blue-LEDs [see www.semiconductor-today.com/news_items/2011/JAN/NCTU_130111.htm]. The new research on the more challenging longer-wavelength green range was carried out by the Chinese Academy of Sciences' (CAS) Research and Development Center for Semiconductor Lighting in Beijing.

The CAS researchers used a Veeco metal-organic

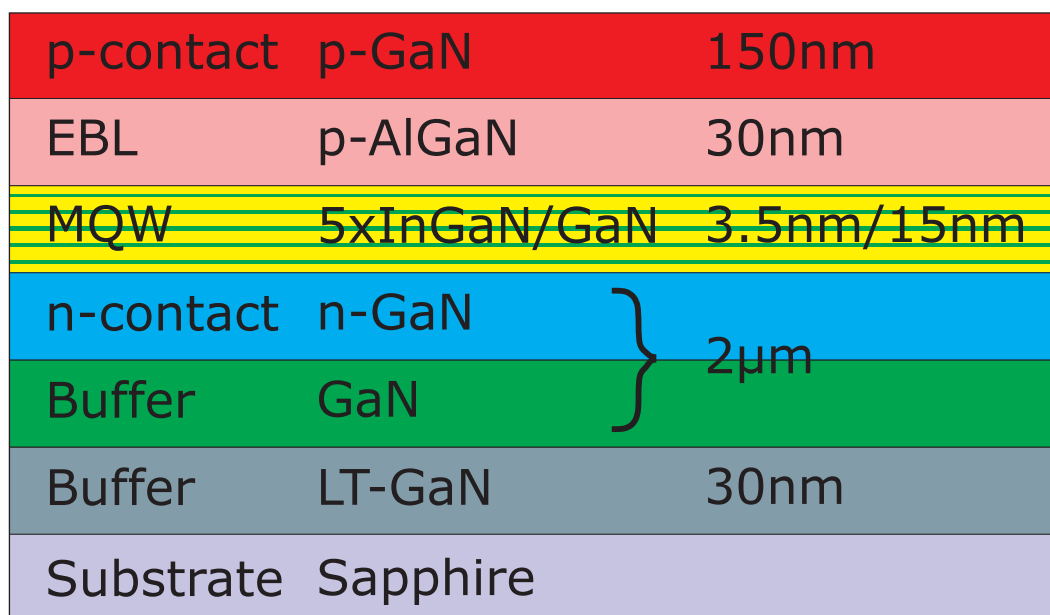


Figure 1. Schematic of GEBL (graded Al content from 0% to 20%) and CEBL (20% Al) devices.

chemical vapor deposition (MOCVD) system to create LEDs with 30nm conventional or linearly graded EBLs consisting of p-type AlGaN with 20% or 0–20% Al, respectively. The growth was in the c-direction (0001) on sapphire substrates. The full structure (Figure 1) included a pre-strain region of two pairs of InGaN/GaN layers and an active region with five quantum wells of InGaN with GaN barriers.

The LED mesa structures were 580µm x 250µm. Indium tin oxide (ITO) transparent conducting layers were deposited on the n- and p-GaN contact layers. The metal electrodes consisted of chromium/gold.

Photoluminescence and x-ray diffraction analysis suggested that the polarization field in the QWs was reduced in the GEBL device. For example, the photoluminescence peak is blue-shifted from 522.4nm in the conventional LED to 518.6nm in the GEBL device.

At 20mA current injection, the GEBL device demonstrates 130% increased peak intensity over the conventional LED. The researchers mainly attribute the increased peak intensity of the GEBL LED to lower polarization fields.

Increased current generally shifts the emission peak in nitride LEDs due to various effects. The shift in the

GEBL device is lower than in the conventional LED — in the range 10–130mA, the shifts are 5.8nm and 9.6nm for the GEBL and CEBL LEDs, respectively. It is common in nitride LEDs for radiative recombination to be concentrated in the last well before the EBL (if present) and the p-contact layers. The effect of using a GEBL mainly affects the last well, improving conditions for radiative recombination and thereby reducing strain and hence the piezoelectric polarization field.

The forward voltage at 20mA is reduced by 0.38V in the GEBL LED. The researchers comment: "The polarization field in the active region produces large triangular barriers that hinder carriers flowing, across which a higher bias must be applied for carriers to flow. For the GEBL LED, the height of the triangular barriers in the valence band is reduced because of the lower polarization field and thereby the hole injection from one well layer to an adjacent well layer is enhanced."

The researchers also see the improved forward voltage as being due to improved hole injection due to a

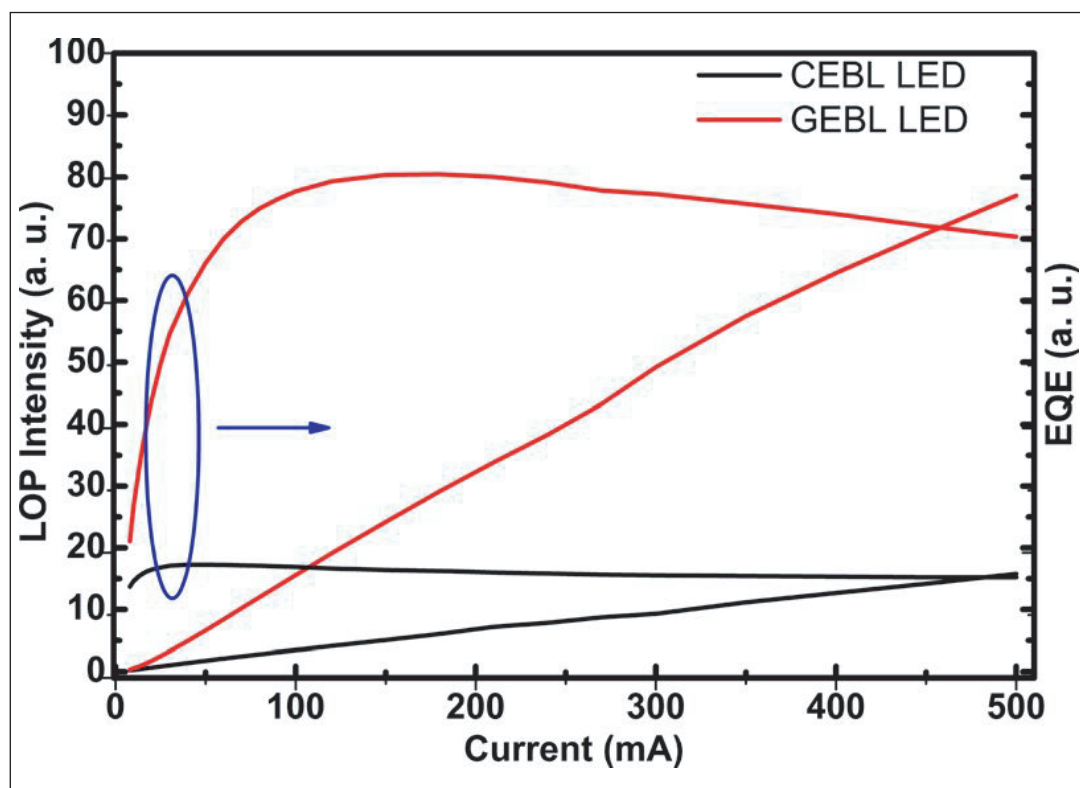


Figure 2. Light output power (LOP) and external quantum efficiency (EQE) versus current for LEDs with CEBL or GEBL.

modified energy band structure in the GEBL material.

The light output power for the GEBL LED is increased by 163% at 20mA and 415% at 350mA, respectively, over the conventional device (Figure 2). The peak of external quantum efficiency (EQE) is delayed to 150mA, compared with the conventional device's 50mA. ■

<http://link.aip.org/link/doi/10.1063/1.3681797>

Author: Mike Cooke

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New approaches to efficiency droop in nitride & phosphide LEDs

New ideas and results from simulations and experiment at varying temperature down to 80K are emerging for efficiency droop problem of nitride semiconductor LEDs. Similar experiments on phosphide LEDs also show droop effects even when absent at room temperature. Mike Cooke reports.

While white-light emitting diodes (LEDs) begin to penetrate the mass market for general illumination, the efficiency characteristics of these devices continue to challenge scientists and engineers. The leading concern is 'efficiency droop' where the device efficiency falls off dramatically beyond a certain injection current (often in the tens of milliamps range). Droop limits the amount of light that can be efficiently extracted from one device so that LED-based illumination requires larger numbers of emitters, increasing production cost.

There are a number of approaches to explaining the droop effects. Since light is produced through electron-hole recombination, a natural explanation would be a competing mechanism that absorbs the energy. Auger recombination is such a mechanism, where the energy is transferred to another carrier. However, there is a wide range of alternative explanations such as polarization effects (particularly strong in nitride semiconductors) creating electric fields that separate electrons and holes, and electron overspill from the active region into the p-type hole injection region.

Here, we look at two alternative approaches to droop. One beginning from the perspective of nitride semiconductor LEDs at varying temperature, the other explores droop effects in the more mature red LEDs with phosphide active light-emitting regions. In the past few weeks, the first approach has also been extended to phosphide emitters.

Effect of unbalanced carrier densities

Rensselaer Polytechnic Institute (RPI) and Samsung LED see the unbalanced nature of the n-type (electron) and p-type (hole) injection regions as playing a more important role in droop than previously considered [David S. Meyaard et al, Appl. Phys. Lett., vol99, p251115, 2011].

A major problem in producing light emission from electron-hole recombination in nitride semiconductor devices is the difficulty in producing p-type conduction. Electron (n-type) and hole (p-type) carriers are created through doping with elements that either donate or accept electrons from the conduction or valence bands, respectively. Silicon (Si) has a donor electron level in gallium nitride that is in the range 12–20meV from the conduction band. By contrast, the magnesium (Mg) acceptor level (E_A) is 140–210meV from the valence band.

These values need to be compared with the typical thermal energy available to excite electrons or holes at room temperature ($\sim 300\text{K}$) of $\sim 26\text{meV}$ (k_bT). The silicon level is therefore almost completely ionized, while only a few holes are created through magnesium doping. A simple Boltzmann factor ($\exp(-E_A/k_bT)$) suggests suppression of hole carrier concentrations by 2–3 orders of magnitude, compared with electron concentrations in silicon-doped n-type regions. This asymmetry is worsened by going to lower temperatures. Unfortunately, there is presently no better way to create the p-type material needed for hole injection into light-emitting structures.

The researchers developed their analysis both with simulations and experimental work. The advantage of simulations is that possible effects of the unbalanced carrier densities of reality ($p \ll n$) can be compared with the more difficult-to-achieve balanced situation ($p \sim n$). To simplify the simulation, a single p-n junction in pure gallium nitride was investigated.

The product of the n- and p-type carrier densities was taken as an indication of the amount of recombination occurring, and hence the amount of radiation. With the balanced situation, the peak for recombination moved slightly (1.6nm) towards the p-end as the current increased. With the more realistic unbalanced situation with electron carrier densities on the n-side very much

greater than hole densities on the p-side, the shift was more than ten times bigger at 18.3nm.

Another effect of having unbalanced carrier densities is that the high electric field/potential drop occurs not just over the depletion region but also extends into p-type region. Since the mobility of electrons ($100\text{--}300\text{cm}^2/\text{V}\cdot\text{s}$) is much higher than that of holes ($1\text{--}5\text{cm}^2/\text{V}\cdot\text{s}$) in GaN, the effect of this electric field is much higher on electrons. In this case of high-level injection, the conductivity of the depletion region can be comparable to that of the p-type region, due to the lack of majority carriers: both the low carrier concentration and low mobility lead to low conductivity in p-GaN.

Real nitride LEDs are usually constructed with undoped quantum wells of indium gallium nitride (InGaN) sandwiched between n- and p-type GaN layers. However, like in the simulation for unbalanced carrier densities, there has been observed a tendency for the radiative recombination to occur toward the p-end of the heterostructure. It has also been found useful to create electron barrier layers (EBLs) between the active light-emitting region and the p-type region, blocking the overshoot of electrons into the p-type GaN. Such overshooting not only produces non-radiative or parasitic recombination, it also reduces the amount of hole injection into the active region.

The researchers tested their ideas by operating nitride semiconductor LEDs emitting at wavelengths around 440nm (blue) under a range of temperatures from 80K to 450K. The 5-period multi-quantum well (MQW) LED epitaxial structure of InGaN with GaN barriers was grown using metal-organic chemical vapor deposition (MOCVD) on sapphire. An electron-blocking layer of aluminum gallium nitride (15% Al) was placed after the MQW structure. The nitride layers were then transferred to silicon substrates by wafer bonding and laser lift-off removal of the sapphire. The exposed GaN N-face was roughened to improve light extraction.

The silicon wafer with flipped nitride layers was then diced into 1mm x 1mm chips. The light-output power was measured using 5 μs pulsed currents (1% duty cycle) to avoid self-heating effects.

At the lowest operating temperature of 80K, one expects the p-type conductivity of the magnesium-doped region to be almost completely frozen out, resulting in the concentration of electrons being very much greater than that of holes in the active region. In measurements (Figure 1) one finds the efficiency

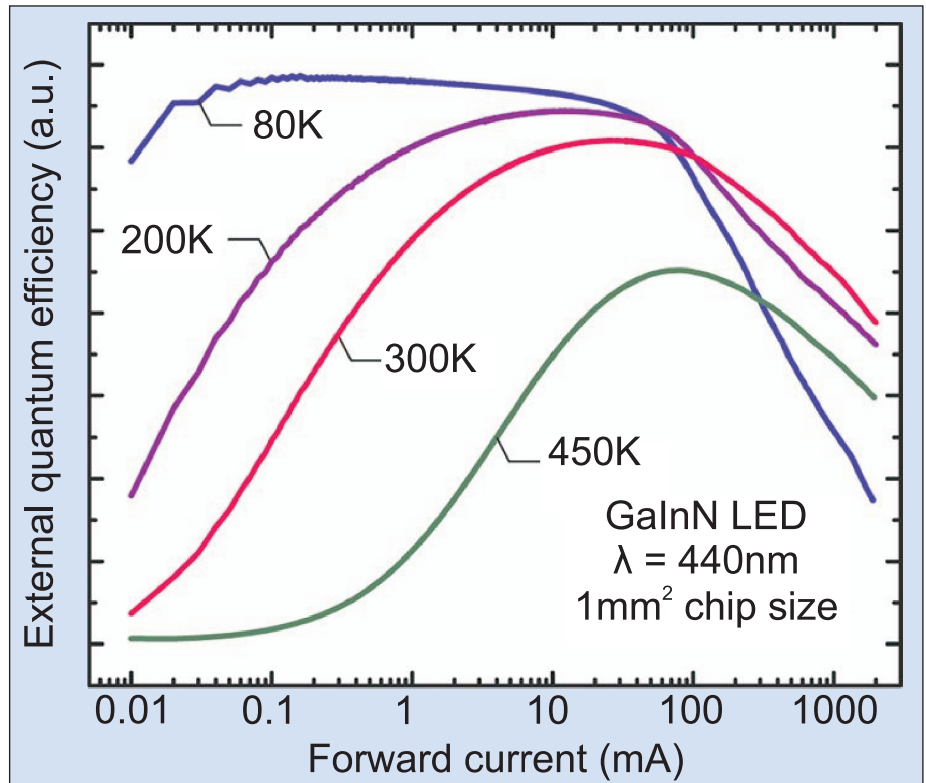


Figure 1. Measured external quantum efficiency of a GaInN LED for several temperatures ranging from 80K to 450K. (Courtesy RPI/Samsung LED.)

droop effect to be greatest as the temperature decreases. At the same time, the maximum efficiency is also greatest at 80K, descending as the temperature rises.

The researchers comment: "We propose that this behavior can be explained by the asymmetry in the transport properties of electrons and holes in GaN-based pn-junction diodes. As the temperature decreases, fewer acceptors are ionized. This leads to a large asymmetry in carrier concentration, and therefore an onset of high-level injection conditions at lower currents."

The higher peak efficiency at lower temperature is explained as being due to minimization of the competing non-radiative electron-hole recombination, as expected from the temperature dependence of the Shockley-Read-Hall (SRH) mechanism.

The researchers also studied high-level injection, which occurs when the diode's current-voltage (I-V) behavior deviates from the exponential of simple Shockley theory. It was found that, soon after the current started falling below the low voltage exponential, the peak light emission efficiency was reached (Figure 2).

The researchers comment: "We propose that the onset of high-level injection results in the buildup of an electric field in the p-type region, resulting in stronger electron leakage and a shift of the recombination location into the p-side".

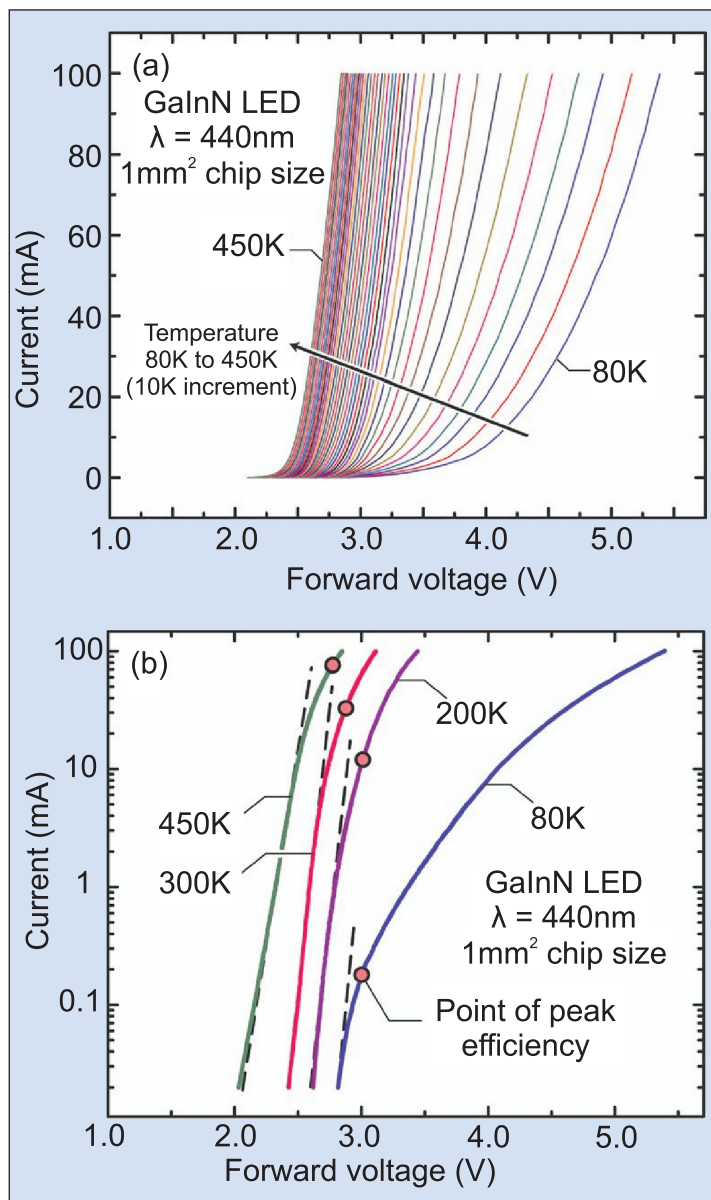


Figure 2. (a) Measured I-V characteristics of the GaInN LED at different temperatures. (b) Measured I-V on a logarithmic scale, showing the onset of high-level injection and series resistance as well as the current at which the efficiency is maximal. (Courtesy RPI/Samsung LED.)

- As the temperature increases, the number of holes increases, and the onset of high-level injection is delayed, shifting the peak efficiency to higher current, resulting in less electron spill-over and lower series resistance.

The team also believes that its results are inconsistent with an Auger recombination explanation of droop, since the Auger mechanism "is a high-carrier-concentration phenomenon that would not be expected to increase at low temperatures".

Another effect of reducing the operating temperature was to increase the LED turn-on voltage. The large shift between 1V and 2V was explained as being due to the temperature dependence of the junction voltage.

Current crowding effects as a cause of droop

Ukraine's Lashkaryov Institute of Semiconductor Physics and Russia's Scientific Research Institute of Semiconductor Devices have been exploring current crowding (CC) effects that lead to droop in 625nm (red) LEDs based on the more mature aluminum gallium indium phosphide (AlGaInP) compound semiconductors [V. K. Malyutenko et al, IEEE Photonics Technology Letters, v23, p1745, 2011]. Such devices have reached internal quantum efficiencies of nearly 90%, compared with the 70% level for the best nitride devices.

The LEDs of Malyutenko et al were made from commercially available epitaxial structures grown on $200\mu\text{m}$ -thick n-GaAs substrates. The p- and n-type cladding layers were AlGaInP. The active light-emitting region consisted of multi-quantum wells (MQWs). A $1.7\mu\text{m}$ distributed Bragg reflector (DBR) made of AlGaAs was grown first, between the substrate and n-cladding. The DBR was designed to reduce light absorption in the chip. The device was capped with a $12.4\mu\text{m}$ -thick transparent p-GaP layer, designed to spread the current evenly across the chip.

The top p-contact metal structure of gold-zinc alloy and gold was patterned (Figure 3). A $1.4\text{mm} \times 1.4\text{mm}$ reference device with intense CC had a $700\mu\text{m}$ circular p-contact (LED1). LED2 and LED3 were $1\text{mm} \times 1\text{mm}$ with more complicated patterning that included a $100\mu\text{m}$ circular central region and rectangular grids. The bottom n-contact consisted of continuous unpatterned layers of gold-germanium-nickel alloy and gold.

The contact areas were 0.385mm^2 (19.6%), 0.3mm^2 (30%) and 0.14mm^2 (14%) for LED1, LED2 and LED3, respectively. Pulsed currents were used to avoid self-heating effects. The devices were also soldered to massive heat-sinks.

Maximum light output power is achieved for LED2 at high current due to its more distributed contact shape (Figure 4). For all the devices a decrease in power conversion efficiency (PCE) was seen beyond a certain injection current. The peaks came at 35mA for LED1, 70mA for LED3, and 150mA for LED2. The droop at 500mA from the peak values was 66% for LED1, 32% for LED3, and only 12% for LED2. Removing the effect of series resistance gave lower droop impacts of 61.5% for LED1 and 18% for LED3. The efficiency degradation for LED2 became negligible.

The researchers believe that much of the PCE degradation in other devices comes as a result of CC and electrical power lost by series resistance of about 17%, but not a decrease in internal quantum efficiency. CC also impacts the near-field light distribution, causing thermal non-uniformity and catastrophic degradation at hot spots as the current increases. The ideality factor is also driven well above its theoretical value. The researchers comment: "The results presented are significant as they indicate that CC gives a remarkable

contribution to the efficiency degradation in AlGaInP LEDs with non-optimized p-contact shape".

The researchers also analyzed the emission pattern using a charge-coupled device (CCD) microscope. At a low current under 1mA, the device emissions are uniform but, as the current increases, current crowding becomes evident in non-uniform emission patterns. At 250mA, the ratios of local power output intensity between the near-contact and peripheral regions are 21, 2, and 13 for LEDs 1–3, respectively.

For LED1, the current spreading length from the contact was estimated to be $425\mu\text{m}$ at low current, but decreased to $75\mu\text{m}$ at 250mA. One difference between LED1 and LED2 is that only about 5% of the former device's area can be considered to be effectively emitting. By contrast, the researchers comment, "practically the whole contact-free area in LED2 remains active at high currents, as the distance between the contact stripes forming the p-contact remains less than double the current-spreading length".

The researchers see their results as having application beyond red AlGaInP/GaAs LEDs. Non-uniform current injection and high series resistance are features also of vertical and lateral blue and green nitride semiconductor LEDs, which also suffer from lower power conversion efficiency.

Malyutenko comments that his group's work concentrates on the efficiency droop in AlGaInP/GaAs LEDs that has rarely been mentioned since 2002. Up to now this effect has been neglected due to the low efficiency droop that resulted from very high red LED quality.

Malyutenko's group was the first to demonstrate large current (and heat) crowding effects combined in blue LEDs [V. K. Malyutenko, et al, Proc. SPIE, vol5941, p59411K, 2005]. Since that time, Malyutenko has considered current crowding as one of the major reasons for low nitride LED performance. He is also critical of efforts to explain droop effects while assuming uniform carrier injection.

Malyutenko also points out that any thermodynamic engine, such as an LED,

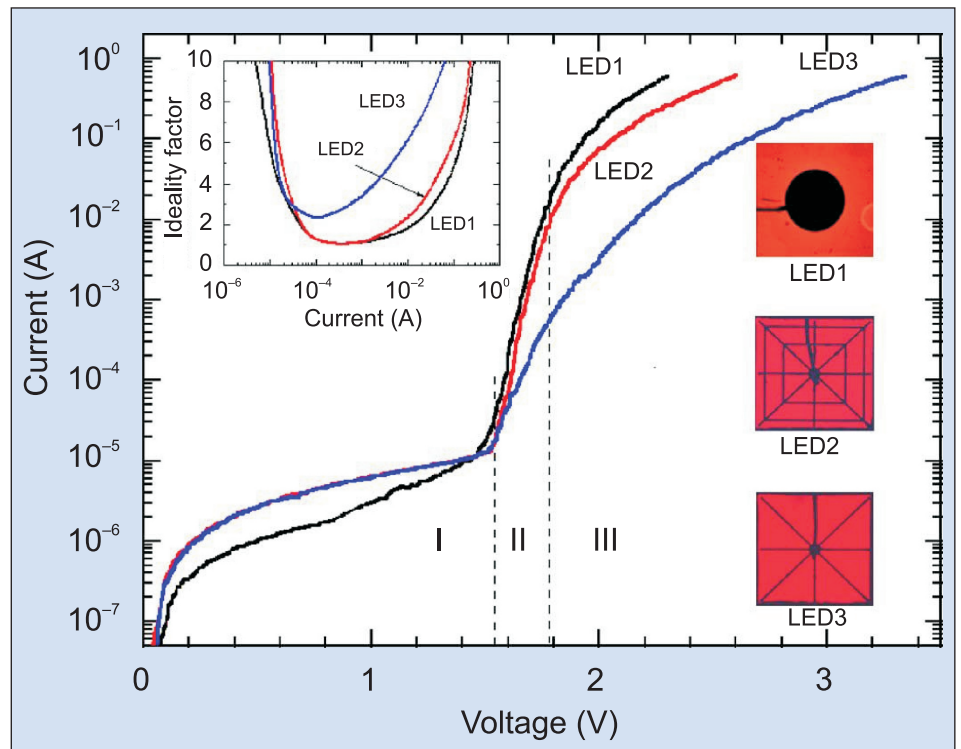


Figure 3. Experimental dependencies of forward-biased LEDs having three regions. Inset: ideality factor as a function of current. Also shown are micrographs of chips under low current injection. (Courtesy Institute of Semiconductor Physics/Institute of Semiconductor Devices .)

has only one practical figure of merit: power conversion efficiency (PCE), defined as the ratio of output and input

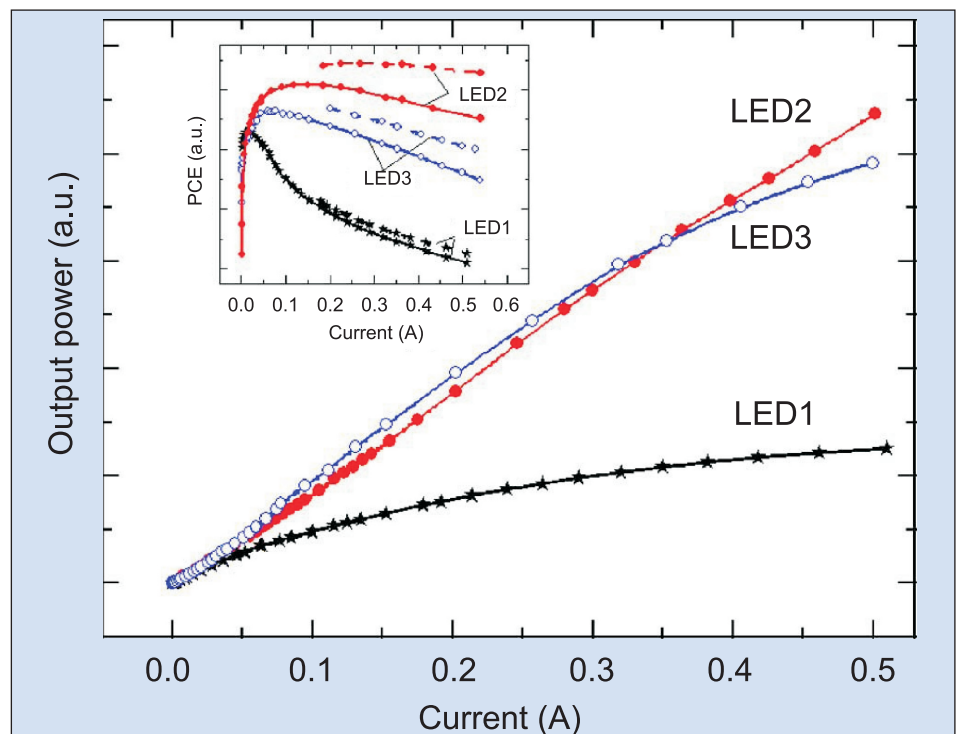


Figure 4. Measured output power versus drive current for different LEDs. Inset: power conversion efficiency as a function of current calculated for input power (solid lines) and power consumed by the junction (dotted lines). (Courtesy Institute of Semiconductor Physics/Institute of Semiconductor Devices .)

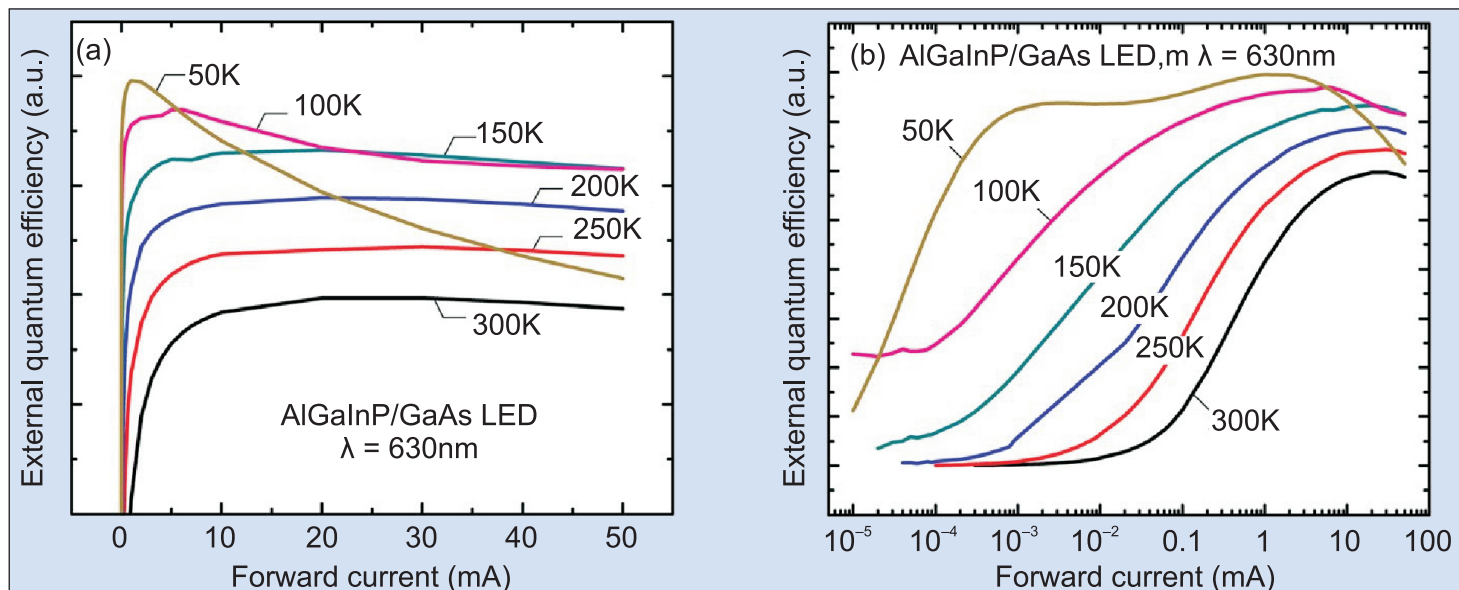


Figure 5. External quantum efficiency versus current of Hanyang/RPI/Samsung AlGaInP LED for different temperatures using (a) linear and (b) logarithmic abscissa.

powers. Ignoring losses in driver circuits, the PCE of LEDs is composed of four factors: electrical, injection, radiative and external efficiencies. Studies of efficiency droop tend to take only injection and radiation losses into account. However, the electrical factors become more significant at higher currents and, if current crowding occurs, the electrical loss is even more catastrophic.

In recent weeks, Hanyang University, RPI and Samsung LED have applied the RPI/Samsung asymmetric carrier transport analysis to AlGaInP LEDs [Jong-In Shim et al, Appl. Phys. Lett., vol100, p111106, 2012]. In particular, the researchers carried out cryogenic measurements and found efficiency droop effects at lower temperatures (Figure 5). The devices had active regions consisting of 38 quantum wells and 39 barriers of AlGaInP. The injection regions consisted of p- and n-type AlInP (Figure 6). The layers were lattice-matched with the GaAs substrate used. Due to the mature, well established growth technique and the material properties of AlGaInP, the droop cannot be attributed to factors such as polarization electric fields or threading dislocations that feature prominently in discussions of nitride semiconductor devices.

Instead, the researchers use a similar approach to the earlier RPI/Samsung paper described above. As the temperature is reduced, the holes are frozen out, creating asymmetric high-level injection effects such as the conductivity of the depleted active region becoming comparable to that of the p-AlInP cladding. As with nitride semiconductors, AlGaInP doping for p-type conductivity has a higher activation energy and lower mobility compared with n-type doping. Typical mobility figures are $100\text{cm}^2/\text{V}\cdot\text{s}$ for n-AlInP and $7\text{cm}^2/\text{V}\cdot\text{s}$ for p-AlInP. However, the activation energy is lower than for p-GaN, allowing non-droop behavior at room temperature. The reduction of peak efficiency as the temperature increases is attributed to the increase of the non-radiative Shockley–Read–Hall recombination mechanism. ■

<http://link.aip.org/link/doi/10.1063/1.3671395>

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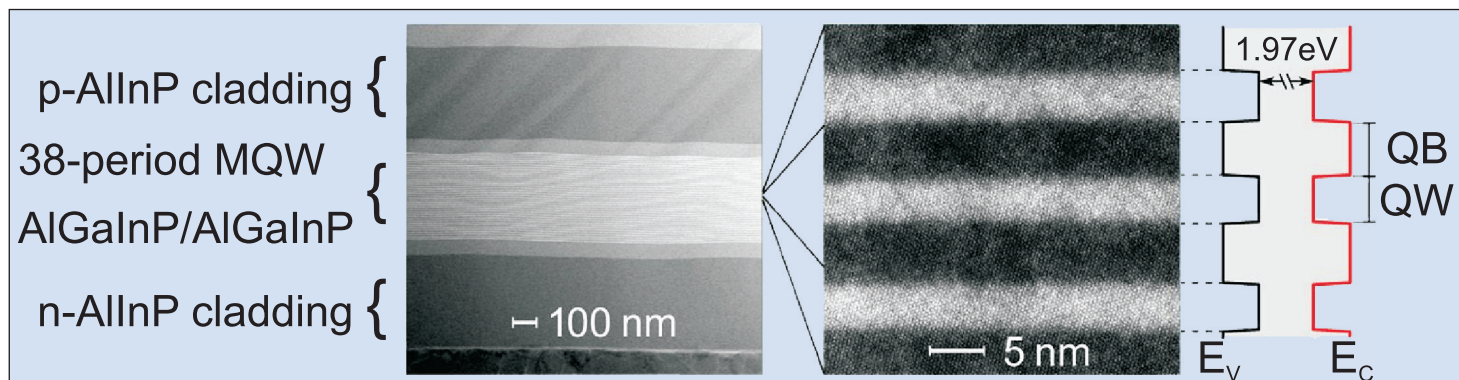
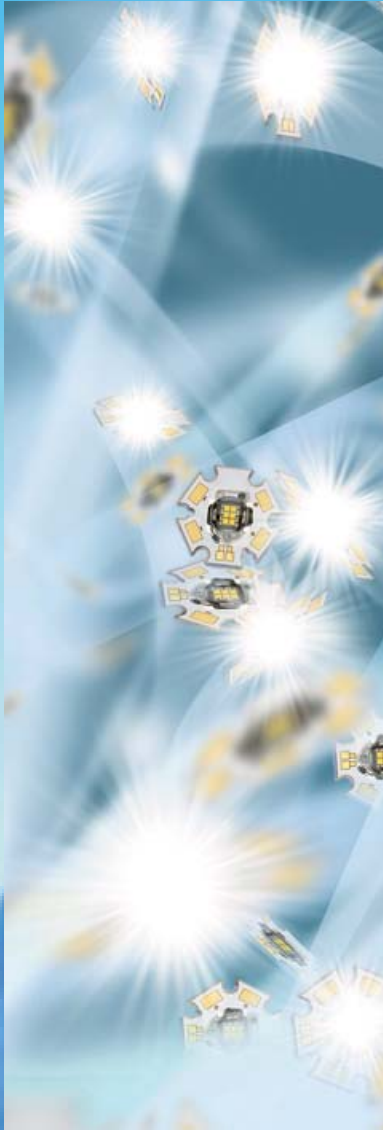


Figure 6. Transmission electron micrograph of the active region of Hanyang/RPI/Samsung AlGaInP LED.



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GaN power electronics market may top \$1bn in a few years

LED makers could convert existing excess LED fab capacity, reckons market research firm Yole Développement.

According to the report 'Power GaN – 2012 edition' from market research firm Yole Développement, the GaN power device sector probably generated revenue of less than \$2.5m in 2011, as only two suppliers — International Rectifier Corp (IRF) and Efficient Power Conversion Corp (EPC), both of El Segundo, CA, USA — are selling products on the open market. However, overall GaN activity has seen extra revenues, as R&D contracts, qualification tests and sampling for qualified customers was extremely buoyant.

In the short term, IRF and EPC remain the two main vendors of GaN power devices in early 2012. The market is likely to stay below \$10m for devices in 2012, with the rest being made through R&D sales.

However, 2013 should signal the transition from qualification to production ramp-up for several new

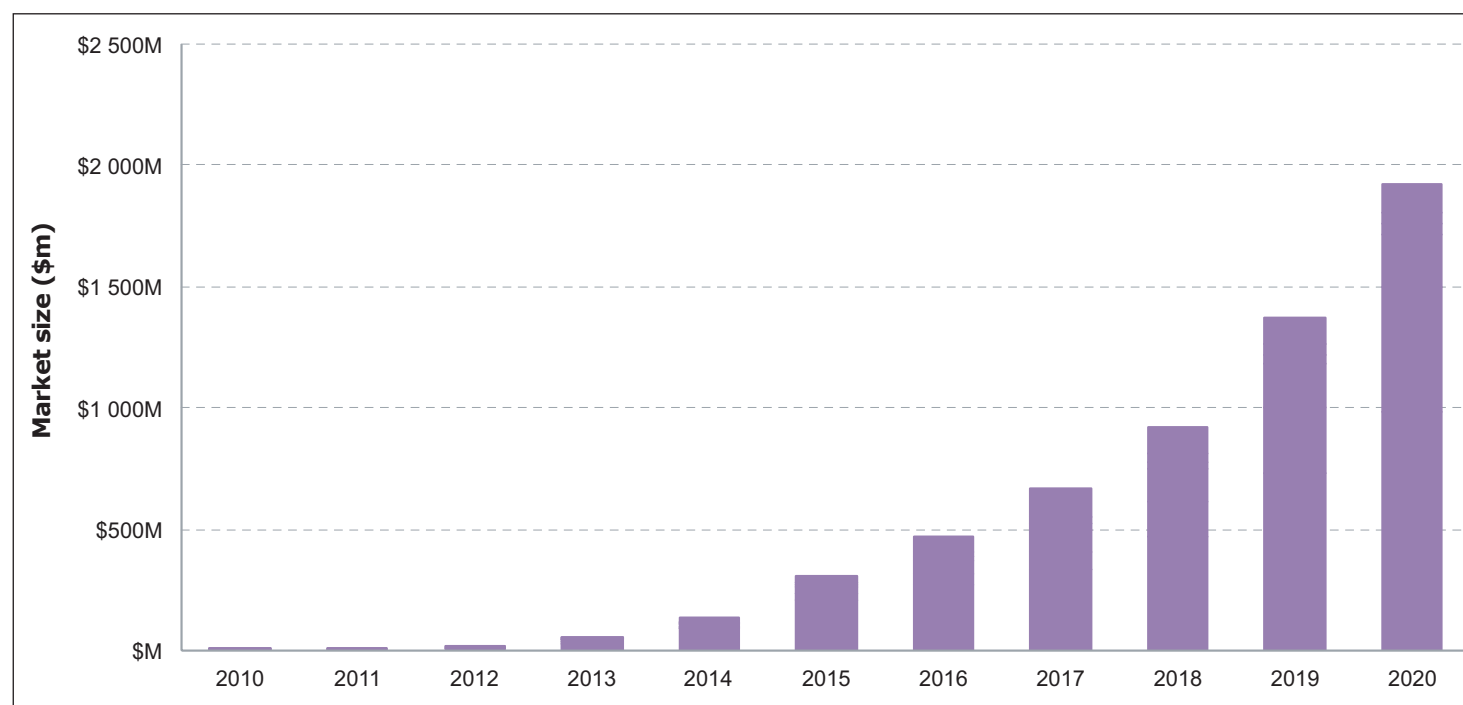
entrants, and the device market could reach \$50m. In 2014, most of these new entrants will ramp-up their capacity, and by 2015 the availability and adoption of qualified 600V+ GaN devices should see the market grow rapidly and open up non-consumer applications, reckons Yole. In 2015, 12–15 players should consume more than 100,000 6"-equivalent epiwafers, the firm reckons.

"Beyond that, if GaN is qualified in the electric vehicle/ hybrid electric vehicle (EV/HEV) sector, GaN device business could top \$1bn and the GaN-on-silicon substrate market could exceed \$300m by 2019," says Dr Philippe Roussel, Yole's business unit manager, Power Electronics. However, it is still unclear how car makers will choose between silicon carbide (SiC), GaN or established silicon technology.

Regarding substrates, research and development activities are still quite fragmented between several different options. These include GaN-on-sapphire, GaN-on-SiC, GaN-on-GaN, GaN-on-AlN and GaN-on-Si.

Of these, GaN-on-Si is likely to take a dominant position, as 6" wafers are now available with GaN epilayers more than 7 μ m thick, and 8" wafers are under qualification. In particular, the availability of 8" diameter epiwafers is probably the parameter that will make GaN-on-Si the obvious choice.

The GaN power sector is attracting more newcomers, says Yole, which identifies five firms on the epiwafer side and more than six pure-play GaN device makers, as well as another 15 silicon-based power device firms developing GaN technology. ▶



Gallium nitride devices could exceed 5% of the overall power device market by 2020.

► Cross-fertilization with LEDs

A new trend is that LED players are now starting to look at GaN power electronics as a new business opportunity and investigating how to put in place a strategy of diversification to convert their existing excess LED fab capacity for power electronics. However, Yole expects that this could cause some disturbance to the expected organic growth of the GaN industry.

The GaN power electronics business has always been interconnected with the LED industry, linked by technology and market dynamics. In the past, the premises of GaN epi technology stemmed from the LED industry, which brought the technology from the lab to mass production. Today, the extensive development of GaN-on-Si epi-wafers has fertilized both the LED

industry and the power device industry. Most epiwafer vendors are now targeting these two segments with dedicated products. In future, it is likely that some incumbent pure-play LED firms will enter the power electronics sector, using their excess fab capacity and existing tool-sets to make at least epiwafers or even power electronics devices.

Hence, says Yole, ultimately, talk will no longer be of 'LED' or 'power' sectors but of the 'GaN device industry' collectively, as the main players could well be the same.

A question of business model

Power device makers usually buy polished silicon wafers, conduct the epitaxial deposition (or buy silicon epiwafers) if necessary (although float-zone thin wafers do not require epitaxy) then process the

devices. This model is roughly the same for SiC technology.

For those planning to enter the GaN field, there are two scenarios:

- don't integrate metal-organic chemical vapor deposition (MOCVD) GaN epitaxy, but buy GaN epi-wafers and process them in existing CMOS front-end lines, as with silicon (or SiC) substrates; or
- fully integrate the GaN process, from bare silicon, through GaN epitaxy, to front-end wafer processing.

Yole says that its report 'Power GaN – 2012 edition' provides a complete analysis of the GaN device and substrate industry in the power electronics field (from epi-wafer to final applications) along with key market metrics. In total, more than 65 companies are covered in the report. ■

www.yole.fr

GaN power semiconductor market to top \$1bn by 2021

The emerging market for gallium nitride (GaN) power semiconductors is forecast to grow from almost zero in 2011 to over \$1bn in 2021, according to a new report from IMS Research. The market analyst firm analyzed all of the key end-markets for the products and found that power supplies, photovoltaic (PV) solar inverters and industrial motor drives would be the three main drivers of growth.

While silicon carbide (SiC) power devices have been around for some years, GaN power semiconductors have only just appeared on the market. One of the key reasons for the promising outlook for GaN power devices is because GaN is a wide-bandgap material which offers similar performance benefits to SiC but has greater cost-reduction potential. "This is possible because GaN power devices will be grown on a larger, lower-cost silicon substrate," says Richard Eden, senior market analyst and author of the report 'The World Market for Silicon Carbide & Gallium Nitride Power Semiconductors — 2012 edition'. "The key market driver is the speed

at which GaN-on-Si devices can achieve price parity with silicon MOSFETs, IGBTs [insulated-gate bipolar transistors] or rectifiers with equivalent performance," he adds.

The speed of GaN transistor development has accelerated in the last two years, possibly due to a realization that the market will be potentially huge. The launch of International Rectifier's 'GaNpowIR' and EPC's 'eGaN FET' devices started the low-voltage market in 2010.

The emergence of Transphorm and its 600V GaN transistors in 2011 created considerable interest in the prospects of GaN competing with high-voltage MOSFETs and IGBTs. Six of the world's top ten discrete power semiconductor suppliers are planning to launch GaN power devices in the near future, and some may already be making devices for in-house end equipment, says IMS.

The report uses IMS' market research on technology markets to analyse applications ranging from consumer electronics to industrial equipment and renewable energy. The first applications to adopt will be power supplies where the total

system cost savings outweigh the unit price penalty of the device. These include PC & notebook adapters, servers etc, and domestic appliances like room air-conditioners, where efficiency improvements are being driven by Government initiatives or regulations. Once reliability and other potential problems are resolved, PV micro-inverters, electric vehicle battery charging and other new applications are likely to adopt GaN power devices in the future, reckons IMS.

However, the market report found that there are some barriers to mainstream market acceptance of GaN power devices. The first is availability, as few GaN transistors are available in mass production. Competing manufacturers' products are non-standard and there are no second-sources. Second, the technology lacks maturity so far. Overall device performance and GaN material defect rates need improvement. A third issue is design inertia; the need to educate customers about both the potential benefits of GaN and how to use the devices. ■

<http://imsresearch.com>

Advantages of GaN versus established semiconductor technologies

Giuseppe Vacca of Bari Polytecnic in Italy gives an overview of the advantages of gallium nitride over established semiconductor materials, and how developments in GaN device technology are opening up new applications.

For several years now, new semiconductor device types have already been replacing silicon devices; indeed, an ever growing number of scientists and researchers agree on the fact that silicon devices have already reached the intrinsic limitations of the material.

This is due to the properties of the material precluding any further performance improvement, so that devices cannot maintain the pace of Moore's law (i.e. doubling in performance every 18 months).

Regarding integrated circuits and other silicon-based devices, the current scaling and miniaturization techniques are too expensive below 50nm in size; in addition, silicon is inadequate for manufacturing high-speed devices such heterojunction field-effect transistors (HFETs) and high-electron-mobility transistors (HEMTs) because its use in all those applications where high speed is required is very limiting. Consequently, the cost of improving performance further is becoming uneconomic.

Post-silicon materials

To overcome the limitations of silicon it is necessary to employ wide-bandgap semiconductors; especially for device structures that are based on quantum phenomena (where the channel length can be less than 20nm) and for devices that make use of both electronic and optical elements at the same time, integrated together on the same chip.

Gallium arsenide is one of the best-placed contenders to replace silicon devices. GaAs technology can be considered mature because it has already become well established in recent years.

In addition, there is the less mature material silicon carbide (SiC) and, more recently, gallium nitride (GaN).

The general level of interest in GaN has risen greatly as it appears to be the most prom-

ising material for electronic applications, with a robustness and potential performance levels that see no serious challengers among other candidate compound semiconductor materials for optoelectronic applications (such as LEDs and lasers) and microwave and high-power electronics applications.

In addition, of all the chemical Group III-V materials, GaN distinguishes itself by having a bandgap energy of 3.4eV, which is two or three times that of more established semiconductors such as silicon and GaAs. Moreover, it has a direct bandgap, as well as a high electron mobility; this has attracted the attention of global players due to its excellent ability to cope with high energy levels in an extremely effective and efficient way.

Along with the electrical parameters of a semiconductor material, its thermal conductivity is an important feature because it shows how easily power can be drawn from the component: if a semiconductor has a low thermal conductivity, this can cause performance degradation in high-temperature applications.

Intrinsically, GaN can offer better performance at high temperature (above 400°C). However, at the moment a limitation is introduced due to the reliability of the gate oxide (the thin oxide), which limits GaN's use to temperatures of 250°C or slightly less.

Nevertheless, GaN-based devices have a maximum junction temperature of 225°C (compared with 150°C for silicon). This translates into the ability to handle temperatures of 85°C in the base plate of an RF power amplifier without decreasing the active devices mean-time-to-failure (MTTF); this property allows safe operation in hostile environments.

Table 1. Properties of various semiconductor materials at 300K.

Properties at 300K	Si	SiC	GaAs	GaN
Bandgap energy [eV]	1.12	2.90	1.24	3.40
Electron mobility [$\text{cm}^2/\text{V}\cdot\text{s}$]	1400	900	8500	900
Breakdown electric field [KV/cm]	300	4000	400	2500
Thermal conductivity [$\text{W}/\text{cm}\cdot\text{K}$]	1.49	3.90	0.55	1.90

GaN devices offer considerably better performances than conventional GaAs devices and solutions such as silicon LDMOS (laterally diffused metal oxide semiconductor) and VDMOS (vertically diffused metal oxide semiconductor): these yield lower breakdown voltages and it is difficult to extract from them high output power values working in high frequencies.

For a better comparison of possible performance at high power and high frequency for different types of semiconductor materials, we can examine Johnson's figure of merit (JFOM). This kind of FOM combines the most important material features related to operation in high-power and high-frequency applications, and combines them into a single number that represents a measure of the relative strengths of the

alternative materials. Johnson's figure of merit is a measure of the suitability of a semiconductor material for high-frequency power transistor applications and requirements. It is the product of the charge carrier saturation velocity in the material and the electric breakdown field, under the same conditions.

Johnson's figure of merit takes into account the breakdown voltage and saturated electron velocity in a defined value for the high-frequency handling capability of a given semiconductor. The power-frequency product depends on the carrier saturation velocity and the semiconductor's critical electric field. The JFOM of GaN is more than 700 times bigger than that for silicon (LDMOS, transistors), almost 100 times that for GaAs, and about double that for SiC.

GaN device structures are suited to use in transmitter power amplifiers up to millimetre-wave frequencies. The superior physical characteristics of GaN microwave transistors adapt extremely well to the high-power and lower-consumption requirements of high-speed wireless communication systems.

Also, the better GaN properties associated with modern high-efficiency biasing techniques make GaN technology a prime candidate for use in RF power amplifiers. The figure of merit for GaN-based RF power devices is increased extraordinarily: the critical electric field rises from about 30V/ μm for silicon to 250V/ μm for GaN.

The achievable power output with some GaN RF transmission systems is well above 500W, and some chain designs have the ability to provide efficient

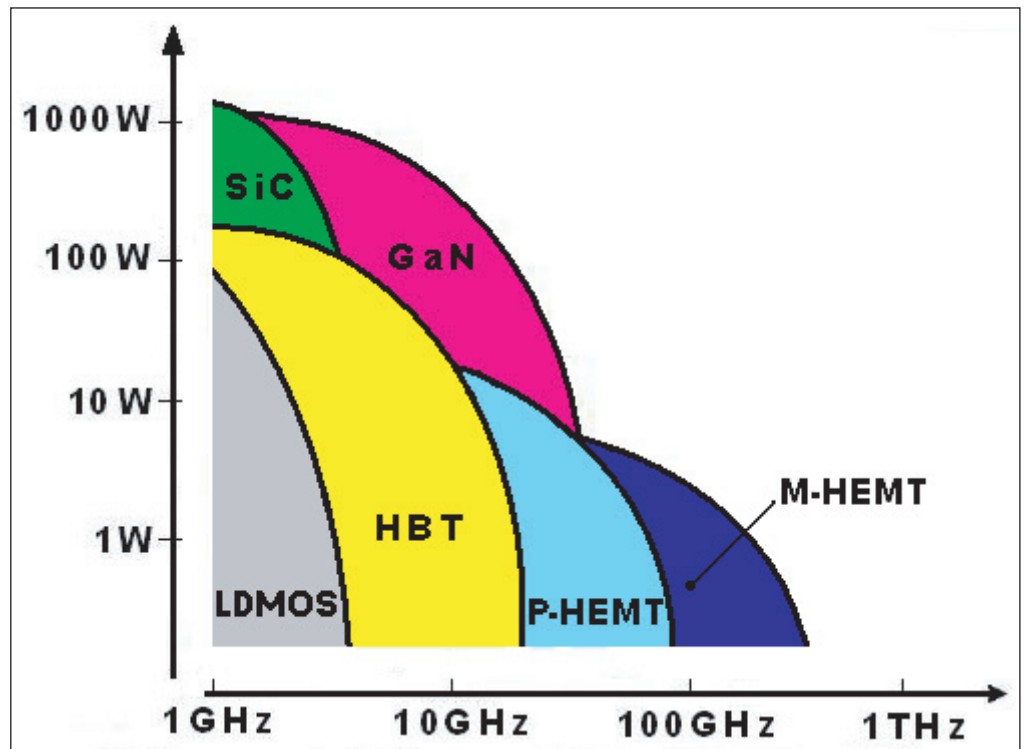


Figure 1. Johnson's figure of merit (power-frequency product) for various materials and transistor types.

power over multi-octave and decade bandwidths.

While GaN-based semiconductor devices possess a high breakdown voltage, the high values of electron mobility and their saturation velocity — combined with a high working temperature — makes GaN an ideal candidate for high-output-power telecommunication systems, as evidenced by its higher FOM. In addition, GaN also has excellent reliability, thanks to an MTTF of more than 20 years.

Substrate materials

The choice of substrate material for GaN devices has not yet been resolved and is still an issue to be addressed: in earlier work GaN crystals were grown on either diamond or sapphire due to their similar cooling speed and comparable volume reduction coefficients. Many other substrates have since been tried, some with a hybrid type with the aim of identifying an alternative that is cheaper than SiC (on which GaN can be grown easily).

The current state of knowledge of GaN epitaxial growth technology allows the fabrication of GaN on silicon into epitaxial heterostructures, using a process compatible with CMOS technology. This allows the adoption of large-diameter silicon wafers (up to 12 inches) as a substrate.

Metal-organic chemical vapor deposition (MOCVD) enables GaN to be grown on silicon substrates, overcoming the mismatch between the thermal expansion coefficients of GaN and silicon, due to the insertion of an intermediate stress-mitigating transition layer. ➤

► This technology allows good-quality GaN to be grown on silicon substrates, and results in a large reduction in process cost. This opens up a real opportunity to introduce GaN into the market, putting it in economic competition with the other more established solutions.

In this manner, silicon can still be used in those IC subsections where high speed is not fundamental, allowing differentiation - using GaN only for those devices where high speed is necessary.

GaN HEMTs with positive threshold voltage

Previously, GaN HFET and HEMT devices have needed a negative voltage bias to cut off the device current (drain current). This was a limitation due to the lack of a negative voltage in certain electronic circuits. In order to overcome this drawback and make devices with a positive threshold voltage, a new GaN HEMT transistor structure has been developed.

A key feature of this innovative structure is the addition of an aluminium nitride (AlN) layer on the top of the n-type GaN layer. This increases the carrier electron density when the device is turned on, as shown in Figure 2.

The gate electrode is obtained after removing a portion of the AlN layer, and this step decreases the carrier density around the region under the gate electrode in order to avoid current flow even in the absence of a negative voltage. For this reason the new transistor structure does not need a negative voltage to remain in the 'off' state.

However, using AlN to make the highest layer can generate microscopic surface imperfections, reducing the breakdown voltage. It is possible to address this new problem by adding another layer of n-type GaN on top of the AlN layer: the result is a multi-layer structure that improves the surface issues and raises the output

level and reliability; the addition of another AlN layer increases the volume of transmitted carriers. With this precaution it is possible to sustain high current density when the device is in the 'on' state.

The multi-layer structure that covers the AlN with another n-type GaN layer reduces surface issues, allowing higher breakdown voltage values of more than 300V. This allows the fabrication of high-efficiency power amplifier devices with low resistance and low power losses; the implementation of this new transistor structure eliminates power wastage in the stand-by state.

Many silicon foundries are currently investing in R&D on this type of field-effect transistor. In particular, the application of hetero-junction devices (GaN HEMTs and HFETs) allows the implementation of radio-frequency transmission systems with considerable output power accompanied by high efficiency compared with existing standards, where there is strong competition from more established LDMOS technology: since 2004, LDMOS has been used for more than 90% of power amplification in civil and military telecom equipment below 1GHz.

Higher power densities

By using GaN it is also possible to reach electron densities about an order of magnitude greater than those in devices made with GaAs, operating at the same frequencies.

Achieving high levels of power density (up to 10 or more Watts per square millimeter) allows considerable simplification of the design of the RF amplifier chain because it eliminates a few intermediate stages due to the higher gain of GaN devices. In addition, the smaller chip area leads to an automatic reduction in losses. In fact, if the number of the stages that make up the

transmission chain is reduced, then there can be savings in power supply stages, protection circuits, cooling fans and active devices.

In doing so, the probability of failure is greatly reduced, because the system is made up of several stages connected in series: if the number of stages decreases, the reliability increases as the number of Pi terms decreases (where Pi is the probability of failure of stage 'i' and is lower or equal to 1); their product represents the total probability of a failure occurring.

New applications

By using GaN technology (characterized by its outstanding properties in terms of power, low noise figure, high frequency and the added ability to

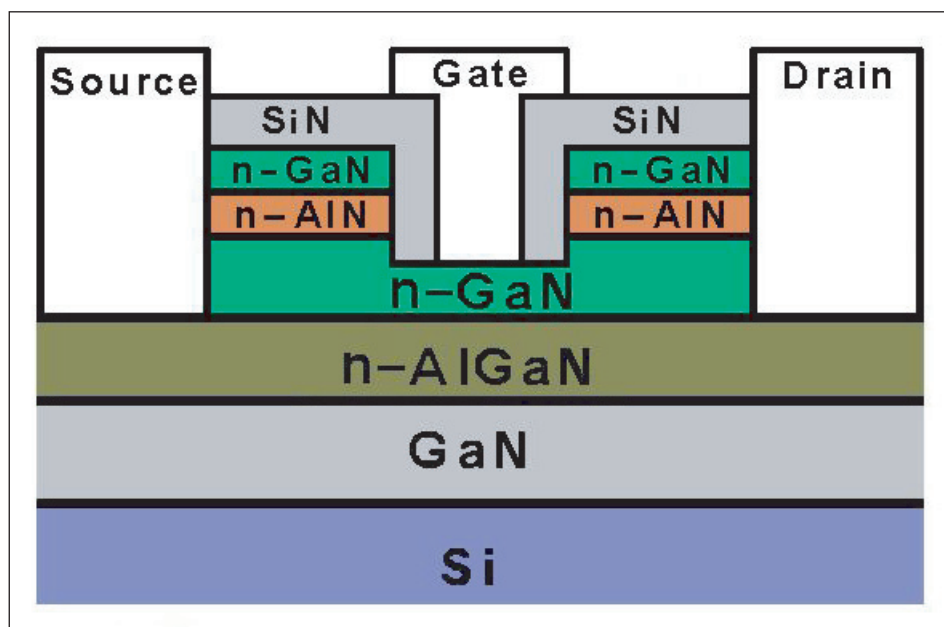


Figure 2. GaN HEMT cross section with positive threshold voltage.

operate at high temperatures), new perspectives are emerging regarding possible new applications in fields such as electric motor drives, hybrid electric vehicles (HEVs) power circuits, solar power converters, domestic appliances, etc.

The increase in operating frequency was obtained by replicating within the device layout the bond wire that normally connects the source with the output lead, through the use of a 'by hole'-type solution: this connection is quite similar to the lateral diffusion used in LDMOS technology, which allows avoidance of the parasitic source inductance that is primarily responsible for the degeneration of gain at high frequency.

Today GaN HEMTs are widely used in satellite broadcasting equipment, GPS navigation systems, broadband wireless access systems and other technologies. In fact, Ku-band (12–15GHz) satellite communications devices are already available and capable of handling power levels of 70W: in this context, GaN technology is replacing electron tubes, which are traditionally used for these high-frequency applications.

GaN FET-type devices are used in base-stations and microwave communications within radar Ka-band frequencies (up to 30GHz), with possible future application up to 70GHz. They can also operate from power supplies with voltages from +28V_{dc} to +50V_{dc}.

Generally, GaN solutions provide better efficiency compared with conventional amplification technologies, with an improvement of 10–15% in terms of bandwidth compared with GaAs or silicon solutions.

In the field of power conversion and its applications, the arrival of a viable commercial platform for GaN power devices has opened up the possibility of solutions for higher efficiency, higher switching frequencies and higher-power-density equipment. In fact, the power electronics industry has certainly benefitted from GaN transistor technology, because it is able to considerably

reduce energy losses due to lower on-resistance and increasing efficiency in switching equipment where solid-state devices are normally used for the conversion of electrical power: GaN is the answer to the demand for an increase in switching frequency and size reduction.

This improvement in density, efficiency and cost reduction — essential for power conversion — is due to the significantly better figure of merit of GaN devices, which in this field is $FOM=R_{on} \cdot Q_{sw}$. This enables an increase in switching frequency with a significant reduction in losses, as well as smaller magnetic devices and a general downsizing in equipment size, compared with the established alternatives.

In this specific field, one of the most important advantages of GaN devices is the lower RD_{S-ON} value compared with the same value for silicon devices. This parameter, along with the higher breakdown voltage, allows much better performance, superior to silicon technology devices.

The optoelectronics industry has already been widely impacted by the advent of GaN technology: blue lasers and LEDs emitting over a wide spectral range (from blue to UV) are already on the market, and many other devices will be launched in the near future.

According to the technical progress that has been made, it is estimated that the global market for GaN technology, starting from 2010, will approximately double each year, ensuring this growth trend for at least the first half of the current decade. ■

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1 Bulk crystal source materials

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 Northants NN8 4PE,
 UK

Tel: +44 1933 220626
 Fax: +44 1933 227814

www.MCP-group.com

Umicore Indium Products

50 Simms Avenue,
 Providence, RI 02902,
 USA

Tel: +1 401 456 0800
 Fax: +1 401 421 2419

www.thinfilmpducts.umicore.com

United Mineral & Chemical Corp

1100 Valley Brook Avenue,
 Lyndhurst, NJ 07071,
 USA

Tel: +1 201 507 3300
 Fax: +1 201 507 1506

www.umccorp.com

2 Bulk crystal growth equipment

MR Semicon Inc

PO Box 91687,
 Albuquerque,
 NM 87199-1687,
 USA

Tel: +1 505 899 8183
 Fax: +1 505 899 8172

www.mrsemicon.com

3 Substrates

AXT Inc

4281 Technology Drive
 Fremont,
 CA 94538,
 USA

Tel: +1 510 438 4700
 Fax: +1 510 683 5901

www.axt.com

Supplies GaAs, InP, and Ge wafers using VGF technology with manufacturing facilities in Beijing and five joint ventures in China producing raw materials, including Ga, As, Ge, pBN, B₂O₃.



CrystAl-N GmbH

Dr.-Mack-Straße 77,
 D-90762
 Fürth,
 Germany



Tel: +49 (0)911 650 78 650 90
 Fax: +49 (0)911 650 78 650 93
 E-mail: info@crystal-n.com

www.crystal-n.com

Crystal IS Inc

70 Cohoes Avenue
 Green Island, NY 12183, USA

Tel: +1 518 271 7375

Fax: +1 518 271 7394

www.crystal-is.com

The Fox Group Inc

200 Voyageur Drive, Montreal,
 Quebec H9R 6A8, Canada

Tel: +1 925 980 5645

Fax: +1 514 630 0227

www.thefoxgroupinc.com

Freiberger Compound Materials

Am Junger Loewe Schacht 5,
 Freiberg, 09599, Germany

Tel: +49 3731 280 0

Fax: +49 3731 280 106

www.fcm-germany.com

Kyma Technologies Inc

8829 Midway West Road,
Raleigh, NC,
USA
Tel: +1 919 789 8880
Fax: +1 919 789 8881
www.kymatech.com

Nikko Materials

125 North Price Road,
Chandler, AZ,
USA
Tel: +1 480 732 9857
Fax: +1 480 899 0779
www.nikkomaterials.com

SiCrystal AG

Guenther-Scharowsky-Str. 1
D-91058 Erlangen,
Germany
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Fax: +49 (0) 9131 / 73 22 37
www.sicrystal.de

sp3 Diamond Technologies

2220 Martin Avenue,
Santa Clara, CA 95050,
USA
Tel: +1 877 773 9940
Fax: +1 408 492 0633
www.sp3inc.com

**Sumitomo Electric
Semiconductor Materials Inc**

7230 NW Evergreen Parkway,
Hillsboro, OR 97124, USA
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Fax: +1 503 693 8275
www.sesmi.com

TECDIA Inc

(see section 16 for full contact details)

III/V-Reclaim

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84568 Pleiskirchen,
Germany
Tel: +49 8728 911 093
Fax: +49 8728 911 156
www.35reclaim.de

III/V-Reclaim offers reclaim (recycling) of GaAs and InP wafers, removing all kinds of layers and structures from customers' wafers. All formats and sizes can be handled. The firm offers single-side and double-side-polishing and ready-to-use surface treatment.

Umicore Electro-Optic Materials

Watertorenstraat 33,
B-2250 Olen, Belgium
Tel: +32-14 24 53 67
Fax: +32-14 24 58 00
www.substrates.umicore.com

Wafer Technology Ltd

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UK
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www.wafertech.co.uk
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www.camchem.co.uk

The Fox Group Inc

(see section 3 for full contact details)

Intelligent Epitaxy Technology Inc

1250 E Collins Blvd, Richardson,
TX 75081-2401, USA
Tel: +1 972 234 0068
Fax: +1 972 234 0069
www.intelliepi.com

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France
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Fax: +33 1 45 10 69 53
www.ommic.fr

Picogiga International S.A.S.

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Villejust, 91971 Courtabouef,
France
Tel: +33 (0)1 69 31 61 30
Fax: +33 (0)1 69 31 61 79
www.picogiga.com

SemiSouth Laboratories Inc

201 Research Boulevard,
Starkville, MS 39759,
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Tel: +1 662 324 7607
Fax: +1 662 324 7997
www.semisouth.com

5 Deposition materials

Akzo Nobel High Purity Metalorganics

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Chicago, IL 60607,
USA
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Fax: +1 312 544 7188
www.akzonobel-hpmpo.com

Cambridge Chemical Company Ltd

Unit 5 Chesterton Mills,
French's Road,
Cambridge CB4 3NP,
UK
Tel: +44 (0)1223 352244
Fax: +44 (0)1223 352444
www.camchem.co.uk

Dow Electronic Materials

60 Willow Street,
North Andover, MA 01845,
USA
Tel: +1 978 557 1700
Fax: +1 978 557 1701
www.metalorganics.com

Matheson Tri-Gas

6775 Central Avenue
Newark, CA 94560,
USA
Tel: +1 510 793 2559
Fax: +1 510 790 6241
www.mathesontrigas.com

Mining & Chemical Products Ltd
(see section 1 for full contact details)**Power + Energy Inc**

(see section 10 for full contact details)

Praxair Electronics

542 Route 303,
Orangeburg,
NY 10962,
USA
Tel: +1 845 398 8242
Fax: +1 845 398 8304
www.praxair.com/electronics

SAFC Hitech

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Wirral,
Merseyside CH62 3QF,
UK
Tel: +44 151 334 2774
Fax: +44 151 334 6422
www.safchitech.com

Williams Advanced Materials

2978 Main Street,
Buffalo,
NY 14214,
USA
Tel: +1 716 837 1000
Fax: +1 716 833 2926
www.williams-adv.com

6 Deposition equipment

AIXTRON SE

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7 Wafer processing materials

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USA
Tel: +1 610 481 4911

www.airproducts.com/compound

MicroChem Corp

1254 Chestnut St. Newton,
MA 02464, USA
Tel: +1 617 965 5511
Fax: +1 617 965 5818

www.microchem.com

Power + Energy Inc

(see section 10 for full contact details)

Praxair Electronics

(see section 5 for full contact details)

8 Wafer processing equipment

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Power + Energy Inc

(see section 10 for full contact details)

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Fax: +1 408 734 0961

www.samcointl.com

SPP Process Technology Systems Ltd

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Wales, UK
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Fax: +44 (0)1633 652405

www.spp-pts.com

TECDIA Inc

(see section 16 for full contact details)

Veeco Instruments Inc

(see section 6 for full contact details)

9 Materials & metals

Goodfellow Cambridge Ltd

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Tel: +44 (0)1954 786800
Fax: +44 (0)1954 786818

www.cambridge-fluid.com

CS CLEAN SYSTEMS AG

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Ismaning, 85737, Germany
Tel: +49 89 96 24 00 0
Fax: +49 89 96 24 00 122

www.cscleansystems.com

Power + Energy Inc

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Fax: +1 215 942-9300

www.powerandenergy.com

SAES Pure Gas Inc

4175 Santa Fe Road,
San Luis Obispo, CA 93401,
USA

Tel: +1 805 541 9299
Fax: +1 805 541 9399

www.saesgetters.com

11 Process monitoring and control

k-Space Associates Inc

2182 Bishop Circle
East, Dexter,
MI 48130, USA
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Fax: +1 734 426 7955



www.k-space.com

k-Space Associates Inc specializes in in-situ, real-time thin-film process monitoring tools for MBE, MOCVD, PVD, and thermal evaporation. Applications and materials include the research and production line monitoring of compound semiconductor-based electronic, optoelectronic, and photovoltaic devices.

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Fax: +1 408 875 4144
www.kla-tencor.com

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Tel: +49 30 39 800 80 0
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www.laytec.de



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Fax: +44 (0)1745 535 186
www.ors-ltd.com

WEP (Ingenieurbüro Wolff für Elektronik- und Programmentwicklungen)

Bregstrasse 90, D-78120
Furtwangen im Schwarzwald,
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Fax: +49 7723 9197 22
www.wepcontrol.com

12 Inspection equipment

Bruker AXS GmbH

Oestliche Rheinbrueckenstrasse 49,
Karlsruhe, 76187, Germany
Tel: +49 (0)721 595 2888
Fax: +49 (0)721 595 4587
www.bruker-axs.de

13 Characterization equipment

J.A. Woollam Co. Inc.

645 M Street Suite 102,
Lincoln, NE 68508,
USA
Tel: +1 402 477 7501
Fax: +1 402 477 8214
www.jawoollam.com

Lake Shore Cryotronics Inc

575 McCorkle Boulevard,
Westerville, OH 43082,
USA
Tel: +1 614 891 2244
Fax: +1 614 818 1600
www.lakeshore.com

14 Chip test equipment

Keithley Instruments Inc

28775 Aurora Road,
Cleveland, OH 44139,
USA
Tel: +1 440.248.0400
Fax: +1 440.248.6168
www.keithley.com

SUSS MicroTec Test Systems

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USA
Tel: +1 800 685 7877
Fax: +1 802 244 7853
www.suss.com

15 Assembly/packaging materials

ePAK International Inc

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Austin, TX 78759, USA
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Fax: +1 512 231 8183
www.epak.com

Gel-Pak

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Hayward,
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USA
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Fax: +1 510 576 2282
www.gelpak.com

Wafer World Inc

(see section 3 for full contact details)

Williams Advanced Materials

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Fax: +1 716 833 2926
www.williams-adv.com

16 Assembly/packaging equipment

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Switzerland
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Fax: +41 329257115
www.ismeca.com

Kulicke & Soffa Industries

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Fort Washington,
PA 19034,
USA
Tel: +1 215 784 6000
Fax: +1 215 784 6001
www.kns.com

Palomar Technologies Inc

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CA 92010,
USA
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Fax: +1 760 931 5191
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17 Assembly/packaging foundry

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Tel: +1 858 674 4676
Fax: +1 8586 74 4681
www.quikicpak.com

18 Chip foundry

Compound Semiconductor Technologies Ltd

Block 7, Kelvin Campus,
West of Scotland, Glasgow,
Scotland G20 0TH,
UK
Tel: +44 141 579 3000
Fax: +44 141 579 3040
www.compoundsemi.co.uk

United Monolithic Semiconductors

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France
Tel: +33 1 69 33 04 72
Fax: +33 169 33 02 92
www.ums-gaas.com

19 Facility equipment

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Fax: +1 541 917 3623
www.marlerenterprises.net

20 Facility consumables

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21 Computer hardware & software

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4 Station Square, Suite 200,
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Fax: +1 412 471 9427
www.ansoft.com

Crosslight Software Inc

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Fax: +1 604 320 1734
www.crosslight.com

Semiconductor Technology Research Inc

10404 Patterson Ave., Suite 108,
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Fax: +1 804 740 3814
www.semitech.us

22 Used equipment

Class One Equipment Inc

5302 Snapfinger Woods Drive,
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Fax: +1 770 808 8308
www.ClassOneEquipment.com

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TECDIA Inc

(see section 16 for full contact details)

24 Consulting

Fishbone Consulting SARL

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France
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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
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9–13 April 2012

2012 MRS Spring Meeting

San Francisco, CA, USA

E-mail: info@mrs.org

www.mrs.org/spring2012

15–17 April 2012

13th Annual IEEE Wireless and Microwave Technology Conference (WAMICON 2012)

Hilton Cocoa Beach Oceanfront hotel, FL, USA

E-mail: ryan_baker@cree.com

www.wamicon.org

15–19 April 2012

IEEE International Reliability Physics Symposium (IRPS-2012)

Hyatt Regency Orange County, Anaheim, CA, USA

E-mail: yuan.chen@nasa.gov

www.irps.org

15–20 April 2012

Light+Building 2012

Frankfurt am Main, Germany

<http://light-building.messefrankfurt.com>

16–17 April 2012

WAMICON 2012 (13th Annual IEEE Wireless and Microwave Technology Conference)

Hilton Cocoa Beach Oceanfront Hotel, FL, USA

E-mail: mumcu@usf.edu

www.wamicon.org

16–18 April 2012

12th European Advanced Process Control and Manufacturing Conference (APCM 2012)

MINATEC, Grenoble - France

E-mail: weber@apcm-europe.eu

www.apcm-europe.eu

16–18 April 2012

CPV-8 International Conference on Concentrating Photovoltaic Systems

Toledo, Spain

E-mail: iinfo@cpv-8.org

www.cpv-8.org/cms

16–20 April 2012

SPIE Photonics Europe 2012

The Square Conference Center, Brussels, Belgium

<http://spie.org/photonics-europe.xml>

17–19 April 2012

7th Annual Photovoltaics Summit

The Westin Hotel, San Diego, CA, USA

E-mail: info@pira-international.com

www.photovoltaicssummit.com

18–20 April 2012

16th European Conference on Integrated Optics (ECIO 2012)

Hotel Melia Sitges, Barcelona, Spain

E-mail: ecio2012@icfo.es

www.ecio2012.com

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19–20 April 2012

**4th Photovoltaics Thin-Film Week, including:
4th Thin-Film Industry Forum (TIF 2012)**

Berlin, Germany

E-mail: info@solarpraxis.de

www.solarpraxis.de/en/conferences

23 April 2012

JEDEC's 27th Annual ROCS (Reliability of Compound Semiconductors) Workshop

The Boston Park Plaza Hotel, Boston, MA, USA

E-mail: ptanner@jedec.org

www.jedec.org/home/gaas

23–26 April 2012

**2012 CS MANTECH:
International Conference on Compound Semiconductor Manufacturing Technology**

The Boston Park Plaza Hotel, Boston, MA, USA

E-mail: csmantech@csmantech.org

www.csmantech.org

23–27 April 2012

SPIE Defense, Security, and Sensing 2012

Baltimore, MD, USA

E-mail: customerservice@spie.org

<http://spie.org/defense-security.xml>

28 April – 3 May 2012

**2012 SVC TechCon:
55th Society of Vacuum Coaters Annual Technical Conference**

Santa Clara Convention Center, CA, USA

E-mail: svcinfo@svc.org

www.svc.org/ConferencesExhibits/Future-Meetings.cfm

6–11 May 2012

221st Electrochemical Society (ECS) Meeting

Seattle, Washington

E-mail: meetings@electrochem.org

www.electrochem.org/meetings/biannual/fut_mtgs.htm

14–18 May 2012

E-MRS 2012 Spring Meeting

Congress Center, Strasbourg, France

Discounted registration deadline: 5 April 2012

E-mail: emrs@emrs-strasbourg.com

www.emrs-strasbourg.com

15–16 May 2012

SEMICON Russia 2012

ExpoCenter Moscow, Russia

E-mail: semimoscow@semi.org

www.semiconrussia.org

20–25 May 2012

ICMOVPE – XVI (16th International Conference on Metal Organic Vapor Phase Epitaxy)

Busan, Korea

E-mail: secretariat@icmovpe2012.org

www.icmovpe2012.org

21–23 May 2011

International Symposium on Photonics and Optoelectronics (SOPO 2012)

Shanghai, China

E-mail: sopo@scirp.org

www.sopoconf.org/2012

22–24 May 2012

Strategies in Light China

Shenzhen Intercontinental Hotel, China

E-mail: LubaH@pennwell.com

www.sil-ledchina.com

29–30 May 2012

International SiC Power Electronics Applications Workshop (ISiCPEAW 2012)

Kista Science Tower Conference, Stockholm, Sweden

E-mail: per.ericsson@acreo.se

www.b2match.com/insicpeaw2012

3–6 June 2012

23rd Conference on Crystal Growth and Epitaxy – West (2012 AACGE-west)

Stanford Sierra Camp, Fallen Leaf Lake, CA, USA

Abstract deadline: 16 April 2012

E-mail: aacg@comcast.net

www.crystalgrowth.us/accge_west23

3–7 June 2012

LIGHTFAIR International (LFI 2012)

Las Vegas Convention Center, NV, USA

E-mail: info@lightfair.com

www.lightfair.com

3–7 June 2012

24th International Symposium on Power Semiconductor Devices and ICs (ISPSD '12)

Bruges, Belgium

E-mail: peter.moens@onsemi.com

www.ispsd2012.com

3–8 June 2012

38th IEEE Photovoltaic Specialists Conference (PVSC)

Austin Convention Center, TX, USA

E-mail: Registration@ieee-pvsc.org

www.ieee-pvsc.org/PVSC38

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