

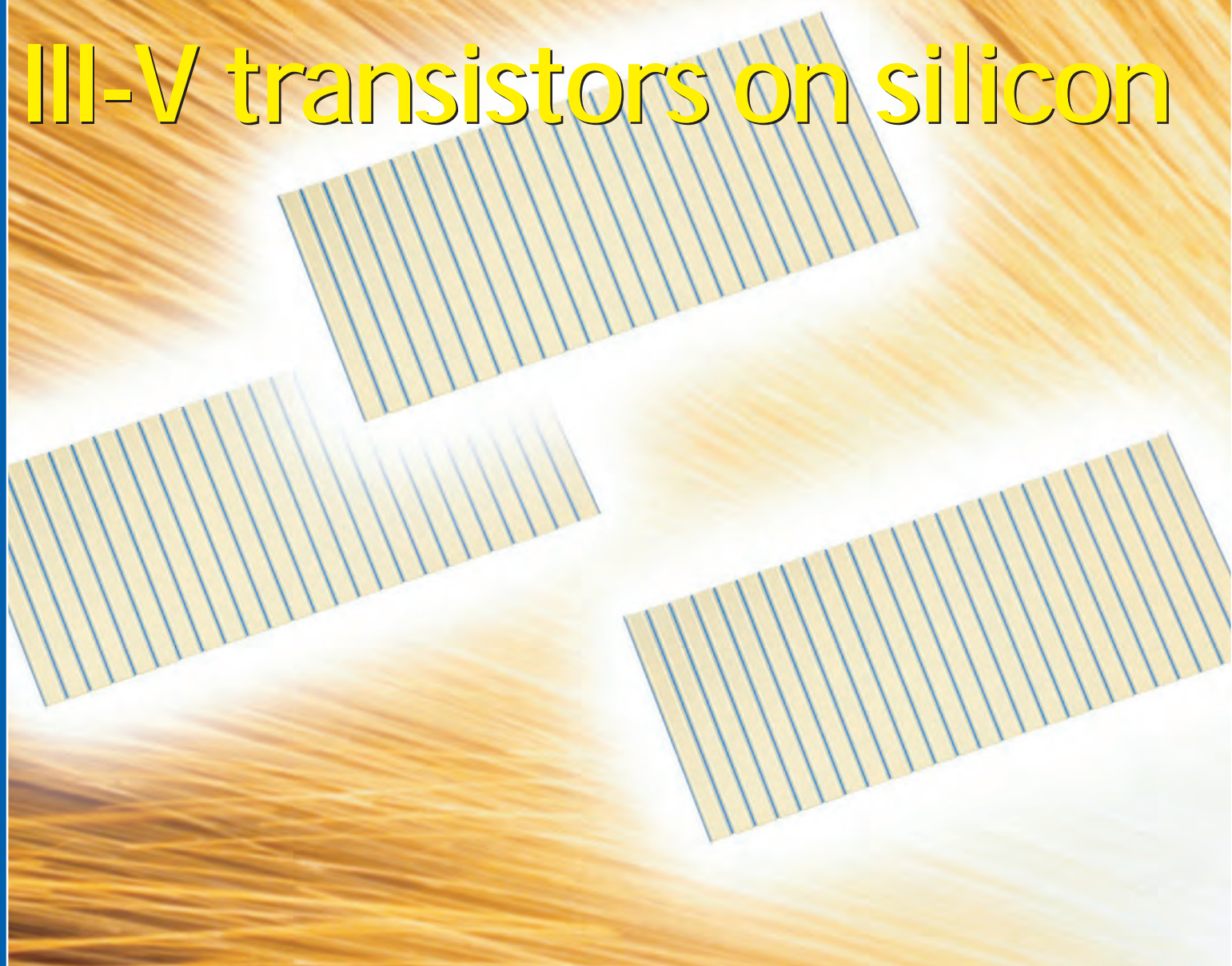
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COMPOUNDS & ADVANCED SILICON

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Transparent conduction for nitride LEDs III-V transistors on silicon



RFMD unveils 900V GaN • First Solar closing German plant
Toshiba invests in Bridgelux • Cree sets 254lm/W R&D record

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Technology focus: Nitride LEDs

Transparent conduction for nitride LEDs

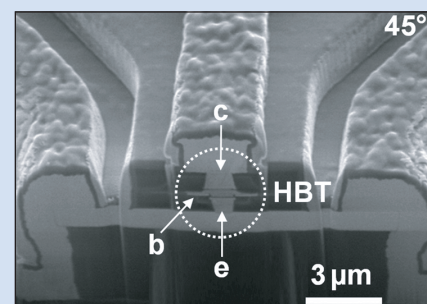
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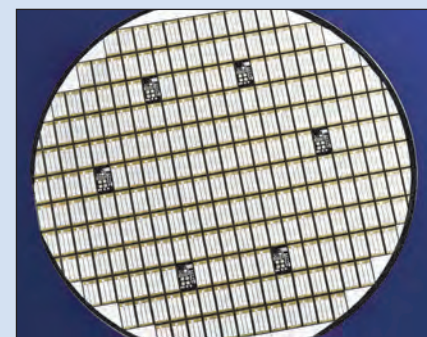
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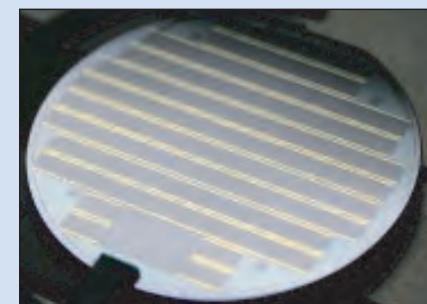
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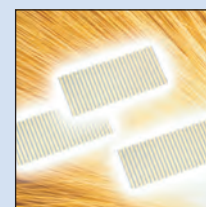
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Cover: Osram Opto Semiconductors' new SPL BKxx-40WFT series of laser bars offer efficiency of up to 65% at 200W optical output power.

Measuring 10mm wide and with a cavity length of 4mm, the new laser bars produce infrared radiation at wavelengths of 915–1020nm. **p75.**

Light output on the rise

Although the current overcapacity of MOCVD systems in the field could take 12–18 months to absorb, the market for epitaxial deposition equipment (MOCVD and MBE) should amount to \$6.1bn cumulatively over 2012–2020, forecasts Yole Développement (see page 102 of this issue).

In particular, after fourth-quarter 2011 saw a drop in MOCVD orders of 43% for both Aixtron and Veeco, in Q1/2012 both firms saw rebounds in MOCVD orders, of 8% and 19% respectively (see pages 40 and 42). Although Aixtron still believes 2012 will be a “transitional year” (between maturity of the LED backlighting market and takeoff of the general lighting market) with lower revenue than in 2011, it retains its positive outlook for second-half 2012, driven by general lighting applications (leading Aixtron to continue increasing its R&D spending — up 12% on last quarter — while cutting other expenses). The firm still targets an operating profit in 2012, but continues to consider cost-saving measures in the short term. While Veeco cautions that it is still unclear when the MOCVD market will recover, it is seeing “increasing tool utilization rates in Korea, Taiwan and China”. Longer term, Veeco estimates that the annual market for GaN LED MOCVD systems will rise to 460 in 2013 then 760 in 2016.

On pages 100–101 we report Yole's forecasts that, after growing just 4% in 2011, the gallium arsenide substrate market will grow at a compound annual growth rate (CAGR) of nearly 11% to more than \$650m by 2017. This will be driven by not only rising GaAs content in wireless handsets but also the rising penetration of LEDs in general lighting as well as automotive applications (with semiconducting GaAs rising from 44% to 62% of the total market versus semi-insulating GaAs).

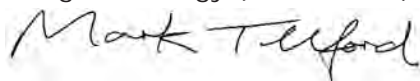
One of the drivers of LED lighting adoption is increasing luminous efficiency and reducing the cost per lumen. On pages 116–122 we round up recent developments in transparent conducting materials (such as indium tin oxide, zinc oxide, and graphene) for LED applications, with the aim of spreading current density more uniformly across the device (to alleviate efficiency droop at high current injection) without restricting light extraction.

Another theme of this issue is III-V transistors (see pages 104–109), starting with metal-oxide-semiconductor field-effect transistors (MOSFETs) that use a ‘nickelide’ (Ni-InAs) alloy for the source/drain contacts and extensions. This yields record low contact resistivity, suitable for the 12nm node of the International Technology Roadmap for Semiconductors (ITRS), perhaps using a self-aligned silicide (salicide)-like process (as used in silicon CMOS). Next we cover Hong Kong researchers' GaInAs high-electron-mobility transistors grown metamorphically by MOCVD on silicon (mHEMTs on Si) with performance comparable to devices grown by MBE on silicon substrates, targeting combining low-voltage, high-speed III-V-based logic circuit blocks with the functional density of silicon CMOS. In addition, we cover the University of Manchester's all-ternary double heterojunction bipolar transistors (DHBTs) with, simultaneously, high breakdown voltage and record cut-off frequency, targeting high-power MMICs and BiFET applications.

Such developments in microelectronics will be covered further in our next issue when we report from the recent International Conference on Compound Semiconductor Manufacturing Technology (CS ManTech).

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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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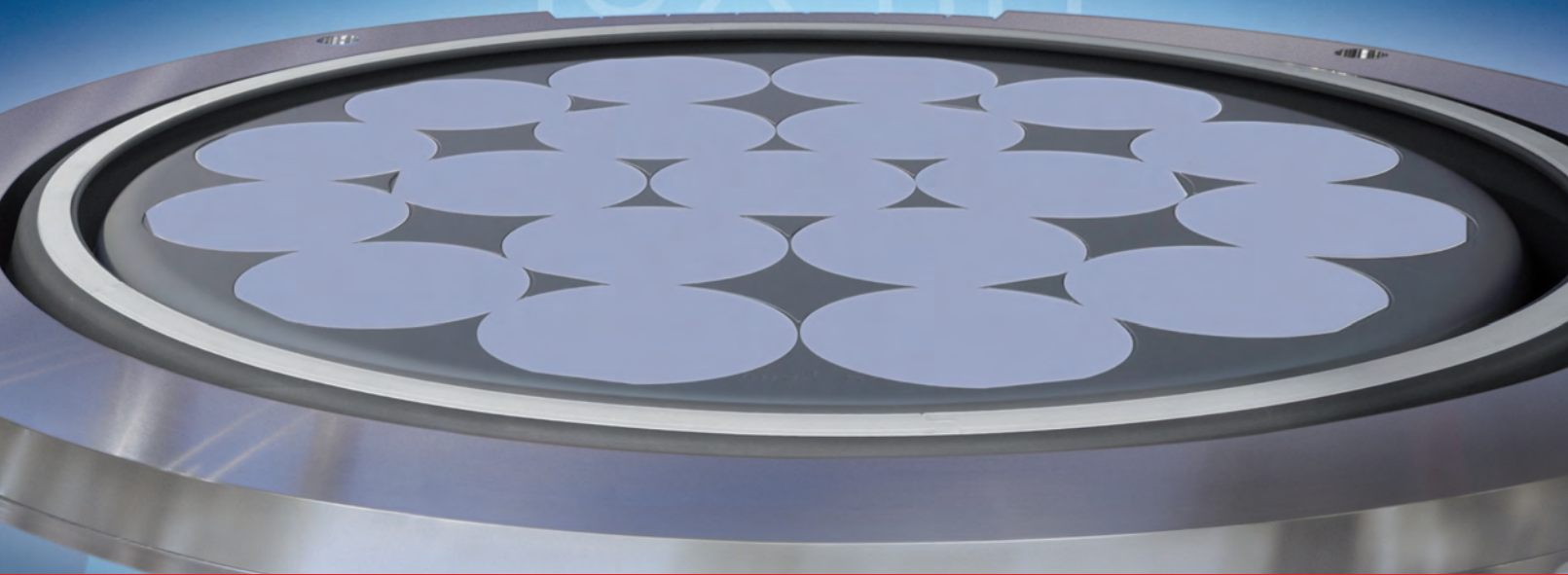
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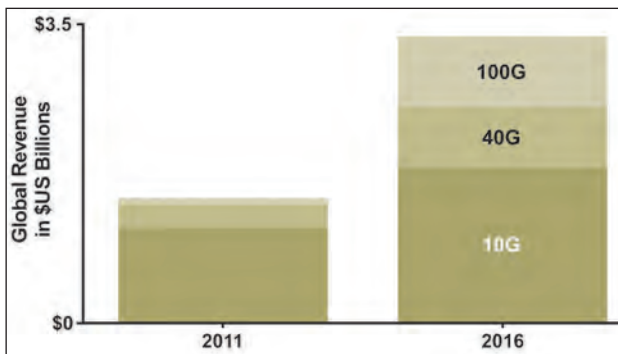
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Optical transceiver market to reach \$3.3bn in 2016

The global 10G, 40G and 100G optical transceiver market will grow to \$3.3bn by 2016, forecasts market analyst firm Infonetics Research in a report that tracks 10 Gigabit, 40 Gigabit and nascent 100 Gigabit optical transceivers and transponders sold into the optical transport, enterprise, and carrier routing and switching markets.

In particular, after nearly doubling from 2010 to 2011, unit shipments of 10G SFP+ modules are expected to rise at a compound annual growth rate (CAGR) of 40% through 2016. Tunable XFP shipments nearly tripled in 2011, spurred by the entry of multiple new suppliers. Unit shipments of wavelength division multiplexing (WDM)-capable mod-



10G, 40G and 100G optical transceiver market, forecast to grow to \$3.3bn in 2016.

ules grew 24% from 2010 to 2011. "10G WDM interface growth continues, with the tunable XFP playing the lead role, while 10G SFP+ volumes in the data center explode," says Andrew Schmitt, principal analyst for optical at Infonetics Research.

The 100G coherent transceiver market is set to surge as supply

floods the market in 2012, led by network equipment manufacturers (NEMs). "2012 will be a pivotal year for 100G design activity, with many new equipment vendors fielding production equipment," expects Schmitt. "This will drive volume in the component world in 2013 as carriers re-boot their optical networks and roll out all-coherent networks," he adds.

The '10G/40G/100G Optical Transceivers Market Size and Forecast' report analyzes the market by module, reach, wavelength, and form factor. Unit volume forecasts are based on Infonetics' 1G/10G/40G/100G Networking Ports forecast, released in April, which aggregates trends from a wide range of enterprise, optical transport, and carrier routing and switching equipment.

www.infonetics.com

Skyworks' 27% growth extended GaAs device market lead in 2011

TriQuint overtakes RFMD, while outsourcing boosts WIN

The merchant gallium arsenide device market slowed considerably in second-half 2011, reducing full-year revenue growth to 6% (to nearly \$5.8bn), compared with 2010's 35%.

The four largest GaAs device maker — Skyworks Solutions, TriQuint, RFMD and Avago Technologies — remain unchanged from a year ago but, despite the slowdown, Skyworks (with revenue growth of 27% greatly outstripping the market) has extended its lead, according to the Strategy Analytics GaAs and Compound Semiconductor Technologies Service (GaAs) Insight 'Skyworks Remains Largest GaAs Device Manufacturer'.

The report explores 2011 GaAs device revenue results and growth

trends, as well as revenue performance of the leading device makers including RF Micro Devices, TriQuint Semiconductor, Avago Technologies, Renesas Electronics, Hittite and WIN Semiconductors. While device makers continue to diversify their target market applications, mobile handset growth (particularly smartphones) continue to drive the GaAs device industry, notes the market research firm. In particular, TriQuint surpassed RFMD for second place.

Growth at WIN indicates their commitment to expansion, and also reflects success for outsourcing foundry operations

"While the 2011 growth rate of the GaAs device market was right around its historical average of 6%, Skyworks and WIN Semiconductors did more than significantly better," says Eric Higham, director of the Strategy Analytics GaAs and Compound Semiconductor Technologies Service. "The big increase at Skyworks is a testimonial to their efforts for diversifying smartphone customers, products, technology and market applications," he adds.

"The growth at WIN Semiconductors indicates their commitment to expansion, and also reflects success for outsourcing foundry operations in the GaAs device industry," notes Asif Anwar, director, Strategy Analytics Strategic Technologies Practice.

www.strategyanalytics.com

Power electronics discrete component market to grow to \$15bn in 2020

The quest for increased energy efficiency has re-energized power electronics, with new materials such as silicon carbide and gallium nitride gaining market share, says Lux Research.

Based on a resurgence in innovation, power electronics is poised to grow to \$15bn in discrete components in four key industry segments (buildings and industrial, electronics and IT, renewables and grid storage, and transportation) in 2020. It's also moving beyond its historic dependence on silicon, with silicon carbide (SiC) and gallium nitride (GaN) taking a 22% market share (\$3.3bn), according to 'Beyond Silicon: Plotting GaN and SiC's Path within the \$15 Billion Power Electronics Market', the inaugural report from Lux Research's new Energy Electronics Intelligence service (which covers LEDs and power electronics).

"There's clearly a growing opportunity in power electronics, but the challenge for both current market players and would-be entrants is finding the places where these emerging technologies meet customer needs at the right price points," says analyst Pallavi Madakasira (lead author of the report).

"While consumer electronics is a 'here and now' opportunity, fast-growing industries such as renewable energy and industrial power applications are likely to challenge power electronics manufacturers to innovate on form factor and improve efficiency at the lowest cost," she adds.

To forecast the adoption of emerging power electronics technologies, Lux Research analysts calculated the payback period for SiC and GaN devices and calculated market shares based on the required payback period for each application, as well as delaying or accelerating factors that reflect industry conservatism, design cycles, timing for capacity build-outs, and other industry drivers. Their findings include the following:

● **SiC and GaN vie for a slice of the silicon pie.** With silicon-based power electronic devices reaching theoretical limits, other semiconductors (notably SiC and GaN, which promise better performance and energy savings) are making inroads into the power electronics industry: SiC will gain a 14% market share and GaN an 8% share. SiC, with its better maturity and reliability, has a head start, but GaN will catch up due to new entrants such as Efficient Power Conversion (EPC) and Transphorm

as well as incumbents such as International Rectifier.

● **SiC grows in renewables, GaN gains in electronics.** SiC is gaining the most in renewables (capturing a 32% market share in solar) and is poised to capitalize on the grid storage boom. Its adoption in transportation is less aggressive, leading SiC and GaN to a relatively even share (at 16% and 15%, respectively) in 2020. GaN eclipses SiC in IT & electronics (carving out 14% share in 2020) and flourishes in smaller-scale applications within buildings in a broad \$2.4bn market.

● **VCs make big bets and corporations jockey for position.** Over the past five years, investors have funneled over \$200m into developers of advanced materials and devices for power electronics. On the venture side, Transphorm, EpiGaN, GaN Systems and Azzurro have closed notable funding rounds, while corporate investments and acquisitions such as TranSiC (Fairchild), SiCed (Infineon), SiCrystal (Rohm) and Crysband (SKC) have continued apace. This year promises to be a record-setting one for transactions, with particular attention on substrate and GaN technology developers, reckons Lux.

www.luxresearchinc.com

LED replacement lamps market to exceed \$3.7bn in 2016

The global market for LED replacement lamps will show unit growth of 30% during 2012–2016, projects Strategies Unlimited.

However, revenue will grow from \$2.2bn in 2011 to \$3.7bn in 2016, moderated by a forecast 14% annual decline in average selling price (ASP).

The research covered LED lamps that are used in existing sockets and serve as replacements for legacy lighting sources in residential and commercial indoor applications.

On the supply side, manufacturers will continue to benefit from the

oversupply of LEDs and governmental subsidies that aim to advance the adoption of LED lighting, says Strategies Unlimited.

On the demand side, the LED replacement market unit growth rate is expected to be the highest in China, at a compound annual growth rate (CAGR) of 44%. In 2011, the LED replacement A19 bulbs were the highest-selling product, with Japan leading the number of units sold. Sales of PAR LED lamps and LED MR16 were driven mostly by commercial appli-

cations in developed economies. However, this trend will be reversed as the construction sector recovers in developing countries, reckons the market research firm.

LED replacements for linear fluorescent lamps yielded the highest unit sales numbers in China and Japan, but between 2010 and 2011 the ASP declined at 23%. The US and European markets yielded fewer sales due to stricter requirements for product quality, concludes Strategies Unlimited.

www.strategies-u.com

RFMD's quarterly revenue falls 16.6% to \$187.9m

8% rebound expected in June quarter, driven by 3G/4G sales and return of Chinese handset makers' growth

For its fiscal fourth-quarter 2012 (to end March), RF Micro Devices Inc of Greensboro, NC, USA has reported revenue of \$187.9m, slightly better than the forecast \$185m but down 11.9% on \$213.3m a year ago and 16.6% on \$225.4m last quarter.

RFMD's Cellular Products Group (CPG) saw revenue fall by 21% from \$179.8m last quarter to \$143m. This was mainly due to a greater-than-seasonal 40% decline at a leading European handset maker and among handset makers in China. Consequently, China fell to just under 25% of total company revenue (down from a third last quarter), while Nokia has fallen to significantly less than 10% of total company revenue after an expected 'significant decline'. Samsung was the only 10% customer (after being their number-1 supplier in calendar 2011, and growing further in this latest quarter). These factors were offset partially by over 15% sequential revenue growth for both RFMD's PowerSmart power platforms and ultra-high-efficiency 3G/4G power amplifiers (PAs), reflecting market share gains in smartphones. Overall, 3G/4G components grew 160% year-on-year to more than two-thirds of CPG revenue, up from just 25% a year ago.

During the quarter, CPG unveiled its second-generation ultra-high-efficiency LTE PAs and its second-generation PowerSmart LTE power platform, and won majority LTE share on an upcoming smartphone family. CPG also launched multiple 3G/4G antenna control solutions and gained 'significant' design-win momentum in this emerging category.

RFMD's Multi-Market Products Group (MPG) was roughly flat sequentially, with revenue of just over \$45m. However, this is better-than-seasonal performance after seeing a stabilization in the macro environment, with particular strength in smart

grid, CATV broadband, and catalog products. Also, a reorganization has sharpened MPG's focus to drive growth in three major markets: Wi-Fi front-end modules, wireless infrastructure and gallium nitride (GaN) power devices ("the most important drivers of MPG's future success," says RFMD, as it aims to reach a broad range of markets and customers by continuing to launch new products and technologies). Correspondingly, the firm has launched six new Wi-Fi front-end modules for consumer premises equipment (CPE) and mobile applications. Of MPG sales, WiFi typically comprises 15–25% and wireless infrastructure 10–20% (although the latter has been at the low end of that range for the last few quarters due to the low capital expenditures of telecom carriers around the world). GaN is expected to comprise 5–10% of MPG revenue in fiscal 2013 (growing 50% annually).

On a non-GAAP basis, gross margin of 32.4% is down on 37.5% a year ago but up on last quarter's 30.2%, as improved product mix more than offset the impact of the sequential revenue decline and lower factory utilization.

Operating expenses have risen 7.8% from last quarter's \$59.2m to \$63.8m, including R&D expenses of \$39.2m (up 9% from \$36m).

"RFMD is investing for product and technology leadership in 3G/4G, in WiFi and in a multitude of switch-based applications," says chief financial officer Dean Priddy. "We expect the payback on these increased investments to begin as

early as the September quarter."

Compared with net profit of \$21.7m a year ago and \$5.1m a year ago, RFMD has reported a net loss of \$5.4m. During the quarter, cash flow from operations was \$20.5m (less than half of last quarter's \$46.2m). Capital expenditure has risen slightly from \$8.7m last quarter to \$9.6m, targeted mainly at test stations to support high-volume opportunities for switches and antenna control solutions (with production on these new testers starting to ramp in the June quarter). Free cash flow was hence \$10.9m (down from \$37.5m). Overall, total cash, cash equivalents and short-term investments rose from \$295.4m to \$300.4m.

Subsequent to the quarter, RFMD paid off the remaining \$26.5m principal balance of its 2012 convertible debt, and currently has \$134.9m par value of convertible debt due April 2014.

RFMD claims that it is winning market share on multiple flagship smartphones, and it forecasts continued sequential growth in 3G/4G components during the June quarter. Among China-based handset makers, RFMD expects growth as a result of market share gains and the country's transition to 3G (which has at least three times the dollar content of 2G; indeed, 3G has already overtaken 2G in CPG's China revenue despite comprising just 20% of unit volume). RFMD says that it has a broad set of growth drivers in place in China, with reference design wins in wideband CDMA and TD-SCDMA and with essentially all baseband providers.

In the markets served by MPG, RFMD sees stabilizing demand and improving order visibility and expects MPG revenue in the June quarter to be roughly flat on the March quarter.

Given the demand environment in its end markets, for the June quarter ►

► RFMD expects a return to sequential revenue growth (up 8% to about \$202m), supported by increasing sales of 3G/4G components (taking increased market share) and a resumption of growth among handset makers in China, as well as increasing market share in the switch and signal conditioning product lines plus growth for the firm's PowerSmart and Phenom products. Although factory utilization will remain flat, gross margin should improve by 100-200 basis points (especially since, for example, the firm's next-generation GSM PAs have a reduced die size, allowing more die per wafer and lowering costs).

"RFMD is growing with the industry's leading smartphone manufacturers and diversifying across a broad set of customers serving all geographies and segments," says president & CEO Bob Bruggeworth. "In just one year, RFMD has transformed itself into a highly diversified 3G/4G supplier, with greater alignment with the industry's leading customers and channel partners," adds Priddy. "We should see continued improvement in this key metric as 2012 progresses." RFMD's second generation of ultra-high-efficiency 3G/4G power amplifiers expands the portfolio to cover even more bands. RFMD has released products covering 10 bands of 3G/4G, and is adding eight more bands in the next two quarters. "We're expanding it to all LTE bands," notes corporate VP & CPG president Steven E. Creviston. "Everything will be covered within the next two quarters, increasing the efficiency in LTE data mode."

Based on current design wins and momentum, RFMD expects to be Samsung's top supplier again in calendar 2012. "In the market for converged power amplifiers, RFMD's PowerSmart supports Samsung across multiple basebands, and we are engaged with Samsung to supply our next-generation PowerSmart LTE, which enables a greater number of bands and band combinations," says Bruggeworth.

"On Samsung's LTE smartphones featuring discrete PAs, RFMD is capturing the majority share with our ultra-high-efficiency 3G/4G PAs, which are optimized for high-speed data and provide improved talk time and thermal performance," he adds. "In fact, RFMD will support the majority of Samsung's flagship smartphones this year with either PowerSmart or our ultra-high-efficiency 3G/4G PAs, and many of these devices will also contain our switch and signal-conditioning components." In LTE, RFMD is forecasting accelerated global adoption (from about 20 million units last year to over 100 million units this year) as consumers demand higher mobile data rates and as customers respond by launching new LTE devices.

"As we begin fiscal 2013, we are especially enthusiastic about RFMD's incremental growth drivers in new segments, including antenna control solutions, 802.11ac front-end modules and GaN power devices, where RFMD's proven technology leadership and early-mover advantage position us to capture market-share leadership as these markets grow," says Bruggeworth. "For next-generation WiFi, we are heavily involved with the leading WiFi channel partners for 802.11ac developments, which are expected to be in shipping in late 2012. This is one of the areas where we've made significant progress in our alignment with the industry's leading channel partners," he adds.

"We are making incremental investments in R&D, targeting continued growth and diversification," notes Bruggeworth. "These include

In just one year, RFMD has transformed itself into a highly diversified 3G/4G supplier, with greater alignment with the industry's leading customers and channel partners

advanced power management systems like envelope tracking (ET) for LTE [for which CPG in the March quarter demonstrated 'industry-leading' performance, it is claimed] and other products and architectures that enable more cellular bands at even smaller form factors. These investments and our proven technology leadership across all active RF semiconductors are leading the smartphone providers to increasingly look to RFMD for complete RF front-end reference designs," he claims. "CPG achieved multiple design wins during the quarter at leading OEMs with highly integrated RF semiconductor solutions containing all 2G and 3G PAs and switch content for the entire cellular RF front end. This is a growing trend where RFMD can capture all of the active RF semiconductor dollar content," he believes.

"In wireless infrastructure, telecom operators and OEMs are developing a variety of small-cell base-stations to extend wireless infrastructure capacity. This is driving up RF component volumes and placing greater emphasis on integration," continues Bruggeworth. "MPG is targeting base stations and microwave backhaul with a growing portfolio of power amplifiers, general-purpose RF products, microwave mimics and integrated multichip modules," he adds.

"In the June 2012 quarter, we expect a stronger, more diversified customer base will support a resumption of sequential revenue growth and continued margin expansion," notes Priddy. "We have structured the RFMD operating model to deliver significant leverage, and we anticipate our product portfolio and R&D investments will continue to drive revenue growth and margin expansion throughout calendar 2012. Importantly, we're confident the targeted, incremental R&D investments RFMD is making in 2012 will generate incremental revenue beginning as early as the September 2012 quarter."

www.rfmd.com

IN BRIEF

RFMD supplying components for LG's Optimus 4X HD and Optimus 3D Max

RFMD has been selected to supply multiple components in support of LG's Optimus 4X HD and the Optimus 3D Max smartphones, which are expected to be available globally in 2012.

LG Optimus 4X HD features a 4.7" HD display (1280 x 720), Android 4.0 'Ice Cream Sandwich', a quad-core 1.5GHz processor, 21Mbps HSPA+ performance, front (1.3MP) and rear (8MP) cameras, and dual-band Wi-Fi connectivity, within an exterior just 8.9mm thick. The Optimus 3D Max has a dual-core 1.2GHz processor, 8GB of storage, a 5MP dual-lens camera, Android 2.3 'Gingerbread', and LG's 'exclusive brightened' WVGA 4.3" display, all in a compact 9.8mm shell.

Both smartphones include RFMD's PowerSmart power platform and the RF5501 802.11 b/g/n Wi-Fi front end module. PowerSmart has an RF Configurable Power Core that delivers multiband, multi-mode coverage of all cellular communications modulation schemes (including 4G) up to LTE 64QAM. The RF5501 satisfies smartphone and tablet makers' requirements for aggressive size reductions in 802.11b/g/n front end solutions, while delivering high linear output power and reduced component count.

"RFMD is pleased to expand our relationship with LG and support these flagship smartphones," says president & CEO Bob Bruggeworth. "RFMD's PowerSmart power platforms continue to lead a product category that is re-shaping the future of multimode, multi-band cellular RF architectures, and we anticipate sequential growth in PowerSmart shipments throughout the calendar year."

RFMD and Silicon Labs team on sub-GHz solution for smart energy

RF Micro Devices Inc of Greensboro, NC, USA has teamed with Silicon Laboratories Inc of Austin, TX, USA, which provides analog-intensive, mixed-signal ICs, to deliver sub-gigahertz solutions for a broad range of smart grid applications.

RFMD's RF6569 smart energy front-end module and Silicon Labs' EZRadioPRO Si4464/63 transceivers have been combined to create the RF6569/Si4464/63 reference design.

Silicon Labs' EZRadioPRO family of transmitters, receivers and transceivers extends the benefits of its EZRadio family, such as high integration, low cost, flexibility and easy design-in, into ISM-band applications. The firm says EZRadioPRO devices offer enhanced parameters and features including continuous frequency coverage over 119–1050MHz and output power up to +20dBm. They also include built-in features such as a wake-up timer, low battery detector, transmit and receive data FIFOs, power-on reset circuit and general-purpose digital I/Os.

The new high-performance sub-GHz solution aims to provide public utilities and consumers more control over how they monitor and save energy, targeting portable battery-powered equipment such as smart energy advanced metering infrastructure (AMI), security and home automation systems, industrial control systems, and sensor networks in the 902–928MHz and 868MHz ISM.

RFMD's highly integrated RF6569 module features a 915MHz/868MHz 30dBm power amplifier, a Tx harmonic output filter, a single-pole double-throw (SPDT) antenna switch, and an Rx through path. Housed in a 5.5mm x 5.0mm x 1mm package, it reduces discrete component content while minimizing footprint and assembly costs. The transceiver interface is single-ended with separate Rx/Tx.

"RFMD and Silicon Labs are leveraging each other's expertise to deliver high-performance, highly integrated solutions that reduce design cycle times, lower customer costs, and accelerate product time-to-market," says Rohan Houlden, general manager of RFMD's Wireless Connectivity business unit.

"Our collaboration with Silicon Labs will directly benefit our smart energy customers while supporting continued growth in the burgeoning smart energy marketplace," he adds.

"The combination of RFMD's RF6569 module and Silicon Labs' Si446x EZRadioPRO provides an energy-efficient solution for long-range RF applications such as smart utility metering," says Silicon Labs' director of wireless products Greg Fyke. "The 4463-TCE30E915R-EK reference design gives developers an accelerated path to boost output power to 1W in a small form factor without sacrificing exceptional low-power operation."

www.silabs.com/EZRadioPRO

Integrated 5GHz SPDT switch and LNA FEM

RFMD says that its new RF5540 is designed for WiFi applications in the 5GHz ISM band, including IEEE802.11a WiFi; IEEE802.11p wave automotive mesh; consumer electronics; mobile devices; gaming; and general-purpose switch and low-noise amplifier (LNA) solutions for the 4.9–5.85GHz range.

The front end module integrates the LNA with bypass mode and an

SPDT (single-pole double-throw) switch. Operating from a single supply voltage of 2.7–4.8V, the integrated 50Ω input and output match minimizes the number of external components required, optimizing the size and cost.

Packaged in a 2mm x 2mm x 0.5mm, 12-pin QFN, the RF5540 is priced at \$0.46 each in 10,000-unit quantities.

RFMD achieves ISO/TS 16949 certification for automotive quality management systems

RF Micro Devices Inc says that its manufacturing facilities at its headquarters in Greensboro, NC, USA have been granted certification to ISO/TS 16949, which is the highest international quality standard for the automotive industry. Certification demonstrates RFMD's commitment to product design and manufacturing processes for automotive applications, the firm says.

ISO/TS 16949 certification is supported by the automotive industry and incorporates ISO technical specifications that are more stringent than ISO 9001 quality management system requirements. The goal of the standard is to enhance existing quality management systems which, when combined with customer-specific requirements, support continual improvement through defect prevention and a reduction in variation and waste in the supply chain. The standard combines North American and European automotive requirements and serves the global automotive market.

"This milestone underscores our commitment to the most stringent standards for manufacturing processes and work procedures, positioning RFMD to significantly expand our presence in the automotive industry," says president & CEO Bob Bruggeworth.

Developed by the International Automotive Task Force (IATF) in conjunction with the International Organization for Standardization (ISO, the world's largest developer of standards), ISO/TS 16949 certification aligns existing automotive quality systems standards within the global automotive industry, and aims to eliminate the need for multiple certifications to satisfy customer requirements and provide a common approach to a quality management system for automotive production. The IATF consists of an international group of vehicle manufacturers including Chrysler, Ford Motor Company, General Motors Corporation, PSA Peugeot-Citroen, Renault and Volkswagen.

www.rfmd.com

IN BRIEF

Linear CATV 40–1008MHz GaAs HBT-based amplifier

RF Micro Devices has launched the RFCA3302, an InGaP HBT monolithic microwave integrated circuit (MMIC) amplifier designed to run from a single +5V supply without the need for an external dropping resistor.

The high gain (21dB), high linearity and low distortion (40dBm IP3; –65dBc CSO; –83dBc CTB) from 40MHz to 1008MHz suits broadband cable applications, says the firm. An integrated bias circuit provides stable gain over temperature and process variations.

Applications include broadband 75Ω gain blocks, CATV distribution amplifiers, pre-amplifiers for CATV multi-dwelling units, and drop amplifiers.

Offered in a small SOT-89 package and is RoHS compliant, the product is currently available in production quantities. Pricing begins at \$1.51 each in 1000-unit quantities.

www.rfmd.com

RF Micro Devices' co-founder Jerry Neal retires

Jerry D. Neal, co-founder & executive VP of marketing, has retired from RF Micro Devices Inc, effective 31 May.

As a co-founder of RFMD, Neal was responsible for securing its initial venture capital investment, as well as multiple licensing deals, branding, and mergers and acquisitions. He was also primarily responsible for many of its corporate relationships, including TRW (now Northrop Grumman), Nokia, IBM, TowerJazz, and others.

"RFMD is both a pioneer and a global leader in communications technologies, and it is an honor to have played a major role in starting and building the company," reflects

Neal on his 21 year career at RFMD. "With my retirement from RFMD, I look forward to pursuing other passions in my life including entrepreneurial, advisory, and charitable endeavours," he adds.

"RFMD has benefited tremendously from Jerry Neal's contributions and expertise," comments president & CEO Bob Bruggeworth. "I personally have enjoyed working with Jerry and have valued his counsel and the strategic relationships he has built in the industry," he adds.

Neal is active in business, education, and charitable organizations and has served on the boards of directors of several semiconductor

firms. He currently serves on the ALSAC Leadership Council at St. Jude Children's Research Hospital, the board of Victory Junction Gang Camp and the board of Richard Petty Motorsports. He has also served on the board of visitors at the Babcock Graduate School of Management at Wake Forest University and regularly speaks to civic organizations and universities on business and inspirational topics. Neal recently developed Linbrook Heritage Estate, an agri-tourism business with numerous attractions and he serves on the Randolph County (North Carolina) Tourism Development Authority board of directors.

TriQuint's revenue drops 5% in Q1 as demand from Apple contractor Foxconn wanes

Demand recovery and capacity expansion to drive rebound in Q3

For first-quarter 2012, RF front-end component maker and foundry services provider TriQuint Semiconductor Inc of Hillsboro, OR, USA has reported revenue of \$216.7m, down 3% on \$224.3m a year ago and down 5% on \$227m last quarter.

The end-market split was 68% Mobile Devices, 22% Networks and 10% Defense & Aerospace. The only greater-than-10% customer remains Foxconn Technology Group (Apple's Taiwan-based manufacturing partner), but its contribution to TriQuint's total revenue has fallen from 41% last quarter to 37% while Apple burns through its inventory of stop-gap iPhone 4S devices before the launch of the iPhone 5 (perhaps in June).

Mobile Devices market revenue fell 8% both sequentially and year-on-year to \$148m. In particular, 3G/4G segment revenue was \$119m, down 7% sequentially. Revenue from connectivity products (i.e. WiLink, largely wireless LAN, where TriQuint has broad penetration in smartphones) fell 24% to \$20m, due to a combination of Q1 seasonality and a time gap between product lines, with demand for older products slowing while new products are just starting to ramp. However, GSM revenue from the 2G segment has regained momentum, up 26% to \$9m.

Excluding Foxconn, combined 2G, 3G and 4G cellular revenue from other customers was up 8% (compared with the typical seasonal decline of 10–15%), due to design wins primarily with customers in Korea and Taiwan. About two thirds of this growth was in 3G/4G products and one third in 2G products.

Despite being early to catch the smartphone wave in 2009, capacity constraints slowed TriQuint's growth and customer penetration in 2011, especially as the firm focused output on Apple contractor

Foxconn rather than other customers. "We are clearly seeing a good response from customers as we re-engage with the market post-capacity constraints," says president & CEO Ralph Quinsey. "Key product drivers for revenue growth are our MMPAs [multi-mode power amplifiers] and transmit modules [seeing good order strength, especially in Korea and Greater China] and our dual products [currently sampling, for production in second-half 2012]." In particular, TriQuint's new multi-mode and quad-band PA modules are now shipping in Samsung Galaxy SII and Huawei Honor smartphones. Also during the quarter, TriQuint opened its International headquarters in Singapore, strengthening customer relationships and supply chain efficiencies in the region.

Defense & Aerospace market revenue was \$21m, up 18% year-on-year but down 4% sequentially, as program timing results in swings quarter-to-quarter. Nevertheless, ramps of new product programs like the F-35 Joint Strike Fighter and the TQP53 counter fire target acquisition radar (formerly known as EQ-36) are progressing as planned. TriQuint also reached a milestone in starting production shipments of GaN products for S-band radars.

Overall, revenue was better than normal seasonality in the first quarter. "We saw signs of improvement in some of our infrastructure markets," says Quinsey. Networks market revenue was \$47m, up 4% year-on-year and 10% sequentially as TriQuint begins to see signs of a recovery in carrier capital spending following a challenging 2011 (when infrastructure spending was down, due largely to macro-economic weakness). In particular, Radio Access revenue (dominated

by base-station products) grew 31% sequentially, bolstered by a one-time end-of-life demand worth \$5–7m from a foundry customer (excluding foundry customers, base-station revenue was still up 20% sequentially). However, Transport revenue was down 3% sequentially (with optical revenue growth of 14% offset by declines in the point-to-point radio and cable product lines).

On a non-GAAP basis, gross margin has fallen from 40% a year ago and 31% last quarter to 30.4% as increased costs associated with placing the new 6-inch GaAs line in production in Richardson, TX offset improved product and business mix. Including legal expenses (related to anti-trust and IP claims against Avago) rising by \$1.6m to \$3.9m, operating expenses were \$61.4m (28% of revenue), up by \$5.5m from \$56.9m last quarter.

Net income has fallen further, from \$26.1m a year ago and \$13.3m last quarter to \$4.1m. During the quarter, total cash and investments grew by \$32.6m to \$194.9m, due mainly to lower capital expenditures (down from \$32.5m to \$14m) and improved working capital management (including the sale of an equity investment for \$7m). The firm also has no debt.

As part of its transition in filter technology from chip-scale packaging (CSP, in the assembly & test facilities in Apopka, FL and Costa Rica) to next-generation wafer-level packaging (WLP, in the firm's GaAs wafer fab), TriQuint plans to restructure its filter-related operations during Q2/2012, involving a charge of \$12–14m, consisting of a non-cash charge of \$10–12m (for excess equipment) and a cash charge of about \$2m (for severance costs). "We are rightsizing our factories in Florida and Costa Rica as

► we transition to WLP and away from commodity duplexers towards a higher-value mix of products," says Quinsey.

For second-quarter 2012, TriQuint expects revenue to fall 18% sequentially to \$170–185m, well below initial expectations (mostly due to lower demand from Foxconn). Lower revenue will reduce factory utilization, driving gross margin down to 27–29%. Due also to litigation costs rising to about \$11m (as the firm prepares for trial), the firm expects operating expenses to rise to \$70m, contributing to a net loss per share of \$0.10–0.15.

"Constraints restricted our customer diversity and increased revenue concentration [in 2011 and Q1/2012]. We are seeing a down side of that in Q2," says Quinsey. "We anticipate a challenging second quarter in the Mobile Devices market, specifically with our largest customer [Foxconn]," he adds. Also, WLAN will continue to fall. "But I believe this is a short-term impact and I expect a recovery in Q3/Q4 with normal demand patterns going forward in a strong and growing market that we plan to fully participate in," continues Quinsey.

TriQuint has expanded its capacity footprint and now has full site capacity, enabling it to address the entire market. "We are completing a capacity investment phase for the company that creates a near-term headwind but positions us well for future growth," says Quinsey.

"We expect to fully support all of our large customers that are making solid progress penetrating a broader revenue base," he notes.

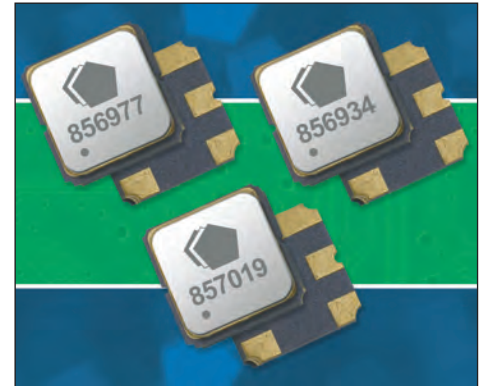
"We are adjusting that gap between older product lines and newer product lines. And some of our customers are seeing weaker demand, which puts pressure on the older product line," comments Quinsey. "We have achieved design-win success with our new products, and I believe we will return to normal revenue levels and growth in the second half of 2012."

New 3G/4G base-station RF SAW filters lower insertion loss and increase power handling, simplifying RF design in LTE and WCDMA

RF front-end component maker and foundry services provider TriQuint Semiconductor Inc of Hillsboro, OR, USA has launched three new RF surface acoustic wave (SAW) filters that can cost-effectively improve performance in 3G/4G network infrastructure and legacy system applications, it is claimed.

TriQuint says that networks are fraught with mobile data traffic demand, and continued double-digit growth is expected. In the first five weeks of 2016 the volume of mobile data traffic is expected to surpass the total data that wireless networks carried in all of 2011. While mobile data traffic volume increases, so does the need for highly efficient networks that can support the broadband designs typical of advanced WCDMA, LTE, TD-SCDMA and multimode systems, the firm adds.

TriQuint says that its new products are focused on the needs of base-station manufacturers that are challenged to add capacity while improving performance in a variety of system architectures. The 856934 (for Band 3 at 1842.5MHz) provides 75MHz bandwidth, a max-



TriQuint's new RF SAW filters.

imum 4.2dB insertion loss and attenuation of 20dB at 1785MHz, while power handling is +9dBm. The 857019 (for an extended Band 5e at 835MHz) offers 30MHz bandwidth, a maximum 3.0dB insertion loss and attenuation of 20dB at 869MHz, while power handling is +20dBm. The 856977 (for Bands 13 and 14 at 787.5MHz) delivers 22MHz bandwidth, a maximum 2.75dB insertion loss and attenuation of 40dB at 843MHz, while power handling is +20dBm.

The three new RF SAW filters are in production now. Samples and evaluation boards are available.

www.triquint.com

\$50m stock repurchase program announced

TriQuint has announced a program authorizing the repurchase of up to \$50m of its common stock through 2 May 2013.

Under the program, stock repurchases may be made from time to time in the open market at prevailing market prices or through privately negotiated transactions at the discretion of company management. The timing of open market and privately negotiated purchases will be dependent on market conditions and other corporate considerations, including price, corporate and regulatory requirements and alternative

investment opportunities.

The program is expected to be funded from existing cash balances and cash generated from operations. The firm is not obligated to repurchase any particular amount of common stock during any period and may choose to suspend or discontinue the repurchase program at any time.

Shares of common stock repurchased by the firm through the repurchase program will become authorized but unissued shares. As of 3 May 2012, TriQuint has about 168.2 million shares of common stock outstanding.

Anadigics' revenue falls 22% in Q1 to \$28.4m

New product design wins expected to drive return to growth in late 2012

For first-quarter 2012, GaAs-based broadband wireless and wireline communications component maker Anadigics Inc of Warren, NJ, USA has reported revenue of \$28.4m, down a greater-than-seasonal 22% on \$36.5m last quarter and down 35% on \$43.5m a year ago. The sequential decline is due almost entirely to lower Wireless revenue from the firm's former largest customer Research in Motion (RIM), which contributed just under 10% of revenue in Q1/2012 compared with \$16.6m (38% of revenue) a year ago.

Down 42% on \$36.2m a year ago, Wireless revenue of \$21m was down 29.8% on \$29.9m last quarter, reverting to 75% of total revenue (compared with 82% last quarter), due to seasonality plus the tailing off of business with RIM. "Our legacy products are slowing down faster than anticipated," notes president & CEO Ron Michels.

Broadband revenue was a higher-than-expected \$7.4m (25% of total revenue, up from just 18% last quarter). This was up only slightly on \$7.3m a year ago but spiked up 12.3% on \$6.6m last quarter, due largely to the easing of supply constraints from Q4/2011 caused by the flooding in Thailand. Of Broadband revenue, \$3.2m was in infrastructure, \$1.7m set-top box, \$1.3m wireless LAN, and \$1m in WiMAX.

The three greater-than-10% customers were Samsung, ZTE and Huawei. Five other customers in the 5-10% range included Cisco, LG, RIM and two distributors Richardson and World Peace Group.

The lower revenue resulted in both lower contribution and less absorption of fixed manufacturing costs (with factory utilization of just 45%), leading to a \$4.1m sequential decline in non-GAAP gross profit. Gross margin has hence fallen further, from 29.4% a year ago and 16.5% last quarter to just 6.7%. Net loss has risen further, from

\$5m a year ago and \$9.5m last quarter to \$14.9m.

Capital expenditure (CapEx) was \$1.4m and depreciation expense was \$4.3m. During the quarter, cash, cash equivalents and short- and long-term marketable securities fell further, from \$93.6m to \$84m.

For second-quarter 2012, Anadigics expects a slight sequential drop in revenue, due mainly to a final step down in sales to RIM.

"To proactively manage costs while prioritizing new product development, we recently completed a reduction in workforce and are implementing other cost-improvement actions," says VP & chief financial officer Terry Gallagher. "In combination with the first quarter's restructuring, these actions are expected to improve our annualized cost structure by over \$8m when fully absorbed by year end," he adds. This has helped Anadigics reduce its breakeven quarterly revenue level from \$50m to about \$45m.

"The majority of these savings are being implemented in areas that improve our operating efficiency while maintaining strong R&D investments in support of growth beginning in the late second half 2012 and into 2013," notes Michels.

Although down on \$13.6m a year ago, R&D expenses rose 11.6% from \$10m last quarter to \$11.6m, mainly in materials as Anadigics accelerates new product sampling for its MMPA (multi-mode multi-band power amplifier), dual-band power amplifier duplexers (PADs), and high-efficiency single-band PAs. R&D spending should return to more normalized levels in Q2. In

Q1 selling, general & administrative (SG&A) expenses were largely flat sequentially. Continued progress in reducing general & administrative expenses enabled a small increase in sales & marketing as Anadigics continues to focus on customers in achieving design wins for future revenues. In Q2, SG&A spending should fall 5–10%, driven by the cost-reduction actions.

During Q1, Anadigics gained wireless design wins and traction at key OEMs. At Samsung, it secured multiple sockets in the Galaxy S3 with the Sprint Network with its latest LTE and CDMA dual-band power amps. "These devices employ our ILD [inter-level-dielectric] process technology, providing Samsung exceptional 3G and 4G performance and value," claims Michels. "At Huawei, we have secured wide-band CDMA positions on the Honor and the Landfire platforms, and at ZTE with one single-band socket in multiple handsets including the Blade 2," he adds.

"Our penta-band 3G/4G amplifier developed for Qualcomm's Gobi chipset is winning sockets at several major OEMs including Sierra Wireless for data-card and hotspot applications," continues Michels. "We are also engaged with OEMs on automotive and tablets applications. This 5-band PA offers high performance for 3G and 4G networks and a very compact highly integrated package," he adds. "In the MMPA space, we are seeing wide-ranging success across OEMs in Korea and Japan with our first-generation products."

"We are making substantial progress with recent design wins and increased sampling of our new products," says Michels. "As we continue to build traction with our new product design wins, we remain confident that our strategy positions us for growth in late 2012 and 2013," he adds.

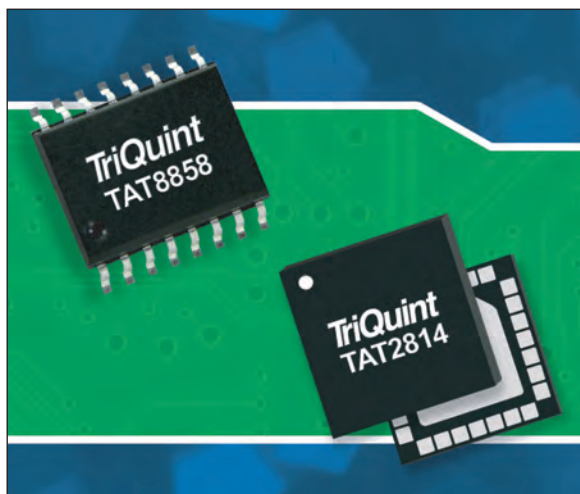
www.anadigics.com

TriQuint launches CATV RF infrastructure & DOCSIS 3.0 TriAccess amplifiers that cut PCB area & power usage

Launched simultaneously at the China Content Broadcasting Network (CCBN 2012) broadband exposition in Beijing (21–23 March) and in Silicon Valley, USA, RF front-end component maker and foundry services provider TriQuint Semiconductor Inc of Hillsboro, OR, USA has announced the availability of two new TriAccess amplifiers that can replace multiple products in cable TV (CATV) systems.

The firm says that the new devices offer manufacturers economical RFICs built with market-tested gallium arsenide technology that supports greater functional integration and higher efficiency. All devices have been used in multiple CATV systems worldwide.

The TAT8858 is a 34db integrated push-pull amplifier suited to 75Ω amplifier and transimpedance receiver applications. It offers flexibility, since it is able to operate efficiently at gain levels of 26–34dB, and can be used in both 12V and 24V applications, which can lower operational costs by significantly reducing current consumption. The device's high gain also off-loads output amplifier demands, while providing very low noise performance. The device uses patented on-



TriQuint's new TAT8858 and TAT2814 TriAccess amplifiers for CATV applications.

die integrated linearization. The TAT8858's performance enables it to replace multiple discrete components in CATV infrastructure RF designs.

The TAT2814A satisfies DOCSIS 3.0 specifications with more than 4dB (typical) performance margin. By integrating two stages of amplification and a variable gain attenuator (VGA), the device can simplify CATV RF design by reducing the number of discrete RF components compared to products previously needed to achieve this level of performance, it is claimed. Legacy solutions require

up to five times the PCB space to deliver DOCSIS 3.0 performance while consuming up to twice the electrical power. TriQuint says that the new product suits DOCSIS 3.0 output-stage amplifier designs including Edge QAM and CMTS (cable modem termination system) applications. The TAT2814A is also suited to Ethernet-over-coax (EOC) approaches that are designed to support DOCSIS 3.0 power amplifier levels.

TriQuint says that it is simplifying RF connectivity by providing products including the TAT8858 that enable a whole family of push-pull amplifiers and receivers based on a single RF circuit. The flexibility to work in 12V and 24V designs supports triple-play (voice-video-data) broadband designs such as network upgrades and greenfield deployments. The TAT2814A offers wide performance margin to overcome losses before the RF chain output connector.

Samples and evaluation boards are available for both the TAT8858 and TAT2814.

www.triquint.com

Anadigics' HELP4 PA powers NEC MEDIAS smartphone

Anadigics Inc of Warren, NJ, USA is shipping production volumes of its AWT6621 fourth-generation High-Efficiency-at-Low-Power (HELP4) power amplifiers (PAs) to NEC CASIO Mobile Communications for the new MEDIAS IS11N smartphone, which features a 3.6-inch display, 8 megapixel camera, and Android 2.3 Gingerbread operating system.

"Our proven high-volume manufacturing capabilities coupled with support centers located around the world allow us to deliver superior service to multiple leading wireless

device manufacturers," claims says senior VP of worldwide sales Michael Canonico. "We are proud to expand our successful relationship with NEC CASIO Mobile Communications and look forward to working together to develop the next-generation of mobile devices."

Anadigics' HELP4 product family uses 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 provides what is claimed to be the industry's lowest

quiescent current of under 4mA.

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 AWT6621 delivers what is claimed to be industry-leading efficiency to extend battery life in 4G handsets, smartphones, tablets, netbooks, and notebooks.

www.anadigics.com

Skyworks' revenue falls 29% quarter-to-quarter, but up 12% on a year ago

Rebound of 5% due in June quarter, driven by LTE and smartphone ramps plus high-performance analog

For its fiscal second-quarter 2012 (to end-March), Skyworks Solutions of Woburn, MA, USA (which makes linear products, power amplifiers, front-end modules and radio solutions for handset and infrastructure equipment) has reported revenue of \$364.7m, down 29% on \$393.7m last quarter but up 12% on \$325.4m a year ago (and exceeding guidance of \$360m), despite March-quarter seasonality.

The three 10% customers were Foxconn, Samsung and Nokia. Of total revenue, 65% came from mobile wireless products and 35% came from linear high-performance analog (HPA) products. Of mobile wireless revenue, 25% came from 2G and 75% from 3G (EDGE, WCDMA).

"Skyworks continues to outperform our addressable markets through diversification, content growth and market share gains," says president & CEO David J. Aldrich. "At the highest level, we're capitalizing on the mobile Internet and demand for ubiquitous connectivity by solving our customers' size, performance, complexity and battery life challenges," he adds. "Skyworks is at the heart of the world's most popular smartphones, tablets, ultrabooks and e-readers as well as within the supporting network infrastructure." During the quarter, Skyworks released a family of LTE SkyHi front-end modules with what is claimed to be record power efficiency (entering high-volume production in support of several major platform launches for 2012); started volume shipments of custom camera flash drivers for multiple smartphone ramps at Samsung and other OEMs; and supported Delphi with automotive satellite radio receiver ICs.

However, on a non-GAAP basis, gross margin has fallen from 44.3% last quarter to 43.2%, down on

43.9% a year ago. Operating expenses have risen from \$69.3m last quarter to \$73.7m, mostly through a rise in R&D expenses to \$45.4m. Net income has fallen from \$96.2m last quarter to \$79.8m, although this is better than guidance and up on \$78.7m a year ago.

Cash flow from operations was \$117m (up from \$77m last quarter — since the beginning of fiscal 2011, Skyworks has generated a cumulative \$560m). Capital expenditure was \$26m; depreciation was \$18m. "We expect capital expenditures to remain above depreciation levels through the remainder of fiscal 2012 as we increase capacity across all of our facilities in preparation for second-half product ramps," says VP & chief financial officer Donald W. Palette. "These CapEx investments consist of equipment add-ons within our existing facilities, which have a very quick payback. That expands our product margins and our return on invested capital," he adds.

However, during the quarter cash and cash equivalents fell from \$446.5m to \$307.3m. The firm completed strategic all-cash acquisitions, including of Advanced Analogic Technologies Inc (AATI) of Santa Clara, CA for about \$200m in net cash, significantly expanding Skyworks' addressable markets. "We retired the remainder of our convertible debt in favorable terms and without any equity dilution. That makes us debt-free for the first time in Skyworks' history," notes Palette. The firm also repurchased 3.5 million shares of its common stock at an average price in the low \$20 range.

"Results demonstrate how our diversification strategy, our flexible business model and ongoing focus on operational execution contributed to healthy financial returns in the seasonal trough, but more importantly, positioned us to outperform through the remainder of the year," says Aldrich.

During the quarter, Skyworks launched GPS solutions enabling navigation functionality in smartphones, tablets and ultrabooks for a second-half 2012 ramp; launched 802.11ac wireless networking solutions with the industry's leading chipset provider; secured RF subsystem design wins at Alcatel-Lucent, Ericsson, Huawei, Nokia Siemens and ZTE for 4G network infrastructure upgrades; and captured new design wins in the high-performance analog business across diverse applications (including connectivity sockets in the next-generation, high-end Sony PlayStation gaming platform, custom switch modules in a military avionics applications for ITT systems, a 16-channel back-lighting controller for high-definition LED TVs for LG and others, a next-generation leadless implantable defibrillators with the firm's portfolio of optocouplers, and remote gas meter reading solutions with Aclara). "We see our momentum strengthening in the current June quarter and accelerating in the September quarter based on strong first-half design win activity and a robust opportunity pipeline," says Aldrich.

For fiscal third-quarter 2012, Skyworks expects revenue to grow 5% to \$383m, driving increases in gross margin to 43.5% and operating expenses to \$76m, as well as an increase in earnings per share. "We expect both top and bottom line sequential growth in the current quarter, driven by LTE and smartphone program ramps as well

During 2012, smartphone adoption will skyrocket in developing countries

► as increasing traction in adjacent high-performance analog applications," says Palette.

"During 2012, LTE devices will hit critical mass," says Aldrich. A recent forecast by Strategy Analytics suggests that LTE shipments could grow by nearly ten-fold in 2012.

"As demand for global roaming expands, smartphones and tablets that incorporate only one or two regional LTE bands will begin to adopt additional LTE frequency, along with full backward compatibility to 3G and to 2G," he adds.

"Also during 2012, smartphone adoption will skyrocket in developing

countries." According to recent market research, smartphone growth in China and India could nearly double this year and approach 200 million units. "The embedded base of 2G subscribers is tremendous, creating a massive upgrade cycle that will play out over the next few years," Aldrich concludes.

"Looking ahead, we do see gross margins continue to improve as revenue growth accelerates through the remainder of the year and as we realize synergies associated with our recent acquisitions," concludes Palette.

www.skyworksinc.com

Kopin's III-V revenue drops 18% in Q1 Consolidation of US plants and 10% staff cut to yield savings in June quarter

For first-quarter 2012, Kopin Corp of Taunton, MA, USA, a supplier of III-V semiconductor products and microdisplays for mobile applications (including smartphones, tablet PCs, military thermal weapons sights and wearable computers), has reported total revenue of \$25.2m, down 28% on both \$34.9m a year ago and \$35.2m last quarter, primarily reflecting a decline in military display revenue associated with expected reductions in US defense spending.

Revenue for display products was \$10.9m, down 37% on \$17.3m a year ago. Revenue from III-V products was \$14.3m, down 19% on \$17.6m a year ago.

Compared with net income of \$2.4m last quarter, net loss was \$2.2m — despite including about \$0.9m gain related to the sale of stock of one of the firm's investments — reflecting the impact of lower revenue partially offset by reduced operating expenses (as cost of goods sold fell by \$4.6m and R&D expenses were cut by \$1.3m, to \$5.1m). Capital expenditure was \$1.78m, up from \$1.2m a year ago. During the quarter, cash and marketable securities fell from \$105.4m to \$102m.

"During the first quarter we consolidated our US display manufacturing activities to Westboro, MA, which enabled us to combine our two domestic III-V manufacturing plants into one facility and close the remaining site," says president & CEO Dr John C.C. Fan. The consolidation resulted in a reduction in staffing of about 10%. "We completed the consolidation plan late in the first quarter of 2012 and therefore did not see the full expense reductions in the quarter," he adds.

"In March we announced that Applied Physics Letters of the American Institute of Physics had published a paper on the record results we achieved with gallium nitride (GaN)-based HEMT materials," says Fan. "This research marks the first of what we expect to be several scientific papers on the performance characteristics of our GaN-based HEMT transistors," he adds. "These devices hold significant promise in decreasing power consumption and improving efficiency in a variety of energy-related applications," he believes.

For full-year 2012, Kopin continues to expect revenue of \$110–120m, down about 12% on 2011.

www.kopin.com

IN BRIEF

Skyworks supports first commercially available 802.11ac platforms

Skyworks Solutions of Woburn, MA, USA (which makes linear products, power amplifiers, front-end modules and radio solutions for handset and infrastructure equipment) says that several of its precision analog semiconductor solutions are being used in some of the first commercially available 802.11ac platforms, including notebooks, ultrabooks, LED TVs, routers, USB data cards and Blu-Ray players.

IEEE 802.11ac technology allows consumers to download content substantially faster than equivalent 802.11n solutions, improving the wireless range in networking applications. With download speeds of more than 1Gb/s, these devices offer the fastest, most reliable wireless coverage for HD-quality video and near-instant data synchronization of music. The solutions also help to address the growing need for a more robust and efficient wireless network.

"Our products continue to push the performance envelope while extending critical battery life," says Liam K. Griffin, executive VP & general manager of high-performance analog. "When combined with innovative chipsets, consumers are able to enjoy some of the fastest download speeds in their home or with other mobile platforms."

According to Gartner, WiFi-enabled devices will grow from under 1 billion units in 2010 to more than 3 billion in 2015, making WiFi one of the most influential mobile and wireless technologies in the years to come. According to Cisco's 2011 Visual Networking Index Forecast, video alone is expected to reach about 90% of global traffic.

Freescale launches GaAs-powered baseband-to-antenna reference design for small-cell base stations

Freescale Semiconductor of Austin, TX, USA has announced a new reference design for small office/home office (SOHO) base-station applications that is partially powered by two gallium arsenide monolithic microwave integrated circuits (MMICs).

The comprehensive baseband-to-antenna reference design combines the QorIQ Qonverge BSC9131 base-station system-on-chip (SoC) with Freescale RF radio boards, and is a multi-protocol solution that scales across a range of cellular bands to ease developers' transition from 3G to 4G LTE. Sourcing the base-station SoC and RF devices from the same vendor speeds time to market and helps ensure optimal compatibility and integration, says the firm.

The Freescale GaAs MMIC devices deployed on the radio boards are the MMZ25332B and MMZ09312B amplifiers. Both provide high linearity and power efficiency and can cover multiple bands, including Band 1/WCDMA and Band 13/LTE. Along with the radio board, the MMICs can be easily tuned to support multiple UMTS frequency bands.

"Creating comprehensive femto-cell base-station solutions using discrete components from multiple

vendors is often cumbersome and expensive," says Ritu Favre, VP & general manager of Freescale's RF Division. "By combining RF radio boards and our new GaAs MMICs with QorIQ Qonverge technology, we've created a one-stop-shop for femtocells that reduces development time and offers designers scalability as they transition from 3G to 4G," he adds.

The QorIQ Qonverge BSC9131 device features a scalable architecture that supports a range of air interfaces, including LTE, LTE-FDD & TDD and WCDMA/CDMA. It combines Power Architecture cores and high-performance StarCore DSPs with Multi-accelerator Platform Engine (MAPLE-B) technology for baseband processing. It also features interconnect fabric and next-node process technology, as well as glueless RFIC communication and antennae interfaces, eliminating the need for additional chips and reducing board space and cost.

The new MMZ25332B and MMZ09312B devices deployed on the radio board (designed by Freescale partner Benetel) belong to a family of RF GaAs MMICs for femtocells. The radio board also includes Freescale's MML09211H and MML20211H low-noise amplifiers, which are designed specifi-

cally for the receiver sensitivity requirements of femtocells.

Freescale provides end-to-end silicon solutions that scale from femtocell to macrocell base-station applications, including Airfast RF power solutions, QorIQ Qonverge SoCs and RF GaAs MMICs. Although Freescale provides silicon RF power LDMOS power transistors used in wireless base stations, it holds numerous GaAs-related patents and was one of the first firms to develop devices based on GaAs technology. It also recently announced the Airfast 28V AFT26HW050GS LDMOS transistor, designed specifically for wide instantaneous-bandwidth microcell/metrocell LTE applications.

The new baseband-to-antenna reference design consists of two complementary boards: a QorIQ Qonverge femtocell base-station development board, and one or more RF radio boards. The BSC9131RDB QorIQ Qonverge reference design board is available for \$900. Priced at \$1700, the RF radio board is part number PSC913XRFB-XXYY (with 'XX' and 'YY' representing the bands supported).

The GaAs MMIC family of devices for femtocell applications is available now and can also be purchased separately.

www.freescale.com/RFMMIC

Hittite's revenue rebounds by 5.2% in Q1/2012

For first-quarter 2012, Hittite Microwave Corp of Chelmsford, MA, USA (which designs and supplies analog, digital and mixed-signal RF, microwave and millimeter-wave ICs, modules and subsystems as well as instrumentation) has reported revenue of \$63.3m, down 5.8% on \$67.2m as year ago but rebounding by 5.2% from \$60.2m last quarter (following an 11.6% decline that quarter) and slightly higher than the guidance of \$61–63m.

Of total revenue, 48.8% (\$30.9m) came from customers in the USA (versus \$27.7m, or 46%, last quarter) and 51.2% (\$32.4m) came from outside the USA (versus \$32.5m, or 54%, last quarter).

Although up on 73% a year ago, gross margin of 73.7% is down from 74% last quarter. Operating income was \$25.5m (an operating margin of 40.2% of revenue), up from \$24.6m (40.9% of revenue) last quarter but down from \$31.2m (46.4% of revenue) a year ago.

Net income was \$16m, down on \$20.2m a year ago and \$21.2m last quarter, although the latter included a \$5.5m discrete tax benefit.

During the quarter, total cash and cash equivalents rose by \$20.2m to \$373.9m.

For second-quarter 2012, Hittite expects roughly level revenue of \$63–65m and net income of \$15.6–16.4m (\$0.51–0.53 per diluted share).

www.hittite.com

Fujitsu adds 4G LTE (TDD and FDD)-optimized multiband single IC to transceiver family for smartphone and other mobile applications

Fujitsu Semiconductor Wireless Products Inc (FSWP) of Tempe, AZ, USA — a subsidiary of Japan's Fujitsu Semiconductor Ltd (FSL) that provides RF transceivers for mobile cellular handsets and other portable wireless devices — has introduced the MB86L13A LTE (FDD and TDD)-optimized multiband transceiver IC, covering 700–2700MHz frequencies. Developed for LTE-only applications, it features the architecture pioneered by Fujitsu that eliminates the need for external low-noise amplifiers (LNAs) and inter-stage surface acoustic wave (SAW) filters. The MB86L13A is sampling now and will be available in volume in second-quarter 2012.

Fujitsu began shipping the industry's first SAW-less transceiver for 2G/3G networks, the MB86L01A, in 2009. In 2010, it launched the MB86L10A, the first 3G and LTE SAW-less transceiver, which has been integrated into dongles, tablets and multimode 2G/3G/4G smartphones. The MB86L12A, the third production-ready Fujitsu 2G/3G/4G SAW-less transceiver, supports the upgraded MIPI DigRF standard. In February, Fujitsu launched the MB86L11A 2G/3G/4G multimode, multiband (MMMB) SAW-less transceiver with several advanced transmit features, including enhanced power control, envelope tracking, and antenna tuning. The MB86Lxxx family transceivers are deployed by multiple baseband providers worldwide, with millions of units shipped to date.

The MB86L13A LTE transceiver now augments the rest of the family to support existing 2G/3G platform vendors. Its addition enhances the Fujitsu family of transceivers, providing the quick time-to-market solutions required

by device makers, the firm claims.

"The MB86L13A can speed time to market for baseband providers looking to add robust LTE capabilities to their existing 2G/3G solution," says FSWP vice president Vivek Bhan. "The new device provides multiband LTE support on a single IC, complementing the 2G/3G-only solutions offered by platform partners for the growing LTE market," he adds.

The advanced application programming interface (API), which is also available on the other Fujitsu transceivers, minimizes factory calibration time, provides flexible port mapping, and adds monitoring of customized key performance indicators (KPIs).

The availability of multiple transmit, receive and diversity ports on the MB86L13A offers the flexibility to map ports and bands for roaming requirements. The transceiver uses an open-standard MIPI DigRF 4G v1.1Rev0.06 interface to the baseband, and supports all global FDD bands 1–21, 23–25, and TDD bands 33–41, as well as all LTE bandwidths up to 20MHz. Future transceivers on the roadmap for this year include a 3GPP Release 10-compliant, single RFIC solution.

"The Fujitsu MB86Lxxx family transceivers offer advanced features, low power consumption, a small footprint and a highly flexible API to bring down the total cost of the device and dramatically speed up time to market for new products," says Bhan.

<http://us.fujitsu.com/micro/rftransceiver>

The new device provides multiband LTE support on a single IC, complementing the 2G/3G-only solutions

GigOptix samples surface-mountable DC–26.5GHz distributed PA

GigOptix Inc of San Jose, CA, USA (which supplies semiconductor and optical components for high-speed information streaming) has begun engineering sampling of the EXH2009, its first surface-mounted MMIC wideband power amplifier, available in a 7mm x 7mm SMT QFN package for use in military electronic warfare (EW), radar, test & measurement equipment and broadband telecom equipment applications.

Augmenting GigOptix's portfolio of power amplifiers with frequency coverage extending up to 90GHz, key features of the EXH2009 include: wideband performance from DC to 26.5GHz, typical drain voltages of +8V_{DC} with supply current of 600mA, and high gain up to 20dB across band with a gain flatness of better than ±1dB.

The EXH2009 leverages GigOptix's MMIC design and its high-speed packaging expertise to enable a device that provides the high performance seen in die-based solutions in a convenient SMT form factor, says Pdraig O'Mathuna, VP & general manager of GigOptix's RF/MMIC product line. "The device provides more than 29dBm of Psat power while consuming 4.8W typically, significantly outperforming competing parts," he claims.

"The EXH2009 significantly simplifies customer's manufacturing by providing internally matched 50Ohm at the RF inputs and outputs in addition to the on-chip DC block capacitors," O'Mathuna continues. "Furthermore, the SMT solution eliminates the need for expensive and labor intensive 'chip and wire' assembly techniques, while the high-speed packaging not only is fully compatible with industry-standard SMT manufacturing flows but also provides the high performance required by our customers' demanding applications."

www.gigoptix.com

Germany's FBH reports high-speed InP HBTs using transferred-substrate technology

Power amplifiers realized for 90GHz operation

At the 7th German Microwave Conference (GeMiC 2012) in Ilmenau, Germany (12–14 March), Berlin-based Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik (FBH) reported how it has established a transferred substrate (TS) technology to optimize the high-frequency and power performance of InP/InGaAs/InP double-heterojunction bipolar transistors (DHBTs) — see T. Al-Sawaf et al, 'W-Band Amplifier with 8dB Gain Based on InPHBT Transferred-Substrate Technology', Proc. German Microwave Conference, paper 1474.

Research on high-speed transistors is driven by applications for imaging and wide band communications, says FBH. Recent technical advances in InP-based transistors with operating frequencies of several hundred gigahertz (GHz) — together with their outstanding material properties — qualify them as key components in such systems, it adds.

FBH's latest 3" wafer-level process enables lithographic access to both the HBT's front-side and back-side, aligned to each other. The resulting linear device (shown in Figure 1) eliminates dominant transistor parasitics and relaxes design trade-offs.

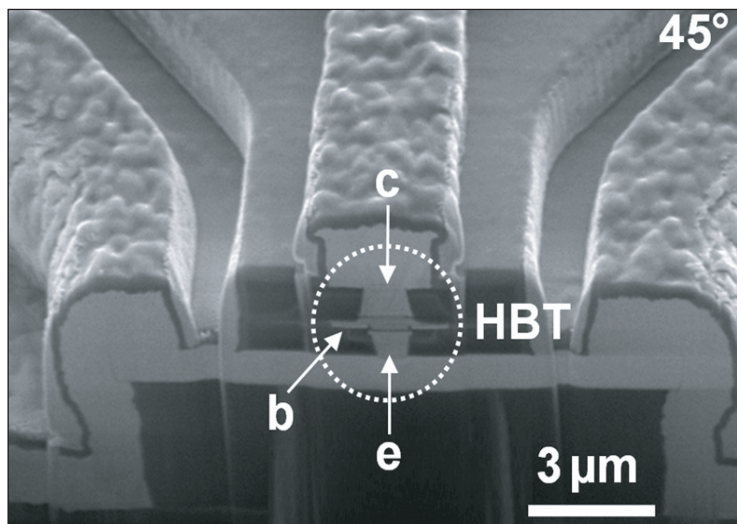


Figure 1: Focused ion beam (FIB) cross section of a TS-HBT, showing emitter (e), base (b) and collector (c).

The essential step for gaining access to both sides of the epitaxial structure is to completely remove the supporting substrate. FBH hence developed a robust adhesive wafer bonding procedure via benzocyclobutene (BCB). This yields a homogenous, crack- and void-free composite matrix of transistors transferred on the wafer-level scale.

The optimized device topology of the two-finger transistor has a total emitter area of $2 \times 0.8 \mu\text{m} \times 5 \mu\text{m}$ (as depicted in Figure 2). This yielded a current-gain cut-off frequency (f_T) of 376GHz and a maxi-

mum oscillation frequency (f_{max}) of 385GHz at breakdown voltages (BV_{CEO}) of more than 4.5V. The InP HBTs combine high-frequency performance with saturated output power (P_{out}) of more than 14.2dBm @77GHz and an inherently good matching to 50Ω. FBH says that the

highly scalable device architecture is capable of even further increases in frequency as well as power performance in the future.

Single-stage power amplifiers have been designed and realized in TS technology for 90GHz operation. Their S-parameter measurements (shown in Figure 3) confirm good agreement with modeling.

FBH notes that the transistor design is currently being used in an ongoing project for the heterogeneous integration of InP-based circuits on top of BiCMOS wafers.

www.fbh-berlin.com

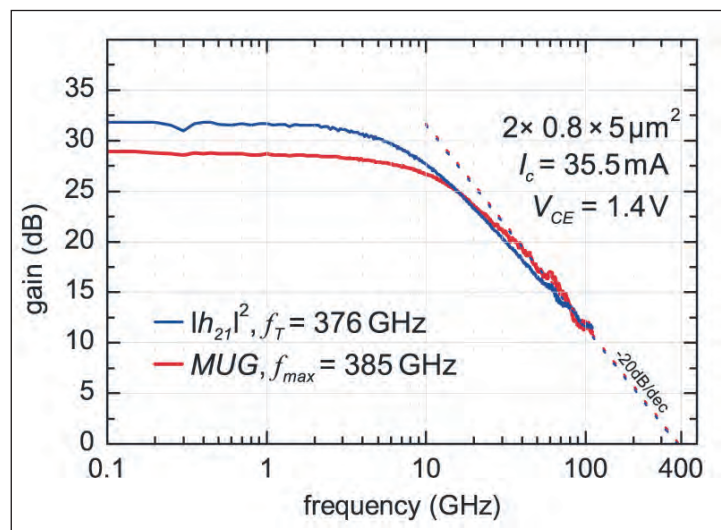


Figure 2: Extrapolated f_T and f_{max} of a TS-HBT.

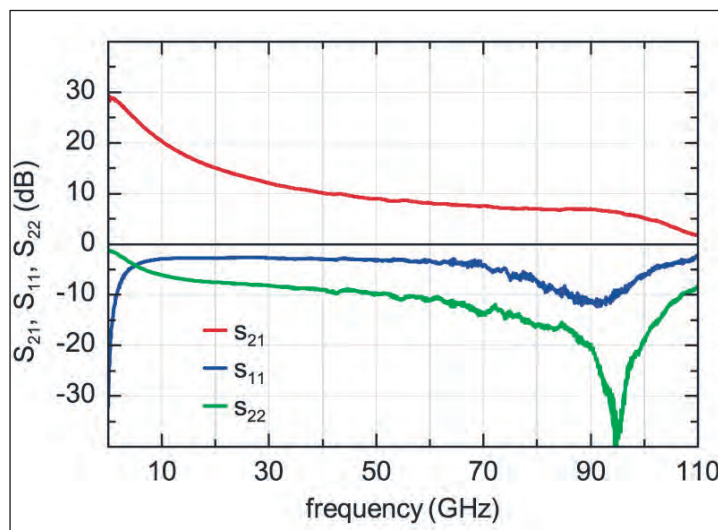


Figure 3: S-parameter measurements of TS-based 90GHz PA.

DAHI program launches Foundry Technology effort to combine compound semi and silicon IC communities

The US Defense Advanced Research Projects Agency (DARPA) says that its Diverse Accessible Heterogeneous Integration (DAHI) program is launching the DAHI Foundry Technology effort to advance novel methods for combining a variety of devices and materials onto a single silicon chip.

High-performance microsystems are vital for a wide variety of Department of Defence (DoD) systems that provide US warfighters with technological surprise over adversaries in areas such as communications, sensing and electronic warfare. Current fabrication technology limits the types of materials and devices that can be integrated, forcing circuit designers to make compromises when selecting devices for an integrated microsystem.

"Enabling the ability to 'mix and match' a wide variety of devices

and materials on a common silicon substrate would allow circuit designers to select the best device for each function within their designs," says Thomas Lee, office director of DARPA's Microsystems Technology Office. "This integration would provide DoD systems with the benefits of a variety of devices and materials integrated in close proximity on a single chip, minimizing the performance limitations caused by physical separation among devices," he adds.

The DAHI Foundry Technology effort also seeks to enable complex signal-processing and self-correction architectures to be brought to bear. It also aims to establish a foundry capability for the production of chips using a wide range of heterogeneously integrated devices.

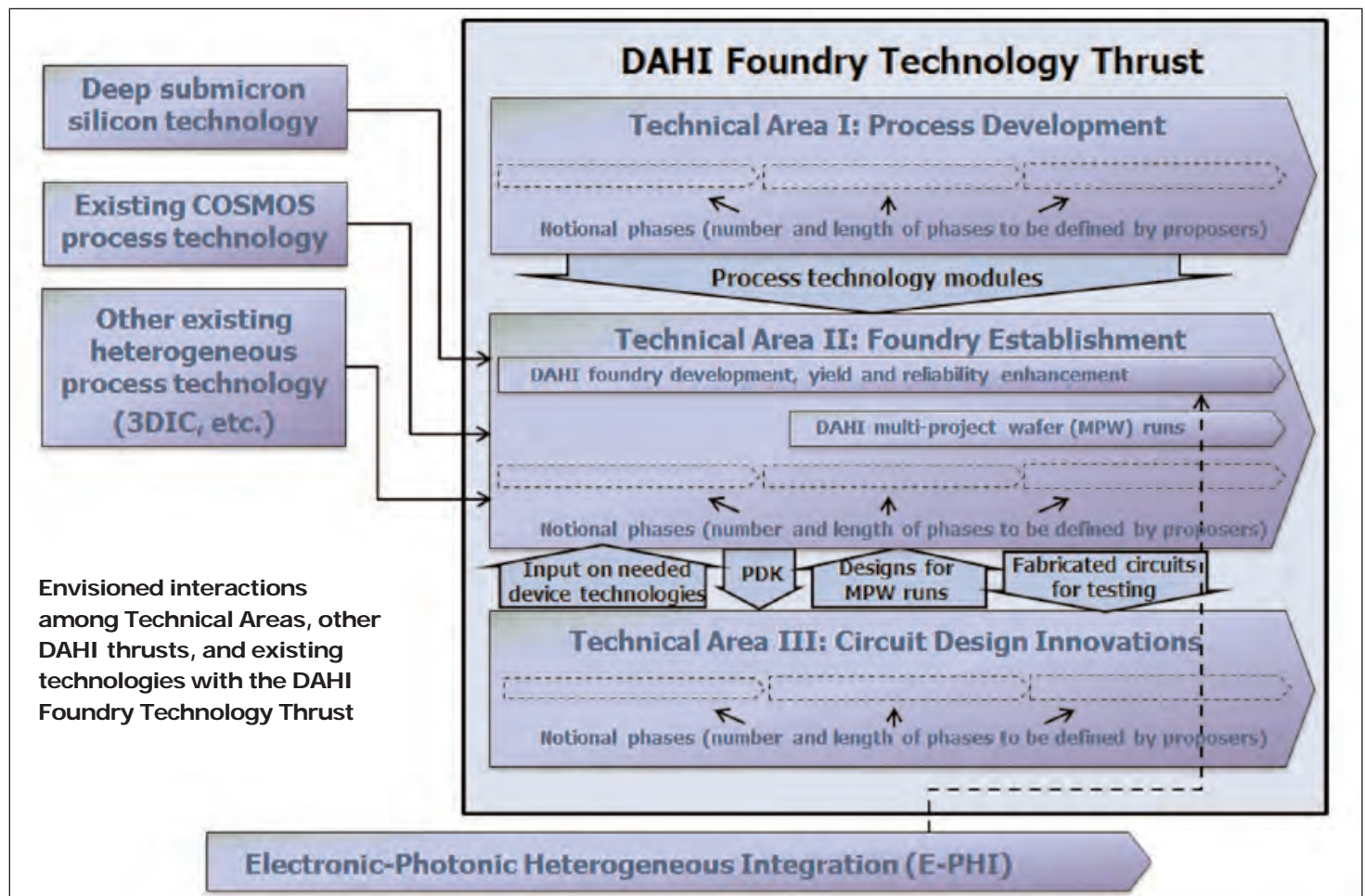
"DARPA anticipates bringing the compound semiconductor and silicon

integrated circuit (IC) communities together for new ways to integrate components onto a single silicon wafer," says DARPA program manager Sanjay Raman. "Such convergence would enable foundry-style production of high-performance microsystems, leveraging today's silicon IC manufacturing base."

DAHI builds on the DARPA Compound Semiconductor Materials on Silicon (COSMOS) program, which focused on indium phosphide (InP) heterojunction bipolar transistor (HBT) integration with silicon. COSMOS is now one of the DAHI program thrusts, along with Electronic-Photonic Heterogeneous Integration (E-PHI), which kicked off in November 2011) and this new DAHI Foundry Technology effort.

Interested parties attended a proposers' day workshop in April.

www.darpa.mil



TowerJazz and UCSD demo first silicon wafer-scale 110GHz phased-array transmitter

Automotive radar, aerospace & defense, passive imaging, security, and mm-wave imaging applications targeted

Specialty foundry TowerJazz (which has fabrication plants at Tower Semiconductor Ltd in Migdal Haemek, Israel, and at its subsidiaries Jazz Semiconductor Inc in Newport Beach, CA, USA and TowerJazz Japan Ltd) and The University of California, San Diego (UCSD), which provides a program in microwave, millimeter-wave and mixed-signal RFICs, have collaborated to demonstrate what is claimed to be the first wafer-scale phased array with 16 different antenna elements operating at 110GHz frequency range.

First-time success was achieved for the RFIC using TowerJazz's proprietary models, kit and the mm-wave capabilities of its SBC18H3 0.18 μ m silicon-germanium (SiGe) BiCMOS process. The device targets applications for automotive radar, aerospace & defense, passive imaging, security, and mm-wave imaging. The collaboration on the phased-array chip was partly funded by the US Defense Advanced Research Projects Agency (DARPA).

Phased arrays allow the electronic steering of an antenna beam in any direction and with high antenna gain by controlling the phase at each antenna element. The radiation beam can be 'moved in space' using entirely electronic means through control of the phase and amplitude at each antenna element used to generate the beam. This beam steering technique is more compact and much faster than mechanically steered arrays. Phased arrays also allow the creation of deep nulls in the radiation pattern to mitigate strong interference signals from several different directions. They have been in use in defense applications since the 1950s and have seen limited use in commercial system due to their relatively high cost. UCSD's design

and use of TowerJazz's existing wafer processes are targeted at greatly reducing the cost of phased arrays, especially at millimeter-wave frequencies.

The wafer-scale SiGe BiCMOS chip measures 6.5mm x 6.0mm and combines the 110GHz source, amplifiers, distribution network, phase shifters and high-efficiency on-chip antennas, allowing a new generation of miniature and low-cost phased arrays for W-band (75–110GHz) applications. TowerJazz says that such an advance better serves the needs of the greater-than-\$100m emerging markets of auto radar and passive imaging (security). The antennas are integrated on-chip, eliminating the expensive and lossy transitions and distribution network between the phased array and the off-chip elements. TowerJazz says that the wafer-scale phased array with 16 radiating elements, together with all the necessary CMOS control circuits, is capable of electronic beam scanning to $\pm 40^\circ$ in all planes. The architecture could be scaled to 64 elements (8x8) or 256 elements (16x16) due to on-chip antenna integration and the single-chip integration of multiple elements.

By developing the wafer-scale chip, UCSD has demonstrated independent amplitude and phase control at 106–114GHz for all 16 different antenna elements, and provides commercial availability of highly scalable (from 16 elements to 256 elements) RF-IC transmitters for W-band and D-band phased-array applications. The chip was designed and tested by Woorim Shin, Ozgur Inac and Bonhyun Ku, all of UCSD's Electrical and Computer Engineering Department under the supervision of professor Gabriel M. Rebeiz, and was partially sponsored by the

DARPA program GRATE (Gratings of Regular Arrays and Trim Exposures) under the direction of Dr Carl McCants. The work was performed under a subcontract to UCSD from TowerJazz.

The phased array chip was developed using TowerJazz's SBC18H3 BiCMOS, which offers both high-performance 0.18 μ m SiGe bipolar and high-quality passive elements combined with high-density 0.18 μ m CMOS, to enable high-speed networking and mm-wave applications. The process offers SiGe transistors with a peak f_{\max} of 280GHz and a peak f_T of 240GHz, suiting low-power, high-performance mm-wave circuits, while replacing the need for more expensive gallium arsenide (GaAs) chips, TowerJazz says. SBC18H3 comes standard with 1.8V and 3.3V CMOS (dual-gate), deep trench isolation, lateral and vertical PNP transistors, MIM capacitors, high-performance varactors, polysilicon as well as metal and N-well resistors, p-i-n and Schottky diodes, high-Q inductors, triple-well isolation, and six layers of metal.

"We have a track record of successful collaboration with TowerJazz, and the ability to bring this innovative design from UCSD to market depends strongly on TowerJazz's SiGe BiCMOS process, which enables lower-cost phased arrays by integrating many functions and high-efficiency antennas on the same silicon chip," comments Electrical Engineering professor Gabriel M. Rebeiz (the lead professor on the chip).

The SBC18H3 process is available through the TowerJazz multi-project wafer (MPW) system. The chip is available via professor Rebeiz at rebeiz@ece.ucsd.edu.

www.ece.ucsd.edu

www.towerjazz.com

TowerJazz partners with Fast Company Brazil

Specialty foundry TowerJazz (which has fabrication plants at Tower Semiconductor Ltd in Migdal Haemek, Israel, and at its subsidiaries Jazz Semiconductor Inc in Newport Beach, CA, USA and TowerJazz Japan Ltd) has announced Sao Paulo-based Fast Company Brazil (a business agency created at the start of 2009 to support companies in the Brazilian market) as its new representative for South America, aiming to expand its presence in a fast-growing semiconductor industry region.

South America, and Brazil in particular, is a major focus for TowerJazz, driven by initiatives taken by the Brazilian government, involving fast-growing local fabless firms and design houses together with the established OEMs in the country. The expertise and close proximity of Fast Company Brazil will provide TowerJazz with additional access to South American countries and their emerging semiconductor markets.

Fast Company Brazil's CEO & founder Jose Antonio Scodiero was previously VP of sales & marketing for AMD in Latin America. The firm is seeing increased business as the Brazilian government has identified the semiconductor industry as a high priority. For example, in the programs CI BRASIL (Integrated Circuit Brasil), the government has sponsored 20 local design houses and trained more than 500 people in microelectronics. TowerJazz aims to utilize such momentum in the country.

According to PwC, growth in the global semiconductor market will be powered by the increasing importance of the BRIC (Brazil, Russia, India and China) economies' demand for semiconductor products. In the report 'Faster, greener, smarter — reaching beyond the horizon in the world of semiconductors', PwC says that both technological advances and the rising economies in those emerging markets will fuel the long-term growth of semiconductor demand, resulting in an annual average growth rate of 7.4% until 2015.

"TowerJazz's portfolio in power management, RF and high-performance analog will enable Brazilian semiconductor companies to make strides in becoming significant players in the global market," believes TowerJazz's VP of sales Dani Ashkenazi. "Partnering with Fast Company Brazil will enable us to establish presence in the region and demonstrate our superior customer support to Brazilian companies," he adds.

"The semiconductor market in

South America is currently being formed and companies see value in personalized service to support their initiatives," says Scodiero. "Our local business development experience combined with TowerJazz's specialty process technologies, proven design enablement tools and excellent customer service will enable us to grow semiconductor business in this significant region."

www.fastcompanybrazil.com.br

www.towerjazz.com



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Custom MMIC's Ka-band LNA offers 1.7dB noise figure and 50mW power dissipation

Monolithic microwave integrated circuit developer Custom MMIC of Westford, MA, USA is offering a new device from its growing MMIC design library. The CMD162 is a gallium arsenide (GaAs) MMIC low-noise amplifier (LNA) chip for applications from 26 to 34GHz (in the Ka-band). Optimized for 30GHz satellite communications, it has a typical noise figure of 1.7dB with a small-signal gain of 22dB and an output 1dB compression point of +7dB. The amplifier delivers high performance with high efficiency, reducing typical industry DC power dissipation for a device in this frequency band from about 340mW to 50mW, it is claimed.

The CMD162 also offers subsystem and device designers a key cost reduction attribute, says the firm. Implementation is simplified since the device only requires positive drain and gate voltages of +2V, eliminating the negative voltages and sequencer circuits commonly associated with LNAs in this frequency range. The CMD162 can be biased with a drain voltage ranging from +1 to +4V and a gate voltage ranging from 0 to +3V.

The amplifier die measures 2.3mm x 1.3mm, includes gold backside metallization, and has full nitride passivation for increased reliability and moisture protection. It can handle input signal levels to +20dBm. The GaAs MMIC amplifier has typical input return loss of 18dB and output return loss of 20dB, both at 30GHz. It is a much smaller, lower-cost alternative to hybrid LNAs for this frequency range, and is uniquely suited for both narrowband and broadband applications requiring small size and low current consumption, including phased-array radar and point-to-point microwave radio systems, it is claimed.

www.CustomMMIC.com

Murata acquiring RF Monolithics

Wireless communications product maker RF Monolithics Inc (RFM) of Dallas, TX, USA has entered into a definitive agreement to be acquired by Murata Electronics North America Inc (a subsidiary of the world's biggest passive electronic components supplier Murata Manufacturing Co Ltd of Kyoto, Japan) for \$1.78 per share to holders of RFM common shares (an 80% premium over the Nasdaq closing price on 12 April). The acquisition is expected to close in third-quarter 2012.

"There is a natural fit between our two companies, and we believe it was a significant factor in our outside directors' ability to attain a favorable price for our stockholders," says RFM's president & CEO Farlin Halsey.

"RFM's proven success in developing business in the healthcare, energy and industrial markets com-

plements Murata's growth strategy," says David M. Kirk president & CEO of Murata Electronics North America Inc (the regional headquarters of Murata Americas). "Additionally, leveraging RFM's expertise in design and development of production-ready RF modules, SAW-based and RFIC short-range radios, stand-alone radio systems and platforms for M2M [machine-to-machine] applications will enable Murata to increase the value of the wireless module solutions delivered to Murata's existing and future customers in the global marketplace," he adds.

The transaction is subject to customary closing conditions, including shareholder and regulatory approvals.

www.RFM.com

www.murataamericas.com

Murata selects Black Sand CMOS PAs for integrated 3G RF front-ends

Fabless IC firm Black Sand Technologies Inc of Austin, TX, USA has been selected to provide its silicon power amplifier (PA) technology for integrated RF front-end products made by Murata Manufacturing Co Ltd. The products will be used to increase integration and improve the performance of 3G smartphones, tablets and datacards.

The new agreement combines Murata's passive components with Black Sand's CMOS PA technology. Integrating the PA together with other RF front-end components into a single module allows better optimization of performance, battery current, size, and cost, claims Black Sand. The firm says it was chosen to work with Murata due to its ability to cost-effectively implement demanding 3G PA specifications using standard silicon CMOS manufacturing technology. "Tier 1 cellular manufacturers are demanding increasing levels of sophistication and integration throughout the handset, and RF is

no exception," notes Norio Nakajima, VP of Murata's module business unit.

"Industry estimates tell us that the market for RF front-end components is growing at a CAGR [compound annual growth rate] of around 15%, and will reach in excess of \$5.5bn by 2014," says Black Sand's CEO John Diehl, citing Needham & Co's 'Mobile device RF front end TAM analysis and forecast'. "A year after we entered production with the BST34 Series devices, entering this relationship is a powerful endorsement of our technology and our ability to deliver."

Black Sand claims that its PAs improve the reliability and data throughput of 3G smartphones, tablets and datacards, while benefiting from the reliability and economies of scale derived from pure CMOS manufacturing, as well as an improved supply chain, higher reliability, and lower cost.

www.blacksand.com

Amalfi closes \$20m in funding, targeting 3G and LTE

Shipments surpass 75 million CMOS transmit modules

Amalfi Semiconductor of Los Gatos, CA, USA, a fabless semiconductor firm specializing in highly integrated CMOS RF and mixed-signal integrated circuits (ICs), has raised an additional \$20m from existing investors Battery Ventures, DCM and Globespan Capital Partners. Amalfi plans to use the funds to expand its business operations and accelerate new product development programs of its next-generation CMOS power amplifier technologies.

"Amalfi is experiencing tremendous growth with worldwide Tier 1 and China ODM handset customers, in addition to having a strong CMOS integration roadmap for the 3G market," says CEO & president Mark Foley. "This commitment from our existing investors demonstrates the confidence they have in our ability to deliver disruptive technology," he adds. "We've had a tremendous

year and a dramatic ramp up in the adoption of our products. As we grow rapidly, this additional funding accelerates our next phase of product development, while allowing us to guarantee exceptional customer service."

With over 75 million transmit modules shipped, Amalfi claims to be the leading CMOS power amplifier firm. Its existing technology is primarily targeted for use in

Amalfi plans to use the funds to expand its business operations and accelerate new product development... Amalfi is experiencing tremendous growth with worldwide Tier 1 and China ODM handset customers

entry-level and ultra-low-cost 2G GSM/GPRS cellular handsets in emerging markets. The firm launched its first family of CMOS-based 2G GSM/GPRS transmit module (TxM) ICs in 2009. In August 2011, it launched its second-generation AdaptiveRF proprietary CMOS-based architecture, which is designed to deliver performance at significantly reduced costs compared to traditional GaAs-based modules.

"We have clearly been able to demonstrate the benefits of our CMOS technology at the 2G level," says Foley. "We will further drive these price and performance benefits for feature and entry-level smartphones while introducing new advanced products that apply these same CMOS integration benefits to 3G and LTE mobile phones and data terminals."

www.amalfi.com

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Infineon launches direct-drive 1200V SiC JFETs, boosting solar inverters

At the PCIM Europe 2012 trade show in Nuremberg, Germany (8–10 May), Germany-based power semiconductor maker Infineon Technologies launched its new CoolSiC 1200V silicon carbide JFET family which, the firm says, takes advantage of more than a decade of experience in SiC technology development as well as high-volume production.

Aimed at markets requiring highly efficient power management, CoolSiC technology is designed specifically to achieve higher performance in solar inverters, says Jan-Willem Reynaerts, product segment head of High Voltage Power Conversion at Infineon Technologies.

Compared with silicon-based IGBTs, the new CoolSiC 1200V SiC JFETs have much lower switching losses, allowing higher switching frequencies to be used without sacrificing overall system efficiency. This enables the use of much smaller passive



components, resulting in smaller overall solution size, lower weight and reduced system cost, says the firm. Alternatively, a higher-output-power solution can be realized within the same inverter housing.

To ensure that the normally-on JFET technology is safe and easy to

use, Infineon has also developed a concept called Direct Drive Technology, in which the JFET is combined with an external low-voltage MOSFET and a dedicated driver IC that ensures safe system start-up conditions as well as fast and controlled switching.

The CoolSiC JFET features a monolithically integrated body diode that has a switching performance comparable to an external SiC Schottky barrier diode. This combination offers optimum efficiency, reliability, safety and ease of use, claims the firm.

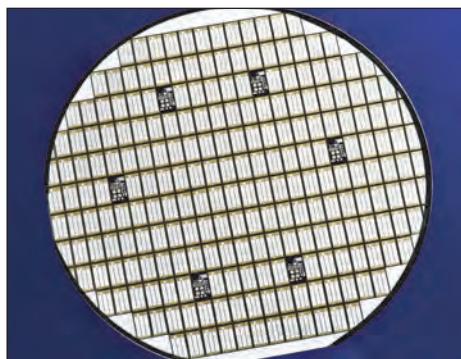
Samples of the CoolSiC JFET products as well as the driver ICs are available in second-quarter 2012. First OEM ramp-ups are expected in first-half 2013. Pricing for the IJW120R100T1 (100mΩ) will be \$24.90 (€18.44) each (in 1000-piece quantity).

www.infineon.com/coolbic

Cree launches 50A silicon carbide power devices, including first 1700V MOSFET

Cree Inc of Durham, NC, USA has announced a new family of 50A silicon carbide (SiC) devices, including the industry's first 1700V Z-FET SiC MOSFET. The firm reckons that the new 50A SiC devices, which also include a 1200V Z-FET SiC MOSFET and three Z-Rec SiC Schottky diodes, will enable a new generation of power systems with record-setting energy efficiency and lower cost of ownership than with conventional technologies.

The new devices, available in die form, are designed for high-power modules for applications such as solar power inverters, uninterruptible power supply (UPS) equipment and motor drives. Cree says that, using the 50A SiC devices, power electronics engineers can set new standards for system cost of ownership through reduced size, lower-



Cree's 50A SiC MOSFET wafer.

cost bill of materials (BOM), and improved efficiency.

Cengiz Balkas, VP & general manager, Cree power and RF, attributes the development to Cree's unique expertise spanning SiC materials technology, wafer processing and device design. "These larger die extend the benefits realized with our 20A SiC MOSFETs to power

applications up to 500kW, making it possible to replace less capable conventional silicon IGBTs [insulated-gate bipolar transistors] in high-power, high-voltage applications," he adds.

Cree says that the higher-rated SiC devices continue its history of SiC technology firsts, including the industry's first 1200V SiC MOSFET and the first production 1200V and 1700V SiC Schottky diodes.

The 50A SiC device series includes a 40mΩ 1700V MOSFET, a 25mΩ 1200V MOSFET and 50A/1700V, 50A/1200V and 50A 650V Schottky diodes. Samples of all these devices are available immediately, with production volumes targeted for fall 2012. Preliminary datasheets are available upon request for samples in die form.

www.cree.com/power

GE expands for SiC product development

Power conversion technology targeted at commercial and military use

GE Aviation (an operating unit of GE) has expanded its location in Pompano Beach, FL, USA, which was established in 1965 and whose 40 staff design and manufacture special application electronic power subsystems for military and other 'high-end' applications.

The new facility (at 2705 Gateway Drive) includes a 30% increase in area (to 30,000ft²) and an R&D lab capable of developing silicon carbide based power conversion products for air, land and sea-based platforms.

"This new facility enables us to continue work on GE-developed SiC

technology, with the potential of reducing the weight on an aircraft by more than 400lbs," says Vic Bonneau, president of Electrical Power for GE Aviation Systems. "GE is committed to Florida and is investing approximately \$20m in program work and R&D related to our Pompano Beach facility over the next five years," he adds.

A new lab in the facility will provide increased capacity for developing, testing and manufacturing advanced electrical power conversion products used on civil and military platforms.

Space and weight are premiums on aircraft, says GE. Airlines are constantly trying to balance the need to create more passenger and storage space, while also meeting increased demand for electrical power on the plane. GE's SiC power devices aim to address this need on both fronts.

"An important part of our strategy is to aggressively invest in the kinds of technologies that will solve large problems for our customers 10 year from now," comments Bonneau.

www.ge.com/aviation

Micross to distribute GeneSiC's die

GeneSiC Semiconductor Inc of Dulles, VA, USA, which develops silicon carbide and silicon-based devices for high-temperature, radiation and power grid applications, has agreed to Micross Components of Orlando, FL, USA (a global provider of distributed and specialty electronic components) being an authorized supplier of its bare die products worldwide. The firms say that the driving force behind the agreement is the shared commitment to increase the availability of SiC bare die to the industrial, military, aerospace, and energy sectors (particularly, drilling and exploration).

GeneSiC says that for years silicon has been the building block of semiconductor design and fabrication because of its natural abundance, processing ease and relatively useful (although limited) temperature range. By comparison, SiC offers enhanced performance, a broader temperature range, greater reliability, and natural radiation resistance. Until recently, challenges and costs associated with SiC production had limited its use among semiconductor manufacturers. However, GeneSiC claims that its design and fabrication advances have increased yields, resulting in more

competitive pricing and offerings (such as its Schottky diodes, claiming significant design and performance advantages).

Extending those advantages to bare die customers will be Micross' role under the new agreement. GeneSiC says that, as an independent distributor of die products worldwide, Micross has both the product and assembly expertise required to certify the GeneSiC bare die for high-temperature/high-reliability applications, as well as the sales channels needed to reach potential customers around the globe. Further, with its technical knowledge and resources, Micross can provide long-term product support to all die customers.

"With Micross' marketing and product support, we can confidently grow this part of our business," says GeneSiC's chief business development officer Michael DiGangi. "Having GeneSiC as a technology partner will be a great advantage for our customers who, by virtue of their specialty applications, are always pushing performance limits," adds Tony Hamby, Micross' general manager for Die Distribution in the USA.

www.genesicsemi.com

www.micross.com

IN BRIEF

Dow Corning orders extra SiC Planetary Reactor systems

Aixtron says that Dow Corning of Auburn, MI, USA is extending its SiC epitaxy capabilities with orders for two extra AIX 2800G4 WW Planetary Reactor platforms with capabilities for 10x100mm and 6x150mm SiC wafers. The reactors are due to be commissioned in second-quarter 2012.

"Dow Corning's epitaxy technology on the Aixtron G4 deposition platform provides our customers with materials capability that enables the creation of high-performance, next-generation power electronics devices addressing the world's growing demand for energy efficient solutions," says Tom Zoes, industry director, Power Electronics business, Dow Corning Corp.

"Repeat orders like this are indicators about the quality of our systems and their ability to provide a solid return on investment for our customers," Dr Frank Wischmeyer, VP & managing director of Aixtron AB, Sweden.

www.aixtron.com

NASA grants Nitronex phase 1 SBIR award

Nitronex Corp of Durham, NC, USA, which designs and makes gallium nitride on silicon (GaN-on-Si) RF power transistors for the defense, communications, cable TV, and industrial & scientific markets, has been granted a Phase I Small Business Innovation Research (SBIR) award by the US National Aeronautics and Space Administration (NASA) to develop a highly efficient 20W X-band GaN power amplifier monolithic microwave integrated circuit (MMIC) for use in long-range space RF telecoms.

Since 2005, Nitronex has won 16 government contract awards that have funded the development of materials, devices, discretes, MMICs and process technologies, as well as manufacturing maturation. This is the third X- or Ka-band contract awarded to Nitronex, further enhancing the firm's GaN-on-Si power amplifier technology.

The firm highlights GaN's much higher power density than incumbent gallium arsenide technologies,

allowing MMIC designers to achieve higher output power and higher system efficiency. This allows system engineers to increase transmit power and reduce associated thermal and power management overhead, lowering size, weight and power consumption (SWAP).

Nitronex claims that its GaN-on-Si technology has several performance advantages over competing GaN-on-SiC offerings. The firm adds that GaN-on-Si high-electron-mobility transistors (HEMTs) have industry-leading thermal performance using 2mil thick substrates, which have very low through-wafer source inductance. GaN-on-SiC-based HEMTs have optimum thermal performance with substrates around 4mil thick, resulting in higher through-wafer source inductance, reducing amplifier gain. Silicon substrates can use thermally superior gold-silicon (AuSi) die attach rather than other methods required by non-silicon substrates. Nitronex also uses industry-standard

ultra-low-loss semi-insulating Si substrates with 0.05dB/mm loss at 10GHz for a 50Ω transmission line, similar to that of GaAs, which is used up to frequencies significantly higher than even the Ka-band. Re-use of the silicon industry's mature supply chain also results in manufacturing and cost advantages versus SiC-based technology.

"GaN-on-Si has inherent performance, reliability, manufacturing and cost advantages, especially when used for MMICs, which have large die sizes," says VP of engineering Ray Crampton. "We believe GaN-on-Si is an enabling technology for high-performance, high-reliability, and cost-effective MMIC products," he adds. "Leveraging our standard NRF1 production-qualified process with over 650,000 production devices shipped, our 0.25μm-gate process platform has no known limitations compared to competing GaN technologies for X- and Ka-band applications," he reckons.

www.nitronex.com

Nitronex develops rugged GaN RF transistor technology to pass toughest robustness tests

Nitronex has developed a rugged transistor technology capable of surviving the industry's most severe robustness tests without significant device degradation.

Based on this new technology, the XPT1015 is a 28V, DC–3.0GHz, 40W power transistor with 17.5dB small-signal gain and 65% peak drain efficiency at 2GHz. Its thermal resistance is 1.9°C/W, which is claimed to be amongst the lowest in the industry in this power class.

Designed from the ground up for ruggedness, the XPT1015 leverages Nitronex's existing 28V NRF1 process platform, which has been used to ship more than 650,000 production devices — including over 50,000 monolithic microwave integrated circuits (MMICs) — since volume shipments began in 2009. A total of 100 XPT1015 devices

from four wafers were subjected to a 15:1 VSWR (voltage standing wave ratio) at all phase angles with 90°C base-plate temperature. During VSWR testing, all devices were operated in a saturated average power condition, being driven by a 4000 carrier 200MHz wide-band signal with a 19.5dB peak-to-average ratio. The devices showed 100% survivability and only ~0.2dB average change in saturated output power.

"Historically, there have been markets which Nitronex could not address because our products did not meet their stringent robustness requirements," says VP of engineering Ray Crampton. "We made reliability, robustness, and ruggedness a priority over the last several quarters. Our new XPT1015 is our first 28V product explicitly

designed for severe operating environments," he adds. "In addition, our recently announced 48V platform was also designed from the ground up to meet very severe environmental requirements."

Nitronex's patented SIGANTIC GaN-on-Si process is claimed to be the only production-qualified GaN process using an industry-standard 4" silicon substrate. Nitronex reckons that this results in a robust, scalable supply chain, and positions it well for the growth expected from emerging GaN markets such as military communications, CATV, radar, commercial wireless, satellite communications, and point-to-point microwave.

Nitronex is providing prototypes to select customers, and the XPT1015 should be available to the broader market later this year.

DARPA awards Raytheon \$1.8m TEGaN contract to develop GaN-on-diamond devices

Raytheon Company of Waltham, MA, USA has been awarded an 18-month, \$1.8m contract by the US Defense Advanced Research Projects Agency (DARPA) to develop next-generation gallium nitride (GaN) devices bonded to diamond substrates. The Thermally Enhanced Gallium Nitride (TEGaN) technology seeks to increase the power-handling capability of GaN devices at least three-fold.

Raytheon says that TEGaN enables transistors and monolithic microwave integrated circuits (MMICs) to achieve their full performance potential by reducing thermal resistance. The technology

acts as a multiplier for GaN's unique qualities, which may dramatically reduce the cost, size, weight and power of defense systems. Over the course of the 18-month contract, Raytheon aims to develop and test TEGaN's capabilities and establish a clear path to technology insertion into military systems.

GaN is a core competency within Raytheon and an integral technology behind some of its major radar programs. The material's unique qualities allow radar, electronic warfare and communications systems to be smaller, more affordable and highly efficient, notes the firm.

"We are pushing the envelope of this proven technology to provide our warfighters with the most advanced sensing, communications and electronic warfare capabilities in the world," says Joe Biondi, VP of Advanced Technology for Raytheon's Integrated Defense Systems (IDS) business of Tewksbury, MA.

Work for the contract will be performed by Raytheon IDS' Advanced Technology group at the Integrated Air Defense Center in Andover, MA. The group specializes in contract R&D programs, particularly multi-function radar frequency systems and advanced semiconductors.

www.raytheon.com

Transphorm delivers first qualified 600V GaN-on-Si products; 99%-efficient DC-DC boost converter and

At the Power Control and Intelligent Motion (PCIM 2012) event in Nuremberg, Germany (8–10 May), Transphorm Inc of Goleta, near Santa Barbara, CA, USA (which designs and delivers power conversion devices and modules) revealed its latest development, aiming to cost-effectively reduce the growing problem of electrical energy waste in power conversion.

Transphorm claims to be the first firm to provide a qualified 600V GaN solution to inefficient power conversion. Last year (starting at last May's PCIM 2011), it announced its first GaN-on-silicon products: power transistors, diodes and modules, based on its patented EZ GaN technology. The following 600V products are now available as evaluation samples to approved customers:

- TPS30xxPK series of 600V, 2-4-6A, GaN diode in the industry-standard TO-220 package;
- TPH3006PS- 600V, 180mΩ GaN transistor in the industry-standard TO-220 package; and
- TPT3044M- 600V, 3-phase GaN

module and related inverter application board TDMD2000E01.

"The opportunity for widespread energy efficiency gains is staggering and our GaN solutions offer unprecedented energy gains," reckons co-founder & CEO Umesh Mishra (a professor of electrical & computer engineering at the University of California, Santa Barbara). "In the motor segment alone, Transphorm's innovations create the potential to save 2.5% of US electricity generation through enhanced electro-mechanical efficiency of the full drive and motor system - equivalent to the energy saving potential of replacing incandescent lighting with white LEDs."

Transphorm claims that its compact and easy-to-embed solutions can cut energy waste by 50% and simplify the design and manufacturing of a wide variety of electrical systems and devices, including motor drives, power supplies and inverters for solar panels and electric vehicles. To demonstrate the performance of its patented GaN-based technology, at PCIM Transphorm showcased its

EZ GaN-based, dc-to-dc Boost Converter (running at more than 99% efficiency) and its Tru-Sine motor drive (delivering 2–8% higher efficiency at 100kHz versus state-of-the-art silicon IGBT-based motor drives at 15kHz).

"For customers looking for a low-risk roadmap to the next generation of power conversion technology, Transphorm's EZ-GaN application boards provide for a simpler design-in and faster time to market," says co-founder & president Primit Parikh.

Electric power waste that occurs during power conversion is equivalent to the daily output of 318 coal plants, and costs the US economy \$40bn per year, it is reckoned. Transphorm's GaN products come in industry-standard packages and are designed for optimum high-frequency switching. The firm says that its proprietary EZ GaN platform can reduce power system size, increase energy density and deliver high efficiencies across the grid, from HVACs to hybrids, and from servers to solar panels.

www.transphormusa.com

TriQuint wins \$12.3m DARPA contract to develop ultra-fast E-mode GaN power switch

Firm selected as prime contractor for MPC Technical Area I

RF front-end component maker and foundry services provider TriQuint Semiconductor Inc of Hillsboro, OR, USA has been selected by the US Defense Advanced Research Projects Agency (DARPA) to lead a \$12.3m development program focused on ultra-fast gallium nitride (GaN) switch technology for the Microscale Power Conversion (MPC) program. TriQuint says that its new GaN modulator has the potential to enable highly efficient RF transmitters substantially smaller than existing solutions.

TriQuint was selected by DARPA as the prime contractor for MPC Technical Area I, which aims to develop a high-speed, DC-to-DC switch (modulator) and related process technology based on the firm's enhancement-mode GaN transistors. TriQuint's technology aims to improve the integration of power switches with advanced RF amplifiers to facilitate ultra-high-efficiency, reduced-size amplifiers for radar and communications applications.

TriQuint has been conducting GaN development and research since 1999. The firm currently leads multiple GaN process and manufacturing technology initiatives for DARPA, including the Nitride Electronic NeXt-Generation Technology (NEXT) program, as well as endeavors for the US Air Force, Army and Naval laboratories.

TriQuint is already exploring and bringing derivative devices to market made possible by milestones achieved in its many GaN programs. "The break-through performance demonstrated in 'NEXT' has helped us develop new devices, like our GaN power switches, that will open up additional radar and communications applications," says James L. Klein, TriQuint VP & general manager for Defense Products and Foundry Services. "We can substantially improve performance in these types of systems," he adds. "This work is also leading to lower-voltage GaN-based products. We see many exciting opportunities to

develop more advanced RF amplifiers with integrated power switches."

The enhancement-mode power switching device for the MPC program will be designed to have a blocking voltage of 200V, ultra-low dynamic on-resistance of 1Ω-mm and a slew rate of 500V/ns. RF amplifiers using these switches will target 75% system efficiency at X-band (8–12GHz) frequencies.

TriQuint is teamed with Rockwell Collins, the University of Colorado at Boulder and Northrop Grumman — Technical Area II contractors — to create a new generation of RF power amplifiers that use contour modulation for very high-efficiency performance that exceeds the capabilities of devices now available. Design approaches focusing on miniature system-in-a-package or monolithic integration to combine TriQuint's switch/modulator with the power amplifier micro-system will be given preference.

www.triquint.com/defense

RFMD unveils 900V-breakdown high-voltage GaN process

rGaN-HV to be used for power device products and external foundry

RF Micro Devices Inc of Greensboro, NC, USA has extended its gallium nitride (GaN) process technology portfolio to include a new technology optimized for high-voltage power devices in power conversion applications.

The firm claims that the rGaN-HV process enables substantial system cost and energy savings in power conversion applications ranging from 1 to 50kW. It delivers device breakdown voltages up to 900V, high peak current capability, and ultra-fast switching times for GaN power switches and diodes.

The new technology complements RFMD's GaN 1 process (which is optimized for high-power RF appli-

cations and delivers high breakdown voltage over 400V) and the GaN 2 process (which is optimized for high-linearity applications and delivers high breakdown voltage over 300V). RFMD will manufacture discrete power device components for customers as well as providing access to rGaN-HV to external foundry customers for their customized power device solutions.

"The global demand for energy savings through improved power

The new rGaN-HV technology complements RFMD's GaN 1 process and the GaN 2 process

conversion efficiency is creating a tremendous opportunity for high-performance power devices based on RFMD's GaN power process technologies," says president & CEO Bob Bruggeworth. "We expect our newest GaN power process will expand our opportunities in the high-voltage power semiconductor market," he adds.

RFMD's Power Conversion Devices Product Line and Foundry Services business unit exhibited a broad portfolio of GaN technologies and GaN power products at the PCIM Europe 2012 (Power Conversion Intelligent Motion) event in Nuremberg, Germany (8–10 May).

www.rfmd.com/products/

TriQuint signs CRADA agreement with US Army to co-develop GaN high-frequency and mixed-signal ICs

ARL researchers to gain access to E/D-mode GaN technology

RF front-end component maker and foundry services provider TriQuint Semiconductor Inc of Hillsboro, OR, USA has signed a Cooperative Research and Development Agreement (CRADA) with the US Army Research Laboratory (ARL) to explore and fabricate new high-frequency and mixed-signal integrated circuits (ICs) based on TriQuint's gallium nitride (GaN) technology. The CRADA is designed to accelerate new programs supporting communications, radar, electronic warfare (EW) and similar applications.

The CRADA will give Army researchers dedicated access to TriQuint's development, fabrication and packaging expertise. Researchers from both TriQuint and ARL should benefit from the new co-development environment. Circuits created as part of the initiative are expected to be based on TriQuint's new E/D (enhancement-depletion mode) GaN technology.

The agreement leverages technology that TriQuint created through on-going R&D programs. This GaN process has been used in US Defense Advanced Research Projects Agency (DARPA) initiatives, including the Nitride Electronic NeXt-Generation (NEXT) program that TriQuint now leads. TriQuint says that, through NEXT, it continues to establish benchmark performance standards for mixed-signal (digital and RF) devices. The firm's GaN achievements have also led to its selection as a prime contractor in the Microscale Power Conversion (MPC) program, which is developing ultra-fast, high-power DC-DC switch modulator technology for integrated RF amplifiers.

"Creative partnerships through Cooperative Research and Development Agreements encourage outside businesses and university organizations to share in the discovery of and investment in tech-



nologies," says ARL director John Miller. "In this case, ARL is leveraging industrial fabrication capabilities, allowing ARL to maximize its return on investment. These advanced IC processes, coupled with ARL's design expertise, could lead to innovations and advancements in both military and consumer applications in communications, radar and electronic warfare," he adds.

"This new CRADA is another example of ways that our work in one program benefits other DoD [Department of Defense] agencies and service branches," says James L. Klein, TriQuint's VP & general manager for Defense Products and Foundry

The ARL's design and testing capabilities will be leveraged with TriQuint's MMIC fabrication, testing and packaging expertise. Both TriQuint and ARL researchers will work towards identifying circuits of mutual interest that have the potential to advance design programs

Services. "We will provide access to our extensive development capabilities, and the ARL will provide designs and test circuits in support of their advanced programs," he adds.

TriQuint's new agreement with the ARL is designed to stimulate high-performance monolithic microwave integrated circuit (MMIC) development. The ARL's design and testing capabilities will be leveraged with TriQuint's MMIC fabrication, testing and packaging expertise. Both TriQuint and ARL researchers will work towards identifying circuits of mutual interest that have the potential to advance design programs.

TriQuint has been conducting defense and commercial GaN development and research since 1999. The firm currently leads multiple GaN process and manufacturing technology programs for DARPA, the US Air Force, Army and Naval laboratories including the Defense Production Act (DPA) Title III manufacturing enhancement program (for radar and EW MMICs based on GaN-on-SiC). It has also led two other DARPA programs that were part of the Wide Bandgap Semiconductor (WBGs) RF research initiative.

www.triquint.com/defense

GaN Systems and APEI to co-develop high-temperature, high-performance package for GaN transistors and diodes

Sustainable Development Technology Canada funding targets power converter for HEVs and EVs

GaN Systems Inc of Ottawa, Ontario, Canada, which is a fabless provider of gallium nitride (GaN)-based power switching semiconductors for power conversion and control applications, and Arkansas Power Electronics International Inc (APEI), which develops technology for power electronics systems, electronic motor drives and power electronics packaging, are to collaborate on the development of a high-temperature, high-performance package optimized for GaN transistors and diodes.

The co-development is funded in part by the Government of Canada through the foundation Sustainable Development Technology Canada (SDTC), which operates a \$590m fund to support the development and demonstration of clean technologies (solutions addressing issues of clean air, climate change, clean water and clean soil). The goal is to demonstrate the efficiency, performance, and reliability of GaN power devices in a power converter for hybrid and electric vehicles (HEVs and EVs).

"As GaN is just beginning to gain acceptance for the next generation



APE International/GaN package.

of power semiconductors, prospective users are keen to see the technology validated through real system design implementations," says GaN Systems' CEO Girvan Patterson. "Advanced packaging is the key that unlocks the vast potential of GaN in high-power applications, so we are delighted to be collaborating with a world leader on a package and system design that will maximize the benefits of this exciting technology," he adds. "This important partnership also marks a powerful endorsement of our patented, island-based topology, validating our unique design approach."

GaN Systems says that gallium nitride offers dramatic efficiency

advantages over conventional silicon devices when used in power conversion systems. "For some time APEI has been looking for an opportunity to get more heavily involved in developing products for newly emerging GaN device technology," says APEI's president & CEO Dr Alexander Lostetter. The partnership with GaN Systems will result in new power module and converter technologies for an industry that is demanding increased energy efficiency, higher performance and reliability, and smaller size and weight, he adds.

"SDTC works to ensure that different partners — from innovators to end-users — are involved in the development and demonstration of new technologies," says SDTC's president & CEO Vicky Sharpe. "GaN Systems and APEI are showing the clear benefits of this approach. By working together, they will make sure that users' needs are reflected in the product's development early enough to pave a smooth path to market."

www.gansystems.com
www.apei.net

Millitech launches GaN-based E- and W-band millimeter-wave solid-state power amplifiers

Millitech Inc of Northampton, MA, USA, a Smiths Interconnect business that designs and manufactures millimeter-wave components, assemblies and fully integrated antenna positioning systems for satellite communications, radar, passive imaging, space and remote sensing applications, says it is now offering GaN-based E- and W-band solid-state power amplifiers able to achieve small size and high power.

The firm claims that the power amplifiers represent a leap in out-

put power at E-band and W-band frequencies, with up to 3W of output power and up to 20% power-added efficiency (PAE) available in standard models. The new AMP models offer catered performance over specific allocated bands or wideband power covering frequencies of 75–102GHz.

The E-band (WR-12) models cover the commercially allocated 71–76GHz and 81–86GHz bands. The W-band models cover 75–102GHz.

Each amplifier has internal bias circuitry that generates gate control voltages, provides proper voltage sequencing, and incorporates reverse voltage protection from a single positive external bias.

Single device models are available with nearly 1W of saturated output power. Standard models also include 2-way and 4-way solid-state power amplifiers (SSPAs) with up to 3W of saturated output power. Higher powers are available.

www.millitech.com

Accel-RF launches RF test-characterization platform

Accel-RF Corp of San Diego, CA, USA (which produces turn-key RF reliability testing systems for compound semiconductor devices) has announced the availability of a standalone integral software and hardware platform capable of functioning as an independent single-channel or virtual multi-channel characterization test subsystem for microwave and millimetre-wave devices.

The platform is USB controlled to provide temperature, RF-signal and bias-control to a device-under-test (DUT) for semiconductor performance measurement. When used in conjunction with Accel-RF's embedded Pulser-Card Assembly, the test device is capable of pulsed DC and RF stimulus.

"With this solution engineers can perform a suite of tests for up to 15

different package types that may be used in their product offering," says CEO & co-founder Roland Shaw. "This provides our customers with ultimate flexibility for characterizing RF devices with a consistent interface and RF/microwave platform," he adds.

"In fact a number of test-sequences and stimulus-definitions may be user-defined in the software and automatically performed. This capability opens a world of test methodologies previously unavailable in a single test system platform," Shaw continues. "A consistent, clean test platform design, with excellent RF performance for the myriad of package types being used in the wireless industry, is not only more efficient, but saves considerable human and financial resources."

Typical test scenarios have integrated the RF platform with other third-party manufacturers' instruments to accomplish step-stress testing, device RF-biased channel-temperature thermal imaging, semiconductor parametric analysis with device aging at elevated temperature, and synchronized DC/RF pulsed-bias performance characterization.

The test platform is also compatible with Accel-RF's AARTS LIFETEST product line and may be used with standard test fixtures used in an AARTS reliability test system.

Accel-RF highlighted the new RF test-characterization platform at the International Conference on Compound Semiconductor Manufacturing Technology (CS ManTech) in Boston, MA (23–25 April).

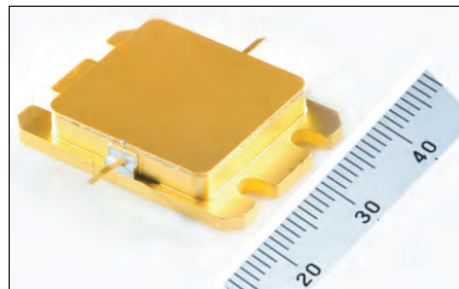
www.accelrf.com

Mitsubishi Electric boosts Ku-band satcom GaN power amplifier output from 62W to record 100W

Tokyo-based Mitsubishi Electric Corp has developed a prototype gallium nitride high-electron-mobility transistor (GaN HEMT) amplifier with record output power of 100W (50dBm) for Ku-band (14GHz) satellite communications. The amplifier is expected to contribute to smaller and lighter transmitters for terrestrial stations used in satellite communications.

Vital satellite communications require robust systems that must work under adverse conditions, such as during natural disasters, notes Mitsubishi Electric. High power output is required for radio transmission from terrestrial stations to satellites in geostationary orbit 36,000km above sea level. Also, terrestrial stations must be small enough to be transported by vehicles and installed.

Gallium arsenide (GaAs) amplifiers have commonly been used for satellite communication transmitters, but GaN amplifiers have become



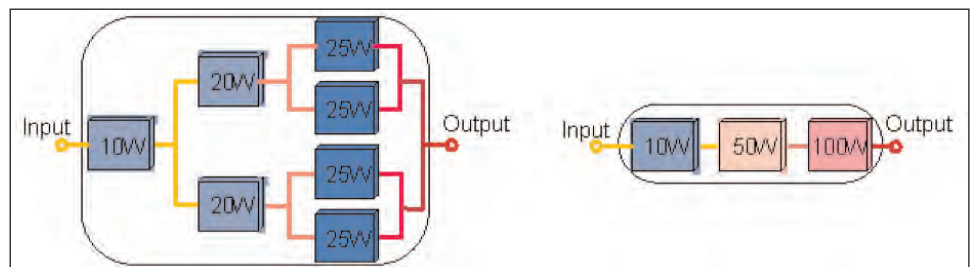
New 100W Ku-band GaN amplifier.

increasingly popular recently since GaN transistors can handle very high voltage.

Mitsubishi Electric began to ship samples of C-band 100W GaN HEMT power amplifiers for satellite

communications in 2011. The new Ku-band GaN HEMT amplifier (which has gain of 8dB) features a downsized configuration and a low-loss circuit. The 100W output power significantly increases that of the firm's existing GaN HEMT amplifier (62W, 47.9dBm; 8dB gain) and quadruples that of its GaAs amplifier (25W, 44dBm; 5dB gain). The firm says that its new amplifier's ability to perform the tasks of four conventional units represents can help to downsize transmitters to one sixth the size of a GaAs amplifier.

www.mitsubishielectric.com



Conventional GaAs (left) and new GaN (right) 100W amplifier system.

IN BRIEF

Air Products brings onstream new hydrogen selenide plant for CIGS PV

Air Products of Lehigh Valley, PA, USA has brought onstream an expansion of its high-purity hydrogen selenide (H_2Se) production capabilities at its electronic specialty materials manufacturing facility in Hometown, PA. The new capacity was added to serve the growing copper indium gallium diselenide (CIGS) thin-film photovoltaic (PV) solar cell manufacturing market.

"Air Products has a long history of supplying hydrogen selenide," says Joe Stockunas, global business director Electronic Materials. The firm can deliver H_2Se to semiconductor and photovoltaic customers at more than 99.99% purity levels.

Air Products notes that industry observers believe CIGS technology holds much promise going forward, based on the significant advances already made by producers in efficiency improvement and high-volume manufacturing.

www.airproducts.com/H2Se

AkzoNobel adds capabilities for magnesium-based LED precursor

AkzoNobel N.V. of Amersfoort, The Netherlands says that, as a key step in adding production capacity for its High Purity MetalOrganics (HPMO) product range, it has recently started production of the magnesium-based metal-organic compound Cp_2Mg , which is used as a dopant in the epitaxy of compound semiconductor structures.

The HPMO business (part of AkzoNobel Functional Chemicals) is a producer of semiconductor-grade indium-, gallium-, aluminium and zinc- and magnesium-based metal-organics that are used as key precursor materials in the production of LEDs, solar cells and other semiconductor devices.

The production unit for Cp_2Mg (bis-cyclopentadienyl magnesium) has been added at the firm's Deventer site in The Netherlands, leverages AkzoNobel's broader technology base for the manufacturing of highly pure metal-organic complexes, used across several indus-

The newly added capabilities can also be used to produce other advanced MO complexes

tries including polymer, pharma and electronics applications.

" Cp_2Mg is a relatively small part of our product range, however, it is a key product for our customers and used extensively in many CVD applications," says Michiel Floor, global business manager of the HPMO product group. "We continue to execute our capacity growth plan across all products in our portfolio, to support further growth of the LED and other compound semiconductor industries. While our expansion efforts are focused on growth of our core products trimethyl gallium (TMGa), triethyl gallium (TEGa), trimethyl indium (TMIn) and trimethyl aluminum (TMAI), we are very happy to bring the new and large-scale Cp_2Mg capacity at Deventer on stream, to the benefit of our global customer base," he adds. "The newly added capabilities can also be used to produce other advanced metal-organic complexes used in the broader semiconductor industry, so we will pursue further development of this product range."

AkzoNobel says the extra capacity will enhance its position as a global producer of high-purity MO-sources.

www.akzonobel.com/hpmo

Neo Material Technologies opens gallium tri-chloride production plant in Korea

Neo Material Technologies Inc of Toronto, Canada (which produces neodymium-iron-boron magnetic powders, rare earths and zirconium-based engineered materials, as well as other rare metals and compounds via its Magnequench and Performance Materials divisions) has officially opened its gallium tri-chloride production facility located in Hyeongok Industrial Zone, Republic of Korea.

In August 2011 Neo Material Technologies acquired 80% of Oklahoma-based Gallium Compounds.

The new facility, which is now operational and is strategically situated in the heartland of Korea's booming LED industry, will utilize Gallium Compounds' technology for the production of gallium tri-chloride in Asia. As well as supplying Asian markets, the facility will also serve as a back-up for the plant located in Quapaw, Oklahoma. Neo Material Technologies owns 80% of this new production facility, with the remaining 20% owned by the founders of Gallium Compounds, Greg Evans and Kevin Reading.

"We are extremely pleased with the progress we have made in the gallium tri-chloride market since acquiring a majority stake in Gallium Compounds," says Geoff Bedford, executive VP & chief operating officer. "Our ability to have this new, state-of-the-art plant in operation within seven months is a testament to our ability to execute quickly in a high growth market," he adds. "This is an important step in our growth strategy for rare metals."

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AXT's revenue rebounds by 10.7% in Q1

...but margins fall due to strong decrease in raw material pricing

For first-quarter 2012, AXT Inc of Fremont, CA, USA has reported revenue of \$23.5m, up 10.7% on \$21.2m last quarter (rebounding from a 25% drop in Q4/2011) but still down 4.4% on \$24.6m a year ago.

Gallium arsenide substrate revenue was \$12.2m, up 10% on \$11.1m last quarter (rebounding from a 41% decline in Q4/2011) but still down 23% on \$15.9m a year ago. Indium phosphide substrate revenue was \$1.5m, doubling on \$724,000 last quarter (returning to the level of Q3/2011) and up 15% on \$1.3m a year ago. Germanium substrate revenue was \$2.6m, down 13% on \$3m both last quarter and a year ago. Raw materials sales have continued to rise, up 64% on \$4.4m a year ago and up 12.5% on \$6.4m last quarter to \$7.2m.

"After a difficult start to the year, the demand environment in March

showed steady improvement and appears to be holding as we move into the second quarter," says CEO Morris Young. "We were pleased to see a strong increase in our semi-insulating [GaAs] substrates for wireless devices after two challenging quarters in the second half of 2011," he adds. "We saw similar rebounds in the markets for semi-conducting [GaAs] and indium phosphide substrates, placing us at the high end of our revenue guidance range [of \$21–24m]."

However, gross margin has fallen further, from 43.4% a year ago and 36.9% last quarter to 34.9% (at the bottom of the target model) as a result of a strong decrease in raw material pricing as well as a strategic decision to leverage profit margins in order to strengthen competitive positioning for certain business opportunities.

Operating expenses have risen further, from \$4.2m a year ago and \$4.5m last quarter to \$4.6m. Yet income from operations has risen from \$3.3m last quarter to \$3.6m (though down on \$6.5m a year ago). Net income has fallen further, from \$4.2m a year ago and \$2.6m last quarter to \$1.6m (\$0.05 per diluted share). Despite this, during the quarter, cash and cash equivalents rose from \$26.2m to \$31.2m.

"While we did underperform our earnings per share expectation, we remained profitable, cash-positive and well-positioned to take advantage of market growth as the demand environment improves over the balance of the year," Young notes.

For Q2/2012, AXT expects revenue of \$23–25m. Net income per share should be steady at \$0.04–0.06.

www.axt.com



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Riber grows 8% year-on-year in Q1, driven by system sales ...but orders fall 8% due to pause between generations of evaporation sources and cells

For first-quarter 2012, Riber S.A. of Bezons, France, which manufactures molecular beam epitaxy (MBE) systems as well as evaporation sources and effusion cells, has reported revenue of €6.2m, down 41% on €10.5m last quarter but up 8% on €5.7m a year ago.

Business is benefiting from the development of system sales, with three research MBE machines and one production MBE machine invoiced during first-quarter 2012 yielding revenue of €4.6m, more than doubling from the €2.1m from just two research MBE machines sold a year ago.

Revenue from evaporation sources and cells was €0.6m, down 76% on €2.6m a year ago, which included the delivery of a

major order for organic LED (OLED) production cells. Revenue from services and accessories showed a positive trend, up 1% on €1m a year ago.

During Q1/2012, Riber booked four MBE system orders for research laboratories in Belgium, Argentina, Russia and the USA. At the end of March, the order book amounted to €19.5m, down 8% on €21.3m a year ago. However, this is due to orders falling from €5m to €0.1m for evaporation sources and cells and from €2.3m to €1.5m for services and accessories. In contrast, the order backlog for systems rose 28% from €14m to €17.9m, with 13 research systems to be delivered in 2012 and 2013 in addition to one production machine.

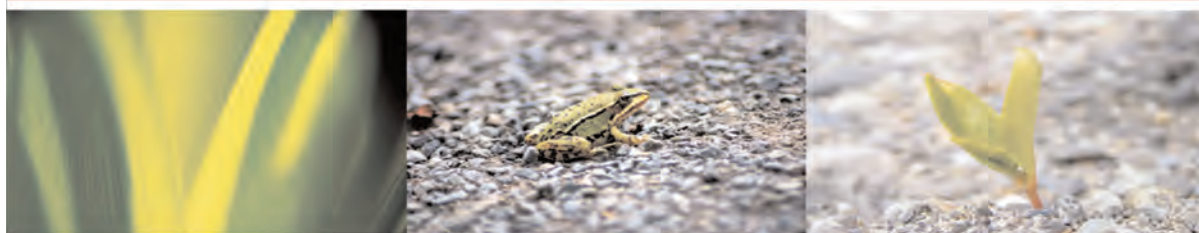
Riber says that the contraction in the order book for cells and sources factors in the delivery of a major investment order during the last 12 months for OLED production equipment. Meanwhile, the firm is

The contraction in the order book for cells and sources factors in the delivery of a major investment order in the last 12 months

focusing on preparing a new-generation range of cells with a view to the next wave of investments.

Nevertheless, the commercial action plan rolled out since the start of 2012 is expected to pave the way for growth in sales over the year.

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IN BRIEF

Lasertel adds Veeco MBE system to expand laser diode production capacity

Veeco Instruments says that Lasertel Inc of Tucson, AZ, USA (a subsidiary of Finmeccanica company SELEX Galileo Inc) has purchased a second high-throughput, multi-wafer GEN200 Edge molecular beam epitaxy (MBE) production system to increase its laser diode manufacturing capacity.

"The additional GEN200 Edge production MBE system provides the extra capacity required to support the increased demand for Lasertel devices," says Lasertel's president Mark McElhinney. "The GEN200 system offers advanced automation, precise process control, and in-situ process monitoring. It is the core enabling technology for Lasertel's leading-edge, high-performance semiconductor diode laser devices," he adds.

Lasertel is enhancing the manufacturing capabilities of its 65,000ft² high-volume semiconductor laser fabrication and packaging facility in Tucson to support growing demand for its existing product portfolio. This increases its in-house complement of MBE tools to four, with the latest to be used to accelerate the development of next-generation, high-performance diode laser products. The expansion is planned to be completed by fourth-quarter 2012.

"We look forward to supporting Lasertel in their continued growth with the Veeco GEN200 system, part of our suite of the industry's most cost-effective and highest-capacity production MBE systems," says Jim Northup, VP & general manager of Veeco's MBE operations.

www.lasertel.com

Veeco's investment in Korean R&D center recognized in signing ceremony

Epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA recently participated in a signing ceremony at the 2012 Korea Investment Forum in New York City to commemorate the firm's investment in a new R&D facility in Seoul, Korea to advance high-brightness LED technology.

The Investment Forum event, jointly sponsored by Korea's national economic development agency KOTRA (the Korea Trade-Investment Promotion Agency, which aims to promote collaborative business relationships between the USA and Korea) and the Korea Ministry of Knowledge Economy (MKE), brought together government officials, investors, industry experts and business leaders from

South Korea and the USA to celebrate and promote investment in South Korea by US-based companies.

Attendees at the ceremony included Ki-won Han, commissioner of InvestKOREA (a division of KOTRA responsible for the attraction of foreign direct investment). Other attendees included Korea Ministry of Knowledge Economy deputy minister Jin-Hyun Han and John P. Kiernan, Veeco's senior VP finance, corporate controller & treasurer.

<http://english.kotra.or.kr>



From left to right: Ki-won Han, Jin-Hyun Han and Veeco's John P. Kiernan at a signing ceremony recognizing Veeco's investment in a Development Center devoted to accelerating MOCVD technology for LED lighting.

Korean research center chooses Veeco MOCVD system for HB-LED R&D

Veeco says that LED-IT Fusion Technology Research Center (LIFTRC) of Korea has selected its TurboDisc K465i GaN MOCVD system for R&D on HB-LEDs, including green LEDs and ultra-violet (UV) LEDs.

"Veeco's K465i enables us to conduct research and development of next-generation LED technology on a fully automated, low cost-of-ownership platform," says LIFTRC's chief director Ja-Soon Jang (a professor in Yeungnam University's Department of Electronic

Engineering). "Veeco's industry-leading position, localized support and technical expertise will help us achieve our goal of collaborating with local and worldwide LED manufacturers," he adds.

"We look forward to supporting LIFTRC and their partners and believe Korea will continue to drive the advancement of LED technology," comments William J. Miller Ph.D., Veeco's executive VP, Process Equipment.

<http://english.liftrc.re.kr>
www.veeco.com/mocvd

Veeco's China Training Center trains 500th customer engineer

Epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA says that it has trained its 500th customer engineer at its China Training Center (CTC) in Shanghai.

The CTC opened in mid-2011 to help key LED makers — including its two largest customers, San'an Optoelectronics and Elec-Tech International — scale-up production, optimize their use of metal-organic chemical vapor deposition (MOCVD) systems, and support the industry's rapid growth.

"By having a strong presence in China and establishing this state-of-the-art center, Veeco has demonstrated industry leadership not just in MOCVD technology, but in customer support as well," comments San'an Optoelectronics' CEO Lin Zhiqiang. "San'an recently achieved record revenues in 2011 as an industry leader of high-quality LEDs for applications such as general illumination, TV backlighting and outdoor displays. Veeco is helping San'an to maximize the future LED growth opportunity by supporting our training needs and capacity ramp," he adds.

"Veeco was first to recognize the importance of customer training as critical in the recipe for success in China," says Greg Crema, CEO of Elec-Tech International's LED Business. "Their strong support, particularly in helping to train our engineers at the CTC, has enabled us to make significant progress scaling LED manufacturing capacity at our two sites in Wuhu and Yangzhou. Our goal is to become a top-three LED company by output and sales revenue in China within two years, focusing on the general lighting and BLU [back-light unit] market, as well as other applications," he adds.



Veeco's office in Shanghai, opened in May 2011.

"In 2010 and 2011 China made an enormous investment to expand LED manufacturing capabilities to respond to its energy challenges and capitalize on the global opportunity as LED lighting hits an inflection point," notes Veeco's CEO John Peeler.

During this timeframe, Veeco shipped over 400 MOCVD systems to Chinese customers

"During this timeframe, Veeco shipped over 400 MOCVD systems to Chinese customers, including the established LED manufacturers, joint venture entities, and start-ups. Every one of these customers is unique, and we are focused on delivering the best-in-class support and systems they will need for future growth and success," he adds.

The CTC is located in Veeco China's headquarters building and is fully staffed by local, highly trained Veeco instructors. About 1700m² in size, it features three fully equipped classrooms as well as Veeco's TurboDisc K465i MOCVD system for hands-on training. The CTC has a comprehensive schedule of classes, including basic MOCVD system training, epitaxial layer optimization introductions, and advanced hands-on classes in hardware maintenance and trouble-shooting.

IN BRIEF

Silan expands blue and green HB-LED capacity with Veeco MOCVD tools

Epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA says that China-based LED maker Hangzhou Silan Azure Co Ltd has placed a multi-tool order for more TurboDisc K465i metal-organic chemical vapor deposition (MOCVD) systems. The equipment will be used to expand Silan Azure's manufacturing capacity for blue and green high-brightness light-emitting diodes (HB-LEDs).

A joint venture of Silan Microelectronics Co Ltd, Silan Azure designs, manufactures and distributes HB-LEDs, epitaxial wafers and chips.

"The growth we are experiencing supplying LEDs for general illumination, backlighting and outdoor display applications required us to add manufacturing capacity at our Hangzhou facility," says Silan Azure's president Zhongyong Jiang. "After evaluating various suppliers, we chose to purchase additional systems from Veeco because of our satisfaction with the production-worthiness and reliability of existing K465i MOCVD tools [ordered in October 2010] at our fab. The excellent field support we have received from Veeco was also a major factor in our decision," he adds.

"We are pleased Silan Azure has chosen the K465i for their manufacturing expansion, and look forward to continuing to build upon our relationship with one of China's top LED manufacturers," says William Miller Ph.D., executive VP of Veeco Process Equipment.

www.silanazure.com/en
www.veeco.com/mocvd

Veeco's revenue falls 27% in Q1, but MOCVD orders show modest rebound

Expense management yields higher-than-forecast margins & earnings

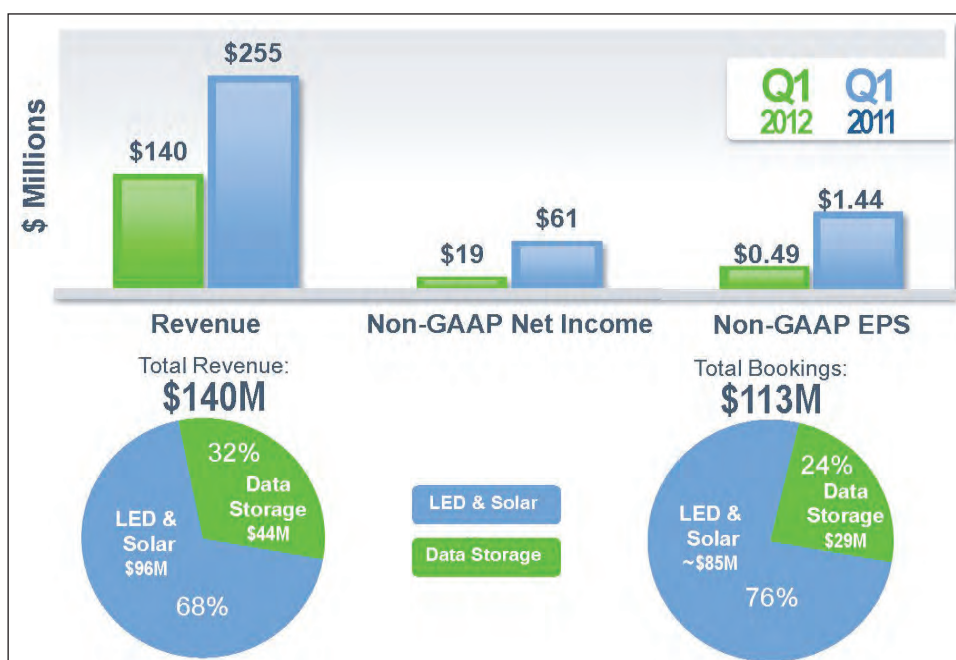
For first-quarter 2012, epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA has reported revenue of \$139.9m, down 27% on \$191.7m last quarter and 45% on \$254.7m a year ago, albeit at the top of the \$115–140m guidance.

Of total Q1 revenue, 32% came from Data Storage revenue of \$44.3m, up 40% on \$31.6m last quarter (just 17% of revenue). The other 68% comprised LED & Solar revenues of \$95.6m, down 40% on \$160m last quarter (83% of revenue) and down 55% on \$214.7m a year ago (84% of revenue). This included revenue for molecular beam epitaxy (MBE) systems of \$14m. Revenue for metal-organic chemical vapor deposition (MOCVD) systems was \$82m, down 45% on \$150m last quarter and 60% on \$204m a year ago. However, Veeco has claimed a 60% share of the MOCVD market in Q1 (continuing the rise from 29% share in full-year 2009 and 44% in 2010 to 51% in 2011, when it took the lead in the MOCVD market).

"We are experiencing growth in our Data Storage and MBE businesses, as well as in Services across all of our technologies," says CEO John R. Peeler. After growing to nearly \$100m in full-year 2011, Services business reached a record \$31m in Q1/2012.

"We are executing well during the downturn in MOCVD demand," comments Peeler. On a non-GAAP basis, gross margin has rebounded from 43.7% last quarter to 46.7% (above the expected 43–45%, but still down on 50.8% a year ago). Though still higher than the \$43.8m a year ago, operating expenses have been cut from \$48m last quarter to \$44.3m.

Due to the rise in gross margin and the management of expenses, net income was \$19m, down on



Veeco Q1 revenue, income and earnings per share for 2012 versus 2011 (top), and revenue and orders by application sector for Q1/2012 (bottom).

\$28.1m last quarter and \$61.3m a year ago but up on guidance of \$5.2–13.2m. Cash flow from operations was \$42m (down on \$57m last quarter). During the quarter, cash and short term investments rose from \$492m to \$524m.

"As anticipated, we experienced a weak bookings environment," notes Peeler. Total orders were \$113.4m, down 21% on \$143m last quarter and 51% on \$230.9m a year ago.

Of total Q1 bookings, 26% came from Data Storage orders of \$28.8m, down 62% on last quarter's record of \$76m (53% of total bookings) as customer consolidation activity temporarily stalled capacity investments. The other 74% of bookings comprised LED & Solar orders of \$84.6m, down 57% on \$198.2m a year ago but up 26% on \$67m last quarter (just 47% of total bookings). Of LED & Solar bookings, MOCVD orders were \$70m, down 62% on \$186m a year ago but up 19% on last quarter's \$59m, with system orders from customers in Korea, China, Taiwan,

Japan and North America (with the biggest sequential changes coming in Taiwan and Korea). MBE orders were \$15m, up 71% on last quarter's \$8m due to production orders from wireless customers. Nevertheless, overall during the quarter, order backlog fell from \$333m to \$305m.

"While MOCVD bookings grew modestly in the first quarter, we have not yet seen a clear inflection in customer buying patterns," notes Peeler. "LED customers remain cautious about capacity investment plans, and it is still unclear when the MOCVD market will recover," he adds. "Some positive signs are emerging, including increasing tool utilization rates in Korea, Taiwan [both about 80%] and China, and a pick-up in customer quoting activity."

For second-quarter 2012, Veeco expects revenue of \$120–145m. However, although operating expenses will be steady at \$43–46m, gross margin will fall to 44–46% and net income to

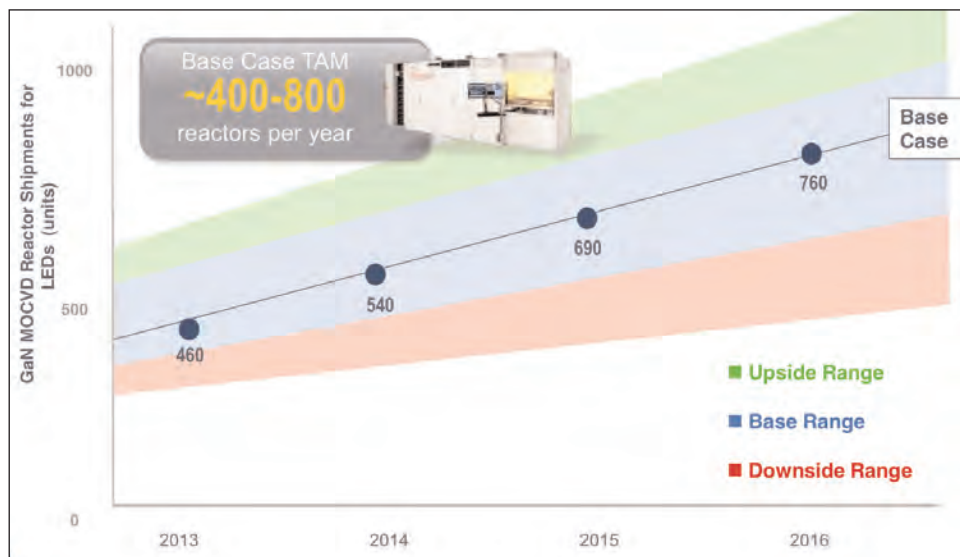
► \$11.3–18.9m.

"Veeco is focused on keeping our infrastructure lean and discretionary costs low, while at the same time developing next-generation technology solutions to drive future growth," says Peeler.

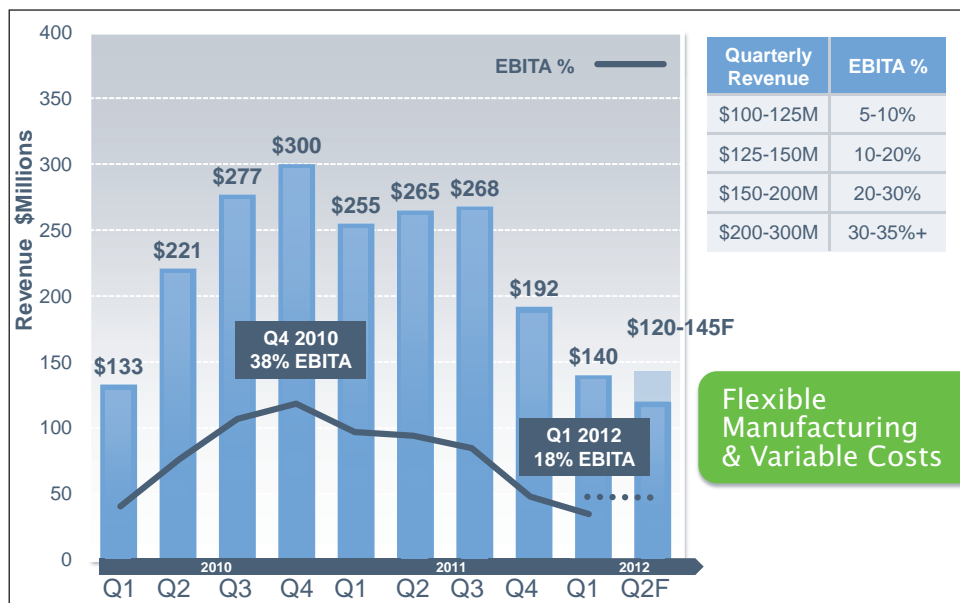
"We are on track to deliver 2012 revenue of \$500–600m," he adds, noting that Data Storage, MBE and Services business is providing a 'cushion' during the LED-induced pause in the MOCVD market (with Data Storage and MBE business collectively rising at a compound annual growth rate of 25%). In particular, with 400 MOCVD reactors due to go 'off-warranty' in 2012 (prompting the sale of extended warranty plans) and Veeco's Asia service centers enabling customer training and process development support — together with the new VCE (Veeco Certified Equipment) business re-selling refurbished tools with Veeco warranties — the Services business is targeting 40% revenue growth this year.

Longer term, recovery in the MOCVD market will be driven by LED lighting investments as well as growing sales for new applications (such as GaN power electronics), believes the firm. "Overall, we are seeing positive trends in LED lighting — lower prices [with LED bulb prices accelerating below \$10 for 40W], more LED lamp products, and heightened consumer awareness. LED manufacturers are focused on how to position their businesses for growth as LEDs become the dominant lighting technology," says Peeler. "Despite the business decline in 2012, we firmly believe that the future MOCVD market opportunity will be larger than what we have experienced so far," he reckons. In particular, driven by the adoption of solid-state lighting, Veeco estimates the base range of total addressable market (TAM) for annual GaN LED MOCVD reactor shipments will rise from 460 units in 2013 to 760 units in 2016.

www.veeco.com



Veeco's estimate for accelerating MOCVD system demand from 2013.



EBITA operating profit, maintained through cycles by Veeco's flexible model.

CEO Peeler assumes Braun's role of chairman

Edward H. Braun has transitioned his role as chairman of Veeco's board to CEO John R. Peeler, who will now hold the title chairman & CEO. Braun will remain an active member of the board of directors.

"Since John became Veeco's CEO nearly five years ago, his leadership and vision have transitioned the company from an industry player to an industry leader," says Braun. "John and his team have delivered world-class products, gained market leadership in their core technologies, and delivered strong results," he adds.

Also, Joel A. Elftmann did not stand for re-election and has retired from the board after 18 years. The board now has seven members, including lead director Roger D. McDaniel.

"I would like to take this opportunity to thank Ed for his stewardship of the company and for his continued valuable participation on our board as chairman of our Strategy Committee," says Peeler. "He will continue to be a trusted partner and an important sounding-board for me, the entire Veeco board, and our leadership team."

Aixtron's revenue falls 70% in Q1 as Asia slumps from 92% to 76% of sales

Orders rise by 8%, indicating rebound from Q1 trough

For first-quarter 2012, deposition equipment maker Aixtron SE of Herzogenrath, Germany reported revenue of €42m, down 80% on €205.4m a year ago and 70% on €140.1m in Q4/2011 (and less than half of the previous trough of €89.8m in Q3/2011). This was in line with expectations following the considerable reduction in order intake in second-half 2011, specifically for MOCVD systems for LED applications.

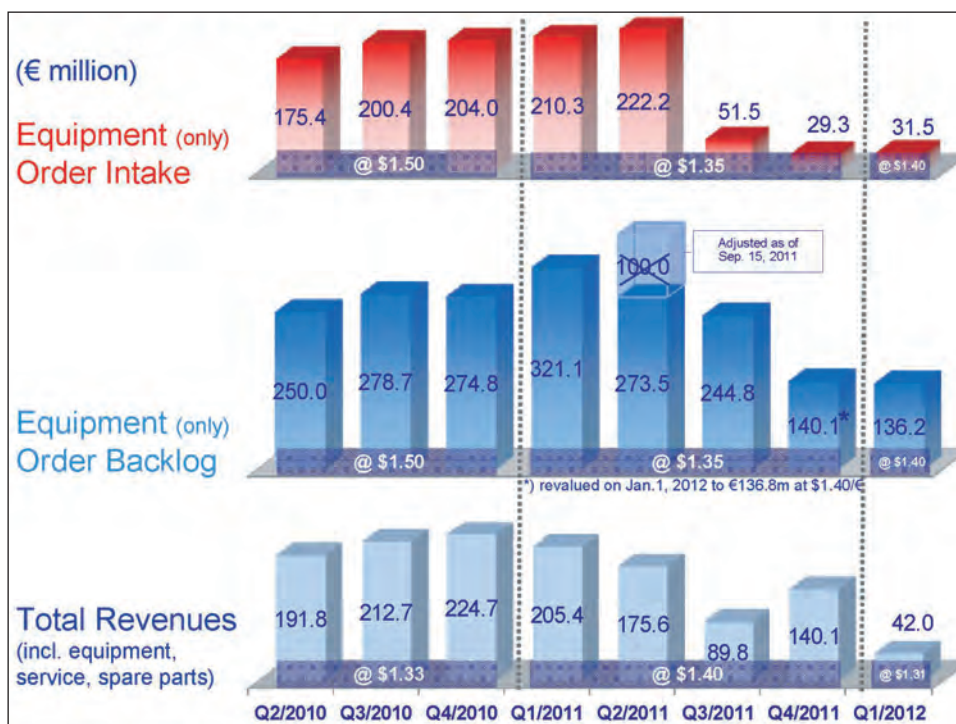
In particular, equipment sales were €29.3m (just 70% of total revenue), down 70% on last quarter's €128.1m (91% of total revenue) and down 93% on €190.5m a year ago (93% of total revenue). By comparison, other revenues (service, spare parts etc) of €12.7m were actually up 9% on €12.1m last quarter.

By region, just 76% came from Asia (down from 92% last quarter), while 8% came from Europe (up from 4%) and 16% from the USA (up from just 4%).

Compared with 51% a year ago, gross margin was 25%, but this represents a rebound from just 8% last quarter.

As forecast, compared with an operating profit of €74.9m a year ago, the earnings before interest and taxes (EBIT) operating result has worsened from a loss of €16.9m last quarter to €18.3m, reflecting the current trough in market demand. Compared with a net profit of €52.3m a year ago, net loss has worsened from €10.9m to €12.3m.

Capital expenditure was €6.2m (cut from €8.8m last quarter). Hence, free cash flow was negative €5.6m. This compares with +€11.7m a year ago, but represents a rebound from negative €27.6m last quarter. During the quarter, cash and cash equivalents (including cash deposits) fell from €295.2m to €288.9m.



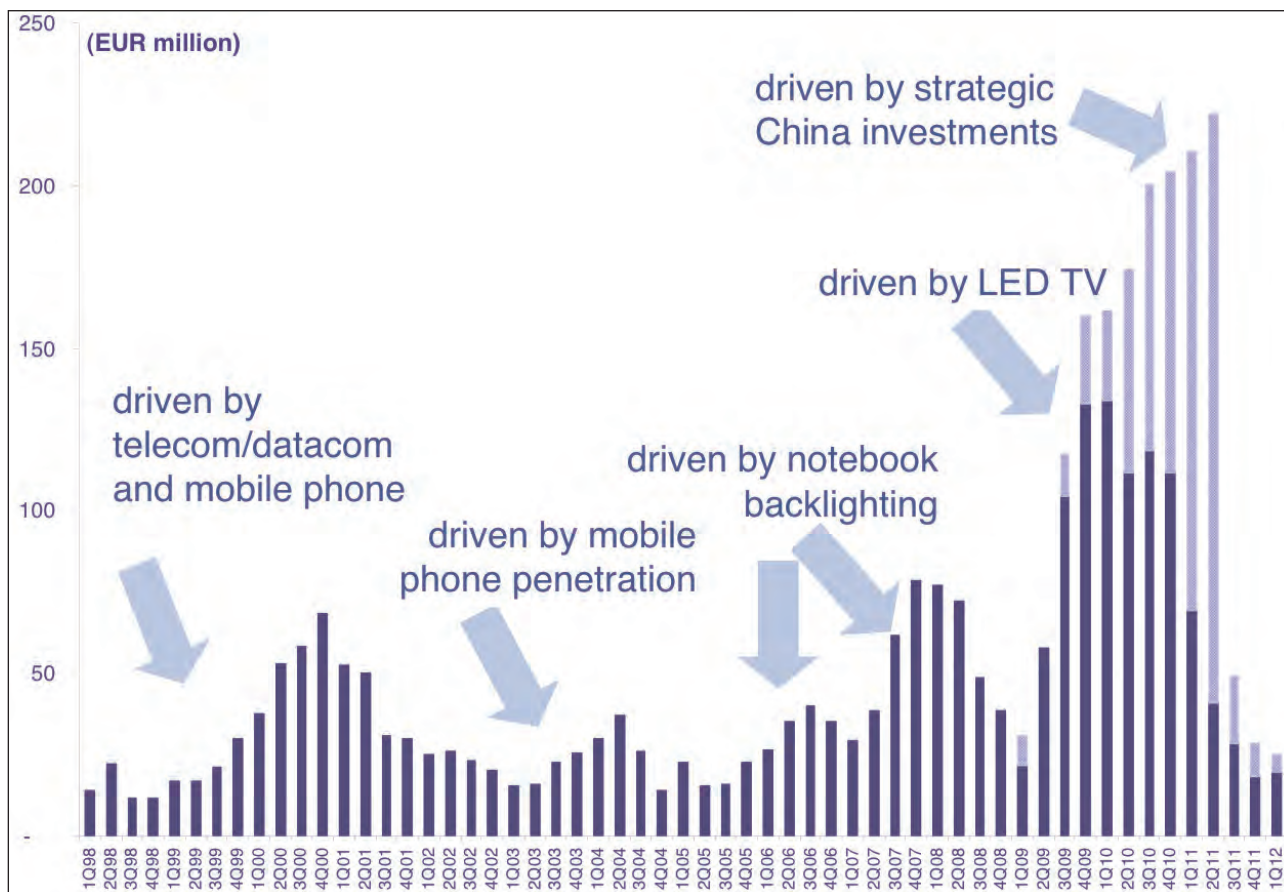
Aixtron's revenue, order intake & backlog in the last 24 months.

Aixtron says that, heavily influenced by fragile consumer confidence, credit tightness, reduced subsidies and ongoing customer overcapacity (with reluctance to invest in the current economic climate, especially in the large Asian markets), its order intake visibility remains limited. However, although down 85% on €210.3m a year ago, equipment order intake of €31.5m is up 8% on last quarter's €29.3m, suggesting that current order levels may represent the trough of the current cycle. Order backlog of €136.2m is down just 3% on €141m last quarter.

Given the maturity of the LED backlighting investment cycle and despite recent improvements in capacity utilization, Aixtron says that it does not expect further significant investments in LED backlighting capacity during 2012. Based on business and market development in Q1/2012, the firm still believes that 2012 will be a transitional year

with lower revenues and potential customer consolidation. However, it retains its more positive outlook for second-half 2012. Specifically, it remains confident that an increase in equipment investments for LEDs in general lighting applications will materialize in the next 12 months.

"Times are undoubtedly very tough — but we remain convinced that we have built a strong and resilient foundation to our business, designed to protect the firm in the difficult climate that the whole industry is currently operating in," says president & CEO Paul Hyland. "Furthermore, we have significantly enhanced our existing product portfolio over the last 18 months, so that we are confident of being highly competitive in the event of a sudden upturn of demand in the market," he adds. Despite current market conditions, Aixtron believes that the development of a sustainable LED lighting industry will follow this uncertain transitory period.



Aixtron's quarterly equipment orders: Q1/12 up 8% on Q4/11 but down 85% on year-on-year.

Set against this difficult environment, the firm remains focused on delivering further improvements to existing products and services and on accelerating specific strategic R&D investments focused on developing new products for future market opportunities. "Despite the very volatile current economic environment, we have more than just sustained our MOCVD R&D efforts — we have accelerated our investments into both next-generation MOCVD products and other 'Beyond LED'

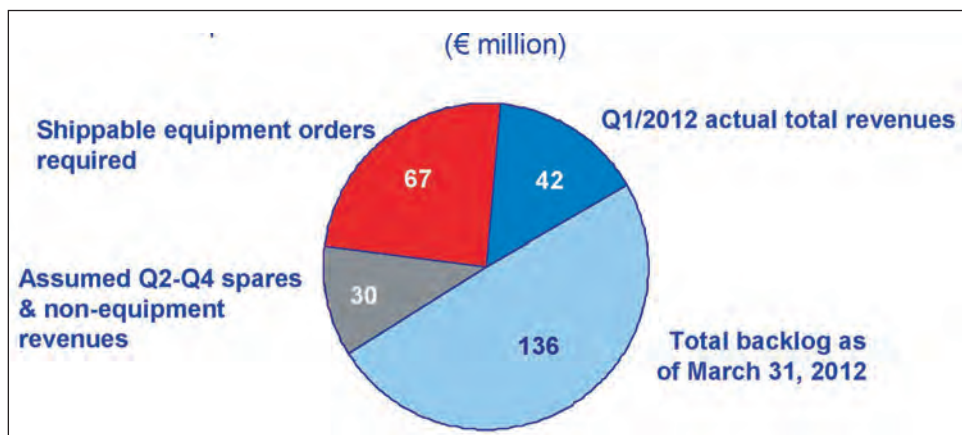
products that we believe are necessary to support our longer-term ambitions," says Hyland.

Correspondingly, Aixtron has continued to increase both R&D staffing (from 252 a year ago and 316 last quarter to 325, or a third of total staffing) and R&D expenses (up 32% on €12.4m a year ago and 12% on €14.6m last quarter to €16.4m, rising from 6% of revenue then 10% to 39%). Meanwhile, selling expenses have reduced from €7.1m last quarter to €6.6m (due

notes that order intake visibility has not yet improved to the point where it can predict full-year revenue. Nevertheless, it still targets staying EBIT profitable for full-year 2012 under the current circumstances, assuming revenue of €275m (versus 2011's €611m), gross margin of 40% (up from 38%) and operating expenditure of €110m. So, as well as Q1/2012 revenue of €42m, order backlog of €136m and assumed Q2–Q4 spares & non-equipment revenues of €30m, shippable equipment orders of €67m are needed.

To achieve EBIT break-even, the firm says it will continue to utilize the advantages of its flexible business model and continuously review and implement cost saving measures in the short term.

On a more positive note, there continues to be solid evidence of emerging new LED lighting product developments, increasingly proactive government engagements, and clear company positioning investments, the firm concludes.



2012 EBIT break-even model: €275m revenue; 40% gross margin; €110 OpEx.

www.aixtron.com

IN BRIEF

CCS reactor for Fujian's laser R&D

In first-quarter 2012 Aixtron delivered a CCS R&D MOCVD reactor in 6x2"-wafer configuration (ordered in Q3/2011) to new customer FJIRSM (the Fujian Institute of Research on the Structure of Matter, Chinese Academy of Sciences).

A service support team from Aixtron China Ltd has installed the reactor in a new cleanroom at the FJIRSM Laser Laboratory, where it will be used for telecom diode laser research.

"After having evaluated the MOCVD market thoroughly, we established that Aixtron offers worldwide the best currently available equipment for our purposes," comments FJIRSM's fab director Dr Su. "Our engineers were very impressed with the ease of operation, run-to-run and wafer-to-wafer uniformity of the CCS system. It is undoubtedly the most suitable platform for the development of the long-wave-length lasers for applications in telecom, datacom, and sensor networks that interest us."

FJIRSM research is focused on laser engineering and technology, promoting the development of novel key cell technology for solid-state laser and systems integration technology, laser crystals and nonlinear optical crystal material exploration, and engineered growth technology.

FJIRSM was founded in 1960 and is one of the most comprehensive research bases in China. Specializing in structural chemistry and new crystal materials, it consists of eight laboratories. Major provincial projects led by FJIRSM have included: 'New Materials and Devices', 'Optoelectronic Information Materials and Devices' and 'Solar Energy Electron Materials and Devices'.

<http://english.fjirsm.cas.cn>

University of Warsaw adds Aixtron CCS Reactor for GaN research

Aixtron says that in fourth-quarter 2011 it received an order from the University of Warsaw, Poland for a Close Coupled Showerhead (CCS) MOCVD reactor in a 3x2"-wafer configuration, to be used for the growth of GaN materials.

The system will be delivered in second-half 2012 as part of a project co-financed by the European Union titled 'Physics as the basis for new technologies — development of modern research infrastructure at the Faculty of Physics of the University of Warsaw'. Aixtron Europe's service support team will install and commission the system at a dedicated cleanroom in the faculty's Institute of Experimental Physics.

"There are few systems that possess such a good all-round combi-

nation of characteristics," says professor Roman Stepniewski of the the CCS reactor. "It is a very stable platform, optimized for the growth of nitride thin films for a range of requirements, and comes with excellent reliability, ease of use and reproducibility," he adds.

"Professor Stepniewski's team has a worldwide reputation for the quality of their work in advanced semiconductor materials, in particular in growth technology and basic studies of nitrides," comments Dr Frank Schulte, vice president Aixtron Europe. "Like many other research groups, they will quickly find the CCS to be not only a robust route to uniformity and scalability, but also an ideal and sustainable solution for their needs," he reckons.

Changchun University of Science and Technology orders Aixtron reactor for laser development

Deposition equipment maker Aixtron says that in fourth-quarter 2011 it received an order from new customer Changchun University of Science and Technology (CUST) for a multi-wafer MOCVD system that will be dedicated to the growth of quaternary materials for laser diodes.

Following delivery in third-quarter 2012, Aixtron's local support team will install and commission the new reactor in CUST's facility in Changchun, Jilin province, China.

"Aixtron MOCVD systems have a very high reputation worldwide for the development and production of compound semiconductor materials," comments Dr Liu, director of epitaxy facilities at CUST. "We received excellent reports of these capabilities from our colleagues at the Changchun Institute of Optics, Fine Mechanics and Physics (CIOMP) at the Chinese Academy

of Sciences (CAS), who have successfully demonstrated a similar application using Aixtron equipment," he adds.

The CUST team will use the new reactor for the development of InGaAlAs and InGaAsP materials, which will form a process technology foundation for the fabrication of advanced lasers. "Aixtron technology also comes with a responsive local service team, and this will help to ensure smooth and efficient progress when we begin materials development using the new system," says Liu.

Founded in 1958 by the Chinese Academy of Sciences, CUST has evolved into a multidisciplinary university with optoelectronics technology as its highlight, along with the integration of optics, mechanics, electronics, computer science and material science.

www.cust.edu.cn

LayTec launches X Link for in-line EVA laminate cross-link determination in PV modules

LayTec AG of Berlin, Germany has launched the X Link in-line metrology system.

As part of LayTec's product line for the photovoltaic (PV) industry, the X Link system enables fast and accurate evaluation of the degree of cross-linking in ethylene vinyl acetate (EVA) directly after lamination. It can be integrated in any crystalline silicon (c-Si) or thin-film based solar module production line, and offers 100% coverage for process and quality control, says the firm.

LayTec developed the system in close cooperation with Fraunhofer USA (a subsidiary of German research organization Fraunhofer-Gesellschaft). The method uses a rheological approach, analysing the response of the laminated EVA back-sheet combination. The meas-

ured stiffness is directly correlated with the level of cross-linking. The data can also be given as "percentage gel content" equivalent. Placed directly after the laminator, the tool gives direct feedback to the lamination process for the adjustment of heating zones and exposure times.

LayTec says that the X Link improves lamination yield through real-time control and gives a detailed proof of the long-term stability of PV modules, increasing bankability. The system replaces the common and coarse gel content test.

LayTec presented live demonstrations of X Link at the SNEC's 6th International Photovoltaic Power Generation Conference & Exhibition (SNEC PV Power EXPO 2012) in Shanghai, China (16–18 May).

www.laytec.de

Aixtron ships CCS MOCVD reactor to NTT for InGaAsP laser research

In first-quarter 2012 Aixtron delivered a CCS reactor MOCVD system to existing customer NTT Photonics of Japan for InGaAsP quaternary diode laser research.

Ordered in second-quarter 2011, the reactor is being installed by a local Aixtron service support team at the NTT Photonics Device Laboratory in Atsugi, Kanagawa Prefecture, Japan.

The new reactor for NTT Photonics is being supplied with several special features, including an Epi-CurveTT, ARGUS, Gap Adjustment and Epison 4 in-line gas concentration monitor.

For the NTT Photonics application, another key selection criterion was the Group V efficiency of the CCS reactor, which directly translates into significantly lower operating costs, says Aixtron.

Aixtron says that, able to deliver even the most challenging MOCVD

applications, the CCS reactor has very good process flexibility due to the Showerhead concept and uniform flow distribution. Combined with gap adjustment and ARGUS in-situ monitoring for temperature mapping of the entire susceptor, it suits research and development of high-end devices such as InGaAsP quaternary diode lasers, says the firm.

NTT Photonics Laboratories has a long history of expertise in R&D on photonic device technology to support next-generation innovation in telecoms. This involves photonics devices, electronic components, modules and materials with the goal of further contributing to progress in telecoms business through developing new technologies such as diode lasers and commercializing the technology.

www.aixtron.com

IN BRIEF

Forepi prepares capacity increase with repeat order for Aixtron CRIUS II-XL and G5 HT systems

Deposition equipment maker Aixtron SE of Herzogenrath, Germany says that in second-quarter 2012 Taiwanese LED chipmaker Formosa Epitaxy Inc (Forepi) ordered several MOCVD tools - four CRIUS II-XL systems in 19x4"-wafer configuration and two G5 HT reactors in a 14x4"-wafer configuration — to be delivered in the third and fourth quarter of 2012 for the manufacturing of ultra-high-brightness (UHB) GaN-based blue and white LEDs as the firm focuses on 4-inch substrates.

"Forepi began using the CRIUS II-XL system a few months ago and, as we must now make provisions for the capacity increase at our new factory in the Pin-Jen industrial zone, we once again turned to Aixtron to provide the epitaxy systems," says a spokesperson from Forepi, which is one of Aixtron's longest-standing customers in Taiwan. "With short time-to-production and highest performance, throughput and yield, these systems are best suited to our needs," he adds.

"An order such as this from Forepi provides further proof of the value of the key features of our equipment, such as seamless process scale-up, excellent uniformity and highest throughput per footprint," Aixtron's chief operating officer Dr Bernd Schulte. "All of these factors come together with the most impressive capacity available in today's equipment market," he claims.

www.aixtron.com

Germany's TU Ilmenau to develop III-V solar cells with Aixtron R&D MOCVD system

Aixtron says that in third-quarter 2011 existing customer Ilmenau University of Technology in Germany ordered an MOCVD system in a double 1x2"-wafer configuration.

The reactor will be installed by Aixtron Europe's service support in Q3/2012 at the new facilities of TU Ilmenau's photovoltaics department. It will be used to develop new materials and structures for III-V-based opto-electronics, high-efficiency concentrator photovoltaics (CPV) and III-V-integration on silicon and germanium.

"This new R&D MOCVD system will make an enormous difference to the effectiveness of our new photovoltaics program," says professor Thomas Hannappel. "We will be able to use its process compatibility with our earlier-generation reactors, which springs from our long-standing close relationship with Aixtron." He adds that the technology has the ability to rapidly become effective for even the most challenging research.

Recently, Hannappel received a Chair for Photovoltaics from TU

Ilmenau which is associated with scientific leadership of the SolarZentrum of the CiS Forschungsinstitut für Mikrosensorik und Photovoltaik GmbH in Erfurt. TU Ilmenau has focused on energy and environmental technologies for many years. Under Hannappel's leadership, it intends to complete basic scientific and industry-related research and to foster further close cooperation with the photovoltaic group at the Helmholtz-Zentrum Berlin für Materialien und Energie.

www.tu-ilmenau.de

IN BRIEF

MicroLink orders further AIX 2800G4 reactor

MicroLink Devices Inc of Niles, IL, USA has further increased its capacity for manufacturing HBT and solar cell epitaxial structures with a second Aixtron 2800G4 MOCVD reactor with automated wafer loading (ordered in third-quarter 2011 and being delivered in second-quarter 2012).

"The material quality and uniformity from our first AIX 2800G4 shows great promise," says MicroLink's president Dr Noren Pan. "Due to the economic advantages of this MOCVD reactor, Aixtron provides the best cost model for high-volume epitaxial wafer manufacturing. Our customers will benefit from this high throughput reactor by experiencing a reduction in their qualification costs," he adds.

"The development of this larger-capacity automated MOCVD system provides benefits in all areas of a production cost model, such as throughput, cycle time, and yield," claims Aixtron's chief operating officer Dr Bernd Schulte.

www.mldevices.com

Japan's AIST achieves graphene production on 300mm wafers

Aixtron says that its BM 300 system has been started up at Japan's National Institute of Advanced Industrial Science and Technology (AIST). The system was installed in 2011 in AIST's cleanroom facility in Tsukuba and was commissioned by the local Aixtron support team. Dr Shintaro Sato, group leader at AIST, presented growth results on 10 April at the 2012 MRS Spring Meeting.

"With the demonstration of monolayer graphene growth on 300mm wafers at AIST, we have achieved a significant milestone," reckons Dr Ken Teo, Aixtron's director of Nanoinstruments. The BM 300 platform for graphene production incorporates a gas delivery system for precise precursor delivery, ARGUS in-situ wafer thermal mapping, a high-uniformity wafer heater and an automated handling system. "The ability to deposit graphene with a high degree of controllability and repeatability onto 300mm wafers is an essential step in enabling large wafer-scale integration of graphene, and paves the way for exploiting the unique properties of graphene in next-generation semiconductor devices," Teo adds.

Sato's team at AIST will use the system to deposit high-quality graphene with a controlled number of layers. This will be a key part of process technology used for creating low-voltage-operation CMOS FETs, in which the power supply voltage will be less than 0.3V.

The research is backed by the Funding Program for World-Leading Innovative R&D on Science and Technology (FIRST), which was approved by the Council for Science and Technology Policy, Cabinet Office, Government of Japan in 2009, and is being operated by the Cabinet Office, Government of Japan and the Japan Society for the Promotion of Science (JSPS). Wafer processing is being performed at AIST's Collaborative Research Team Green Nanoelectronics Center (GNC) within the research project 'Development of Core Technologies for Green Nanoelectronics' (core researcher, Dr Naoki Yokoyama), which has been adopted for the FIRST Program. The GNC was established in April 2010 and involves researchers from both research and industry.

www.aist.go.jp

www.aixtron.com



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NanoLab@TU/e adds OIPT plasma etch & dep systems

The open-access facility for nano-technology-related research, NanoLab@TU/e (Technische Universiteit Eindhoven) in The Netherlands, is continuing to expand its capabilities with the recent addition of two new plasma systems from UK-based Oxford Instruments.

"The PlasmaPro System100 RIE and PlasmaPro System100 ICP-PECVD tools are multi-purpose systems that complement the already existing tool-set dedicated to the processing of III-V photonic devices, many of which are Oxford Instruments tools," says professor Erwin Kessels, Plasma & Materials Processing Group, Department of Applied Physics, TU/e. "They strengthen our capabilities for our own research as well as that for our partners within the NanoLabNL initiative. They also complement the extensive atomic-layer deposition (ALD)-capability of our clean-room, that already contains the two FlexAL and one OpAL plasma and



NanoLab@TU/e. (Image: TU/e.)

thermal ALD systems from Oxford Instruments," he adds.

"With the capability to run both F- and Cl- chemistries, the PlasmaPro System100 RIE tool will be used for 'standard' processing of silicon-containing materials (SiO_2 , Si_3N_4 , Si) as well as for etching more 'exotic' materials such as NbN," Kessels says.

The etching of niobium nitride thin films is used to fabricate nanostructured superconducting single-photon detectors. For this application TU/e needed to define an ultra-narrow (50nm) constriction in a 5nm-thick NbN film, by e-beam lithography

and etching with F-based chemistry.

When the resulting device is cooled down to 4K and biased close to the critical current, a single-photon absorbed in the constriction region (and only there) gives rise to a superconducting-resistive transition, producing a voltage pulse. This results in a single-photon detector with a spatial resolution of a few tens of nanometers, which could be used for near-field imaging with unprecedented sensitivity.

"Our broad, flexible and reliable system and process offering has led to a number of nanotechnology research institutes globally becoming established as Oxford Instruments centres of excellence," says Mark Vosloo, sales & customer support director at Oxford Instruments Plasma Technology (OIPT). "Several long-term relationships have developed between research centres and our company," he adds.

www.phys.tue.nl/nanolab

www.oxford-instruments.com

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Oxford Instruments Plasma Technology promotes general manager to managing director

UK-based etch, deposition and growth system maker Oxford Instruments Plasma Technology (OIPT) has appointed Dan Ayres (formerly operations director then general manager) as its managing director. With over 10 years of experience within the Oxford Instruments Group, he has held roles in the fields of operations, product management and project management.

Ayres will report to Jonathan Flint, CEO of Oxford Instruments plc. "Our business strategy demands an organization that can meet the challenge of expanding markets, new products, and growing numbers of customers and employees," says Flint. "Dan's new appointment will ensure that Oxford Instruments Plasma Technology continues its current growth plans, and I am confident that with Dan heading the strong executive team in place



Managing director Dan Ayres.

at the company, this will be achieved," he adds.

"In line with our strategic plan we will focus on innovating improved etch, deposition and growth solutions to meet our customers' needs for new systems, continuous performance improvement and after-sales support," says Ayres. "We will support our focus on innovation by investing in improved business processes to ensure we deliver a healthy and growing business for



Sales, CS & marketing director Mark Vosloo.

our employees, shareholders and other stakeholders," he adds. At the same time, sales & customer support director Mark Vosloo has assumed responsibility for all customer-facing functions (including strategic marketing) and holds the new title of sales, CS & marketing director. OIPT reckons that this promotion will ensure that it aligns more effectively with customers and the provision of high-tech products and services geared to their specific requirements.

www.oxford-instruments.com

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www.oxford-instruments.com/plasma



Multi-tool surface prep order shipped for LEDs on 150mm

Semiconductor capital equipment provider OEM Group of Phoenix, AZ, USA says that in April it shipped the first systems of a multi-tool order to a major LED manufacturing firm. The order included Spray Ozone Tool (SOT) and Spray Acid Tool (SAT) surface preparation systems from OEM Group's Cintillio product line (acquired from Applied Materials—Semitool in May 2011). Available initially only in Europe, the wet-chemical processing tool set has now been introduced throughout Asia and the Americas by OEM Group.

"Cintillio's innovative and proprietary Enhanced Spray Technology — featuring up to six rows of nozzles — ensures high throughput and reliable wafer surface wetting with chemical mixtures," says OEM Group chief technology officer Christian Forgey. "Cintillio breaks technological ground in 25/50-wafer batch process by offering a common platform for solvent, acid and ozone applications," he adds. "With the smallest cabinet footprint (1.78m²) among similar equipment, SAT/SOT saves fab-floor real estate while its convenient side

access makes routine maintenance checks both safe and user friendly," Forgey claims.

SOT's HydroOzone post-ash clean was recognized with the 'Sustainable Technologies Award' at SEMICON West 2009 for its ability to: eliminate thousands of gallons of sulphuric acid and hydrogen peroxide; reduce deionized water consumption by 84%; reduce cycle time; reduce defects; and increase yield.

OEM Group's customer — an international supplier of light-emitting diodes for display, backlighting, automotive and general lighting applications — says that they selected Cintillio SAT and SOT because of the systems' "flexibility to handle both resist strip as well as organic cleaning after etching". The systems will support the LED maker's 150mm production.

"Like so many chip makers we've talked with since we acquired the Cintillio portfolio last May, our LED customer was particularly impressed by the cost-effective high-throughput potential of SAT and SOT," says CEO Wayne Jeveli. "Because of Cintillio's semi-automated batch-system

capabilities, numerous wafer lots may be processed simultaneously. And that saves fabs time and money," he adds.

The Cintillio line also includes the single- and dual-chamber Spray Solvent Tool (SST) with one, two or three chemical system configurations that accommodate most solvent-based process applications.

Cintillio is the 11th product line addition to OEM Group's LEGENDS portfolio, which was launched at SEMICON West in 2008.

"Since our debut, LEGENDS systems have steadily expanded their reputation as field-proven and game-changing for both established semiconductor markets and emerging-technology innovators," says Jeveli. "The spray system manufacturing expertise we gained through last year's (Applied Materials/Semitool) acquisition bolstered LEGENDS' value proposition by adding cutting-edge and proven dry-in/dry-out wet chemical process technology that optimizes our customers' processing times and return on investment."

www.oemgroupinc.com

SÜSS launches multi-market resist coat & develop tool

SÜSS MicroTec AG of Garching, near Munich, Germany, a supplier of equipment and process solutions for microstructuring in the semiconductor and related markets, has launched the RCD8, a new manual resist coat and develop platform for substrates. The firm says that the new platform offers high flexibility in application, coupled with low investment costs as well as an easy transfer of processes from the RCD8 manual platform to a SÜSS MicroTec production tool.

The RCD8 is claimed to be the only tool on the market offering the option to convert from a spin coater (with patented GYRSET closed cover coating technology) to a spray developer within a few minutes. This coat and develop plat-

form can be customized to anything between, for example, a basic manual spin coater to a semi-automated GYRSET enhanced coater and puddle & spray developer tool, serving daily R&D work up to small-scale production.

In the past, multiple dedicated tools of in the firm's Delta Series were used for specific applications in MEMS, advanced packaging, LED or R&D applications. The different types of tool are now brought together in the RCD8 platform, which covers all necessary coating and developing processes for these applications.

As an additional option, the patented GYRSET rotating closed cover coating technology can be integrated into the RCD8 spin coating

module. For various photoresists and applications, the GYRSET technology enables a wider process window and reduces material consumption significantly, it is claimed. Furthermore, the technology allows even square substrates and pieces to be coated all the way to the corners with homogenous resist thickness.

"Whenever process changes are required over time, this versatile tool can be field upgraded with various options," notes president & CEO Frank P. Averdung. "With its large variety of available chucks and configurations, literally all kind of substrate materials and shapes can be coated and developed on the RCD8," he adds.

www.suss.com

Edwards opens 'Center for Excellence' for customer service & training

Vacuum and exhaust-abatement equipment maker Edwards Ltd of Crawley, UK has opened a new 'Center for Excellence' vacuum and abatement support facility at its site in Hillsboro, OR, USA. The 11,000ft² facility will employ 30 people and serve the local semiconductor manufacturing industry.

"The new facility further strengthens Edwards' commitment to supporting our customers," says chief operating officer Ron Krisanda. "The Hillsboro facility will house a wide selection of products, including some of the latest models of dry vacuum pumps, which will be dedicated for training," he adds.



The center will offer training for customers on equipment they may have installed, like the Atlas abatement system.

"A wide variety of courses will be available for customers as well as Edwards' own service and support personnel."

www.edwardsvacuum.com

New turbo pump boosts throughput by 40% and maximum flow by nearly 90%

Edwards has launched the STP-iXR1606 series of magnetically levitated turbo-molecular pumps (TMP) with a fully integrated onboard controller.

The new TMP incorporates a new rotary design that delivers about 40% improvement in throughput at high gas flow rates and an increase of nearly 90% in maximum gas flow compared to existing products, it is reckoned.

"It matches the peak pumping speed of our highest performing pump in the 8" TMP class, but with significant improvements in throughput performance and maximum allowable gas flow," notes STP product manager Masahide Tanaka.

The fully integrated controller eliminates the connection cable and rack conventionally required with a non-integrated controller. This helps to reduce the footprint (saving fab real estate) as well as

installation time and cost. The onboard controller also incorporates a small power supply which — compared to existing products — delivers a reduction in energy consumption of about 32% at high gas flows.

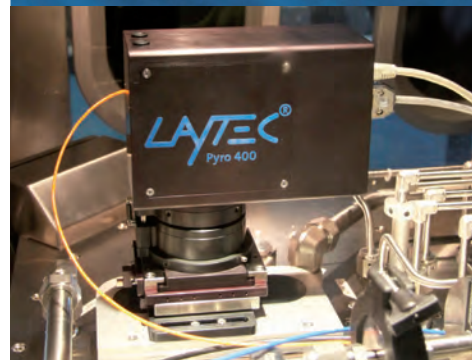
"As with all of our magnetically levitated TMPs, it requires no maintenance," says Tanaka. "The STP-iXR1606 series provides our customers with an all-in-one TMP solution for all their applications, with reduced footprint, simplified installation and reduced energy costs."

Edwards says that the STP-iXR1606 series delivers high reliability in dirty environments with equivalent IP54 protection against dust and humidity. It also has I/O remote, RS232C, RS485 and STP-link standard communication ports, with Profibus and DeviceNet available as options.

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Brewer Science launches thin wafer handling systems for compound semi device processing

Brewer Science Inc of Rolla, MO, USA (which provides specialty materials and equipment for the micro-electronics industry) has introduced new wafer processing equipment designed for thin wafer separation and post-debonding cleaning, steps that are critical for ultra-sensitive compound semiconductor (CS) device processing. The latest equipment designs enable thin wafer handling technologies that can broaden process windows and lower total cost of ownership by reducing yield loss and increasing throughput, the firm claims.

"Brewer Science Cee lab-scale processing equipment offers track-quality precision and is suitable for low-volume prototype processing that enables transfer to high-volume manufacturing," says Wayne Farrar, director of equipment. "With our temporary bonding materials and lab-scale equipment, we bring a breadth and depth of process experience that is unequalled by any other company," he claims.

The following are the new semi-automatic thin wafer handling tools manufactured by Brewer Science for CS processing applications:

- Cee 1300CSX thermal debonder, which enables high-temperature slide-off debonding of thinned III-V and CS materials (GaAs, GaN, InP and SiC) in a confidential laboratory setting.

- ZoneBOND separation tool, which has been enhanced with compliant seal clamps and fail-safe abort hardware to accommodate thinned

III-V and CS materials. The latest generation provides superior precision control for debonding materials that are highly sensitive to mechanical and thermal shock, flexibility for sizes ranging from 2 inches to 300mm, and very low-stress room-temperature debonding.

- Cee 300MXD megasonic cleaning system, which applies uniform acoustic energy to spinning substrates to gently remove adhesive residues and contaminants without damaging fragile device structures.

Brewer Science is exhibited at the International Conference on Compound Semiconductor Manufacturing Technology (2012 CS MANTECH) in Boston, MA (23–26 April).

www.brewerscience.com

Shin-Etsu Chemical joins EV Group's open platform for temporary bonding materials

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, says that Tokyo-based semiconductor materials supplier Shin-Etsu Chemical Co Ltd has joined EVG's open platform for temporary bonding/debonding (TB/DB) materials. Shin-Etsu's adhesives will be qualified with EVG's EZR (Edge Zone Release) and EZD (Edge Zone Debond) modules, which support the new ZoneBOND room-temperature debonding process used in the production of 3D ICs.

"Having worked closely with EVG's process development teams, we are pleased to have successfully completed the stringent test procedures for their ZoneBOND equipment," says Jim Edmonds, president of subsidiary Shin-Etsu MicroSi Inc of Phoenix, AZ, USA. "We look forward to working with

customers that require temporary bonding to commercialize 3D packaging in a volume manufacturing environment," he adds.

"Through our open materials platform approach, we are building a strong supply chain for EVG's market-leading TB/DB technologies — unlocking another key barrier in the advancement of 3D IC commercialization," says Markus Wimplinger, EVG's corporate technology development & IP director. "Enabling the use of a wide range of adhesives from various suppliers for our equipment gives customers the most flexible choice of bonding materials for increased flexibility during thin wafer processing," he adds.

ZoneBOND-capable technology, in tandem with EVG's EZR and EZD modules, provides an approach for temporary wafer bonding, thin wafer processing, and debonding applications that overcomes the remaining limitations associated

with thin wafer processing, it is claimed. EVG claims that benefits of its TB/DB equipment and open materials platform include: the use of silicon, glass and other carriers; compatibility with existing, field-proven adhesive platforms; and the ability to debond at room temperature with virtually no vertical force being applied to the device wafer. To support grinding and backside processing at high temperatures and to allow for low-force carrier separation, the concept defines two distinctive zones on the carrier wafer surface with strong adhesion in the perimeter (edge zone) and minimal adhesion in the center zone. As a result, low separation force is only required for carrier separation once the polymeric edge adhesive has been removed by solvent dissolution or other means.

www.shinetsu.co.jp

www.microsi.com

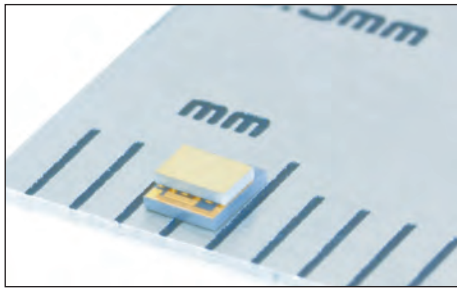
www.EVGroup.com

Nextreme achieves 55°C cooling performance in production-level thin-film thermoelectric coolers

Nextreme Thermal Solutions of Durham, NC, USA, which designs and manufactures microscale thin-film thermal management and power generation modules and sub-systems, has announced the availability of new thin-film thermoelectric cooling (TEC) products that offer 55°C of cooling performance at an ambient temperature of 25°C.

The 55°C temperature milestone (ΔT_{\max}) reflects the ability of the thermoelectric device to pump heat efficiently. The firm says that this new level of performance translates to improved cooling efficiency, lower input power requirements, and greater opportunities for solving thermal issues in electronics, photonics and avionic applications. Nextreme will launch new products with this higher level of cooling performance in late Q2/2012.

The electronic industry's continued trend to smaller form factors, greater circuit density, and highly integrated packaging has translated into significant thermal problems for optoelectronics manufacturers, says Nextreme. Bulk TEC devices



Nextreme's eTEC HV14 TEC product.

have been used to provide temperature control of laser diodes and other optoelectronic devices, but have not kept pace with these new requirements due to their larger size and power density limitations. With Nextreme's thin-film modules, manufacturers of laser diodes, photodiodes, infrared (IR) sensors and other semiconductor chips can now integrate cooling and temperature control functionality directly into the package during assembly, resulting in a high-volume, lower-cost thermal management solution, claims the firm.

Nextreme reckons that its eTEC HV14 is one of the world's smallest thermoelectric modules, with a

footprint of only 3mm. The thin-film module can pump up to a maximum power density (Q_{\max}/area) of 120W/cm² compared with less than 10W/cm² for a bulk TEC. In addition, the eTEC HV14's response time is on the order of milliseconds, compared with seconds for bulk devices.

These devices are only 0.6mm high, making them the thinnest, highest-heat-pumping thermoelectric coolers on the market, it is claimed.

The miniature size and heat pumping capability make thin-film thermoelectric modules suitable for cooling laser diodes, photodiodes, LEDs, infrared (IR) sensors, pump lasers, crystal oscillators and optical transceivers, the firm notes.

Nextreme demonstrated its cooling and thermal management product family at the SPIE Defense, Security & Sensing (DSS 2012) exhibition in Baltimore (24–27 April).

The eTEC thin-film TEC product line will be available through Nextreme's worldwide strategic distribution and design partner Laird Technologies Inc, and through Mouser.com.

www.nextreme.com

Carsem extends packaging services to high-brightness silicon substrate LED arrays

Carsem Inc of Scotts Valley, CA, USA, which provides turnkey semiconductor packaging & test services, is partnering with a key customer to assemble and further develop LED packaging technologies.

Carsem has assembled and qualified high-brightness silicon substrate LED arrays and will begin offering high-volume, full turn-key manufacturing services, including electrical testing, laser mark and tape-and-reel, in early 2012.

The firm says the manufacturing process fully utilizes the advantage of standard mass-production process of assembly & test including matrix substrate design; auto die

attach, wire bond and high-reflectivity coating dispense; compression molding through automold system; mapping of units on substrate and bin sort per test mapping.

The silicon substrate LED array offers higher white light brightness with much less energy required (luminous efficacy of more than 50lm/W). The life expectancy of the product is estimated to be 10 years. General applications include home use, cars, and special-effect light.

"Because of our extensive experience in providing turnkey solutions, we are able to share our expertise with our LED customers and assist them in getting their products to

market faster with turnkey solution on high-density and high-volume packaging," claims Albert Law, Carsem's VP of worldwide sales & marketing, "Carsem is expanding the company's portfolio to include LED packaging solutions for the high-brightness LED applications," he adds.

"By capitalizing on our extensive semiconductor experience in materials, process & equipment we have successfully advanced into the LED arena, thereby enhancing the manufacturability and efficiency of high-brightness LED," says chief technology officer L.W. Yong.

www.carsem.com

Trinity qualifies ARC's sapphire at LED chip makers

8-inch c-axis boules target production of large-diameter substrates

ARC Energy of Nashua, NH, USA, which was founded in 2007 to provide sapphire crystal growth technologies and turnkey processing solutions for the LED solid-state lighting and other clean-energy markets, says that sapphire grown using ARC Energy's Controlled Heat Extraction System (CHES) furnaces has been certified for production at two leading LED chip companies. Trinity Material Co Ltd of Jurong City, Jiangsu, China, which specializes in the production of LED-grade sapphire substrate material (2–8" boules and ingots), is partnering with ARC Energy to use its CHES furnaces.

Sapphire boules are grown on c-axis by ARC Energy's CHES method, compared with conventional processes where a-axis boules are grown and c-axis wafers are extracted. "LED chip qualification results prove that CHES wafers

perform as well as, or better than sapphire grown by the a-axis growth process, without any color problems at the boule or wafer levels," says Trinity Material's chief operating officer Champion Yi. "LED chips manufactured on CHES wafers show a significant increase in light output when compared to devices grown using wafers from conventional a-axis-grown boules," he claims.

Trinity Material and ARC Energy reckon that they are paving the way for new industry opportunities based on c-axis growth orientation for LED manufacturing. Trinity is ramping up to produce very high volumes of sapphire crystals to meet the growing demand for large-diameter sapphire wafers in the LED market

"We look forward to continuing our strong relationship with ARC Energy, and to utilizing ARC

Energy's leading edge CHES furnaces and our strong production capabilities to ramp up production to high volumes," says Trinity Material's CEO Jamin Sheng.

ARC Energy says that its proprietary and fully automated CHES technology produces c-axis boules that are the optimum orientation for LED applications and, when compared with conventional a-axis technologies, lead to higher material utilization and lower overall costs for large-diameter sapphire production.

"Our unique and flexible c-axis CHES furnaces allow Trinity Material to serve the rapidly expanding demand for large-diameter sapphire substrates, ranging from 4 " to 8"," says ARC Energy's co-founder & chief technology officer Dr Rick Schwerdtfeger.

www.trinity-material.com

www.arc-energy.com

Oxford Instruments transfers HVPE subsidiary TDI to Ostendo as part of strategic partnership

UK-based Oxford Instruments plc (which manufactures etch, deposition and growth equipment through its Oxford Instruments Plasma Technology division) has transferred ownership of its subsidiary Technologies and Devices International (TDI) to privately owned firm Ostendo Technologies Inc of Carlsbad, CA, USA (which develops solid-state lighting based display technologies and products).

Acquired by Oxford Instruments in April 2008, TDI develops hydride vapour phase epitaxy (HVPE) technology for the production of compound semiconductor materials such as GaN, AlN, AlGaIn and InN used in the manufacturing of high-brightness (HB)-LEDs.

The gross assets that are the subject of the transaction are \$0.6m. In the year to March 2011, TDI incurred a loss (after development

expenses) of \$4.3m (including amortization of acquired intangible assets of \$1.9m).

Oxford Instruments has received 0.65 million shares of Ostendo

common stock plus \$0.65m in cash, of which \$0.15m will be paid six months after the closing date. Oxford Instruments will also receive a royalty when certain HVPE reactor sales are realised.

Ostendo are well placed to use this technology, and Oxford Instruments is delighted that it will continue to be developed by them... Ostendo should allow us to maximize value from our technology investment in HVPE

"The capability to produce semiconductor materials using HVPE has the potential to improve products used in solid-state lighting and displays," says Oxford Instruments' chief executive Jonathan Flint.

"Ostendo are well placed to use this technology, and Oxford Instruments is delighted that it will continue to be developed by them," he adds.

"This partnership with Ostendo should allow us to maximize value from our technology investment in HVPE."

Under the terms of the transaction, Oxford Instruments is subject to certain restrictions on the transfer of the stock in Ostendo and consequently, until a liquidity event, will ascribe no value to the Ostendo stock acquired. The cash component of the proceeds of the disposal will be used in Oxford Instruments' existing business.

www.ostendo.com

BluGlass grows high-quality crystalline GaN using low-temperature RPCVD

Reduction of impurities to acceptable levels expected to lead to placement of demo tool

BluGlass Ltd of Silverwater, Australia says it has advanced its proprietary remote-plasma chemical vapor deposition (RPCVD) technology in recent months and has now produced high-quality gallium nitride at low temperature on a commercial metal-organic chemical vapor deposition (MOCVD) GaN template.

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

Transmission electron microscopy (TEM) analysis of its samples by an independent third-party expert has now confirmed a 'radical improvement' in GaN top-layer film quality and an 'impressive microstructure' with a low defect density consistent with the underlying commercial MOCVD GaN template.

BluGlass says that low-defect-density high-crystallinity material grown at low temperature using RPCVD is a breakthrough for the firm, essential to demonstrating the technology's commercial potential for the LED equipment market. The firm reckons that its RPCVD technology, due to its low-temperature and highly flexible nature, offers manufacturers many potential benefits, including higher efficiency, lower costs and greater scalability.

The firm says that the improved material quality has been enabled mainly by progress in reducing trace amounts of chemical impurities incorporated into GaN films during growth. BluGlass says that its research has previously been limited by the presence of two critical impurities that significantly affected

material quality. Through process iterations and hardware upgrades, one of the impurities (oxygen) has now been reduced almost to levels acceptable to industry, so that it is now no longer affecting material quality. The other critical impurity (carbon) is also actively being reduced towards acceptable levels.

"These achievements demonstrate for the first time that high-quality crystalline GaN films can be grown at low temperature using RPCVD," says CEO Giles Bourne. "This is a critical step in proving to industry the potential of breakthrough technology," he adds. "A low-temperature commercial process would have

BluGlass is now focused on reducing the impurity levels further to within industry accepted ranges

truly exciting implications for the LED industry," he believes. "It has the potential to offer significant advantages for both device performance and low-cost manufacturing."

BluGlass is now focused on reducing the impurity levels further to within industry accepted ranges, to enable the firm to reach, in the short term, the following technical milestones: (i) producing films with properties similar to MOCVD-grown films (with industry-accepted electrical properties); and (ii) demonstrating improved device efficiency (confirming RPCVD's competitive advantages).

The firm believes that achieving these milestones will lead to customer engagement and the placing of a demonstration tool with a leading LED maker. Also, the technical advances are expected to result in new intellectual property, for which BluGlass aims to file patents.

www.bluglass.com.au

GT receives \$12.6m follow-on order from Shangcheng for ASF sapphire furnaces

GT Advanced Technologies Inc of Merrimack, NH, USA (a provider of polysilicon production technology plus sapphire and silicon crystalline growth systems and materials) has received a \$12.6m follow-on order from Zhejiang Shangcheng Science & Technology Co Ltd for additional ASF sapphire growth furnaces.

Shangcheng is a vertically integrated sapphire manufacturer producing boules, cores and wafers for LED makers. The furnaces will increase its production capacity, which it believes is needed to meet expected demand from LED makers and other industrial applications.

"This follow-on order for our ASF furnaces demonstrates Shangcheng's confidence not only in the robustness of our sapphire growth technology, but in the continued growth of the LED industry," says GT's president & CEO Tom Gutierrez.

"The winners in this industry will be the companies that are positioning themselves for the future by investing today in best-in-class technology that enables low-cost production of high-quality sapphire. Shangcheng has demonstrated the kind of leadership and technological expertise needed to prepare the company for long-term success," he believes.

"The ASF furnaces we initially purchased are now qualified and already producing high-quality ASF-grown material," says Shangcheng's general manager Yuncai Wu. "Our manufacturing operations and technology teams worked closely with GT's local sales, service and support teams to ensure a successful startup of our new sapphire production plant, which is demonstrated by the fact that we have already qualified our material by some top LED manufacturers at 2", 4" and 6" diameters," he adds. "We are very grateful for the level of support GT has provided during the ramp up of our new plant."

www.gtat.com

SETi announces JDA with Cascade Designs

Sensor Electronic Technology Inc of Columbia, SC, USA has entered into a joint development agreement (JDA) with Cascade Designs Inc of Seattle, WA, USA, which makes equipment for outdoor applications, to develop the next generation of portable water purification systems for commercial, military and disaster relief/humanitarian applications. The water purification systems will take advantage of SETi's germicidal UV LEDs to provide potable water to small groups from any source of fresh water anywhere.

SETi says that germicidal UV LEDs represent new technology that offers an alternative to mercury lamps or chemical treatment and enables a compact, lightweight and mechanically robust disinfection solution that can stand up to the rigors of military and humanitarian use and, when powered with an alternative energy source, can offer a sustainable source of drinking water for many months.

Through a development program funded by the US National Science Foundation (NSF), SETi has already demonstrated the use of its germicidal UV LEDs in a bench-top disinfection chamber. The collaborative effort with Cascade Designs will further this work and targets development of the first multi-stage UV LED-based water purification system.

Cascade has 40 years of experience developing and making products for outdoor and military markets. Under the Mountain Safety Research (MSR) and Platypus brand names, it has a significant share of the portable, point-of-use water treatment market. The firm is the standard-issue supplier of sleep pads, snowshoes, camp stoves, and on-the-move water treatment systems for the US Army and Marine Corps.

Together, the firms believe UV LEDs, combined with proprietary filtration and absorption technologies, will have breakthrough potential for the military and humanitarian relief work.

"With SETi's UV LED technology and our experience in designing and manufacturing a broad range of water treatment products, we believe we can develop revolutionary new water treatment systems that will advance the work we're already doing to supply the US military and bring sustainable relief to people around the world who lack potable water," says Cascade Designs' president Joe McSwiney.

"With a strong track record of taking new technologies to market, Cascade Designs is the obvious choice for SETi to partner with," comments SETi's president & CEO Dr Remis Gaska. "This collaborative effort will demonstrate the effectiveness in UV LEDs for disinfection and will not only address the need of the public sector markets, but will also pave the way for the development of UV LED-based disinfection products in the private sector."

www.cascadedesigns.com

www.s-et.com

NGK's GaN substrate yields HB-LED chip with 90% internal quantum efficiency at 200mA drive current

NGK Insulators Ltd of Nagoya, Japan has developed gallium nitride wafers that double the luminous efficiency of an LED light source compared with conventional materials, it claims.

Grown using original liquid phase epitaxial (LPE) technology, NGK's GaN wafer (which was exhibited at SEMICON Japan last December) has shown low defect density and colorless transparency over the whole wafer surface.

With the assistance of an external research institute, a light-emitting test was performed on an LED chip made using NGK's GaN wafer. The test demonstrated an internal quantum efficiency (IQE) of 90% at an injection current of 200mA (compared with 30–40% for LED chips currently on the market). Luminous efficiency was 200lm/W, which is twice that using wafers



LED chip under light-emitting test: substrate size, 1cm²; chip size, 0.3mm square; injection current, 200mA; center wavelength, 450nm.

currently on the market, it is reckoned. For the same brightness, this halves power consumption. Since the wafer reduces heat generation within LEDs, it can lengthen the lifetime of LEDs and enable the downsizing of lighting equipment,

the firm claims.

Earlier this month, NGK established the new department 'Wafer Project', aiming to speed the commercialization of wafer products. This year the firm aims to start shipping sample 4"-diameter GaN substrate, which is reckoned to be the world's first 4" GaN wafer produced using LPE growth technology.

NGK is also accelerating its development of GaN wafers with lower defect density and larger diameters (6"), targeting applications such as power devices for hybrid cars, electric vehicles and power amplifiers for cellular base-stations. The firm reckons that GaN substrates are optimum for such applications, taking advantage of features such as high breakdown voltage and high frequency operation.

www.ngk.co.jp/english

SETi reaches UV-C LED external quantum efficiency of 11%

UV LED maker Sensor Electronic Technology Inc (SETi) of Columbia, SC, USA has achieved what it reckons are record efficiencies for UV LEDs operating in the germicidal UV-C range of 11% external quantum efficiency (EQE) with a corresponding wall-plug efficiency (WPE) of 8%. The result was achieved under the US Defense Advanced Research Projects Agency (DARPA) Compact Mid-Ultraviolet Technology (CMUVT) program and in collaboration with the Army Research Laboratories (ARL).

SETi says its latest development represents more than a five-fold improvement in performance, due mainly to improved light extraction from encapsulated LED chips with a novel transparent p-region and a reflective contact and further reductions in defect density in the LED structure, grown on sapphire substrates.

Traditionally, UV LEDs have been manufactured with gallium nitride

p-type layers, due to the difficulties of p-doping AlGaN materials. However, GaN absorbs light with wavelengths shorter than 365nm, and hence reduces the extraction efficiency of UV LEDs operating at short wavelengths. So, instead, SETi has developed a completely new p-type region using doped AlGaN, which is transparent, even in the UVC range. This coupled, with a transparent p-contact, significantly increases extraction efficiencies.

SETi has also further developed its migration-enhanced metal-organic chemical vapor deposition (MEMO-CVD) growth process to reduce dislocation densities in the quantum well structure of UV LEDs grown on sapphire substrates, demonstrating threading dislocation densities (TDD) of less than 2×10^8 , as measured by transmission electron microscopy (TEM). This improvement in TDD has led to a high internal quantum efficiency (IQE) of 60%.

The milestone represents "a major step forward in reaching efficiencies of incumbent technologies, such as medium-pressure mercury vapor lamps, which typically operate at efficiencies of 15% or less," says president & CEO Dr Remis Gaska.

The $350\mu\text{m} \times 350\mu\text{m}$ encapsulated LEDs were designed for emission at 278nm and measured at ARL, where they were reported to emit 9.8mW at 20mA (record output for an LED with a sub-365nm wavelength at this forward current) and 30mW at 100mA. Details were presented at the Conference on Lasers and Electro Optics (CLEO 2012).

SETi has previously reported LED-based water treatment systems that disinfect (with a more than 4 log reduction) drinking water flowing at 0.5l/min with less than 35mW of optical power at 275nm. The latest results put UV LED disinfection within reach of consumer markets.

www.s-et.com



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Soraa appoints both COO and VP of global sales to drive production, sales and distribution

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 added two executives to its leadership team: chief operating officer (COO) Dr Tom Caulfield and VP of global sales Ray Letasi.

Caulfield has held executive positions in publicly traded and private companies, including serving as COO of Ausra Inc, where he led a repositioning of the firm that ultimately led to a strategic partner acquisition. Previously, he was executive VP of sales, marketing & customer satisfaction at Novellus Systems Inc, where he oversaw worldwide field operations for over 1200 individuals. Caulfield also has extensive semiconductor industry experience, having served, over his 17 year tenure, as VP of semiconductor operations at IBM.

"Tom will play an integral role in expanding Soraa's ability to meet the growing market demand for



COO Tom Caulfield. his unique experience with

semiconductor technology and manufacturing - spanning production, manufacturing, equipment engineering and technology and product development - Tom will be key to Soraa's execution plans in this sector," he adds.

Letasi is former president & COO of global solid-state lighting solutions firm EcoSense Lighting. He was formerly VP of international sales for Color Kinetics (now Philips Solid-State Lighting Solutions) and, during 10 years there, held several sales management and business development positions, spearheading the firm's Japanese joint venture partnership as well as

high-performance LED lighting," says CEO Eric Kim. "With his distinguished track record of senior executive leadership and

launching sales, marketing and distribution programs throughout Europe, Asia Pacific, Japan and the Middle East. Letasi has nearly 15 years of global business experience in the semiconductor, LED and lighting industries.

"Ray's extensive experience in the lighting industry gives Soraa a major advantage in navigating a rapidly changing industry landscape," says CEO Eric Kim. "His veteran perspective on the global industry will help build Soraa's reach internationally."

Soraa made its public debut in February when it launched its flagship family of GaN-on-GaN based LED MR16 lamps. The firm's proprietary GaN-on-GaN technology foundation enables it to produce LEDs that produce light sources which are claimed to be much brighter than conventional LEDs, and which allow it to develop lighting products with superior performance and simple, elegant design.

www.soraa.com

First full-spectrum MR16 lamp beating halogen color performance

Soraa has added to its family of LED MR16 products by launching VIVID, claimed to be the first full-spectrum LED MR16 lamp with color quality and rendering superior to both traditional halogen and competitor LED lamps. With a color rendering index (CRI) of 95 and R9 of 90, it is claimed to be the highest-output LED MR16 lamp with the best color performance on the market.

With rich saturated color rendering and color stability, the VIVID LED MR16 suits demanding display applications, while being 75% more energy efficient than comparable halogen lamps, it is reckoned. It is designed to replace standard 40-50W MR16 halogen lamps and is available with correlated color temperatures (CCTs) of 2700K and 3000K.



black-body curve (as is produced by halogen and incandescent lamps), which is widely considered the optimal light color spectrum. Soraa claims that, unlike competitor LED lamps, VIVID offers full coverage over the entire spectral range and has no pronounced blue peak and cyan dip (common in all other LED lamps). Having overcome the blue overshoot commonly associated with poor color quality, Soraa claims that the VIVID lamp is unparalleled in color quality and color rendering,

Soraa's proprietary GaN on GaN technology allows for LED products that match the

"With the launch of the VIVID MR16, we demonstrate a very clear link between performance and our breakthrough GaN-on-GaN technology," says CEO Eric Kim. "We believe that, with GaN-on-GaN, there is no longer any reason to compromise light quality or color performance in the name of energy efficiency," he adds.

"For years, lighting designers have been holding back on embracing LED MR16 lighting, mostly due to both inadequate light output and only mediocre color quality," comments lighting designer Jim Benya. "Now, here is the first example of LED MR16 technology providing both high output and excellent color, allowing large-scale, mainstream adoption of LEDs in the critically important MR16 marketplace."



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LED lighting fixture maker Ephesus developing prototype chip with Group4 Labs

Ephesus Technologies LLC of Syracuse, NY, USA (a firm founded in June 2010 by former Lockheed Martin employees that designs and makes LED lighting fixtures for commercial and municipal markets) has partnered with Group4 Labs Inc of Fremont, CA to engineer and manufacture its own prototype LED chip as it aims to become vertically integrated.

With a manufacturing facility at the University of Albany's College of Nanoscale Science and Engineering (CNSE) Smart System Technology and Commercialization Center of Excellence (STC) in Canandaigua, NY, Group4 Labs develops and supplies 'extreme materials' that aim to improve the performance of gallium nitride (GaN)-based devices. The firm's technology enables epitaxial GaN layers to be atomically attached (regardless of lattice mismatch) to a free-standing, proprietary chemical-vapor-deposited (CVD) synthetic polycrystalline diamond substrate, providing GaN-on-diamond epiwafers.

Ephesus initially resided in Syracuse University's Center for Advanced Systems and Engineering (CASE Center). The firm now has 16 staff and is based in the Syracuse Technology Garden (with a manufacturing location at Ansen Corp in Ogdensburg, NY), but plans to relocate to Baldwinsville in Central New York as it expands.

The EG4 is reckoned to be the first LED to be completely developed and manufactured in New York State. Ephesus says that development was aided by upstate New York's research and manufacturing strengths in the regional innovation cluster related to clean technologies and through collaboration with upstate New York academic institutions and several New York Centers of Excellence (CoE).

In February, Ephesus received a \$50,000 grant from the SyracuseCoE Commercialization Assistance Pro-

gram (CAP), which was established in partnership with Syracuse-based CenterState CEO (Corporation for Economic Opportunity, formerly the Metropolitan Development Association) and Empire State Development (ESD) with grants received under the auspices of New York Assemblyman William Magnarelli. The firm also received a \$1m tax incentive from the ESD. STC provided support and infrastructure to enable Group4 Labs to produce demonstration LEDs as a first step toward the development of super-bright LEDs.

Ephesus has also benefited from the New York Energy Regional Innovation Cluster (NYE-RIC) — a consortium led by Syracuse University in partnership with City University of New York (CUNY), NYSTAR (New York State Office of Science, Technology and Academic Research), and the State University of New York (SUNY) Research Foundation.

NYE-RIC's 'Bridge to Markets' program — funded by SyracuseCoE and NYSERDA (New York State Energy Research and Development Authority), and conducted in collaboration with CenterState CEO — connects New York State firms that have developed innovative products for advanced buildings with the diverse and critical stakeholders in the target market of New York City.

Existing Ephesus LED lighting products target a broad range of applications, including warehouses, manufacturing facilities, parking lots/garages, roadways, stadiums, tunnels and bridges. Currently, fixtures are produced in New York State using LED chips from third-party companies, and the LED

array comprises over 47% of the cost of the entire Ephesus lighting fixture. By developing its own LED chip, Ephesus aims to cut the cost of its LED fixtures by 30%.

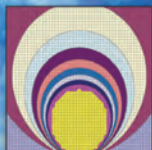
"Our EG4 LED chip will be commercialized through small-scale production and be demonstrated and used in Ephesus lighting fixtures," says CEO Amy Casper. Ephesus reckons that the EG4 will differentiate its products from other LED-based products and allow it to capture more market share in the LED fixture market.

"This new chip can meet a rapidly growing demand for highly efficient lighting and smart lighting technology," reckons CenterState CEO's president Robert Simpson. "For our region, this will result in new jobs and investment, and offer further evidence that our collective effort to create a strong entrepreneurial ecosystem is paying real dividends," he adds.

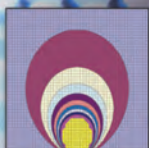
Other organizations involved with Ephesus in developing the technology include Alfred University, American Dicing, Ansen Corp, Binghamton University, Clarkson University, Clean Tech Center, Cornell University, Lighting Research Center, LINC, Onondaga County Economic Development, Rensselaer Polytechnic Institute (RPI), Syracuse University, and the Tech Garden.

"The state's partnership with Ephesus Technologies is a great example of what can be accomplished through collaboration between the private-sector, academia and government," comments Jim Fayle, Central New York regional director with Empire State Development. "The success of this home-grown small business will create much-needed jobs and generate significant economic activity for Upstate New York," he adds.

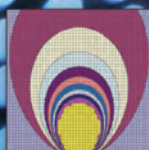
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For more information, visit us at www.temescal.net



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IN BRIEF

Toyoda Gosei and SDK to form GaN LED joint venture TS Opto

SDK's operations to focus on AlGaInP, GaAs and GaP LEDs

Tokyo-based chemical manufacturer Showa Denko K.K. (SDK) has decided to split off its gallium nitride (GaN)-based blue LED chip business, and transfer 70% of the shares in the new company (tentatively named TS Opto Co Ltd) to fellow Japanese LED maker Toyoda Gosei Co Ltd by the end of this year (targeting December).

With planned capital of about ¥490m (\$6.07m) and owned 70% by Toyoda Gosei and 30% by SDK, the joint venture will specialize in the production and sale of GaN-based LED chips, and be established at SDK's plant in Ichihara City, Chiba Prefecture.

SDK already collaborates with Toyoda Gosei, which develops and sells GaN LEDs. The firm says that the GaN-based LED joint venture will further strengthen its relations with Toyoda Gosei, as well as expanding overall supply capacity. In addition, SDK targets synergy in R&D, with the aim of improving LED brightness and production efficiency.

As well as GaN, SDK produces and sells a wide variety of LED chips, including aluminum gallium indium phosphide (AlGaInP), gallium arsenide (GaAs), and gallium phosphide (GaP), for which SDK will continue independent operations.

www.sdk.co.jp

www.toyoda-gosei.com

Toshiba invests in Bridgelux to boost GaN-on-Si LED lighting

Best performing 8" GaN-on-Si LEDs claimed

Just a few months after a reaching joint collaborative agreement earlier this year, Tokyo-based semiconductor manufacturer Toshiba Corp and Bridgelux Inc of Livermore, CA, USA (which claims to be the only vertically integrated manufacturer of LED solid-state light sources specifically for the lighting industry) have achieved what is claimed to be the industry's best-performing 8" GaN-on-silicon LED, emitting 614mW from a 1.1mm-square chip (with an operating voltage of 3.1V and a drive current of 350mA). The firms aim to further accelerate their development efforts for LED chips, which are seeing increasing demand for lighting systems.

Toshiba has also made an equity investment in Bridgelux, with the intent of jointly pursuing innovative solid-state lighting (SSL) technology. The firms reckon that the investment will further advance both

their efforts in the SSL industry, with the aim of boosting Bridgelux's GaN-on-silicon LED chip technology development efforts, based on Toshiba's silicon process and manufacturing technology development.

"Toshiba and Bridgelux have already been engaged in the development of the technology, and the equity investment brings both companies one step closer to a more strategic relationship and achieving our shared goal of driving down the cost of solid-state solutions for the general lighting market," says Bridgelux's CEO Bill Watkins.

"We will continue to pursue more advanced development targeting commercialization of the technology," says Makoto Hideshima, executive VP of Semiconductor and Storage Products Company, corporate VP of Toshiba.

www.toshiba.co.jp/index.htm

www.bridgelux.com

Rich Power appointed as Asia distributor

Bridgelux has announced the Rich Power Group (RPG), a subsidiary of WPG Holdings Ltd, as its primary distributor in Asia.

RPG will carry the full line of Bridgelux LED products including chips and packaged products consisting of arrays and emitters such as the new Micro SM4. In addition, PRG will distribute Bridgelux approved infrastructure products such as drivers, optics and thermal management systems to aid customers with new lamp and luminaire development.

RPG will join Bridgelux's group of current distribution partners and will support its customers and its other regional distributors in China, Taiwan, Korea, Malaysia, Singapore and India.

"RGP will help provide the infrastructure and resources required to support our rapidly growing Asian

customer base," says Bridgelux's chief sales & marketing officer Jim Miller. "The relationship with RPG further solidifies Bridgelux's commitment to the Asia Pacific region, allowing not only for faster delivery of Bridgelux products to the market, but also the availability of regionally based applications engineering support and testing services to assist customers with new product development," he adds.

"Rich Power is positioned as a demand-creation partner, providing a spectrum of value-added services," says RPG's chairman & CEO Richard Wu. "Teaming with Bridgelux in greater China and South Asia, we believe RPG will help streamline product development, technical support and system-level integration for Bridgelux customers."

www.rich-power.com.tw

Bridgelux launches Zhaga-compliant spot-light module

LED chip and lighting array maker Bridgelux Inc of Livermore, CA, USA (which claims to be the only vertically integrated manufacturer of LED solid-state light sources specifically for the lighting industry) has launched the Cetero spot-light module (SLM), a compact high-flux-density light source delivering consistent white light without pixilation and engineered to comply with the upcoming Zhaga spot-light module specification.

The Cetero SLM will offer light output ranging from 800lm to 2300lm across multiple color temperatures, all in one common form factor. Mechanical compatibility with the upcoming Zhaga interface specifications ensures interchangeability and a modular product platform that will expand luminaire design options for users, the firm notes.

Bridgelux is an active member of Zhaga, an industry-wide cooperation aimed at the development of standard specifications for the

interfaces of LED light engines. With more than 180 members from the lighting industry, Zhaga is a global consortium aimed at ensuring interchangeability of LED light sources from different manufacturers. Adherence to this design specification allows for design flexibility and a future-proof upgrade path for both OEM customers and end users, claims Bridgelux, addressing market concerns regarding the rapid evolution of LED technology and delivering on the promise of sustainability.

"Bridgelux remains committed to providing customers with leading-edge LED technology in a package that simplifies their design efforts and reduces product development risks and costs," says Jason Posselt, VP for channel marketing. "Working with Zhaga to help develop common standards will help pave the way for accelerated adoption of solid-state lighting technology," he believes. "The Cetero, with its simple bolt-

down installation and wire connection features, combines the high quality of light benefits delivered by Bridgelux LED arrays with a simple-to-install standardized interface to help speed time-to-market."

The Cetero modules will be available in 2700, 3000, 3500 and 4000K color temperature options — all providing a minimum color rendering index (CRI) of 80 and color consistency of 3 SDCM (standard deviation of color matching), and leveraging the production-proven Bridgelux ES product family. Initially, three lumen categories will be available, delivering 800, 1100, and 2000 operational lumens, all in a common light-emitting source area to enable compatibility with secondary optics. The Cetero SLM will be commercially available in late 2012.

Bridgelux exhibited its latest products at April's Light+Building 2012 trade fair in Frankfurt, Germany.

www.zhagastandard.org
www.bridgelux.com

Bridgelux expands Decor 97 CRI LED array range from 1200–2500lm to 500–5000lm

Bridgelux has expanded its Decor line of ultra-high color rendering index (CRI) LED arrays.

Addressing growing demand in the shop and retail, architectural, hospitality and museum lighting markets, Bridgelux has expanded its Decor 97 CRI product series (launched last October). The Decor series now offers increased efficiency as well as a broader range of light sources — from 500 to 5000 operational lumens (compared with the existing 1200–2500lm) in three color temperatures (2700, 3000 and 3500K) — to satisfy the increasing number of applications demanding high light quality. The Decor series expands lighting options available to the lighting designer, complementing Bridgelux's standard products with minimum CRIs of 80 and 90, respectively.

Bridgelux says that, with a CRI of 97 and a 3-step MacAdam Ellipse color control option, the latest Decor arrays enable lighting designers to accurately render a full palette of colors over a wide range of light levels to create sophisticated lighting effects. The series has been spectrally engineered to virtually replicate the light quality of halogen and incandescent light sources. The arrays deliver R9 and R15 values of 98, to both enhance reds and more accurately represent many skin tones, delivering clean and natural lighting.

"Bridgelux's introduction of the higher lumen output Decor arrays will allow us to significantly expand our ARONDO LED luminaire line," comments David Rice, vice president of BAERO North America Inc. "Designed specifically for super-market lighting, BAERO's ARONDO

LED fixtures currently offer 10 different light engine options, with three of those options utilizing the high 97 CRI Decor arrays for premium presentation," he adds. "Fixtures with the Decor option range from 1936 to 3304 lumens while also providing unmatched color. This has allowed BAERO to capture a greater share of applications in supermarket lighting, converting them from conventional lighting technologies to energy efficient solid state lighting. The quality and performance is excellent as is the support we have received from Bridgelux as we developed the ARONDO LED."

The Decor arrays feature the same form factors as current Bridgelux array products, allowing a simple upgrade path for existing customers while minimizing design efforts.

IN BRIEF

LED light engine introduced for high-intensity spot lighting

At the Light + Building 2012 exhibition in Frankfurt, Germany (15–20 April), Luminus Devices Inc of Billerica, MA, USA, which manufactures PhlatLight (photon lattice) LEDs for illumination applications, announced the availability of its new LD10 LED light engine.

Designed for both indoor and outdoor lighting applications, the LD10 is available at 800 and 900 ‘hot’ lumen output levels, color temperatures of 3000K and 4000K, and a color rendering index (CRI) of more than 80. The light engine incorporates Luminus’ ‘Big Chip’ LED technology, which enables high-lumen fixtures with what is claimed to be industry-leading center-beam intensity. For spot lighting applications, the LD10 can deliver 17,000 candela into a 9° beam using off-the-shelf optics.

On-board electronics provide power, dimming and protection feedback to the LED. The LD10 accepts a 24VDC power input and a 0–10V dimming signal. In addition, it has thermal feedback protection circuitry that ensures longevity and reliability.

“The LD10 reduces the engineering design cycle for our customers, and enables them to accelerate time to market for their lighting fixtures,” says Chuck DeMilo, global director of product marketing. “It delivers the optical punch that our customers need, and the thermal protection circuitry gives them peace of mind,” he adds.

Luminus Devices exhibited the new LD10 LED light engine at April’s Light + Building show in Frankfurt.

www.luminus.com

Luminus launches first round LED

At April’s Light + Building 2012 show in Frankfurt, Germany, Luminus Devices Inc of Billerica, MA, USA launched a family of round LEDs that, the firm reckons, can accelerate the adoption of solid-state technology by displacing conventional light sources in high-brightness lighting applications.

“Optical architectures of high-power entertainment fixtures are frequently defined by a circular aperture, so using a traditional square LED was like putting a square peg into a round hole,” says Don McDaniel, global marketing director for Entertainment Lighting. “Our new round LED increases system-level efficiency by as much as 30%, enabling our customers to use a single LED to replace a 250W HID lamp.”

Other markets and applications that can include medical, machine vision, portable and retail spot lighting, it is reckoned. “There are obvious benefits to fiber-coupled lighting systems,” notes Chuck DeMilo, global director of product marketing, Lighting Business Group, at Luminus. “The fiber is



round, the optic is round, but the LED has always been square — it was an optical mismatch. This has now been resolved with the round LED breakthrough that will enable us to replace the 300W Xenon lamp in an application like endoscopy,” he adds.

“We made a decision to invest significantly in R&D and operational infrastructure to revolutionize LED lighting — making the round LED concept a reality,” says president & CEO Keith T.S. Ward.

Luminus’ first round LED product will be commercially available in third-quarter 2012.

www.luminus.com

Luminus launches high-CRI CBT-90 white LEDs enabling conversion of HID lighting

Luminus Devices says that its CBT-90 white LED is now available with a guaranteed minimum CRI (color rendering index) of 90 and typical CRI of 93. It also has a typical R9 value of 85, enhancing rendering of deeply saturated reds.

“Physicians can now accurately render deep red colors of tissue and blood during endoscopic surgery,” says global director of product marketing Chuck DeMilo.

“Entertainment lighting fixtures will make flesh tones look warmer and more vibrant during theatrical productions,” he adds. “Retail display lighting designers emphasize high CRI, as it makes merchandise look more attractive and increases sales.”

Luminus recently increased the lumen output of the CBT-90 by 25%. The product is fully qualified at input currents up to 1.5A/mm², delivering thousands of lumens with what is claimed to be unparalleled brightness.

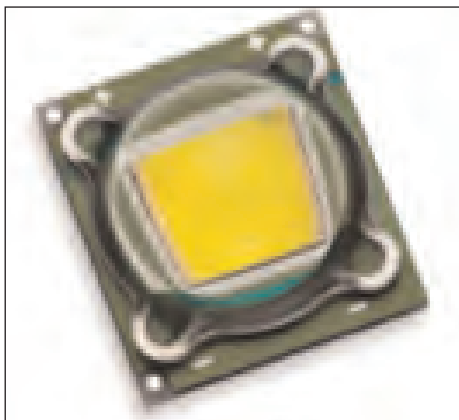
Manufactured and sold by Luminus since 2009, the CBT-90 has been designed into volume lighting products by leading companies. Typical applications include medical, automotive, machine vision and entertainment lighting, where Luminus’ ‘Big Chip’ LED technology has displaced traditional lighting technologies including xenon, metal halide and halogen.

www.luminus.com

Luminus' lighting-class white LEDs now delivering 120LPW efficacy tested at DOE's standard conditions

At April's Light + Building 2012 show in Frankfurt, Germany, Luminus Devices Inc of Billerica, MA, USA, which manufactures PhlatLight (photonic lattice) LEDs for illumination applications, announced that its white-light LEDs are achieving 120 lumens per watt (LPW) at standard test conditions, as specified by the US Department of Energy (DOE). The 120LPW efficacy represents the middle of the firm's production distribution and aligns it with the DOE roadmap for best-in-class efficacy.

"Luminus' efficacy performance is measured with its commercially available LEDs driven at DOE standard current, and represents the median of our production distribution — not just our top bin," says



Luminus' 120LPW white LED.

VP of engineering Arvind Baliga. "Frequently, efficacy is reported using low drive current that artificially inflates the result or using laboratory results for an LED that is not commercially available," he adds.

"The recent accreditation of our test laboratory to the LM-80 standard, awarded by NVLAP (National Voluntary Laboratory Accreditation Program), illustrates Luminus' commitment to providing our customers with accurate performance data about our LEDs," says president & CEO Keith T.S. Ward.

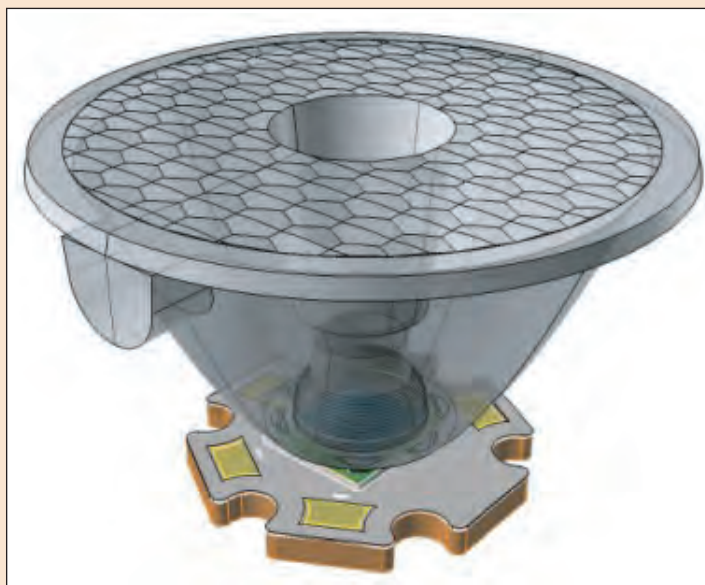
"Our 'Big Chip' LED technology provides customers with an efficient and powerful point source of light that enables precise optical control and the highest center-beam candle power in the lighting industry for applications including retail display spot, high-bay and outdoor area lighting," claims global director of product marketing Chuck DeMilo.

www.luminus.com

Fraen's total internal reflection optics to boost LED center beam candle power and uniformity for retail spot lighting

LED maker Luminus Devices Inc of Billerica, MA, USA and Fraen Optics of Reading, MA (a division of Fraen Corp that designs and manufactures optics for high-powered LEDs) have announced the release of the FML series of patent-pending total internal reflection (TIR) optics, designed specifically to maximize the performance of Luminus' SST-90 and SSM-80 LEDs, in conjunction with Luminus' 'Big Chip' LED technology.

When mated with the SST-90 warm-white LED, the FML spot optic produces a full divergence angle of under 10° with 17,000 candela and Energy Star-compliant efficacy. The FML series consists of a complete range of optics with output beam patterns including spot, narrow, medium, wide, elliptical and flood.



"The FML optics enable our customers to capture and deliver those lumens on task at unprecedented levels of intensity, efficiency and uniformity," says Luminus' global director of product marketing Chuck DeMilo. "Using an LED to outperform a 50W MR-16 halogen lamp used to be a dream, but the combination of

technologies from Luminus and Fraen has made this a reality," he adds.

TIR optics are frequently preferred over reflectors due to higher optical efficiency and center beam brightness in spot lighting applications. The FML series has an innovative optical mixing chamber that homogenizes the input from the LED to deliver a uniform beam, says Fraen Optics' chief operating officer David Cohen. "Luminus LEDs

are unique because optically they can be considered a high-intensity point source of light, and this opens many new degrees of freedom for our optical designers," he adds.

Luminus exhibited the new optics at April's Light + Building show in Frankfurt, Germany.

www.fraenomg.com

LUXEON R launched for outdoor and industrial lighting

Philips Lumileds of San Jose, CA, USA has launched the LUXEON R LED, designed for outdoor and industrial lighting applications such as streetlights, high-bay lights, wall packs and bollards.

LUXEON R is an illumination-grade LED, and is hence hot tested and specified (at a junction temperature of 85°C) so that its performance at operating conditions is well understood. It also offers 'Freedom From Binning' to ensure uniformity from solution to solution. Furthermore, the LUXEON R is footprint compatible with the LUXEON Rebel and LUXEON Rebel ES, while delivering more light output, higher efficacy and better quality of light. With a minimum color rendering index (CRI) of 70 and correlated color temperatures (CCTs) of 3000K, 4000K, 5000K, 5700K and 6500K, the new LED meets the most stringent standards required by municipalities, utilities, and property



Lumileds' new LUXEON R LED.

owners, says Lumileds. Minimum luminous flux is 160–200lm. The minimum forward voltage is 2.5V.

LUXEON R is footprint compatible with the LUXEON Rebel and LUXEON Rebel ES

LUXEON R represents the continued evolution of Lumileds' chip, phosphor, and packaging technologies, says Lumileds' vice president of marketing Rahul Bammi. "For our customers and ultimate end-users, our innovations are lowering the cost of providing ever improving lighting in parking lots and roadways," he adds.

LUXEON R has already been implemented in Lumec's SoulCity, which is a modern family of outdoor lighting solutions that blends uniformity in design and optimum style with the performance and energy efficiency of LED technology.

The LUXEON R LED is available from Future Lighting Solutions. It was exhibited at the Lightfair International (LFI 2012) trade show (9–11 May) in the booths of both Philips and Future Lighting Solutions.

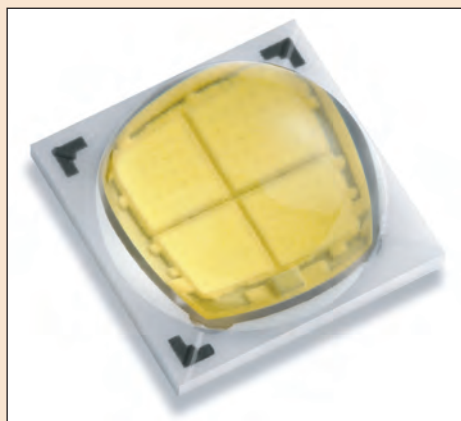
www.philipslumileds.com

Lumileds' LUXEON M LED enters volume production

Philips Lumileds of San Jose, CA, USA has fully launched the LUXEON M LED, which is now in volume production. The new emitter has already been approved for street lighting in major US cities.

LUXEON M's high lumen output (of more than 1100 lumens) and typical voltage of 11.2V drives down system cost and improves system performance through the use of low-cost, highly efficient drivers, Lumileds says, adding that the light output and efficacy at operating conditions lowers overall solution costs.

Solutions are simpler and use fewer parts and off-the-shelf drive electronics, optics, and thermal solutions that are readily available from distributor Future Lighting Solutions. As a result, costs are lowered while optical control and the quality of light required for outdoor lighting is optimized, claims Lumileds.



Lumileds' LUXEON M LED, now in volume production.

LUXEON M improves the design and cost parameters of new solutions in much the same way LUXEON Rebel did in 2007,

The new LED is offered in CCTs of 3000, 4000 and 5700K, and delivers more than 1100lm with a minimum CRI of 70

claims Lumileds' VP of marketing Rahul Bammi. "Everything from the footprint to the drive requirements has been optimized based on hundreds of discussions with our customers, municipalities, and private property owners to ensure that LUXEON M exceeds their expectations and objectives," he adds.

The new LED is offered in three different correlated color temperatures (CCTs) of 3000K, 4000K and 5700K, and delivers more than 1100 lumens with a minimum color rendering index (CRI) of 70. Each LUXEON M is hot tested and specified at 85°C and delivers 'Freedom From Binning'.

The new products were exhibited in the booths of both Lumileds and Future Lighting Solutions at the Light+Building trade fair in Frankfurt, Germany (15–20 April) and at Lightfair International in Las Vegas (9–11 May).

Lumileds launches its first white mid-power LEDs for general illumination applications

Philips Lumileds of San Jose, CA, USA launched its first white, mid-power LED, raising expectations for mid-power reliability, performance over time and temperature, and color maintenance, it is claimed. Intended for office and other distributed LED lighting solutions, the company uniquely specifies correlated color temperature (CCT), color rendering index (CRI), and R9 for each of its new mid-power emitters.

Lumileds has hence extended its mid-power portfolio to general illumination applications. The firm's other mid-power products include SuperFlux, SnapLED and SignalSure LEDs (the most widely used LEDs for automotive exterior lighting).

"The lighting industry's performance expectations of mid-power LEDs are well below the expectations for power LEDs," says Rahul Bammi,



Lumileds' new 5630 mid-power LED.

VP marketing. "Distributed light solutions like those found in offices should deliver quality of light, color stability and useable life-times similar

Many of the mid-power solutions being implemented today will see unplanned and unexpected color shift over time

to what our LUXEON LEDs deliver," he believes. "Most importantly, lighting designers and technical specifiers should have the confidence that the light source inside will perform as intended. We are certain that the new Lumileds 5630 emitters will outperform other options over their lifetime."

Lumileds says that it has used its expertise, including proprietary phosphor technology, to create its first illumination mid-power LED. "Many of the mid-power solutions being implemented today will see unplanned and unexpected color shift over time, and we think the industry needs better LEDs," says Bammi.

The new 5630 LEDs are available now via Lumileds' distributor Future Lighting Solutions.

www.futurelightingsolutions.com

www.philipslumileds.com

SemiLEDs cuts loss as revenue rebounds a further 17% Margins improve as operating expenses cut

For its fiscal second-quarter 2012 (to end-February), LED chip and component maker SemiLEDs Corp of Hsinchu Science Park, Taiwan has reported revenue of \$7.9m, down 21% on \$10m a year ago but up 17% on \$6.75m last quarter (following a 27% rebound from the trough of \$5.3m the previous quarter). This was also at the top end of the expected range of \$7-8m.

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

cations, including street lights and commercial, industrial and residential lighting).

On a non-GAAP basis, net loss was \$6.1m, up from \$0.7m a year ago but cut from \$7.1m last quarter. Compared with +23% a year ago, gross margin was negative 9%, but this is an improvement on negative 12% and negative 93% the previous two quarters.

Likewise, compared with negative 6% a year ago, operating margin was negative 73%, but an improvement on negative 95% last quarter. Margins continue to improve through continued expense management. R&D expenditure rose from \$1.7m last quarter to \$2m, but selling, general & administrative (SG&A) expenditure was cut further, from \$3.9m to \$3m, so total operating expenses fell from \$5.6m to \$5m.

"Given the ongoing challenging industry environment, we are pleased with our quarterly financial and operational results," says chairman & CEO Trung Doan. "Our strategy of pursuing the indoor lighting market has proved successful as it continues to improve our revenue growth, and we remain cost conscious in areas of the business that won't impede our innovation and technology advantage," he adds. "We continue to maintain the slow, steady growth and improvement that we have shown over the last two quarters."

Cash used in operations during the quarter was \$4.5m. Overall cash and cash equivalents fell from \$74m to \$66.4m.

For its fiscal third-quarter 2012 (to end May), SemiLEDs expects revenue to grow by 6% to \$7.9-8.9m.

www.semileds.com

Cree's revenue hit by transition in lighting agents after acquisition of Ruud Lighting

Rebound expected as orders pick up amid lighting product launches

For its fiscal third-quarter 2012 (ended 25 March), Cree Inc of Durham, NC, USA has reported revenue of \$284.8m, up 30% on \$219.2m a year ago but down 6% on last quarter, and below the targeted \$290–\$310m.

Both LED and Power & RF revenues were in line with targets. Revenue for Power & RF devices grew by 22% from last quarter's \$14.2m to \$17.3m as demand in both product lines started to improve. Revenue for LED products (components, chips and materials) was \$180.9m, down 6.8% on \$194.2m last quarter but in line with seasonally lower targets. In particular, LED component sales improved following the Chinese New Year. Sales through LED component distributors were lower than fiscal Q2 but in line with seasonal trends, and channel inventories were in a similar range.

However, revenue for Lighting products (indoor & outdoor LED lighting plus traditional lighting systems) fell a more-than-expected 9.6% from \$95.7m to \$86.5m. Both product lines lost momentum short-term as a result of Cree's transition to new agents during the integration with Ruud Lighting Inc of Racine, WI, USA (acquired last August) causing greater-than-expected disruption to the project pipeline.

Sales for the Cree indoor product line were most affected due to shorter project cycles, with some projects being delayed and some proceeding instead with traditional lighting technology in the near term. The changes to agents is intended to drive revenue synergies in fiscal first-half 2013. "We do not believe that the decrease in lighting sales was an indication of lower end-user demand," comments chairman, CEO & president Charles M. Swoboda.

On a non-GAAP basis, gross margin was 35.6%, down from 42.4% a year ago but rebounding slightly from 35.3% last quarter (and in the middle of the targeted range of 35–36%), despite the lower-than-expected revenue due to 'solid execution across the company'. Pricing declines were offset by slightly higher factory utilization, combined with cost reductions and improvements in productivity and yield.

Operating expenses have risen from \$76m last quarter to \$76.9m. In particular, while R&D expenditures were flat sequentially, SG&A (selling, general & administrative) expenditures rose by \$0.5m, although this was about \$2m lower than expected due mainly to lower-than-planned selling expenses and legal fees. Operating margin has continued to fall, from 14.9% a year ago and 10.3% last quarter to 8.6%.

Net income has fallen from \$30.1m a year ago and \$28.7m last quarter to \$23.3m. Cash flow from operations was \$48.3m (down on \$81m last quarter). Property, plant and equipment (PP&E) capital expenditure was cut slightly from \$23m last quarter to \$22.2m but, including \$4m of patent spending, total CapEx was \$26m. Although down from \$58m last quarter, free cash flow was hence \$22m, boosting cash and investments rose from \$687.2m to \$710.1m. "Our ability to generate solid free cash flow in a challenging market bodes well for the company as we target increased revenues in Q4," comments Swoboda. "We continue to be in a strong position to signifi-

cantly increase LED chip production from current levels with modest capital spending, and we are well positioned to support significant growth in LED lighting," he adds.

Over the last several weeks, Cree has launched several new lighting products. These include:

- XSP Series LED street-lights (the first Cree outdoor product to leverage an integrated development approach from the LED chip to the lighting system), which more than double the lumens per dollar (increasing payback);
- an expanded CR Troffer Series to address more applications and eliminate the use of fluorescent technology in new or retrofit commercial and industrial settings;
- the Aeroblades outdoor lighting product line (the first outdoor product to take full advantage of the latest generation of high-power LEDs).

Regarding LED components, Cree has launched the XLamp XT-E LED, the second product based on the new SC3 Technology Platform (which doubles the lumens per dollar of lighting-class LEDs). Also during the quarter, Cree started shipping both its XLamp XB-D and XT-E products (based on the firm's new SC3 Technology Platform). Cree also recently launched high-voltage versions of these products. "There's a lot of design activity around these products, both for new design as well as upgrades to existing ones," says Swoboda. "We target incremental revenue growth from these products in Q4 and a growing pipeline of design activity for the first half of fiscal 2013," he adds.

Cree also recently launched its next-generation XLamp MT-G LED (based on the SC3 Technology Platform), which is 25% brighter than the previous version. It also released an expanded portfolio of XLamp LMH2 modules (now available in 2000 and 3000lm versions). ➤

We do not believe that the decrease in lighting sales was an indication of lower end-user demand

► The firm has also set a new R&D record with a prototype LED with luminous efficacy of 254lm/W.

Lighting orders have improved for both indoor and outdoor products. LED customers continue to maintain low inventory levels and rely on short lead-times, but the demand forecast from both customers and distributors has improved, says Cree.

"We continue to closely manage inventory in LEDs and Power & RF to similar levels as Q2 while working to respond to short lead-time expectations in the market," says Swoboda. Overall inventory rose by \$9.5m to \$196.8m (from 85 days to 96 days of inventory on hand). LED and Power & RF inventories fell slightly, while inventory in Lighting products rose in anticipation of new product launches and higher demand in fiscal Q4.

"Overall company backlog is stronger than it was at this point last quarter, with Lighting, LEDs and Power & RF all tracking ahead of Q2," notes Swoboda. "We see good trends in lighting and LEDs,

but we still have limited order visibility." Both product lines are operating with short lead-times, which increase the variability and reduce the accuracy of forecasts.

For its fiscal fourth-quarter 2012 (ending 24 June), Cree targets 7.5% revenue growth to \$295–\$315m. This includes double-digit growth in Lighting (driven by indoor and outdoor sales); single-digit growth in LED product sales (for both direct and distribution customers); and higher Power & RF sales. Non-GAAP gross margin is targeted to rise to 36%, depending on slightly improved factory utilization and cost-reduction efforts, offset by product mix and the competitive environment.

"The LED market remains very competitive, but we target improved margins as our new products gain traction in the market," says Swoboda.

We target improved margins as our new products gain traction in the market

Operating expenses are targeted to rise by \$4m, all due to SG&A expenses. The increase in selling (sales & marketing) expense is due mainly to higher commissions from increased sales of lighting products through the lighting agent channel plus supporting three major trade shows (Light+Building in Frankfurt; Lightfair in Las Vegas; and Lightfair in Guangzhou, China). The G&A increase is due mainly to the timing of patent-related litigation fees. Net income is targeted to be \$23–\$30m.

"Based on our prior capital additions, along with incremental investments, we believe we are well positioned from a capacity point to support significant growth," says chief financial officer John T. Kurtzweil. "We have updated our PP&E commitment target for the fiscal year to be \$65–\$70m."

"Our focus remains on driving adoption through innovation, and we believe we are well positioned to continue leading the transition to LED lighting and drive growth in our business," says Swoboda.

First LED module designed to replace ceramic metal halide lighting

Cree has expanded its 2000lm and 3000lm LMH2 module family (launched in early April) by offering lighting manufacturers a new dome lens and universal driver with dimming options.

The new lens enables an increase of up to 5% in system efficacy compared with the standard lens and delivers what is claimed to be an unrivalled hemispheric light pattern. The LMH2 modules enable true 50W and 70W ceramic metal halide LED replacements and support a range of lighting applications, including downlights, wall sconces, pendants, flush-mounted, spot, track and ceiling fan lights.

The LMH2 module is also now available with a 120–277V universal driver with 0/1–10V dimming capability. The modular LMH2 LED offers a range of lumen, color temperature, driver and beam-shape options in one common form factor,



enabling lighting manufacturers to customize their applications and speed time-to-market, it is claimed.

Optimized with the new hemispheric beam shape of the dome lens, the drop-in-ready LMH2 delivers up to 80lm/W system efficacy combined with 90+ CRI. Featuring Cree TrueWhite Technology, the 2000lm and 3000lm modules deliver more than 95lm/W efficacy at the light source, and are available in color temperatures of 2700K, 3000K, 3500K and 4000K.

Designed for 50,000 hours of operation and dimmable to 5%, the

LMH2 is also UL-recognized and complies with multiple international regulatory and safety standards. Luminaire makers seeking ENERGY STAR qualification will have access to specification and performance data, including LM-80 reports, which can speed regulatory approvals.

"Lighting manufacturers no longer need to settle for inferior quality and performance offered with ceramic metal halide lighting," says Mike Watson, Cree senior director marketing, LED components. "Cree's LMH2 family lets designers quickly and easily convert their traditional lighting portfolio to LEDs and simultaneously deliver their end-users improved color quality, efficacy and performance."

Cree exhibited the new LMH2 options at the Lightfair International show in Las Vegas. (9–11 May).

www.cree.com/products/modules_lmh2.asp

Cree adds 2000lm and 3000lm LMH2 LED modules

LED chip, lamp and lighting fixture maker Cree Inc of Durham, NC, USA has extended its LMH2 module family (launched last November) with new 2000 and 3000 lumen output options, delivering what is claimed to be better performance, longer lifetime and lower system cost than comparable compact fluorescents in commercial lighting, and offering a wider range of lighting applications within a compact, cost-effective design.

The LMH2 is claimed to be the only LED module delivering 82lm/W system efficacy combined with a color rendering index (CRI) greater than 90 in all available color temperatures. The LMH2 features Cree TrueWhite Technology, delivering high efficiency while maintaining color consistency over the product's rated lifetime. LMH2 modules are available in a range of lumen, color temperature and driver options, which is claimed to enable lighting manufacturers to meet their needs quickly and easily.

"With its high lumen output and superior combination of high efficacy and high CRI, the new Cree LMH2 LED module enables us to



Cree's LMH2 LED module.

address the commercial lighting market," says Antonio Di Gangi, general manager of Italy-based lighting firm DGA srl.

The compact, two-piece design of the LMH2 module separates the light source and power supply to enable a wide selection of mounting and wiring options, giving lighting manufacturers the flexibility needed for rapid LED luminaire design and development. The modules also feature primary thermal management, potentially eliminating the need for costly secondary thermal management systems.

"The LMH2 LED module family now obsoletes the need to even consider compact fluorescent alternatives," claims Mike Watson,

Cree's senior director marketing, LED components. "Not only does the family of LMH2 LED modules outperform this traditional lighting technology, but it does so across a wide range of color and lumen options with unparalleled color quality, efficacy and warranty, enabling lighting manufacturers to address an entire range of lighting applications."

Designed for 50,000 hours of operation, LMH2 modules deliver 82 lumens-per-watt system efficacy combined with 90+ CRI in color temperatures of 2700K, 3000K, 3500K and 4000K. The module is available with Digital Addressable Lighting Interface (DALI) and DALI touch dimming (dimnable to 5%). Luminaire makers seeking ENERGY STAR qualification will have access to specification and performance data, including LM-80 reports, which can speed regulatory approvals.

Cree exhibited the module used in different applications at April's Light+Building 2012 trade fair in Frankfurt, Germany, where DGA luminaires based on the LMH2 family were on display.

Cree SC³ Technology Platform yields brighter, high-voltage versions of XLamp XT-E and XM-L LEDs

Cree Inc of Durham, NC, USA has announced the availability of brighter XLamp XT-E and XM-L High-Voltage LEDs to provide manufacturers with more efficient, cost-effective components.

The new LEDs leverage the SC³ Technology Platform, which also powers the existing XLamp XB-D and XT-E LEDs. Built on Cree's silicon carbide (SiC) technology, the platform features advances in LED chip architecture and phosphor, as well as a new package design.

The new, brighter XT-E and XM-L High-Voltage LEDs deliver up to 22% more lumens than their predecessors, and are designed to use lower-cost, higher-efficiency and

smaller-size drivers than standard-voltage LEDs. By providing comparable performance to their standard-voltage counterparts, they eliminate the trade-off of optimizing for either LED efficacy or driver efficiency, says Cree. The new high-voltage LEDs provide more design options to address a wider spectrum of small indoor and outdoor lighting applications, such as accent lights and replacement lamps, the firm adds.

"Leveraging the power of the SC³ Technology Platform, Cree has fundamentally transformed price-performance with the XB-D LED, set new performance standards with the XT-E LED and — with the

introduction of the new XT-E and XM-L High-Voltage LEDs — redefined performance limits for LEDs of this size," claims says Mike Watson, senior marketing director, LED components.

The XT-E High-Voltage LEDs can deliver up to 357 lumens at 3W in cool white (6500K) and up to 275 lumens at 3W in warm white (3000K), both at 85°C. The XM-L High-Voltage LEDs can deliver up to 647 lumens at 6W in cool white (6500K) and 555 lumens at 6W in warm white (3000K), both at 85°C. Samples are available immediately and production volumes are available with standard lead times.

Cree sets R&D record with 254lm/W power LED SC³ Technology Platform helps to exceed previous record of 231lm/W

Cree Inc of Durham, NC, USA has reported an R&D-stage white power LED with luminous efficacy of 254 lumen per watt, exceeding Cree's previous industry record of 231lm/W.

The record R&D result has been enabled by elements of Cree's SC³ Technology Platform, available commercially now in the firm's XLamp LEDs. Built on Cree's silicon carbide (SiC) technology, the platform features advances in LED chip

architecture and phosphor, as well as a new package design.

Cree says that the LED's efficacy was measured at 254lm/W at a corre-

The record R&D result has been enabled by elements of Cree's SC³ Technology Platform, available commercially now in the firm's XLamp LEDs

lated color temperature (CCT) of 4408K, using standard room-temperature, 350mA testing.

"The core of the Cree R&D culture is a relentless focus on innovation that ultimately drives LED adoption," says John Edmond, Cree co-founder & director of advanced optoelectronics. "Higher-performance LEDs can enable new and better LED-based applications and drive down the solution cost of LED designs."

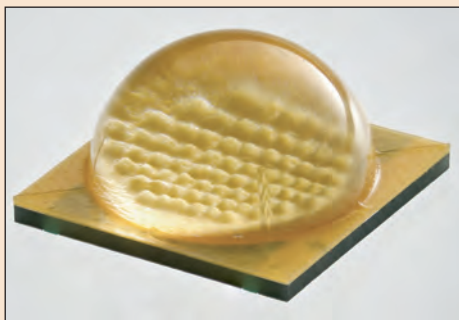
www.cree.com

Cree's XLamp MT-G2 LEDs 25% brighter than MT-G due to SC³ Technology Platform

LED chip, lamp and lighting fixture maker Cree Inc of Durham, NC, USA has launched the XLamp MT-G2 LED — the first EasyWhite LED array built on the SC³ Technology Platform.

The MT-G2 LED delivers LED lighting makers 25% brighter LEDs compared to the previous MT-G, enabling a wider spectrum of high-lumen applications. MT-G2 LEDs are designed for high-output, directional lighting applications and suit replacement lighting for applications that currently use halogen lamps. The new LEDs are optimized for use in track, accent, lamp retrofit, downlighting and other applications where color quality, consistency and optical control are required.

"The MT-G2 LED truly pushes the envelope of what's possible, redefining lumen levels and efficacy while delivering color consistency and superior optical control," comments Richard Turner, R&D director at lighting firm Havells Sylvania. "Combined with the small footprint and uniform emitting surface, the MT-G2 is an especially attractive device to further grow our leading position in professional-quality LED retrofit lamps," he adds.



Cree's XLamp MT-G2 LED.

Featuring Cree EasyWhite Technology, the MT-G2 LED delivers up to 2100 lumens in warm white (3000K) at 25W, 85°C. The new, brighter LED shares the same footprint as the original MT-G, providing an upgrade path to shorten the LED luminaire and retrofit lamp design cycle and improving customer time-to-market, claims Cree. The MT-G2 is designed to be used as a single component in an LED design to better emulate the filament appearance of incumbent lighting products and simplify design and manufacturing.

"Innovation in performance and optimization of LEDs to a variety of applications are critical to driving LED adoption," says Mike Watson, Cree's senior marketing director, LED components. "The new MT-G2 LEDs enable true halogen perform-

ance across a wide range of single-source lighting applications and provide the industry's best color consistency," he claims.

The MT-G2 is the latest product built on Cree's SC³ Technology Platform, joining XB-D, XT-E, XT-E High-Voltage and XM-L High-Voltage LEDs. Built on Cree's silicon carbide (SiC) technology, the platform features advances in LED chip architecture and phosphor, as well as a new package design.

With an 8.9mm x 8.9mm footprint, the MT-G2 is available in 2- and 4-step EasyWhite color temperatures ranging from 2700K to 5000K. The new LEDs are available in minimum 80 and 90 CRI (color rendering index) options and feature multiple voltage selections, including higher voltages that enable the use of smaller, more efficient drivers to lower system cost.

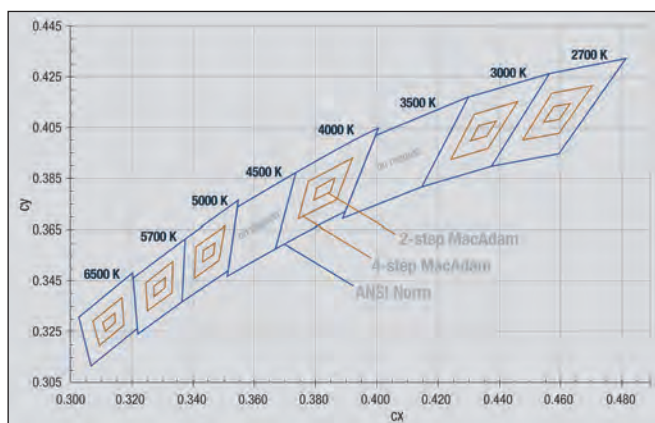
The new MT-G2 LED was exhibited at the Light+Building trade fair in Frankfurt, Germany (15–20 April) and at the Lightfair International trade show in Las Vegas (9–11 May). Samples are available now and production quantities are available with standard lead times.

www.cree.com/accelerate

Osram Opto launches its first chip-on-board LED

Osram Opto Semiconductors GmbH of Regensburg, Germany has launched the Soleriq series, its first chip-on-board LED, which it says yields the high luminous flux required by downlights providing high-quality background lighting in professional applications (e.g. shopping malls, offices, industrial buildings and high-end residential premises). Even at high application temperatures the new LEDs create the basis for highly efficient luminaires with a luminous flux of 1500–4500lm, the firm adds.

Just one Soleriq-E-LED is needed to give a luminaire enough light, says Osram, making designing luminaires easier because only one component needs to be integrated instead of many LEDs. Also, the individual chips are all under the conversion layer (chip-on-board), giving the impression of a homogeneous light-emitting surface. This ensures a uniform color and light appearance in the luminaire, and coupling into external light-guiding optics is simple, the firm adds. The light generated can be used with much lower



Grouping by 4-step MacAdam ellipses.

optical losses, increasing LED lamp and luminaire efficiency.

The Soleriq E is available in two versions, covering the entire color spectrum from 2700K to 6500K. Even at 85°C (close to the temperature in the application), the two LEDs offer a luminous efficiency of 103lm/W at 4000K. At t85°C, the larger Soleriq E 45 (36mm x 36mm x 1.7mm) has a typical brightness of 4000lm (rated current 880mA); the smaller Soleriq E 30 (30mm x 30mm x 1.7mm) produces a lumen output of 2700lm (at 600mA).

Thermal resistance is 0.38K/W (E 30) and 0.25K/W (E 45). Lamp life is over 50,000 hours for both. The beam angle is 120°.

Good color homogeneity is achieved by a narrow white grouping, corresponding to a range of 4-step MacAdam ellipses. For solutions requiring a particularly high level of color homogeneity,

grouping based on 2-step MacAdam ellipses is also available.

“Downlights are in widespread use in many areas such as shop, office and residential lighting but need high-lumen packages between 1500 and 4500lm to perform their task,” notes Andreas Vogler, marketing manager, general illumination. “We can achieve these high values with just one LED component. This makes it easier to couple the light into external optics and to integrate the light source in the luminaire.”

www.osram-os.com

Osram's Duris P 5 LED enhances corrosion stability and lifetime

Osram Opto Semiconductors has launched the Duris P 5 LED, which offers a luminous efficacy of up to 110lm/W (at 100mA, 3.0V and a color temperature of 3000K) and an average lifetime (at a forward current of $I_f = 200\text{mA}$ and a junction temperature of $T_j = 125^\circ\text{C}$) of over 50,000 hours (L70/B50), even at high currents and temperatures. Luminous flux (for 3000K) is up to 33lm at 100mA and 56lm at 200mA.. Color temperatures are 3000K, 4000K and 5000K (further color temperatures will follow this Spring). Minimum color rendering index (CRI_{min}) is more than 80.

Luminaires in the professional sector (for both indoor and outdoor lighting) are increasingly being equipped with LEDs, says Osram. In the process, luminaire

makers are placing particular focus on durable, efficient, high-quality LEDs. “Demand for high-quality and robust light-emitting diodes will continue to increase in the future,” says product manager Christian Neugirg. “The Duris P 5 represents a leap in innovation, in particular owing to its minimal error rate during long-term use,” he claims.

A radiation angle of 130° enables homogenous illumination without any noticeable individual points of light. As luminaires typically contain over 100 mid-power LEDs, a low LED failure rate is of particular importance to ensure high luminaire quality throughout their lifetime.

Supplied in a 2.6mm x 2.2mm package, the LED is also claimed to be first on the market for medium-power classes with particular

resistance to adverse environmental conditions. Long-term tests with corrosive gases such as sulphur or chlorine cause no harm to the LED, while inducing no significant luminous flux decrease, says the firm. Nor did long-term tests under sauna-like conditions (with high temperature and humidity levels) have any adverse effect on the LED.

Higher corrosion stability is not only a key factor when used for outdoor applications. The new LEDs suit linear and area luminaires (in offices, shops and billboard lighting), and LEDs are also exposed to corrosive influences indoors, e.g. from circuit board materials, rubber seals or adhesives. Increased corrosion resistance hence gives an extra guarantee for the durability of professional lighting.

Philips and Optogan form JV for road lighting in Russia, Kazakhstan and Belarus

Lighting solutions provider Royal Philips Electronics and Russian LED chip and luminaire maker Optogan have signed an agreement in Moscow, Russia to form a joint venture (owned 51% by Philips and 49% by Optogan) focusing on the fast-growing LED road lighting market in Russia.

Founded in Helsinki, Finland in 2004 by Russian entrepreneurs and scientists from Ioffe Institute in St Petersburg, Optogan is a vertically integrated developer and manufacturer of HB-LEDs for applications including solid-state lighting. In addition to having an R&D facility in Helsinki, since founding Optogan GmbH in Germany in 2005 it has established epitaxy and chip R&D plus a pilot line in Dortmund and, last year, its Fab1 chip fabrication plant in Landshut. Also, after founding CJSC Optogan in Russia in 2009, in 2010 it acquired an industrial facility in St Petersburg, where it has established LED component and luminaire production lines.

The JV aims to combine Philips' latest LED road lighting solutions and international quality standards with Optogan's LED expertise, solutions and understanding of local market requirements. Products developed and manufactured by the JV will be sold in the Russian Federation and within its customs union with Kazakhstan and Belarus.

The Philips-Optogan partnership will focus on developing a local LED industry, supporting the energy-efficiency initiatives of the Russian government. Switching to LED street and road lighting can reduce energy consumption by up to 80% and lead to significant savings in service and maintenance costs, it is reckoned. The enhanced visibility created by the brightness of the lighting can also contribute to enhanced security and can help to improve road safety.

The joint venture with Optogan represents "the beginning of a new, ambitious journey to become a key player on the Russian outdoor lighting market," says Arjan de Jongste, CEO Philips Russia and CIS. "It will unlock new potential for us to bring innovative lighting solutions to Russia that save energy, reduce maintenance costs and increase road safety," he adds.

"With proven innovative, energy-efficient and cost-efficient solutions in the fields of high-brightness chips, LED components, LED lamps and LED luminaires. Optogan has a very deep understanding of the local Russian market," claims Optogan Group's Maxim Odnoblyudov. "By joining forces with Philips we will be able to serve the Russian customers even better."

Road lighting in Russia is an attractive market segment, says Optogan, as it is anticipated to become one of the leading growth segments for LEDs. Driven mainly by government energy-efficiency programs for the modernization of road lighting, the Russian road lighting market is expected to double over the next four years to €100m by 2015, when the penetration of LEDs into this sector will reach 50%.

www.optogan.com



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Osram Opto launches high-power blue laser diode for professional projectors

Osram Opto Semiconductors GmbH of Regensburg, Germany has unveiled its PL TB450 high-power blue laser diode, which is based on indium gallium nitride (InGaN). Mounted in a compact TO56 package, it has an optical power of 1.4W, and is particularly suitable for high-quality projectors in the professional field. Other applications range from laser systems for stage and decoration illumination to medical applications.

Professional projectors with a luminous flux of more than 1000lm are the main area of application for the PL TB450. The firm says that, emitting at a wavelength of 450nm (± 10 nm), it produces exactly the desired blue and — with an output of 1.4 W (at room temperature and a current of 1.2A) — the high optical power that is required. The operating temperature range is 0–70°C.

Due to its efficiency of 27% (ratio of light produced to electric power consumed), the temperature of the laser will rise only slightly. Hence it has a long service life: up to 10,000 hours at 40°C in continuous operation, depending on use. The long lifetime facilitates maintenance-free operation of projectors at low energy consumption, says the firm.

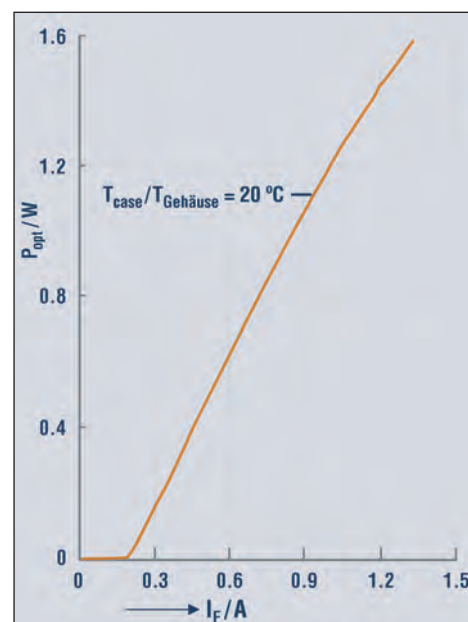
Osram Opto says that there are various approaches for the use of a



The new PL TB450 blue laser diode.

laser diode in a professional projector: usually red LEDs are combined with blue high power lasers. The green color emerges when blue lasers excite a special phosphor to emit light. Red light can also be generated this way, so that the projector light source can be designed without red LEDs, making it even smaller, if required.

“By starting serial production of a blue high-power laser diode in the 1W power range we further strengthen our leading role in the field of blue lasers,” reckons Dr Thomas Hoefer, head of R&D for infrared products and lasers at



The PL TB450 produces typically 1.4W of optical power output at 1.2A.

Osram Opto. “When developing these diodes we were able to draw on many years of experience with other types of lasers,” he adds. “We could also implement the results of publicly funded research projects,” notes Hoefer. The basic technology for the InGaN laser diodes was developed in the course of the MOLAS Project, which was supported by the German Federal Ministry of Education and Research.

www.osram-os.com

Riber and TRUMPF collaborating on MBE for GaAs facet passivation in bar-based high-power lasers

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 Germany-based TRUMPF to collaborate on epitaxy process technologies for next-generation III-V high-power laser devices. This follows process qualification at the Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik (FBH) of Berlin, Germany.

In the quest for higher power and increased life-time of lasers within TRUMPF’s semiconductor program, laser component maker TRUMPF Photonics Inc of Cranbury, NJ, USA (formerly part of Princeton Lightwave Inc, before acquisition by industrial laser manufacturing subsidiary TRUMPF Inc of Farmington, CT) – together with its partners – is exploring facet passivation processes to prolong the life of lasers at higher power densities. Together with Riber,

efficient passivation techniques for GaAs facets will be tackled.

The facet passivation process is implemented through both high-quality MBE and the capability to handle substrates for bar-based lasers. Riber’s MBE412 system, sold to TRUMPF, allows for ultra-high-vacuum conditions and delivers processed wafers automatically and rapidly, it is claimed.

www.riber.com

www.trumpf.com

Osram's 65%-efficient laser bars provide 200W cw

Osram Opto Semiconductors GmbH of Regensburg, Germany says its new SPL BKxx-40WFT series of laser bars offer efficiency of up to 65% at 200W optical output power, and can simplify the design of laser systems and reduce their cost. Laserline, which manufactures high-power diode laser systems for industrial material processing, is taking advantage of these benefits in its new fiber-coupled diode lasers, which can be used in applications from welding of metals and plastics to surface treatment and cutting.

Measuring 10mm wide and with a cavity length of 4mm, the new laser bars produce infrared radiation at wavelengths of 915–1020nm. Due to their high efficiency, average operating lifetime is over 30,000 hours, amply meeting requirements for industrial laser systems.

Apart from the optical pumping of fiber lasers, one of the main applications of infrared lasers — with more than 1kW of power — is the direct processing of metals (welding, brazing, cutting, hardening, cladding and coating) for use in automotive manufacturing. Direct diode lasers are the most efficient laser light sources for such fiber-coupled systems and are a more efficient alternative to the carbon dioxide lasers that have traditionally been used.

Osram says that its new laser bars are at the core of the latest and most powerful fiber-coupled diode laser series from Laserline. The complete system is water-cooled and supplies 2–15kW of power via a fiber with a core diameter of 1–2mm. Due to the high efficiency of the laser bars, its overall efficiency reaches maximum levels of more than 40%.

"Our developments in the field of laser bars are pushing the utilization of direct diode lasers into ever higher power ranges," says Michael Klein, Osram Opto's marketing manager for laser bars. "This enables our customers to open up new markets, and benefits from the improved technology include lower investment cost because fewer laser bars

are required to generate the needed power," he adds. "The cost for electricity and maintenance will also decrease due to their high efficiency and long operating lifetime."

The laser bars have been developed on the basis of results generated by Osram in the HEMILAS project, which was supported by the German Federal Ministry of Education and Research

with the goal of developing a new generation of semiconductor lasers with higher output powers, narrower emission areas, and extremely high optical power densities. The main results to date are the efficiency-optimized structure of epitaxial layers and improved mirror technologies with a high damage threshold.

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European Photonics Industry Consortium appoints SEMI Europe's director general Carlos Lee as its DG

At its annual general meeting the European Photonics Industry Consortium (EPIC) of Paris, France has announced that Carlos Lee has been appointed as its director general. He succeeds secretary general Thomas P. Pearsall, who has led the association since its founding in 2003.

With 80 voting members and over 400 associate members, EPIC promotes sustainable growth for photonics industries and R&D organizations across Europe through initiatives to build revenues, improve access to R&D resources, and develop timely market and technology information. Members have played a leading role in creating and operating the European Technology Platform, Photonics-21, as well as European projects such as LIFT (for fiber laser development) and Nexpresso (which supports commercial innovation by SMEs).

Lee is currently director general at SEMI Europe (the European branch of global industry association Semiconductor Equipment and Materials International), where he leads the



DG Carlos Lee.

advocacy program. EPIC says that he has a background of 15 years in industry association management, with experience in building mem-

bership value through standardization, collaboration, networking platforms and events, and other activities of collective interest that benefit the industry at large.

"Carlos' appointment comes at a time of growth for EPIC. Over the last years we have increased our work in supporting our members and their business and in developing photonics technologies and innovation both in Europe and worldwide," says EPIC's president Drew Nelson, CEO & president of epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK. "Our objective is to build on this foundation, to further provide a strong platform supporting all

actors and in particular SMEs [small and medium enterprises]. Carlos has a real passion for collaboration and is excellent at engaging members into working together to create value," he adds.

"Carlos emerged as our first choice because of his experience and his energy to drive new initiatives to benefit our members," says Pearsall. "I will be working with Carlos throughout 2012 to help ensure a successful transition," he adds.

"As director general I will further expand the solid value proposition for our members active in displays, lasers, lighting, optical fibers, optics, semiconductor, photovoltaics, sensors, telecommunication and other critical photonic-related fields," said Lee during his address to the EPIC membership. "EPIC will open an office in Brussels. We will implement closer collaboration with the EU in order to better represent the interests of our members and photonics, a key enabling technology and future EU Public-Private Partnership."

www.epic-assoc.com

Osram and Mouser expand distribution into Asia

Mouser Electronics Inc of Mansfield, TX, USA, a design engineering resource and global distributor for semiconductors and electronic components, has announced the Asian expansion of its agreement with Osram Opto Semiconductors GmbH of Regensburg, Germany.

Mouser says that the extended distribution partnership strengthens its Asian line card by providing Osram Opto Semiconductors' portfolio of high-performance LEDs for diverse applications.

The expansion, announced at the recent Electronica China Show 2012 in Shanghai in March, fits Mouser's strategic emphasis on supplying innovative solutions to design engineers and small production buyers.

"We are pleased to now offer design engineers across Asia the highly innovative lighting solutions from Osram Opto Semiconductors," says Mark Burr-Lonnon, Mouser's VP of APAC Business.

"Osram Opto Semiconductors is known as a world leader in the production of LED and IRED

The extension of our distribution agreement with Mouser to Asia will be beneficial to our customers, especially for solid-state lighting customers who are geographically scattering across the whole region

products. Both our existing and new customers will benefit greatly from this expanded agreement," he adds.

"Asia is a dynamic and fast-growing region full of business opportunities. We look forward to tapping these opportunities by expanding our engagement with Mouser in the region," says Louis Lam, VP of worldwide sales at Osram Opto Semiconductors. "The extension of our distribution agreement with Mouser to Asia will be beneficial to our customers, especially for solid-state lighting customers who are geographically scattering across the whole region, and is also a natural expansion of our business."

www.mouser.com

www.osram-os.com

Leti and III-V Lab report results from first year of partnership

Expertise in silicon, microelectronics and heterogeneous integration combined

III-V Lab (formed in 2004 as a privately held Paris-based joint venture between telecoms-focused Alcatel-Lucent Bell Labs France and defense & aerospace-focused Thales Research and Technology) has reported results of its activities for the first year after micro/nano-technology R&D center CEA-Leti of Grenoble, France joined it in March 2011. The expanded public-private partnership combines III-V compound semiconductor with CEA-Leti's silicon technologies, opening up new perspectives in research, targeting applications in telecoms, industrial control, environmental testing, defence, security and space.

To add the performance benefits of III-V components to silicon CMOS platforms, the partnership is leveraging the complementary expertise of Alcatel-Lucent Bell Labs France, Thales Research and Technology and CEA-Leti in silicon, microelectronics and heterogeneous integration, aiming to bring specific benefits to four primary areas of research and applications. III-V Lab says that, after a year, it has already enabled the rapid development of a common platform for the dual use optoelectronic and microelectronic technology. The first results to be unveiled are as follows:

- Integrated photonic circuits that gather the active and passive functions of III-V and silicon for high-speed telecoms and data transfer. For the first time, a tunable laser source has been integrated on silicon, representing a milestone

towards fully integrated transceivers. CEA-Leti and III-V Lab claim a breakthrough in its development by integrating on the same chip complex devices such as a fully integrated transmitter working above 10Gb/s or a tunable single-wavelength laser.

- Thermal and near-infrared imagery for security and defence applications. III-V Lab is developing new types of detectors with increased resolution while reducing overall cost and speeding their adoption in the industrial quality control, transportation and environmental markets.

- III-V Lab is developing a new generation of cost-effective, compact, ultra-sensitive, highly selective gas sensors for use in security, industrial process control, and environmental monitoring.

- The enlarged partnership in III-V is working on high-power and microwave gallium nitride-based microelectronics to increase the power density, robustness, energy efficiency and compactness of telecom, avionics, satellite, defence, energy and transport systems

The partnership in III-Vs has also demonstrated single-wavelength tunable lasers, with a 21mA threshold current at 20°C, a 45nm tuning range and a side-mode suppression ratio larger than 40dB over the tuning range.

"We have a great opportunity to work together to achieve our goals," says Salvatore Cinà, deputy head of the Optoelectronics Department at CEA-Leti. "After a year, the partnership brings some exciting cooperation opportunities," he adds. "Our cooperation has already made an important impact in optical telecommunications, providing several innovative breakthroughs."

www.leti.fr

www.3-5lab.fr

IN BRIEF

Intense appoints director of European sales

Intense Inc of North Brunswick, NJ, USA (which makes monolithic laser array products, high-power single-emitter laser diodes, and electro-optical subsystems) has appointed Beate Sauter as director of European sales.

Sauter has more than 25 years of international sales & marketing experience (more than half in the photonics industry). She will oversee all sales & marketing efforts in the European Union, including direct management of key accounts and channel partners in the region. She will also be responsible for business development and strategic marketing within the territory.

"As Intense continues to grow at an aggressive pace in the EU, our focus is supporting OEMs, end-users, and distribution partners across the region," says CEO Kevin Laughlin, who adds that Sauter is a "seasoned, multilingual executive who knows how to balance the many demands of a global team... We will support her efforts by continuing to develop new and innovative, high-performance products while providing the highest level of customer support and service at a global level."

Before joining Intense, Sauter was key account manager for South Europe for Edmund Optics. Prior to that, she held the position of sales manager, Italy, for Laser 2000, a Munich-based distributor of photonics products. She has also worked as global sales & marketing director for laser system maker Optica Photonics.

www.intenseco.com



Silicon photonics firm Kotura unveils low-power 100Gb/s optical engine

In March at the 2012 Optical Fiber Communication Conference and Exhibition/National Fiber Optic Engineers Conference (OFC/NFOEC) in Los Angeles, silicon photonics firm Kotura Inc of Monterey Park, CA, USA, which designs and makes silicon photonics application-specific integrated circuits (ASICs) for the communications, computing, sensing and detection markets, demonstrated its low-power 100Gb/s optical engine for supporting the interconnect fabric for next-generation data centers and high-performance computers (HPC).

The new optical engine chips are based on Kotura's micron-scale manufacturing platform currently in mass production and deployed in live networks around the world since 2006. With three of the five largest telecom OEMs already using Kotura products in their 10, 40 and 100Gb/s networks, the firm is approaching 1 million channels per year currently in production.

Kotura's silicon photonics platform supports optical engines using wavelength division multiplexing (WDM). Claiming to be the only silicon photonics provider to offer WDM, Kotura says that its optical engine can reduce the cost of fiber and associated connectors within the interconnect fabric for 4x25GHz solutions by a factor of four, as well as readily expanding from 4 channels to 8, 16 or even 40 channels over a single strand of optical fiber. The silicon photonics platform also supports optical engines using parallel fiber channels.

"The optical engine provides our customers with an inexpensive, small form factor that reduces power consumption and provides a high level of integration," says chief technology officer Mehdi Asghari. "Moreover, we are addressing the need for green solutions that will alleviate some of the strain associated with power hogs such as data centers and high-performance

computers," he adds.

"Since our inception, we have been focused on developing a platform that enables innovative solutions based on silicon photonics that can take us to the next generation of connectivity."

Kotura says that, because its platform is capable of high-yield manufacturing, attractive price volume curves can be achieved. The firm has integrated key functionalities — such as flip-chip-attached lasers, high-performance WDM de/multiplexers, fast low-power modulators and high-speed detectors — into a single pair of silicon chips, eliminating the need for hundreds of piece parts and dozens of assembly steps. The optical engine is so small that a 100Gb/s transceiver will easily fit inside a QSFP package (the smallest 40G package on the market), greatly increasing the panel density of 100Gb/s transceivers.

"We are in the early stages of a market with huge potential," says Brad Smith, senior VP at Light-counting, a market research analyst firm tracking high-speed interconnects. "100G in a QSFP package over a single strand of single-mode fiber is exactly what the HPC, traditional data center and switch/routing infrastructure is looking for to support next-generation systems and to gear up for the 'exa-flood' of data coming," he adds.

Finding fast enough interconnects has become the limiting factor for the entire industry. With 10 core microprocessors, four per server, virtualization and 48–60 servers per rack, the aggregate bandwidth at the top-of-rack switch will hit

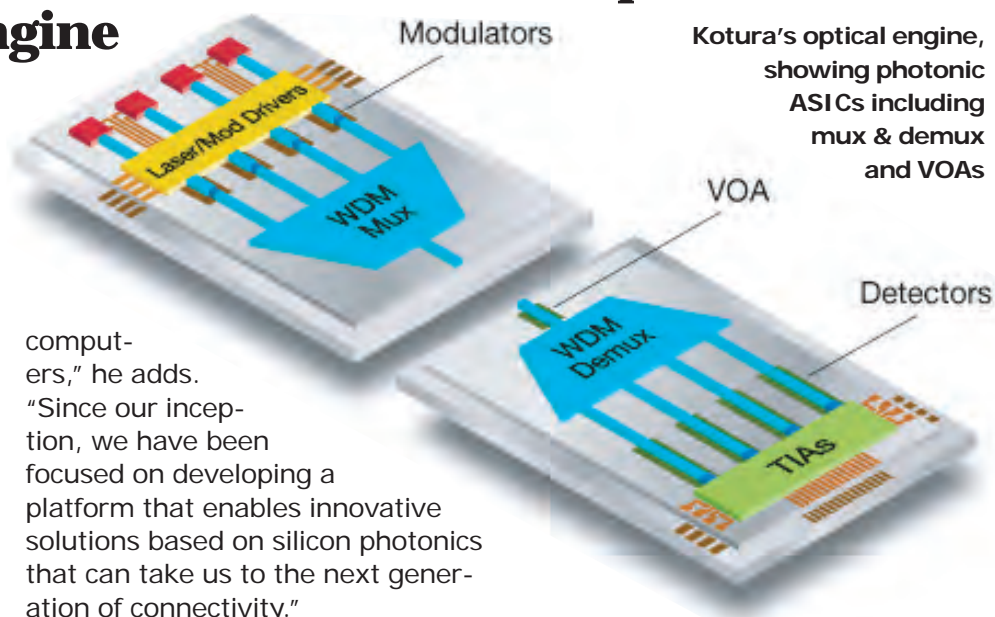
480–600G. This will require four to five 100G up links per rack and large data centers using 200–500 racks.

According to Smith, silicon photonics enable long-haul optical WDM to move to the server and switch rack. Together with WDM, it allows modulation speed to rise to 40G/50G and more channels in the future without having to upgrade the entire fiber plant.

As part of Kotura's optical engine demonstration at OFC, Anritsu Company will be using its MP1800A bit-error-rate tester (BERT) to support 100Gb/s networking applications. As a provider of high-speed test instrumentation, Anritsu was selected because the MP1800A is a modular BERT with a built-in pulse pattern generator (PPG) that supports the output of high-quality, low intrinsic jitter signals, as well as a built-in error detector (ED) with high input sensitivity of 10mV. The MP1800A also supports signal analyses, including bathtub and Q measurements.

Kotura says that its devices have reliably logged more than 1 billion channel hours of operation. The firm has 140 issued and applied patents. At OFC, the chips for the optical engine were on display at Kotura's booth, while the demonstration was shown privately.

www.kotura.com



Kotura signs Japanese distribution agreement with Nissho

Kotura Inc of Monterey Park, CA, USA, which designs and makes silicon photonics application-specific integrated circuits (ASICs) for the communications, computing, sensing and detection markets, has agreed for Tokyo-based Nissho Electronics to distribute its entire suite of integrated silicon photonic solutions in Japan, including high-speed single-channel variable optical attenuators (VOAs), VOA arrays, and WDM multiplexers for 40 and 100Gb/s data-center applications.

"Photonics integration in silicon provides small, low-power solutions for next-generation networks," says Nissho Electronics president & CEO S. Gene Kawatani.

"Combining Kotura's technology with our specialized global high-tech partnerships will bring real value to our customers," Kawatani adds.

"Nissho Electronics has a large customer base in Japan and an excellent reputation in the high-tech industry," comments Kotura's VP of product marketing & sales Xavier Clairardin. "We look forward to working closely with Nissho to expand our global customer base and our position in the Japanese market."

Nissho Electronics exhibited Kotura's products at the 12th Fiber Optics Expo (FOE 2012) in Tokyo (11–13 April).

www.nissho-ele.co.jp

Kotura appoints VP of business development

Kotura says that, as the market for silicon photonics is heating up, it has appointed Samir Desai as VP of business development to oversee expansion of its strategic relationships and business development activities in the rapidly expanding market of optical interconnects.

The firm says that Desai has well-rounded expertise in business development, strategic marketing/sales and account management in the enterprise optics market.

"At a time when all of the key market players are evaluating the tradeoffs between electrical and optical interconnects,

All of the key market players are evaluating the tradeoffs between electrical and optical interconnects

Samir will be instrumental in expanding our partnerships and strategic relationships in the data-center and high-performance computing markets," says president & CEO Jean-Louis Malinge.

"With its low power, compact size and WDM scalability, Kotura's 100Gb/s optical engine offers the best silicon photonics solution," claims Desai. "I look forward to working with the Kotura team as we unlock the company's full potential to develop integrated optoelectronic solutions that provide increased processing speed, reduced heat and energy consumption, and lower costs."

Lately, Desai was responsible for active optics global business development at TE Connectivity. He has led two business acquisitions: one for Primarion Opto Group to Zarlink Semiconductor in 2006; one for Zarlink's optical communication group to TE in 2010. Desai started his career at QLogic Corp, where he held several growing responsibilities in applications engineering, product marketing, and leading the fiber channel marketing group. Desai has a bachelor's degree in electrical engineering from California State University, Fullerton.

www.kotura.com

IN BRIEF

Kotura stresses role of government initiatives in opto manufacturing

The future of US optoelectronics manufacturing was spotlighted during a one-day industry-centric workshop on 5 March at OFC/NFOEC 2012 (Optical Fiber Communication Conference & Exhibition/National Fiber Optic Engineers Conference) in Los Angeles. Sponsored by the Optoelectronics Industry Development Association (OIDA), the workshop gathered industry and government players with the aim of ensuring that the industry's voice is heard and has a partner in government. Decision makers from both the government and private sector spoke, including Kotura.

"With the escalating end-user demand for bandwidth, coupled with pricing pressures, the industry needs new ideas and new technologies," believes Kotura's chief technology officer Mehdi Asghari, who spoke at the workshop. "Our manufacturing focus is one of innovation, integration and automation. We believe there is a role for government partnership in these areas," he adds.

The first part of the workshop featured talks from public and private companies, academia and the financial community offering their perspectives, followed by technology-focused presentations of relevance to optoelectronic manufacturing. Along with Kotura, speakers included representatives from organizations such as the US Defense Advanced Research Projects Agency (DARPA), the National Institute of Standards and Technology (NIST), Finisar, Infinera, and Carnegie Mellon University.

www.oida.org/events/manufacturing12

CyOptics selects Verian's requisition and workflow automation software to enhance SAP functionality

Verian of Charlotte, NC, USA says that it is providing requisition and workflow automation solutions to CyOptics Inc of Lehigh Valley, PA, USA, which makes indium phosphide (InP)-based and silica-on-silicon optical chips and components.

"Our employees needed a faster and easier way to make requisitions and route them for approval," says CyOptics' procurement director Kim Leader. "The Verian system will serve as a requisitioning and approval workflow tool that integrates directly into SAP."

CyOptics designs and develops a full line of InP optical chips and components for integration into access, metro and long-haul communications. Its products are enabled by an automated 'nano-tech'-capable manufacturing process that, it is claimed, delivers optimum performance, uniformity

and cost. The ISO9001:2008-certified firm's InP design, device fabrication and packaging operations are in Lehigh Valley, PA; its silica photonic lightwave circuit (PLC) fab is in South Plainfield, NJ; and its planar automated packaging & testing operations are in Matamoros, Mexico.

"We're seeing a growing demand in the marketplace for a requisitioning and approval workflow tool that integrates easily with SAP, Oracle or other ERP [enterprise resource planning] systems," says Verian's senior product

We're seeing a growing demand in the marketplace for a requisitioning and approval workflow tool that integrates easily with SAP

manager Ganesh Sundaresan. "CyOptics will be the third customer this year to integrate Verian's requisitioning and approval workflow solutions into SAP. Organizations are finding Verian's solutions are much easier to learn and adopt than tools within the major ERP systems," he claims.

The flexibility and modular nature of Verian's purchasing and invoice processing allows customers like CyOptics to choose only the modules and functionality they need from Verian's full suite of purchasing and invoice processing solutions, the firm says.

"We look forward to helping CyOptics increase their visibility into SG&A [selling, general & administrative] expenditures," says Verian's president & CEO Tehseen Ali Dahya.

www.Verian.com

www.CyOptics.com

Infinera's losses grow as revenue falls 6.5% in Q1

Shipment of new 500G platform to boost revenue in second-half 2012

For first-quarter 2012, Infinera Corp of Sunnyvale, CA, USA, a vertically integrated manufacturer of digital optical network systems incorporating its own indium phosphide-based photonic integrated circuits (PICs), has reported revenue of \$104.7m, down 6.5% on \$112m last quarter but up 12.7% on \$92.9m a year ago.

An internet content provider was the sole greater-than-10% customer, while three wholesale carriers and one cable company completed the top five customers. The firm also added four new customers for its DTN platform. In addition, Telstra International became the first announced DTN 40G customer. Q1 also saw the start of the Telcordia OSMINE certification process to satisfy a North American tier-1 carrier request.

"Activity in our first quarter reflected demand from our customers for both our existing and next-generation platforms," says president & CEO Tom Fallon.

On a non-GAAP basis, gross margin has fallen further, from 48% a year ago and 42% last quarter to 40%. Net loss has risen from \$4m (\$0.04 per share) a year ago and \$6.7m (\$0.06 per share) last quarter to \$11.2m (\$0.10 per share).

"Our new 500G PIC-based DTN-X platform, with super-channels and integrated OTN (optical transport network) switching, is generating strong inter-

Our first quarter reflected demand from our customers for both our existing and next-generation platforms

est among potential and existing customers, who now have a choice between our DTN and DTN-X," says Fallon. "As planned, we are on track to ship the new platform by the end of the June quarter and to begin revenue recognition in the second half of this calendar year," Fallon adds.

"We are pleased to have announced our first DTN-X win, with Cable&Wireless Worldwide, a new tier-1 UK-based customer," says Fallon. "In total, we have received DTN-X purchase orders from four customers, including Cable&Wireless and three existing customers," he adds. "We are very pleased with the early traction with this new product, as we believe this is the first step toward our ushering in a new era in network optical infrastructure."

www.infinera.com

NeoPhotonics' revenue grows 8% year-on-year in Q1

For first-quarter 2012, NeoPhotonics Corp of San Jose, CA, a vertically integrated designer and manufacturer of both indium phosphide (InP) and silica-on-silicon photonic integrated circuit (PIC)-based modules and subsystems, has reported record Q1 revenue of \$54.2m, down 5% on \$57.2m last quarter but up 8% on \$50m a year ago (and above the expected \$46–51m).

Results exceeded projected ranges for revenue, gross margin and earnings per share. "We experienced continued strong demand in our speed and agility product categories, particularly for coherent 40G and 100G products, as deployments of faster networks continue to proliferate globally," says chairman, president & CEO Tim Jenks. Overall, 40/100G products exceed 10% of total company revenue for the second consecutive quarter.

"We are also pleased with the demand for products we acquired from Santur Corp [in October 2011], particularly InP-based PIC products such as tunable lasers," says Jenks. "Revenue and gross profit from those products continued to grow from the prior quarter as new customer engagements since the acquisition have started to generate revenue and existing customer engagements have continued to expand," he adds.

During the quarter, NeoPhotonics announced completion of phase 1 in

its plan to significantly increase production capacity of narrow-linewidth tunable lasers (NLW-TL) in support of rapidly growing demand. The firm has doubled NLW-TL output since initiating the production plan in fourth-quarter 2011. Demand for these products has outstripped industry capacity due to the rapid uptake of coherent optical technology coupled, with industry supply constraints attributable to the flooding in Thailand in October 2011.

On a non-GAAP basis, gross margin has fallen further, from 25.8% a year ago and 23.5% last quarter to 23.9% (though above the expected 20–22%). Loss from continuing operations was \$5.4m (\$0.22 per diluted share), an improvement on \$6.4m (\$0.26 per diluted share) last quarter, although still down on break-even a year ago. During the quarter, total cash, cash equivalents and short-term investments fell from \$86.4m to \$83.8m, due mainly to cash used in operations, partially offset by strong collections, and scheduled debt payments.

During the quarter (in early March), NeoPhotonics announced sample availability of its PIC-based Multicast Switch for next-generation ROADM (reconfigurable optical add/drop multiplexer) applications. The Multicast Switch is intended to build on current WSS (wavelength selective switch) and ROADM technology to enable next-generation

'colorless, directionless and contentionless' (CDC) networks.

As of the end of first-quarter 2012, NeoPhotonics had substantially completed the integration of Santur. Since the acquisition, NeoPhotonics has combined the respective organizations, consolidated certain operations, merged ERP (enterprise resource planning) systems, eliminated redundancies, and trained and engaged the respective firms' sales channels to support the expanded product offerings.

For second-quarter 2012, NeoPhotonics expects revenue to rise to \$55–61m and gross margin to be 23–25%. The firm also expects diluted loss per share from continuing operations to be cut to \$0.14–0.22.

Also, after the end of Q1/2012 (at the end of April), NeoPhotonics announced that it has received an investment of \$39.8m in gross proceeds from RUSNANO, a \$10bn sovereign investment corporation based in Moscow, Russia. RUSNANO acquired 4.97 million newly issued common shares in a private placement at a price per share of \$8. NeoPhotonics intends to use the net proceeds to establish design and production capabilities in Russia for the benefit of its global organization and for general corporate purposes.

www.neophotonics.com

M/A-COM showcases new products at Fiber Optics Expo

At the Fiber Optics Expo (FOE 2012) tradeshow in Tokyo, Japan in April, M/A-COM Technology Solutions Inc of Lowell, MA, USA (which makes analog semiconductors, components and subassemblies for RF, microwave and millimeter-wave applications) showcased its portfolio of new products for optical communications and networks.

Products on display include two new modulator drivers and transimpedance amplifiers (TIAs) for

10G, 40G, and 100G systems.

The MAOM-002204 100GbE modulator driver is an ultra-low-power integrated quad-channel driver that includes four 28G EML drivers in one surface-mount package.

The firm's portfolio of 100G coherent modulator drivers has been developed for 100G DP-QPSK applications. The drivers are available as single- or dual-channel in surface-mount packages, or as a quad-channel in a GPPO package, such

as the new MAOM-003105, which has low power consumption (4W for four channels @ 6V_{pp}) and gain of more than 30dB.

Both the MAOM-002204 100GbE and MAOM-003105 100G DP-QPSK 4-channel modulator drivers were launched at March's Optical Fiber Communication Conference & Exhibition/National Fiber Optic Engineers Conference (OFC/NFOEC 2012) in Los Angeles.

www.macomtech.com

Oclaro's growth constrained by Thailand flood recovery and Shenzhen plant stoppage

June quarter to complete recovery; cash reserves to be boosted by transition of assembly to Malaysia

For its fiscal third-quarter 2012 (to end-March), optical communications and laser component, module and subsystem maker Oclaro Inc of San Jose, CA, USA has reported revenue of \$88.7m, up 2.5% on \$86.5m last quarter (returning to growth after last quarter's drop of 18%). However, this is still down 23% on \$115.7m a year ago and below the guidance of \$90-97m.

Revenue and operating results continued to be materially impacted by October's flooding at Thailand-based primary contract manufacturer Fabrinet Co Ltd (which made 30% of Oclaro's total finished goods). However, revenue was also adversely impacted by about \$4m due to a 10-work-day stoppage in Oclaro's back-end assembly & test facility in Shenzhen, China (which has since been resolved and is back in full production). "Unfortunately, this work stoppage is becoming more common in this part of China," comments chairman & CEO Alain Couder.

Flood recovery is largely completed, with commercial shipments re-starting (at Fabrinet's Pinehurst facility) for high-power lasers in November, tunable dispersion compensators at the end of January, and amplifiers in December (all now back to pre-flood production capacity). However, two product lines — lithium niobate external modulators and wavelength-selectable switches (WSS) — will only return to full capacity in June. Commercial shipments re-started for modulators in January (from Pinehurst) and for WSS products in May (but only from Oclaro's alternative facilities in the West).

Although down on \$47.4m a year ago, revenue from Amplification, Filtering and Optical Routing (amplifiers, micro-optics, dispersion compensation, WSS modules and subsystems and ROADM line-cards)

has rebounded from a low of \$20.6m last quarter to \$23.6m, due mainly to increased production output on flood recovery product lines.

While down on \$33.9m a year ago, revenue from Telecom Components (lasers, modulators, laser pumps, receivers, and integrated lasers and modulators) has rebounded from \$22.3m last quarter to \$23.5m, due partly to initial shipments of 10G modulators that had been impacted by the flood previously.

Although still up on \$24.9m a year ago, revenue from Transmission Modules (10G and 40G transponders and transceivers) has fallen back from \$31.4m last quarter to \$28.3m, with 40G relatively flat and a decrease in the 10G product.

Revenue from Industrial & Consumer products has rebounded from a low of \$12.2m last quarter to \$13.3m, with high-power laser revenue up due to flood recovery, and vertical-cavity surface-emitting lasers (VCSELs) for consumer applications up after a seasonally weaker December quarter.

Fujitsu was the only greater-than-10% customer, at 16%, leaving "a nice diversification of our remaining revenues broadly across our other major customers", says Couder. However, the mix of 10% customers (which last quarter included Infinera and Ciena, and previously Huawei and Alcatel) has been atypical in the short term, following the Thailand flood, which affected customers varying according to their mix of product types and the corresponding manufacturing sites.

"Despite lower-than-forecasted revenues resulting from a short-term work stoppage in our China factory, progress with our cost-reduction and margin improvement initiatives enabled Oclaro to achieve gross margin and adjusted EBITDA within

the guidance ranges we provided on 26 January [of 14–19% and negative \$13.5–9m, respectively]," says Couder.

On a non-GAAP basis, gross margin of 15.9% is down from 24.9% a year ago but showing recovery from last quarter's 13% as the firm makes "meaningful progress towards pre-flood levels" (especially as March is usually a challenging quarter because much of the new customers pricing takes effect on 1 January).

R&D expenses have been cut further, from \$16.7m last quarter to \$14.7m as a result of cost-control efforts. Selling, general & administrative (SG&A) expenses were \$14m, up from \$13.5m last quarter. However, this was down on the average of \$15.9m for the three prior quarters.

Although still worse than \$3.3m a year ago, operating loss has been cut from \$18.9m last quarter (excluding \$9.1m of write-offs and expenses due to the flooding in Thailand) to \$14.6m (excluding a net gain of \$3.3m, comprising \$6.4m from preliminary insurance advances, offset by \$3.1m of flood related expenses).

Although still down on a profit of \$0.7m a year ago, adjusted EBITDA has improved from –\$14.3m last quarter to –\$9.9m. This bottom-line improvement of \$4.4m (on revenue growth of just \$2.2m) shows that profitability improvement initiatives are having an effect, says the firm. Non-GAAP net loss has been cut from \$17.4m last quarter to \$15.5m (although this is still worse than \$4.5m a year ago).

Capital expenditure (CapEx) was \$6.8m, mostly related to flood recovery. During the quarter, cash, cash equivalents and restricted cash fell from \$54.2m to \$51.1m. This included the \$6.4m from the

► flood-related preliminary insurance advance plus an additional \$6m drawn under the firm's \$45m credit facility (making a total outstanding balance of \$25.5m drawn).

In addition, Oclaro expects to receive substantial additional insurance proceeds in calendar second-half 2012. It also expects the June quarter to generate \$10–15m of cash as a result of starting the transition (over the next three years) of assembly & test operations in Shenzhen to the Malaysia facility of Singapore-based contract manufacturer Venture Corporation Ltd (announced on 21 March). "The move to Malaysia will provide us with a much more stable manufacturing environment," reckons Couder. Oclaro is actively marketing its Shenzhen building for sale (with production there expected to cease in last-quarter 2013).

For fiscal fourth-quarter 2012 (to end-June), Oclaro expects revenue to continue to recover, to \$100–109m, despite still being impacted slightly by the flood. Gross margin should recover to 19–23%, and adjusted EBITDA to negative \$6.5–1.0m. CapEx should be within \$6m per quarter on an ongoing run rate (much less than pre-flood periods).

Guidance is based on performance as a standalone firm and does not include any of the operating results of optical component, module and subsystem maker Opnext Inc of Fremont, CA, USA, with which Oclaro in late March agreed a merger (which should make the combined firm the second largest optical component and module maker). The transaction is due to close in July.

"As part of the synergies, we will be moving their manufacturing out of Japan and out of California," says Couder regarding Opnext. "We will reduce the number of suppliers for our customers and provide them with a larger and more stable supplier," he adds. "We plan to be non-GAAP operating margin positive in the December 2012 quarter and to realize \$35–45m of analyzed synergy by the December 2013 quarter."

www.oclaro.com

NeoPhotonics receives \$39.8m strategic investment from RUSNANO

Photonic integrated circuit-based firm to establish design and production capabilities in Russia by end-July 2014

NeoPhotonics Corp of San Jose, CA, a vertically integrated designer and manufacturer of both indium phosphide (InP) and silica-on-silicon photonic integrated circuit (PIC)-based modules and subsystems for bandwidth-intensive, high-speed communications networks, has received an investment from RUSNANO, a \$10bn sovereign investment corporation in Moscow, Russia.

Founded in March 2011 as an open joint stock company through a reorganization of the state corporation Russian Corporation of Nanotechnologies and owned by the Government of the Russian Federation, RUSNANO's purpose is to develop the Russian nanotechnology industry through co-investment in nanotechnology projects with economic potential or social benefit.

RUSNANO acquired 4.97 million newly issued common shares of NeoPhotonics in a private placement transaction at a price of \$8 per share for gross proceeds of \$39.8m. The firm's per-share closing trading price on 27 April was \$4.49. The shares are restricted from resale pursuant to a lockup agreement for up to two years, at the end of which the firm is obligated to register the shares for potential resale. NeoPhotonics has also appointed RUSNANO's managing director Sergey Polikarpov to its board of directors.

"We welcomed this investment as it aligns with our strategy to accelerate growth globally, with particular emphasis on fast-growing and emerging markets, including in Russia and the CIS [Commonwealth of Independent States] countries," says NeoPhotonics' chairman, president & CEO Tim Jenks.

"Not only are these markets deploying high-speed, agile and fiber-to-the-home [FTTH] networks but we are also seeing more of our customers target service providers and invest locally in Russia and more broadly in Eastern Europe," he adds. "We started to see and investigate this growth opportunity several years ago, and we added sales capability in the region and have since been engaged with and supplying several customers in Russia. With the planned support from RUSNANO, we believe that NeoPhotonics is well positioned to capitalize on new and greater opportunities in the region," continues Jenks.

"One of the unique advantages of NeoPhotonics is its vertically integrated design and manufacturing processes for photonic integrated circuit-based products," notes Polikarpov. "The company's planned research and production facilities in Russia are intended to be able to perform a wide range of steps from PIC development to processing and fabrication... with our support in Russia, we can further enhance the company's development cycles and shorten the time for broader adoption for NeoPhotonics products in Russia and the global market," he believes.

NeoPhotonics intends to use a portion of the net proceeds from the sale of the shares for general corporate purposes as well as to establish design and production capabilities in Russia for the benefit of the global organization. The expansion in Russia is targeted for completion by end-July 2014, and is not expected to have a material impact on results of operations in 2012.

www.neophotonics.com

www.rusnano.com

GigOptix grows product revenue for 10th quarter

Growth driven by demand for 40G and 100G optical products and datacom parallel devices

For first-quarter 2012, GigOptix Inc of San Jose, CA, USA (a fabless supplier of semiconductor and optical components for high-speed information streaming) has reported a tenth consecutive quarter of sequential growth in product revenue, to \$9.2m. This is up 7% on \$8.6m last quarter and up 30% on \$7.1m a year ago (or up 19% on \$7.7m a year ago, including government contract revenue of \$0.6m, which comprised 8% of total revenue).

On a non-GAAP basis, net loss has been cut further, from \$432,000 a year ago and \$414,000 last quarter to \$409,000. Correspondingly, adjusted EBITDA (earnings before interest, taxes, depreciation and amortization) has risen further, from \$38,000 a year ago and \$279,000 last quarter to \$515,000. However, during the quarter, cash and investments fell from \$16.2m to \$15.8m.

"We are pleased to report strong revenue growth with improved EBITDA, good cash management and closely managed expenses in the first quarter," says chairman & CEO Dr Avi Katz. "Our continued growth is attributed to the important strategic progress that we are making in each of our three product lines — extending our optical product offerings from telecom to datacom and consumer electronics; further expanding our RF-MMICs product offering into the E-band and wide-band markets; and extending our ASIC focus into the development of high-speed CMOS drivers and receivers for the consumer market through the combined efforts of our optical and ASIC engineering lines," he adds. "We also continued to make progress in productizing our 40G and 100G offerings, specifically through our bundled solutions, and in moving these to production with global tier-1 communication

customers," Katz continues.

"In addition, we have met another major milestone in our 5 year strategic plan for GigOptix that was launched with the inception of the company in 2007: being traded on a national exchange through our recent listing [in late April] on the NYSE Amex," says Katz. "We expect that our NYSE Amex listing will provide GigOptix with access to new sources of capital and our stockholders with a more efficient market in which to trade. In concert with our listing on NYSE Amex, we announced the extension of the modified 'Dutch auction' tender offer to purchase up to \$2m of common stock through 15 May," he adds.

GigOptix is maintaining its outlook for full-year revenue growth of about 30%, driven by strong demand for its 40G and 100G optical products and datacom parallel devices.

www.gigoptix.com

Sales presence expanded into South America and Eastern Europe

GigOptix has expanded its global sales presence with customer engagements in both Eastern Europe and South America.

Chairman & CEO Dr Avi Katz and chief technology officer Andrea Betti-Berutto were invited to participate in the Government-Industry workshop 'Towards Terabit per Second Optical Networking: International Workshop on Trends in Optical Technologies' in San Paulo, Brazil on 9-10 May, and Betti-Berutto presented the GigOptix technology approach to the topic. GigOptix says that its participation in the workshop closely complements the growing interest in its products for 100G and beyond in the region.

Also, GigOptix is now shipping production units of its LX8901 and LX8220, a 100G DPSK and a 40G

DQPSK Thin Film Polymer on Silicon (TFPS) Mach-Zehnder modulator, respectively, to aerospace and communication customers in Eastern Europe. "The LX8901 is unique in that it provides a low drive voltage over a very wide optical bandwidth of up to 65GHz, making it uniquely suited for a number of ultra-high-frequency applications in the field of microwave photonics, such as antenna remoting, RF beam steering and ultra-high-frequency signal sampling," says Betti-Berutto.

"Five years ago, GigOptix's customer base was located in the tra-

Five years ago, GigOptix's customer base was located in the traditional optical development centers

ditional optical development centers, mainly in North America and Europe," notes VP of marketing Padraig OMathuna. "It is exciting to see the growth in optical communication development as we have extended our reach to the Japanese and Chinese markets over the last couple of years, and now spreading into the new fast-growing regions," he adds.

"GigOptix is dedicated to supporting the growth of high-speed end-to-end information streaming targeting telecom and datacom optical communications, military, aerospace, ASIC and RF microwave and millimetre-wave systems, and we look forward to working closely with these highly innovative new companies as they expand into new optical communication markets."

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Emcore's Fiber Optics revenue rises 20% sequentially

Further growth of 10–20% expected in June quarter as Thailand flood recovery progresses

For its fiscal second-quarter 2012 (to end-March), Emcore Corp of Albuquerque, NM, USA, which makes components, subsystems and systems for the fiber-optic and solar power markets, has reported revenue of \$37.8m. This is down 20% on \$47.2m a year ago and below guidance of \$38–40m, but up 1% on last quarter due mainly to higher Fiber Optics revenue, offset partially by a reduction in Photovoltaics business.

After falling from 59% of total revenue in the September quarter to just 49% in the December quarter, the Fiber Optics segment rebounded to 58%. Fiber Optics revenue was \$21.9m, down 27% on \$30m a year ago but up 20% on \$18.3m last quarter. This was due mainly to initial recovery efforts after last October's flooding in Thailand that suspended operations at primary contract manufacturer Fabrinet Co Ltd (which normally accounts for half of Emcore's Fiber Optics revenue), submerging most of Emcore's process and test equipment as well as its inventory materials, and significantly impacting its ability to meet demand for fiber-optics products. "We are currently on schedule and focused on rebuilding the manufacturing infrastructure for our impacted product lines," says Emcore.

Although unaffected by Thailand's floods, the Photovoltaics segment fell from 51% of total revenue last quarter to 41% (reverting to the level of the September quarter). Photovoltaics revenue was \$15.8m, down 8% on \$17.2m a year ago and 17% on \$19.1m last quarter due to a postponement (to the latter part of 2012) in shipping a large satellite solar cell order worth more than \$4m to an international customer. However, Photovoltaics revenue has historically fluctuated significantly due to the timing of program completions and product shipments of major orders, notes the firm.

Although down from 22.4% a year ago, gross margin has risen from just 9.3% last quarter to 14.2%, due mainly to improved operational efficiency and the Fiber Optics segment's recovery. Fiber Optics gross margin was 9.4%, down from 18% a year ago but recovering from the flood-hit –4.8% last quarter. Photovoltaics gross margin has fallen further, from 30.2% a year ago and 22.7% last quarter to 20.9% due to the lower revenue base.

Lower fiber-optics-related revenue due to the flood resulted in higher manufacturing overhead as a percentage of revenue. Manufacturing of certain fiber-optics-related components was moved to Emcore-owned facilities in the USA, involving higher labor and other related costs. Instead of completely rebuilding all flood-damaged manufacturing lines, it was decided to realign the fiber-optics product portfolio and focus on business areas with strong technology differentiation and growth opportunities.

During the March quarter, the firm identified \$0.4m of inventory on order related to manufacturing product lines for legacy products that were destroyed by the flood and will not be replaced.

It was decided to realign the fiber-optics product portfolio and focus on business areas with strong technology differentiation and growth opportunities. The firm identified \$0.4m of inventory on order related to manufacturing product lines for legacy products that were destroyed by the flood and will not be replaced

Although up from \$4.7m on a year ago, operating loss has been cut from \$2.8m last quarter to \$8.9m, due mainly to the improved gross margin as well as a decrease in flood-related losses from \$5.7m last quarter to just \$0.1m.

Also, there has been a reduction from about \$1m last quarter to \$0.2m in operating losses related to the Suncore concentrated photovoltaic (CPV) component- and system-making joint venture with San'an Optoelectronics Co Ltd in Xiamen, China.

Although up on \$4.1m a year ago, net loss has been reduced from \$14.2m last quarter to \$9.3m. As of end-March, cash, cash equivalents and restricted cash totaled \$25.4m, and working capital totaled \$13.5m. Net cash fell significantly from last quarter, due mainly to increased inventory levels (to meet the ramp up in production), equipment purchases associated with the Fiber Optics production line rebuild, and operating losses.

As of end-March, order backlog for Photovoltaics totaled \$55.7m, up 8% on \$51.7m last quarter, driven partly by an increase in orders for satellite solar cells. The backlog includes \$10.1m of terrestrial solar cell orders from Suncore. However, in the Fiber Optics segment, revenue is still constrained by the rebuilding of production capacity. Since order backlog exceeds what it can fulfill, Emcore says it is hence not using backlog as a measure of Fiber Optics business at this time.

Regarding October's flood, Emcore is rebuilding the impacted production lines at another Fabrinet site in Thailand (Pinehurst, instead of the nearby Chokchai facility) as well as at its own manufacturing facility in China. The new CATV production line in China is online and manufacturing products to meet customers demand. The new production line at Fabrinet for narrow-linewidth ➤

► lasers for coherent 40 and 100Gb/s transmission applications has been up and running since early March (ahead of the original schedule); products have passed Telcordia qualification requirements, and customers are completing their qualification and starting to take shipments, says the firm.

Near the end of the quarter, on 27 March, Emcore agreed to sell certain assets and to transfer certain obligations associated with its Fiber Optics segment's vertical-cavity surface-emitting laser (VCSEL)-based product lines 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) in exchange for \$17m in cash. The assets include inventory, fixed assets (including the VCSEL fab in Albuquerque) and intellectual property. The product lines include VCSEL and

For fiscal Q3 (to end-June), Emcore expects revenue of \$38–41m, due to a further 10–20% recovery in Fiber Optics production capacity and higher shipment from the Photovoltaic business

photodiode components, parallel optical transceiver modules, and active optical cables (AOCs), which collectively yielded \$4.3m of revenue in the March quarter. The asset sale was completed on 8 May.

For its fiscal third-quarter 2012 (to end-June), Emcore expects revenue of \$38–41m, due to a further 10–20% recovery in Fiber Optics production capacity and higher shipment from the Photovoltaic business. Including the contribution of VCSEL-based products (being sold to Sumitomo) for the entire quarter would raise revenue to \$42–45m, up 15% on the March quarter's \$37.8m.

www.emcore.com

Emcore samples micro-ITLA tunable laser for coherent applications

At the Optical Fiber Communication Conference & Exhibition/National Fiber Optic Engineers Conference (OFC/NFOEC 2012) in Los Angeles in March, Emcore said that it had begun sampling customers for qualification of its new micro-integrable tunable laser assembly (ITLA), which it expects to be at full production in fall 2012.

The micro-ITLA is based on Emcore's external-cavity laser (ECL) ITLA technology, which is claimed to be the most widely used tunable laser source for high-speed 40 and 100Gb/s coherent transmission systems due to its narrow

linewidth, low noise and frequency accuracy. Additional standard features include a grid-agnostic channel plan, off-grid tuning, and in-operation power and frequency adjustment capability.

The micro-ITLA integrates proprietary cooled ECL technology in a miniaturized package that offers all the benefits of Emcore's ITLA in a form-factor that is three times smaller with 25% less power consumption. It also comes with a standard ITLA RS-232 digital user interface, allowing technology-independent control. The smaller form-factor and reduced power

consumption enable users to design higher densities and improved performance into their coherent system, says the firm.

"Leveraging Emcore's field-proven ClearLight ECL technology in an ultra-small form-factor, the micro-ITLA represents a dramatic next step in tunable laser technology," claims VP of business development Jaime Reloj. "By leveraging our in-house semiconductor design and manufacturing, we continue to provide our customers with highly differentiated tunable laser solutions for high-performance telecom applications."

Ball Aerospace awards Emcore \$6m solar panel manufacturing contract

Emcore has been awarded a contract by Ball Corp subsidiary Ball Aerospace & Technologies Corp (BATC) to design, manufacture, test and deliver solar panels for a new spacecraft. BATC designs and manufactures aerospace systems including spacecraft, instruments, RF & microwave technologies, and data exploitation solutions for governmental and commercial customers. The period of performance for the program is about two years,

with a total contract value of nearly \$6m.

The solar panels will be populated with Emcore's ZTJ multi-junction solar cells, which are claimed to be the highest-performance space-grade solar cells in volume production available to the global market.

"Our proven manufacturing capability, technology leadership and high-reliability solar panels make Emcore the supplier of choice for demanding spacecraft power sys-

tems," reckons Emcore's chief operating officer Christopher Larocca.

With a beginning-of-life (BOL) conversion efficiency nearing 30% and the option for a patented, onboard monolithic bypass diode, Emcore's multi-junction solar cells provide the highest available power to interplanetary spacecraft and earth-orbiting satellites, it is claimed.

www.ballaerospace.com

www.emcore.com

Luminescent 'LED-type' solar cell design breaks efficiency record

To produce the maximum amount of energy, solar cells are designed to absorb as much light from the Sun as possible, but researchers from the University of California, Berkeley (UCB) have now demonstrated a counter-intuitive concept: solar cells should be designed to be more like LEDs, able to emit light as well as absorb it.

The findings were presented in paper CF2J.1 'The Opto-Electronics which Broke the Efficiency Record in Solar Cells' by Eli Yablonovitch and Owen D. Miller at May's Conference on Lasers and Electro Optics (CLEO 2012) in San Jose, CA.

"The better a solar cell is at emitting photons, the higher its voltage and the greater the efficiency it can produce," says principal researcher Yablonovitch, professor of electrical engineering.

The researchers say that since 1961 scientists have known that, under ideal conditions, the absolute limit to the amount of electrical energy that can be harvested from sunlight hitting a typical solar cell is, theoretically, about 33.5% (i.e. 33.5% of the energy from incoming photons can be absorbed and converted into useful electrical energy).

Yet researchers were unable to come close to achieving this efficiency: as of 2010, the highest achieved was just more than 26% (flat-plate, single-junction solar cells, which absorb light above a specific frequency, rather than multi-junction cells with multiple layers and absorption frequencies, which can achieve higher efficiencies).

More recently, Yablonovitch and his colleagues aimed to understand why there has been such a large gap between the theoretical limit and the limit that researchers have been able to achieve. As they worked, a 'coherent picture emerged', says graduate student and group member Owen Miller. They came across a relatively simple, yet counterintu-



An Alta Devices solar cell. (Photo: Joe Foster, Alta Devices).

itive, solution based on a mathematical connection between absorption and emission of light.

"Fundamentally, it's because there's a thermodynamic link between absorption and emission," Miller says. Designing solar cells to emit light — so that photons do not become 'lost' within a cell — has the natural effect of increasing the voltage produced by the solar cell. "If you have a solar cell that is a good emitter of light, it also makes it produce a higher voltage," which in turn increases the amount of electrical energy that can be harvested from the cell for each unit of sunlight, he adds.

The theory that luminescent emission and voltage go hand in hand is not new, but the idea had never been considered for the design of solar cells before now, Miller continues.

In the past year, Alta Devices of Santa Clara, CA, USA, which was co-founded by Yablonovitch in 2007, used the new concept to create a prototype solar cell made of gallium arsenide (GaAs) that raised the efficiency record from 26% to 28.3%. The firm achieved this mile-

stone partly by designing the cell to allow light to escape as easily as possible — using techniques that include, for example, increasing the reflectivity of the rear mirror, which sends incoming photons back out through the front of the device.

Solar cells produce electricity when photons from the Sun impact the semiconductor material within a cell. The energy from the photons knocks electrons loose from this material, allowing the electrons to flow freely. But the process of knocking electrons free can also generate new photons through luminescence. The idea behind the solar cell design is that these new photons — which do not come directly from the Sun — should be allowed to escape from the cell as easily as possible.

"The first reaction is usually, why does it help [to let these photons escape]?" Miller says. "Don't you want to keep [the photons] in, where maybe they could create more electrons?" However, mathematically, allowing the new photons to escape increases the voltage that the cell is able to produce.

The work is "a good, useful way" of determining how scientists can improve the performance of solar cells, as well as of finding creative new ways to test and study solar cells, says Leo Schowalter, co-founder & chief technology officer of Crystal IS Inc of Green Island, NY, USA and visiting professor at Rensselaer Polytechnic Institute (RPI), who is chairman of the CLEO committee on LEDs, photovoltaics, and energy-efficient photonics.

Yablonovitch hopes that researchers will be able to use the new technique to achieve efficiencies close to 30% in the coming years. Also, since the work applies to all types of solar cells, the findings have implications throughout the field.

<http://berkeley.edu>
www.altadevices.com

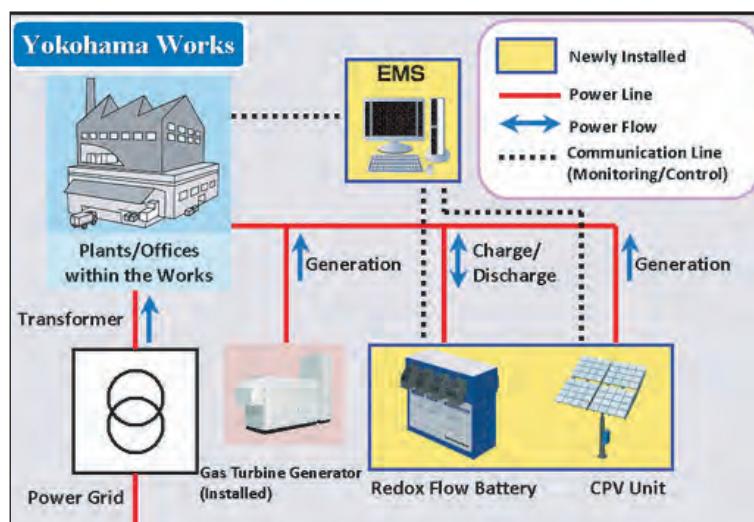
Sumitomo Electric building demo megawatt CPV power generation/storage system

Sumitomo Electric Industries Ltd (SEI) has developed a megawatt-class electric power generation/storage system consisting of what is claimed to be the world's largest redox flow battery and Japan's largest concentrated photovoltaic (CPV) units. The firm is currently constructing a facility to test the system at its Yokohama Works (Sakae-ku Yokohama), aiming to start the demonstration in July.

To meet the expected growth in demand for distributed power systems using renewable, SEI has been working on R&D of technology for effective power conversion/control and generation/storage. As part of its development, the firm started testing its micro smart-grid system at the Osaka Works last June. In this system, natural energy sources — including an in-house developed CPV system and a small redox flow battery — are DC-interconnected, and the energy management system (EMS) controls fluctuations in natural energy (excluding solar and wind power) and power consumption by relatively small electric loads (excluding lighting and home appliances). Consequently, the overall system enables the most reliable and efficient power control, particularly from the viewpoint of general consumers, it is claimed.

Recently, there has also been increasing expectation for major energy consumers, such as plants and companies, to promote the use of renewable energy and energy saving measures. In view of this, SEI has developed a large-scale electric power generation/storage system consisting of a redox flow battery and CPV units. The system with megawatt-level capacity and output power will be tested at the Yokohama Works with the aim of accelerating the development and commercialization of large power systems and related facilities.

The system consists of 28 CPV units (giving maximum total power



Megawatt-class power generation/storage system.

generation of 200kW) as energy sources and one redox flow battery (with a capacity of 1MW for 5 hours) as a storage facility for the CPV-generated power and low-cost electricity provided by power companies during the night, while connected to external commercial power networks. Using the EMS, the system aims to regulate the amount of electricity provided by power companies using the redox flow battery's charge/discharge control function. The system also targets systematic use of solar power by using the battery to balance the fluctuations in CPV power generation (which is susceptible to the weather).

The redox flow battery is a storage battery consisting of a charging/discharging cell section and a tank full of metal ion electrolyte. Charge/discharges is via oxidation–reduction of vanadium or other ions.

The battery has a long service life, as the electrodes and electrolyte are not subject to deterioration even after repeated charge/discharge operations. It is also easily maintained, as it uses the same electrolyte in both the cathode and anode. The battery is also claimed to provide increased safety, as it does not require any combustible substances and is operated at ambient temperatures. It is suitable for irreg-

during the night, the firm claims.

The CPV unit is a photovoltaic system incorporating small-size photovoltaic cells for energy conversion, directing high-intensity sunlight converged by a lens to photovoltaic cells. Since the CPV cells are made from compound semiconductor material, the power generation efficiency of the CPV panel is reckoned to be about twice that of silicon solar panels currently on the market. Installed in an elevated position, CPV panels provide a usable space beneath them. The newly developed CPV unit offers 7.5 times more output power (7.5kW/unit), yet the CPV panels are thinner and lighter than conventional panels.

The EMS monitors the amounts of electric power generated by the 28 CPV units, via commercial power networks, stored in a redox flow battery, and consumed at an office or plant in order to manage the electric power flow. The data obtained is sent by optical communication networks to be collectively controlled at the central control server. This system will be used in the demonstration test at Yokohama to achieve optimal balance between supply and demand (with maximum demand control of 1MW) as well as power demand control based on preset schedules.

<http://global-sei.com>

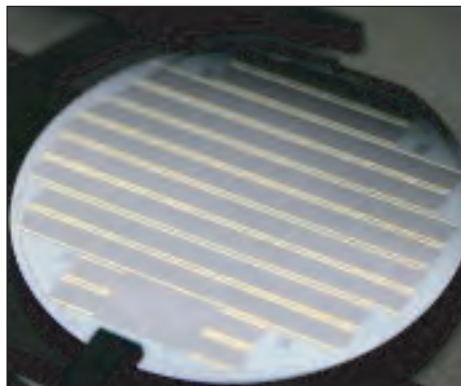
Solar Junction receives SUNPATH award from DOE

'Scaling Up Nascent PV At Home' award to aid expansion of CPV cell manufacturing

Solar Junction Corp of San Jose, CA, USA, a manufacturer of III-V multi-junction solar cells based on proprietary adjustable-spectrum lattice-matched (A-SLAM) materials for concentrated photovoltaics (CPV), has received a SUNPATH (Scaling Up Nascent PV At Home) award from the US Department of Energy (DOE) as part of a \$21.5m program to increase its CPV cell manufacturing capacity.

Through the program, Solar Junction is targeting a median cell efficiency of 42% on 150mm substrates. It is reckoned that these factors should make a substantial impact on reducing CPV's \$/Watt module costs by driving down the cost of the cell, while increasing the CPV module power output via increased cell efficiency.

"It is an honor to be in such a select pool of SUNPATH awardees



Wafer bearing Solar Junction's cells.

through the SunShot program," says CEO Jim Weldon. "This allows Solar Junction to move into the next

This allows Solar Junction to move into the next phase of commercialization and will allow for a path to volume manufacturing

phase of commercialization and will allow for a path to volume manufacturing."

SUNPATH falls under the DOE's SunShot Program, which aims to increase PV manufacturing in the USA through investments in technologies that are sustainable with competitive cost and high performance. SunShot investments are designed to help achieve \$1/Watt by 2020.

In February, Solar Junction announced a \$19.2m investment round, as well as an exclusive manufacturing agreement with epi-wafer foundry and substrate maker IQE plc of Cardiff, Wales, UK. The firm says that, coupled with the SUNPATH award, it is on a path to high-volume manufacturing of its A-SLAM cell.

www.sj-solar.com

www1.eere.energy.gov

IQE appoints VP of global projects to drive strategic agreement with Solar Junction

Epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK has appointed Russ Wagner as VP, global projects.

His initial responsibility will be to drive the strategic agreement with Solar Junction in support of IQE's strategy to become a global supplier of CPV wafers for solar power markets. The agreement (announced in February) will include the transfer of CPV technology, the establishment of wafer manufacturing capability, and the subsequent ramp into high-volume production, working closely with various teams around the globe.

Wagner has 20 years of semiconductor industry experience, most recently as VP of operations at gallium arsenide RF IC maker Anadigics Inc of Warren, NJ, USA. His previous positions include general manager of Fairchild Semi-



Russ Wagner, IQE's VP, global projects.

conductor's RF Power Group, VP business & strategic development at Raytheon RF Components, and VP finance & corporate development of Litton Systems Inc's Airtron Division. All of these roles included responsibility for the

strategic and tactical management of worldwide operations, partnerships, and corporate growth initiatives.

"Russ brings extensive industry experience and demonstrated success at creating value-generating partnerships to our team," says IQE's chief executive Dr Drew Nelson.

"I am confident that, under his leadership, IQE and SJC will achieve the goals we have set for our strategic relationship," he adds.

Wagner achieved his B.S. degree from the University of Dayton and pursued postgraduate work on the Litton Executive Education program at the Wharton School, University of Pennsylvania and the Raytheon Business Leadership program at the University of Chicago's Graduate Business School.

www.iqep.com



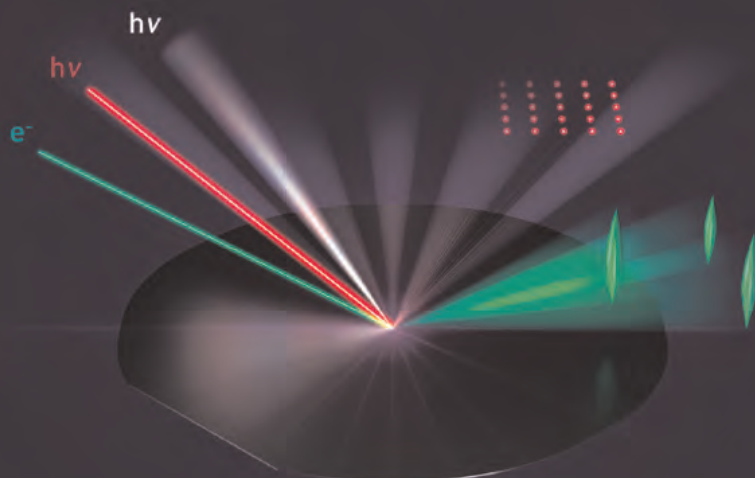
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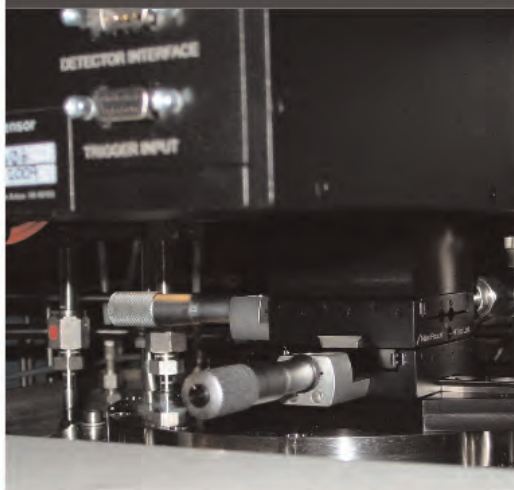
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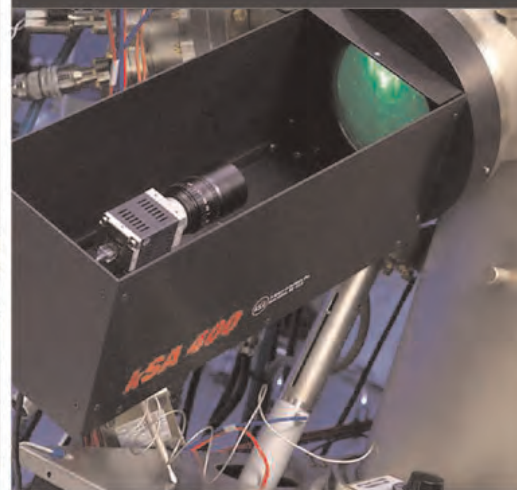
kSA BandiT Wafer Temperature



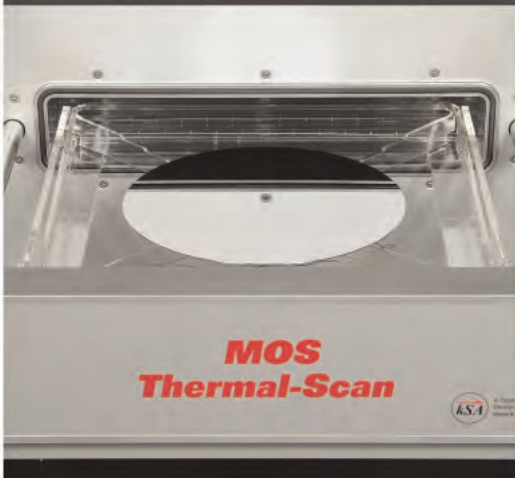
kSA MOS and kSA Mini-MOS Thin-Film Stress



kSA 400 Analytical RHEED



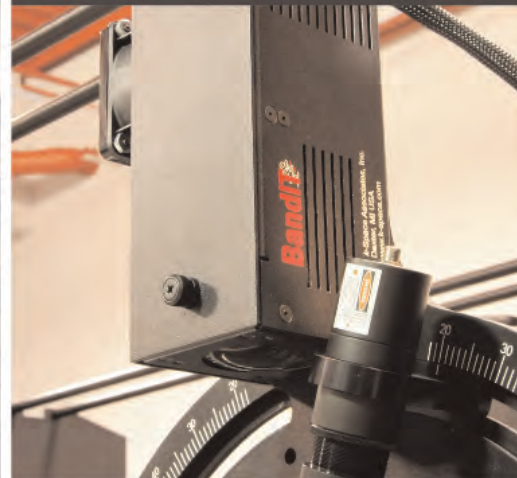
kSA MOS Ultra-Scan and Thermal-Scan Stress Mapping



kSA Rate Rat Pro Thickness & Deposition Rate



kSA BandiT PV Process Tuning



First Solar to close German manufacturing facility and idle four lines in Malaysia

Staffing cut of 30% to save \$100–120m annually at restructuring cost of \$245–370m

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 — is restructuring its operations in response to deteriorating market conditions in Europe and to reduce costs and align its organization with sustainable market opportunities.

As part of this program, in fourth-quarter 2012 First Solar will close its manufacturing operations in Frankfurt (Oder), Germany. Also, from 1 May it will indefinitely idle four production lines at its manufacturing center in Kulim, Malaysia. These actions, combined with other personnel reductions in Europe and the USA, will reduce the global workforce by about 2000 positions (about 30% of the total).

The restructuring initiatives are expected to reduce First Solar's costs by \$30–60m this year and \$100–120m annually going forward. In addition, the firm's average manufacturing cost is expected to improve to \$0.70–0.72 per watt in 2012 (under prior expectations of \$0.74 per watt). In 2013 the firm estimates that average module manufacturing costs will be \$0.60–0.64 per watt.

To achieve these cost savings, the firm will record restructuring and other related charges of \$245–370m (of which \$80–120m are cash expenditures), consisting of:

- \$150–250m in asset impairment, primarily related to the Frankfurt (Oder) plants;
- \$50–70m in severance;
- \$30m for repayment of a government grant related to the Frankfurt (Oder) operations; and
- \$15–20m for other charges representing valuation allowances for deferred tax assets in Europe and costs associated with the repayment of the German debt.

First Solar expects to incur these charges primarily during first-quarter 2012 and the rest over the course of this year. It has also voluntarily paid down about \$145m of debt ahead of schedule in 2012, representing repayment in full for outstanding amounts under the firm's German loan agreement.

"After a thorough analysis, it is clear the European market has deteriorated to the extent that our operations there are no longer economically sustainable, and maintaining those operations is not in the best long-term interest of our stakeholders," says chairman & interim CEO Mike Ahearn.

"Decisions like this are not easy, especially given how important the European markets and our associates in Europe have been to the development of our company and the solar industry as a whole. We are committed to treating all affected associates fairly, and to building our relationships with European business partners that are aligned with our strategy of pursuing utility-scale solar opportunities in sustainable markets around the world," he adds.

"The solar market has fundamentally changed, and we are quickly adapting our market approach and operations to maintain and build upon our competitive advantage," continues Ahearn. "After a period of robust growth, First Solar is scaled to operate at higher volumes than currently exist following the reduction of subsidies in key legacy markets. As a result, it is essential that we reduce production and decrease expenses to reflect the smaller volume of high-probability demand we forecast," he adds. "These actions will enable us to focus our resources on developing the markets where we expect to generate significant growth in coming years."

www.firstsolar.com

5N Plus' supply agreement unaffected by First Solar's restructuring

5N Plus Inc of Montreal, Québec, Canada, a producer of specialty metal and chemical products including cadmium and tellurium, has commented on the restructuring announced by cadmium telluride (CdTe) thin-film photovoltaic module maker First Solar Inc of Tempe, AZ, USA, in which it will close its manufacturing operations in Frankfurt (Oder), Germany in fourth-quarter 2012 and, from

1 May, indefinitely idle four production lines at its manufacturing center in Kulim, Malaysia.

"The supply agreement we have signed with First Solar at the beginning of the year is in no way impacted by this restructuring, and the manufacturing activities of our plant in Eisenhüttenstadt, Germany, are not compromised, as most of this facility's production was already being shipped to

First Solar's plants in Malaysia," says 5N Plus' president & CEO Jacques L'Écuyer.

"We do not foresee any reduction of our sales to First Solar in 2012, and the conditions of our agreement will provide us with the opportunity to fully benefit from the future growth of our customer in sustainable markets," L'Écuyer adds.

www.5nplus.com

First Solar's revenue falls 25% in Q1 to \$497m

Guidance raised for full-year 2012 earnings and operating cash flow

For first-quarter 2012, First Solar Inc of Tempe, AZ, USA, which makes thin-film photovoltaic modules based on cadmium telluride (CdTe) as well as providing engineering, procurement and construction (EPC) services, has reported net sales of \$497m. This is down 25% on \$660m last quarter (due mainly to lower volumes for module-only sales) and down 12% on \$567.3m a year ago (due also to lower average selling prices, offset partially by higher systems revenue).

Compared to net income of \$116m (\$1.33 per fully diluted share) a year ago, net loss has worsened from \$413.1m (\$4.74 per fully diluted share) last quarter to \$449.4m (\$5.20 per fully diluted share). However, this was impacted by \$5.12 per share by pre-tax charges consisting of:

- \$401m (reducing earnings per share by \$4.64) related to restructuring actions (including asset impairments) announced on 17 April, and
- \$43m (reducing earnings per share by \$0.48) related to costs in excess of normal warranty expense associated with a previously announced 2008 to 2009 manufac-

turing excursion (including about \$31m in accruals reflecting the completion of processing for all remaining claims during Q1).

Hence, on a non-GAAP basis (excluding charges), net loss was \$6.7m (\$0.08 per fully diluted share). This compares with net income of \$110m (\$1.26 per fully diluted share) last quarter and \$116m (\$1.33 per diluted share) a year ago. During the quarter, cash and marketable securities fell from \$788m to \$750m.

"First Solar's performance in the quarter was impacted by an aggressive competitive environment resulting from persistent supply/demand imbalances in the market, as well as restructuring costs that will improve our operating efficiency and help position us for the future," says chairman Mike Ahearn. The restructuring involves the

First Solar's performance in the quarter was impacted by an aggressive competitive environment resulting from persistent supply/demand imbalances

firm closing its manufacturing operations in Frankfurt (Oder), Germany and, from 1 May, idling indefinitely four production lines at its manufacturing center in Kulim, Malaysia.

Based on reductions in First Solar's ongoing cost structure related to the restructuring initiatives, the firm is increasing its full-year 2012 guidance for earnings per fully diluted share from \$3.75–4.25 to \$4.00–4.50 (excluding restructuring and impairment charges, and costs in excess of normal warranty expense) and for operating cash flow from \$800–900m to \$850–950m. Net sales are still expected to be \$3.5–3.8bn (up 30% on 2011's \$2.76bn).

"Looking forward, we are confident we have the right long-term strategy and the right platform to enable long-term growth and value creation," says Ahearn. "We believe that by executing our strategic roadmaps and completing our restructuring program we can achieve our targets of 2.6–3.0GW of sales in sustainable markets, earning a return on invested capital of 13–17% by 2016."

First Solar appoints chief commercial officer as CEO

First Solar has appointed James Hughes as CEO, succeeding founder & chairman Mike Ahearn (who has been interim CEO since last October and will continue as chairman). Hughes joined First Solar in March as chief commercial officer.

"Jim has been instrumental in developing the strategic plan that will enable us to compete and win in this new era for the solar industry, and it became clear he is the right person to lead the execution of that plan," says Ahearn. "Jim brings a wide range of experience that will be invaluable in leading our organization, having owned and operated utilities, built power

projects, cultivated partnerships, and led profitable growth in a wide array of key markets around the world," he adds.

Hughes has nearly 20 years of experience in the global energy industry. Before joining First Solar, he was CEO of AEI, which owned and operated power distribution, conventional and renewable power generation, natural gas transportation and natural gas distribution businesses in 19 countries. Prior to that, he was president & chief operating officer of Prisma Energy.

Hughes earned a juris doctor from the University of Texas at Austin School of Law, a Certificate

of Completion in international business law from Queen Mary's College, University of London, and a bachelor's degree in business administration from Southern Methodist University.

"First Solar is unrivaled in terms of talent and experience and has the premier platform from which to implement solar power at a meaningful scale around the world," believes Hughes. "The rapid cost reductions in the industry position solar at the threshold of the mainstream energy markets, and we are well-positioned to capitalize on that opportunity."

www.firstsolar.com

First Solar establishes Indian operating company

First Solar Inc of Tempe, AZ, USA, which makes thin-film photovoltaic modules based on cadmium telluride as well as providing engineering, procurement and construction (EPC) services, has appointed Sujoy Ghosh as country head, to lead business development in India and manage the firm's new entity based in New Delhi. Ghosh will be responsible for advancing and executing the business strategy to expand the market for utility-scale solar photovoltaic (PV) power plants and to deliver value to Indian solar power producers. He reports to Jim Brown, executive VP for global business development.

With more than 20 years of industry experience, Ghosh joins First

Solar from GE Energy, where he was the regional general manager for the Power Generation business. He has worked in a diverse range of businesses from transmission and distribution to thermal power generation to renewable energy. Prior to joining GE, Ghosh worked at Tata Honeywell in sales and market development for 13 years.

"India is a land of immense opportunity for solar energy and First Solar, and we will continue to invest here as part of our strategy to develop sustainable, utility-scale solar markets where energy demand is strong and growing," says Brown. "Sujoy's extensive experience in the energy industry and strong understanding of the

Indian market will be invaluable to First Solar as we work to help India meet its energy needs with clean solar power," he adds.

"India is taking a progressive approach by incorporating clean, renewable sources of power in its plans to address its growing energy needs," comments Ghosh.

India is expected to become one of the world's major solar markets due to its strong growth, significant energy demand and abundant solar resource. First Solar entered the Indian PV market in 2011 and claims to be a local market leader for large-scale PV power plants. India accounted for about 8% of the firm's net sales in 2011.

www.firstsolar.com

Reliance commissions 40MW plant in Rajasthan

First Solar has announced the commissioning by Mumbai-based Reliance Power Ltd (a Reliance ADA Group company) of a 40MW (AC) ground-mounted solar photovoltaic power plant in the state of Rajasthan that will provide energy to Mumbai. The recently completed project was built in just five months.

Comprising about 500,000 First Solar modules, the power plant (near the village of Dhursar in Jaisalmer district of Rajasthan in northwestern India) is expected to generate more than 60 million kilowatt hours (kW-hr) of energy

per year, making it one of the country's largest solar power plants in terms of electricity generation. Covering 350 acres, it is 23 times the size of Calcutta's Eden Gardens cricket grounds and is expected to meet the annual electricity needs of more than 70,000 average Indian households. It will displace more than 60,000 metric tons of carbon dioxide emissions per year (equivalent to taking more than 25,000 cars off the road).

"We applaud India on its visionary solar policies and Reliance Power for their leadership in implement-

ing them," says First Solar's chairman & interim CEO Mike Ahearn.

"This power plant demonstrates the huge potential of solar energy to help India meet its growing energy needs," says Reliance's chairman Anil D Ambani. "It is also a testimony of the quick timeframe in which solar power plants can be built and commissioned."

The Dhursar project is the first of several that Reliance plans to build with First Solar modules as part of a 100MW module order placed last September.

www.reliancepower.co.in

Antelope Valley project receives first DOE loan advance

Chicago-based Exelon Corp and First Solar Inc of Tempe, AZ, USA have announced that the Antelope Valley Solar Ranch One project in northern Los Angeles County has received the first advance of a loan guaranteed by the US Department of Energy's Loan Programs Office, finalizing the project's acquisition from First Solar by Exelon (announced last October).

First Solar is constructing the 230MW photovoltaic power project

(one of the world's largest such projects) and will operate and maintain the project for Exelon. The first portion of the project is expected to come online in late 2012, with full operation planned for late 2013.

Using about 3.8 million solar panels, AV Solar Ranch One will generate enough electricity to power the equivalent of 75,000 average California homes — with no water use, no air emissions and

no waste production — displacing about 140,000 metric tons of carbon emissions per year (equivalent to taking about 30,000 cars off the road).

The project has a 25-year power purchase agreement (approved by the California Public Utilities Commission) with Pacific Gas & Electric Company for the full output of the plant.

www.exeloncorp.com

www.firstsolar.com

First Solar appoints new chief technology officer

First Solar Inc of Tempe, AZ, USA has announced the retirement of chief technology officer Dave Eaglesham, and the appointment of Raffi Garabedian as his successor.

Garabedian joined First Solar in 2008 as director of Disruptive Technologies, and was promoted to VP of Advanced Technologies in 2010, overseeing the firm's advanced R&D operations in Santa Clara, CA.

Eaglesham joined First Solar in 2006 and, during his six years as the firm's top technologist, the R&D group has achieved multiple records for cadmium telluride (CdTe) cell and module efficiency.

"We thank Dave for his tremendous contribution to our success and his unwavering commitment to our mission," says chairman Mike Ahearn.

"Raffi is an experienced technology leader with a proven track record in our R&D organization, and we are confident in his ability to execute and extend our technology roadmap going forward,"

Ahearn adds. "Raffi has been an integral part of our

"Raffi is an experienced technology leader with a proven track record in our R&D organization, and we are confident in his ability to execute and extend our technology roadmap going forward," says Ahearn

success, and I am very confident in his ability to lead our R&D program and to carry on our tradition of innovation," comments says Eaglesham.

Garabedian earned a BSEE degree from Rensselaer Polytechnic University and an MSEE degree from the University of California at Davis. Prior to joining First Solar, he was founder & CEO of semiconductor test equipment firm Touchdown Technologies. Previously, Garabedian worked in the semiconductor and micro-electro-mechanical systems (MEMS) industries for over 15 years, developing new products ranging from automotive sensors to telecoms switching systems, and holds more than 20 issued patents in these fields.

www.firstsolar.com

First Solar nominates two new board members and seeks two further independent directors

First Solar has nominated two new candidates for election to its board of directors, and expanded the size of the board from nine to 11, creating two vacancies as it continues to seek additional independent directors.

First Solar has nominated George 'Chip' Hambro and Richard 'Rick' Chapman to stand for election to the board at the Annual Meeting of Stockholders on 23 May. Chapman will serve as an independent director.

To fill the two new vacancies, First Solar has retained an executive search firm to help identify candidates with experience that will support the firm's strategy to compete as a vertically integrated provider of photovoltaic power plants in energy markets that are sustainable without subsidies.

The firm has also announced that, due to personal commitments, José Villarreal (a director since 2007) will retire from the board and will not seek re-election at the annual meeting.

"Chip and Rick are both knowledgeable about First Solar's strategy and operations and have diverse experience and expertise that will make them valuable additions to our board," says chairman & interim CEO Mike Ahearn. "We are also committed to further expanding our board by adding two additional independent directors to support our long-term strategic plan," he adds.

Chapman is chief financial officer of Walton Enterprises Inc, where he has worked since 1983. Currently he oversees all aspects of the Walton Family Office in Arkansas. Chapman also serves as a director on the boards of the Arvest Bank Group; the University of Arkansas Foundation (on the executive and finance committees); and the Razorback Foundation (as a member of the investment committee). He was previously a member of the board of managers of First Solar Holdings LLC prior to its initial public offering and equity investment firm

JWMA (formerly True North Partners LLC). Chapman earned a B.S.B.A. in Accounting from the University of Arkansas and is a Certified Public Accountant.

Hambro previously held various positions at First Solar from June 2001 through June 2009, including serving as chief operating officer from February 2005 through May 2007. Prior to joining First Solar, he was VP of engineering & business development for Goodrich Aerospace from May 1999 to June 2001 and VP of operations for ITT Industries from February 1997 to May 1999. For the last five years, Hambro has been a director of both the Toledo Zoo and Imagination Station, Toledo's children's science museum. He currently serves on the board of directors of Soladigm Inc, a developer of next-generation green building solutions. Hambro graduated from the University of California at Berkeley with a B.A. in Physical Science (Applied Physics).

www.firstsolar.com

MidAmerican and First Solar start major construction on world's largest solar project

MidAmerican Solar of Phoenix, AZ (a subsidiary of MidAmerican Renewables LLC, itself part of global energy services provider MidAmerican Energy Holdings Company of Des Moines, Iowa) and cadmium telluride (CdTe) thin-film photovoltaic module maker First Solar Inc of Tempe, AZ have marked the start of major construction at Topaz Solar Farms in San Luis Obispo County, CA. The firms' representatives held a groundbreaking ceremony at which they discussed the project's construction schedule, environmental values and community-centered plans with local and state community leaders and landowners. The event was followed by a community celebration at nearby Santa Margarita Ranch attended by more than 400 people.

The 550MW_{AC} photovoltaic project will employ about 400 workers during its three-year construction

period; will generate nearly \$417m in local economic impact (most of which will be generated during construction); and will provide California with renewable electricity. When complete, it will be the world's largest solar electric power plant, providing enough energy to power about 160,000 average California homes.

Pacific Gas and Electric Company will purchase the electricity from the Topaz project under a 25-year power purchase agreement, helping California meet its mandate to generate 33% of its power from renewable sources by 2020. Electricity generated by Topaz will displace about 377,000 metric tons of carbon dioxide per year (equivalent to taking about 73,000 cars off the road). "As Topaz is phased-in over time, it will help us meet that commitment while moving the state one step closer toward achieving its long-term environmental objec-

tives," says John Conway, PG&E's senior VP for energy supply.

"In addition to providing clean energy and jobs, we're committed to working hand-in-hand with stakeholders to demonstrate how large-scale solar projects and geographies, such as the Carrizo Plain, can co-exist and benefit native biological species," says MidAmerican Solar's president Paul Caudill.

"Utility-scale PV projects like Topaz are the quickest and most cost-effective way to bring significant solar power to the grid," says Jim Lamon, First Solar's senior VP of engineering, procurement and construction, and operations and maintenance.

The Topaz project is owned by MidAmerican Solar and will be constructed, operated and maintained by First Solar. Construction began in November and is expected to be completed by early 2015.

www.firstsolar.com

NRG, MidAmerican and First Solar celebrate 100MW milestone for 290MW Agua Caliente project

In late April, representatives from First Solar Inc, NRG Energy Inc of Princeton, NJ, MidAmerican Solar of Phoenix, AZ (a subsidiary of MidAmerican Renewables, part of energy services provider MidAmerican Energy Holdings Co of Des Moines, Iowa) gathered with federal and local officials at the 290MW_{AC} Agua Caliente solar project in Yuma County, AZ, to celebrate the project's first 100MW being delivered to the grid, making it North America's largest photovoltaic (PV) power plant in operation.

Once completed in 2014, Agua Caliente will be one of the world's largest PV power plants, supplying enough energy to power more than 225,000 homes. Its construction phase is creating an average of 400 jobs, with over

80% of the workforce coming from Arizona.

"Getting to this milestone of our first 100MW at Agua Caliente illustrates the success of public-private partnerships to stimulate the construction of these large-scale solar projects," said Tom Doyle, president of NRG Solar LLC (a subsidiary of NRG). "Large-scale projects like this also help drive down the price of solar, which will make it even more cost-competitive with conventional electricity generation in the near future," he adds.

"Projects such as Agua Caliente will play a central role in our nation's long-term electric energy supply and in our national transition to cleaner energy sources," said MidAmerican Solar's president Paul Caudill.

First Solar designed and is constructing the project using its CdTe thin-film photovoltaic modules and will operate and maintain the facility for NRG and MidAmerican Solar. Pacific Gas and Electric Company has a long-term power purchase agreement (PPA) for all of the project's generation, which is projected to offset about 5.5 million metric tons of carbon dioxide over 25 years (equivalent to taking over 40,000 cars off the road annually).

"We're grateful for the robust support at the local, state and federal levels that enabled us to realize this project," said Jim Lamon, First Solar's senior VP of engineering, procurement & construction and operations & maintenance.

www.nrgsolarenergy.com

www.midamericanrenewablesllc.com

Calyxo reaches record CdTe PV cell efficiency of 16.2% 17–18% cell efficiency and 14–15% module efficiency targeted this year

Calyxo GmbH of Bitterfeld/Wolfen-Thalheim, Germany (founded by Q-Cells SE in 2005) says that its cadmium telluride (CdTe)-based thin-film photovoltaic cell has reached record energy conversion efficiency of 16.2%, as confirmed officially by the testing body SGS Germany.

Calyxo says that this confirms the performance potential of photovoltaic devices based on CdTe technology made by its proprietary low-cost atmospheric deposition technology. "This result shows the efficiency potential of Calyxo's hot and fast deposition technology," says chief technology officer Michael Bauer. "Based on this



A Calyxo solar cell being analysed.

achievement, we are confident of reaching 17–18% cell efficiency and 14–15% top module efficiency later this year," he adds. Previously, in February, the firm announced that it had reached a module efficiency of 13.4%.

Calyxo operates a 25MWp module line with over 150 staff at a manufacturing plant that has been in commercial production in Bitterfeld/Wolfen-Thalheim (known as Solar Valley in Saxony-Anhalt) since 2009.

After splitting from Q-Cells in February 2011, Calyxo was taken over by original technology provider Solar Fields LLC of Toledo, OH, USA, which has invested in a second line with an annual capacity of 60MWp (starting production this year). Calyxo adds that research and the rapid further development of its CdTe technology is being conducted in collaboration with US parent firm Calyxo USA Inc of Perrysburg, OH.

www.calyxo.com

Installation of First Solar CdTe panels begins on Australia's largest PV project

Australia's largest solar photovoltaic (PV) power project has reached a construction milestone as contractor and cadmium telluride (CdTe) PV panel provider First Solar Inc of Tempe, AZ, USA has joined owners Verve Energy of Geraldton, Western Australia and GE unit GE Energy Financial Services of Stamford, CT, USA to mark the start of panel installation at the Greenough River Solar Farm in a ceremony attended by Western Australia's Energy Minister Peter Collier, landholders, members of the Geraldton community and local contractors.

Western Australian state-owned power utility Verve Energy and GE Energy Financial Services each own 50% of the Greenough River Solar Farm, with the WA Government having provided A\$20m in funding, including A\$10m from the WA Royalties for Regions program.

Construction of the 10MW solar farm 50km south of Geraldton began just four months ago. With above-ground electrical work completed and structural supports now

installed, the next phase of construction will see local workers install about 150,000 First Solar thin film PV modules. First Solar is also supplying engineering, procurement & construction (EPC) services, in addition to operations and maintenance support once the solar farm is operational. Scheduled for completion in mid-2012, the project is expected to create almost 100 jobs. The WA Water Corporation, which is building the Southern Seawater Desalination Plant near Binningup, has committed to purchasing 100% of the solar farm's output.

"Demonstration of this proven technology in WA on a commercial scale should encourage the development of larger projects and reduce renewable energy costs in the medium to long term," the Minister commented at the ceremony.

"The successful delivery of the Greenough River Solar Farm will help kick-off a long-term, sustainable market for utility-scale solar in Australia," reckons Jack Curtis, First

Solar's VP - business development & sales. "First Solar has a strong record of successful project delivery, enhanced by working with local communities to ensure projects make a meaningful and lasting contribution," he claims.

"GE Energy Financial Services sees Australia as a key growth market that will continue to need capital to fuel its expanding renewable energy industry," says Jason Willoughby, GE Energy Financial Services' Australia business leader. "We hope this is the first of many such milestones in the country," he adds.

"The Greenough River Solar Farm is providing valuable experience for Verve Energy in the development of solar energy in WA," says Tony Narvaez, Verve Energy's general manager, strategy & business development. "This experience will be very useful when Verve Energy pursues its aim to develop other solar farm projects in the near future."

www.firstsolar.com

www.verveenergy.com.au

www.geenergyfinancialservices.com

QD solar cell surpasses short-circuit current of reference GaAs device

Quantum dots without defects have been achieved by varying the growth temperature of the spacer layer between quantum dot layers.

Researchers from the UK and Spain have increased the performance of indium arsenide (InAs) quantum dot solar cells by varying the growth temperature [F. K. Tutu et al, J. Appl. Phys., vol111, p046101, 2012]. The participating institutions were University College London, Sharp Laboratories of Europe Ltd, Spain's Centro Andaluz Superior de Estudios Marinos (CASEM, Andalusian Centre for Marine Studies), and the University of Oxford.

Quantum dot (QD) devices have been explored extensively as a means to improve conversion efficiencies for both emission and absorption. While 3- to 5-layer QD structures are adequate for laser diodes, photovoltaic applications need far larger active volumes of about 30 layers. In such structures, it can be particularly tricky to avoid defects.

The QD solar cells (QDSCs) were grown using solid-source molecular beam epitaxy (SS-MBE) on n-type gallium arsenide (n-GaAs) substrates. The active region consisted of 30 layers of InAs/InGaAs dots in a p-i-n structure. A dot layer was made up of 2.2 monolayers of InAs grown on 2nm of $\text{In}_{0.15}\text{Ga}_{0.85}\text{As}$ and then capped with 4.5nm of $\text{In}_{0.15}\text{Ga}_{0.85}\text{As}$. The InAs layer tends to break up/self-assemble into dots.

The layers were spaced with 29nm of GaAs to give a dots-in-a-well structure (DWELL). The i-region was completed with 25nm of GaAs before deposition of the p-layers. The InAs QD density was estimated to be $5.5 \times 10^{10}/\text{cm}^2$.

The p-type and n-type emitter regions were 400nm and 3000nm, respectively. Further p-type layers consisted of a 43nm aluminum gallium arsenide (AlGaAs) window and a 1000nm p+-GaAs contact.

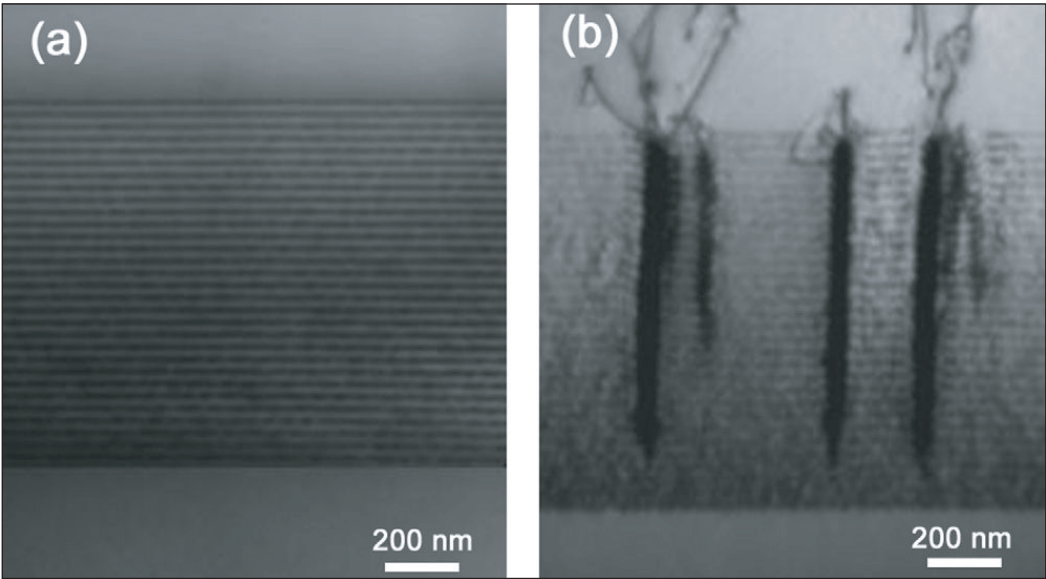


Figure 1. Dark-field (200) cross-sectional TEM images of 30-layer InAs/GaAs QDSC structures (a) with and (b) without HGTSL. The growth direction is in the vertical direction for these two images.

Three device types were produced: a reference without QDs, one where the active region was grown at constant temperature, and one where the spacer regions were grown at higher temperature than the dots. The dot growth temperature was 510°C in both the latter cases. In the high-growth-temperature spacer layer (HGTSL) device, the first 3nm was grown at 510°C and the final 26nm at 580°C.

The effect of the HGTSL was to remove threading

Table 1. Short-circuit current (J_{sc}), open-circuit voltage (V_{oc}), fill factor (FF), and efficiency (η) for QDSC with and without HGTSL and GaAs SC under 1 sun air-mass (AM) 1.5 illumination.

Solar cell	J_{sc} (mA/cm ²)	V_{oc} (V)	FF (%)	η (%)
GaAs reference cell	19.53	0.95	65	12.04
QDSC with HGTSL	20.17	0.71	71	10.12
QDSC without HGTSL	3.75	0.59	62	1.36

dislocations (TDs) from the structure (Figure 1). The non-HGTSL had severe TDs from the fifth layer, and in these layers the QD density was reduced, along with an increase in size variation. The difference is attributed to a rougher surface for low-temperature GaAs, leading to nucleation of larger InAs islands when the next layer of dots is initiated.

Photoluminescence experiments gave peak emissions for the HGTSL at wavelengths of 1100nm and 1230nm for 10K and room-temperature measurements, respectively.

Standard techniques converted the epitaxial material into solar cells with gold-zinc-gold p-contacts and indium germanium alloy-gold n-contacts.

Although the HGTSL cell had improved performance over the non-HGTSL device, both had degraded overall performance compared with the GaAs reference (Table 1 and Figure 2a). The researchers comment: "This reduction of efficiency in both cases of the QDSCs with and without HGTSL is likely due to the fact that carrier lifetime in QDs is smaller than in bulk GaAs".

However, the HGTSL cell did have the best short-circuit current of the three devices at 20.17mA/cm². The lower open-circuit voltage is attributed to narrowing of the bandgap due to the introduction of the InGaAs quantum wells (Figure 2b inset). High short-circuit current is desirable in multi-junction devices, where currents between the devices need to be matched.

External quantum efficiency (EQE) measurements show absorption in the GaAs cells only above the bandgap, creating the drop beyond 870nm (Figure 2b), while the QD structures absorb up to 1240nm. The higher current in the HGTSL device is attributed to extended absorption at wavelengths longer than the GaAs bandgap.

The higher absorption of the non-HGTSL device at the longer wavelengths is the subject of further investigations. An explanation in terms of the reduced thermal activation energy of carriers in these devices is tentatively offered. ■

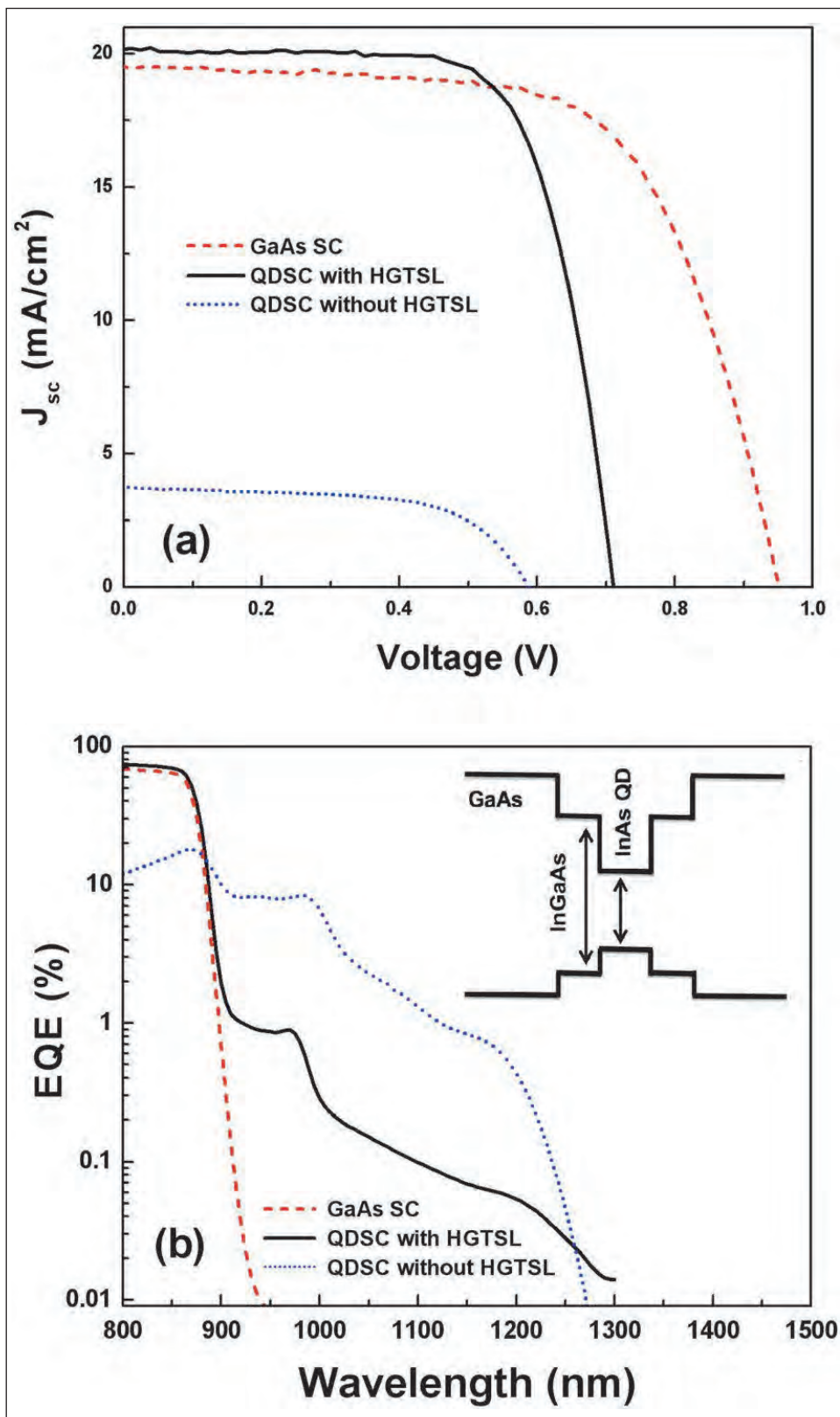


Figure 2. (a) Current density vs voltage curves of InAs/GaAs QDSCs with and without HGTSL and the reference GaAs solar cell. (b) External quantum efficiency (EQE) of InAs/GaAs QDSCs with and without the HGTSL and the reference GaAs solar cell. Inset: schematic band diagram of InAs/InGaAs dot-in-a-well structure.

<http://link.aip.org/link/doi/10.1063/1.3686184>

Author:

Mike Cooke

GaAs wafer market to exceed \$650m by 2017

RF electronics applications are fueling the GaAs wafer market, but LEDs will lead growth, says market research firm Yole Développement.

After recovering strongly from 2009 with growth of 22% in 2010, the gallium arsenide (GaAs) substrate market slowed sharply in 2011, rising just 4% to nearly \$360m, due to weak demand in RF circuits (handsets and WLANs) and in optoelectronics (LEDs and laser diodes), according to market research firm Yole Développement in its report 'GaAs Wafer Market & Applications'.

However, the market is expected to recover in 2012, driven by:

- (i) the sheer volume of the handset market and
- (ii) consolidation of the LED industry (balance of capacity).

The GaAs substrate market should hence increase at a compound annual growth rate (CAGR) of nearly 11% to more than \$650m by 2017 (Figure 1), fuelled primarily by: rising GaAs content in handsets; and rising penetration of LEDs in general lighting and automotive applications.

RF electronics (power amplifiers, switches etc) initially comprised the main market for GaAs wafers and will continue to fuel the business in the coming years due to the development of sophisticated smartphones, the development of 3G/4G networks, and the increased demand for data communications, says Yole.

But recently the development of new GaAs-based devices is boosting the market with associated high-volume applications (e.g. LEDs, which are currently booming due to their advantages over traditional light

sources). Other devices such as solar cells for high-concentration photovoltaics (HCPV) will also add to the development of the GaAs substrate market, but to a lesser degree, reckons Yole. ➤

The GaAs substrate market should increase at a CAGR of nearly 11% to more than \$650m by 2017

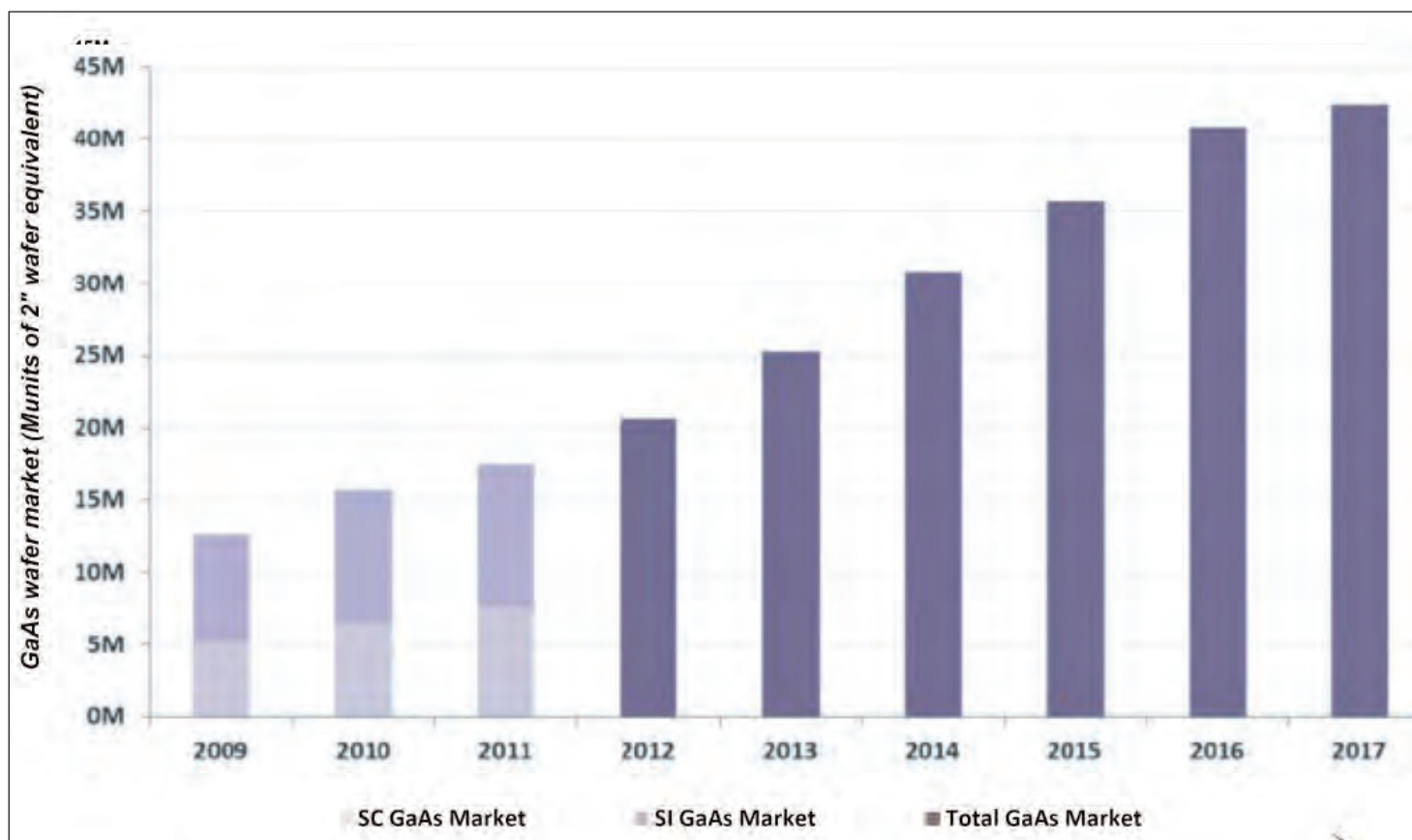


Figure 1. Trend in the gallium arsenide wafer market (volume), split by type of substrate.

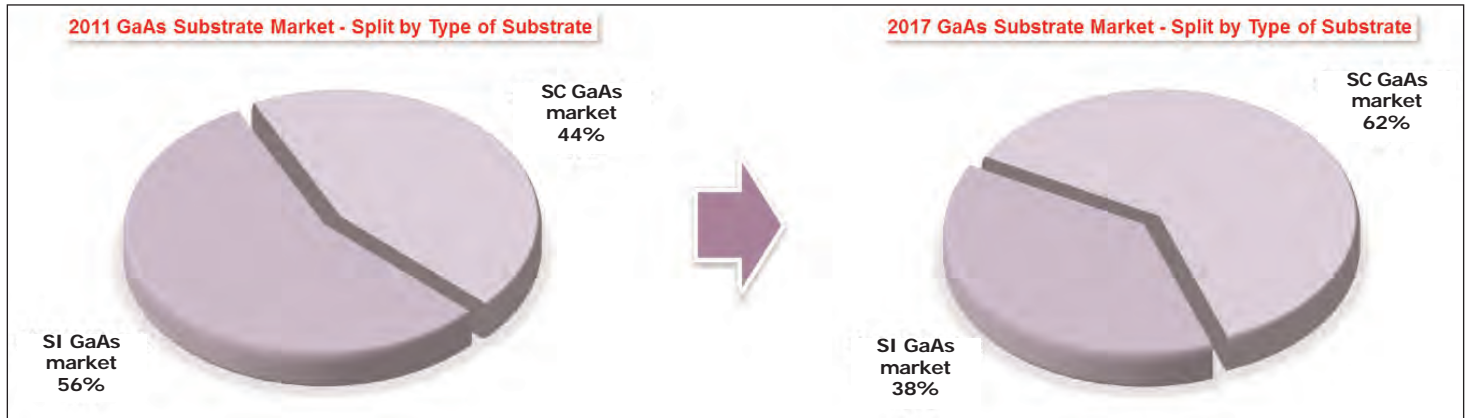


Figure 2. Market share (\$m) of SI GaAs and SC GaAs (2011 and 2017).

► **Boosted by LEDs, semi-conducting GaAs substrates to lead growth**

In 2011, the semi-insulating (SI) GaAs substrate market represented about 56% of the overall GaAs substrate market by value, versus 44% for semiconducting (SC) GaAs. However, this trend is likely to reverse in the short term, as GaAs substrate demand for LEDs should rapidly surpass demand for RF electronics devices (Figure 2).

Globally, the penetration rate of LEDs is increasing in applications including TVs, signs & displays etc. Also, if fundamental technology improvements are achieved to improve LED efficiency and increase the total amount of light generated per package, then

General lighting should be the next 'killer application', boosting the SC GaAs substrate market in 2012–2013. The automotive industry is also shifting from the use of traditional light sources to LEDs for products such as headlamps and interior lights. SC GaAs substrate volumes are likely to equal SI GaAs substrate volumes by 2013 due to steady growth in the RF electronics market compared to booming growth in the optoelectronics market

general lighting should be the next 'killer application', boosting the SC GaAs substrate market in 2012–2013. Moreover, the automotive industry is also shifting from the use of traditional light sources to LEDs for products such as headlamps and interior lights.

In that context, SC GaAs substrate volumes are likely to equal SI GaAs substrate volumes by 2013 due to steady growth in the RF electronics market compared to booming growth in the optoelectronics market.

Earthquake in 2011 shifted revenue of some Japanese players to competitors

The Japanese earthquake/tsunami in 2011 damaged several manufacturing plants and strongly impacted the production capacity of some key GaAs substrate suppliers, who lost market share to competitors (Figure 3).

Whether these companies will invest to recover operations, reduce operations or exit the business is still unclear, says Yole. However, the GaAs wafer industry is evolving and some players have already announced plant expansion in order to gain market share and prepare future growth of the market, the market research firm notes.

At this level, due to its lower labor cost, China seems to be the new 'El Dorado' of GaAs wafer manufacturing: all expansions plans announced will be localized in the country, Yole reckons. ■

www.yole.fr

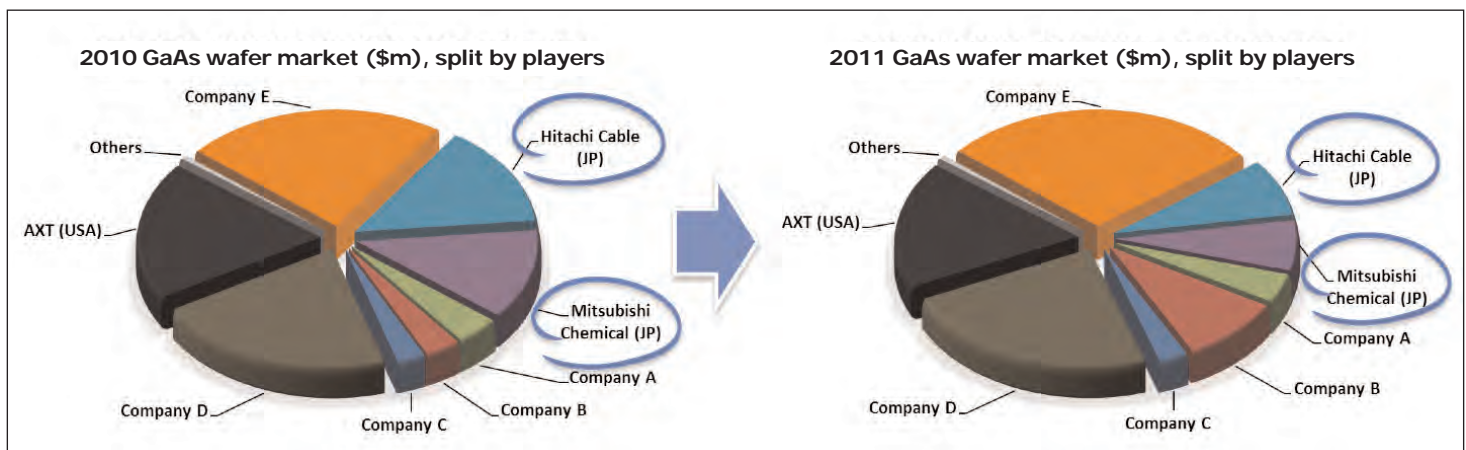


Figure 3. GaAs wafer market (\$m), split by players (2010 and 2011).

III-V epi substrate & tool market a \$6.1bn opportunity over 2012–2020

MOCVD overcapacity will take 12–18 months to absorb, while metal-organic precursor oversupply could last from 2012 beyond 2016, says market research firm Yole Développement.

The combined revenue opportunity for molecular beam epitaxy (MBE) and metal-organic chemical vapour deposition (MOCVD) tools is estimated to be US\$6.1bn for 2012–2020, according to market research firm Yole Développement in its report 'III-V Epitaxy Substrates & Equipment Market'.

LEDs represent by far the single largest application for MOCVD. In 2010 and 2011, the MOCVD market experienced the largest investment cycle in its history, driven by a combination of demand for LED-backlit LCD TVs; subsidies by the Chinese central and local governments; and anticipation of the general lighting market.

This has created significant overcapacity in the market that could take 12–18 months to absorb, says Yole. The next investment cycle — driven by lighting applications and expected to start in 2013 — will be more limited than the previous cycle due to improvements in equipment throughput and yields, the firm notes. Following this cycle, further cost of ownership (COO) improvements offered by the next generation of MOCVD reactors should justify the replacement of two-generation-old reactors installed during the 2010–2011 boom and drive a last small equipment cycle in the second half of the decade, Yole forecasts. By then, power GaN devices will also represent a substantial upside for MOCVD reactor makers.

For MBE, the applications covered in the report represent less than 40% of the total equipment market opportunity. Overall MBE use is heavily driven by R&D systems (over 50% of the total market) and laser applications (telecom, industrial, medical, research), which are not covered in the report.

For the applications covered, the MBE market will be driven essentially by the continuous growth in the cell-phone and wireless applications that make heavy use of GaAs-based RF components. Emerging applications such as smart grid and the trend toward increasing connectivity and 'intelligence' incorporated in many consumer products will provide further opportunities, Yole says. However, alternative technologies — silicon CMOS, LDMOS, silicon-on-sapphire (SoS), high-resistivity (HR) silicon-on-insulator (SOI) etc — represent a

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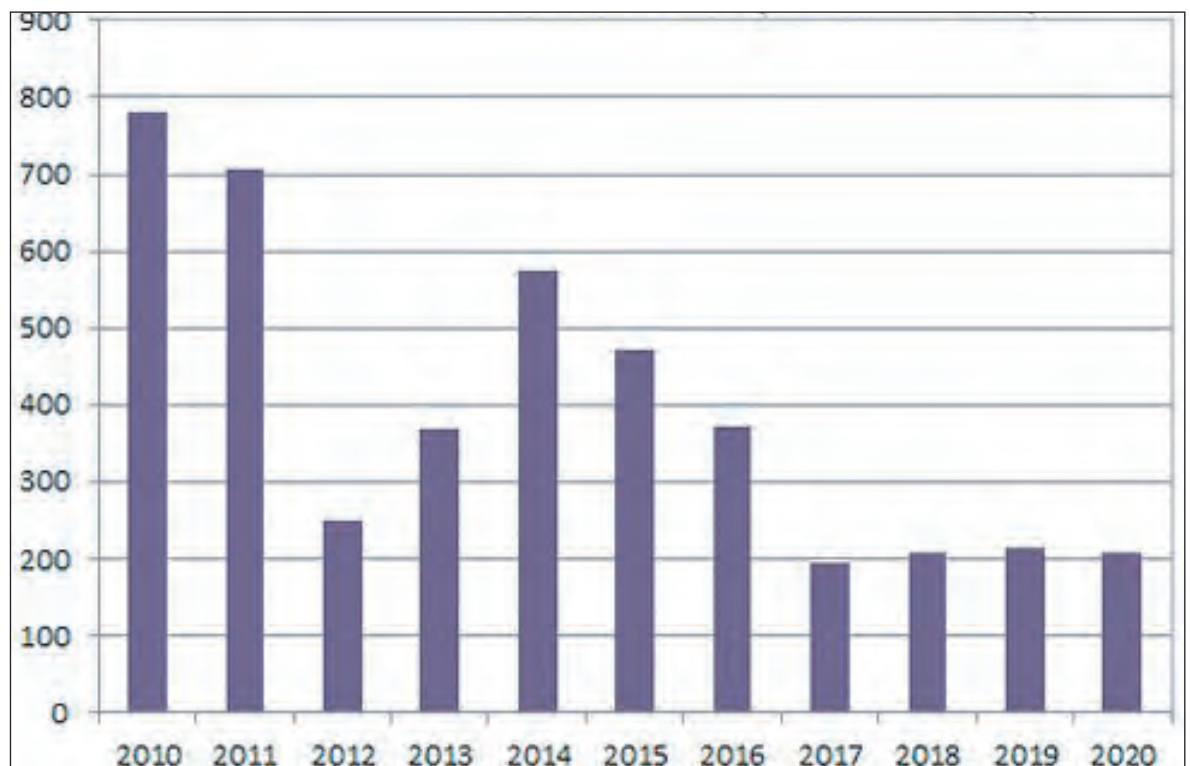


Figure 1. Annual new epi reactor sales (units), 2010–2020.

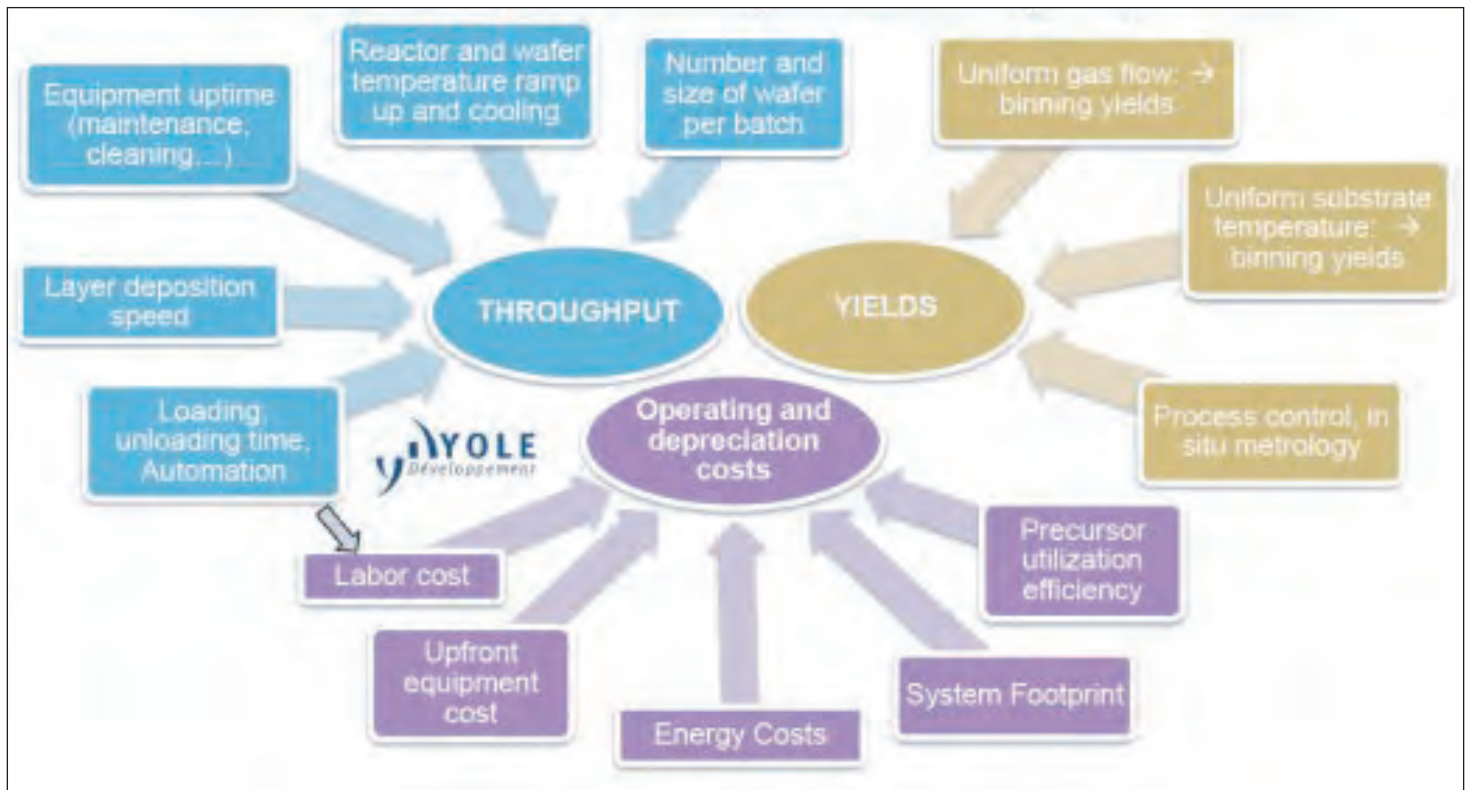


Figure 2. The multiple factors driving the cost of ownership of an MOCVD system.

potential threat and could capture a share of the GaAs RF market and reduce the opportunity for MBE. In addition, MOCVD is making progress in manufacturing of high-electron-mobility transistors (HEMTs). However, high-concentration photovoltaics (HCPV) could provide a small potential upside for MBE reactor makers, reckons Yole.

MOCVD and MBE equipment markets

The MOCVD and MBE equipment markets are duopolies, but many emerging players could change the landscape.

Aixtron and Veeco dominate MOCVD, together representing 96% of the market in 2011. Production MOCVD reactors are complex systems, notes Yole. Their design and optimization require expertise in multiple fields, including flow dynamics, thermodynamics, chemistry, and mechanical and electrical engineering, so the technical barriers to entry are fairly high. More than 15 emerging players have been identified, but so far they have been struggling to capture any sizeable market share. However, pressure is mounting, and established MOCVD reactor makers will need to maintain that technology gap to keep emerging competitors at bay, reckons Yole. The main battlefield is that of total cost of ownership. Established MOCVD makers all have technology roadmaps to enable COO reduction of 3–4x

MO synthesis technology improvements could provide opportunities for cost reduction. However, the usually volatile prices of raw indium and gallium also have a significant impact on cost

in the next five years through a combination of improved yields, throughputs and precursor utilization efficiency.

For MBE, Riber and Veeco are the only two players offering large-capacity/large-throughput MBE production tools for volume manufacturing. Yole expects that they will maintain this dominant position. However, there are about 10 other MBE manufacturers offering R&D or pilot-production systems (e.g. DCA, SVT, Eiko etc) that also have a strong presence on the general MBE market.

Potential overcapacity in MO precursor supply

The metal-organic (MO) precursor market will also be driven essentially by LED applications. However, MOCVD reactor technology improvements (e.g. yield, consumption, wafer size etc) will lower the amount of trimethyl-gallium (TMGa) and trimethyl-indium (TMIn) needed per cm² of epiwafer.

The metal-organic shortage of 2010 ended in mid-2011 due to aggressive capacity expansion by leading suppliers, notes Yole. Further capacity expansion plans from established and emerging suppliers could come online within the next three years. If executed as announced, Yole expects significant oversupply, starting from 2012, that could continue through 2016 and beyond. This situation could put pressure on prices. Further MO synthesis technology improvements could provide opportunities for cost reduction. However, the usually volatile prices of raw indium and gallium also have a significant impact on cost, comments the market research firm. ■

www.yole.fr

InAs nickelide meets 12nm ITRS requirements

Reaction of nickel with InGaAs yields estimated source/drain contact/extension resistance of $25\Omega\text{-}\mu\text{m}$.

Researchers based in Belgium, Taiwan, the UK and the USA have developed a 'nickelide' source/drain (S/D) contact scheme for III-V metal-oxide-semiconductor field-effect transistors (MOSFET) with a record specific contact resistivity between the contact pad and metallic S/D of $2.7 \times 10^{-9} \Omega\text{-cm}^2$ [R. Oxland et al, IEEE Electron Device Letters, published online 21 February 2012].

Nickelide is a recently developed stable metallic phase formed by reaction of nickel with indium gallium arsenide (InGaAs) III-V compound semiconductor. The new research concerns InAs nickelide and was carried out by TSMC R&D Europe and Hsinchu Taiwan, University of Glasgow, and Texas State University.

In recent years, the use of III-V compound semiconductor channels (Figure 1a) has been widely explored as a means to improve integrated circuit performance. As practical implementation nears, there will be a need to address the practical issue of contacts with the devices. In laboratory devices micron-sized contacts are typical. However, these will need to be reduced to the nanometer scale in practical devices. Reduced size will increase parasitic resistance to impractical levels unless new approaches are developed.

The researchers are developing the technology for the '12nm technology generation' of the International Technology Roadmap for Semiconductors (ITRS). [ITRS has abandoned its traditional 'technology nodes' in recent years, given the different pacing of different device types. The time scale for the 12nm processors is given as ~2020 in the 2011 ITRS.] The researchers aimed at meeting the external source/drain resistance

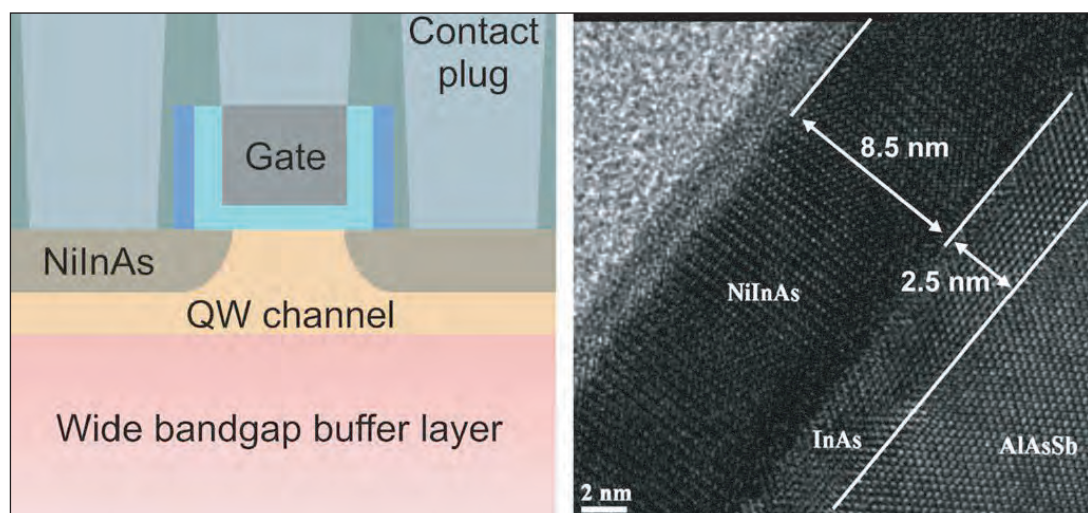


Figure 1. (a) Heterostructure quantum well (QW) MOSFET device architecture showing nickelide S/D and extensions. (b) Transmission electron micrograph of low-sheet-resistance NiInAs ternary phase.

figure of $110\Omega\text{-}\mu\text{m}$ given in the 2009 ITRS documents.

The team also wants to develop a process that could be implemented in a self-aligned process, analogous to the present self-align silicide ('salicide') source/drain contacts used in silicon CMOS production.

The new contact process was developed on 11nm InAs layers grown on GaAs substrates. The lattice mismatch between the InAs and GaAs materials was bridged 'metamorphically' by a 960nm buffer layer of AlAsSb of graded composition. The InAs layer was found to have a surface roughness of 0.61nm in a square field with $10\mu\text{m}$ sides.

Before the electron-beam evaporation deposition of nickel, the InAs surface was cleaned to remove native oxide. The nickel was patterned into various structures using various lithography techniques. The metal was then reacted using rapid thermal annealing (RTA) for 1 minute to create NiInAs. The lowest sheet resistance

Table 1. Carrier density, mobility and sheet resistance for InAs channel and nickelide material.

Layer	Carrier concentration	Mobility	Sheet resistance
11nm InAs channel	$8 \times 10^{11}/\text{cm}^2$	$4980\text{cm}^2/\text{V-s}$	$1428\Omega/\text{square}$
Reacted NiInAs	$2.2 \times 10^{17}/\text{cm}^2$	$0.3\text{cm}^2/\text{V-s}$	$110\Omega/\text{square}$

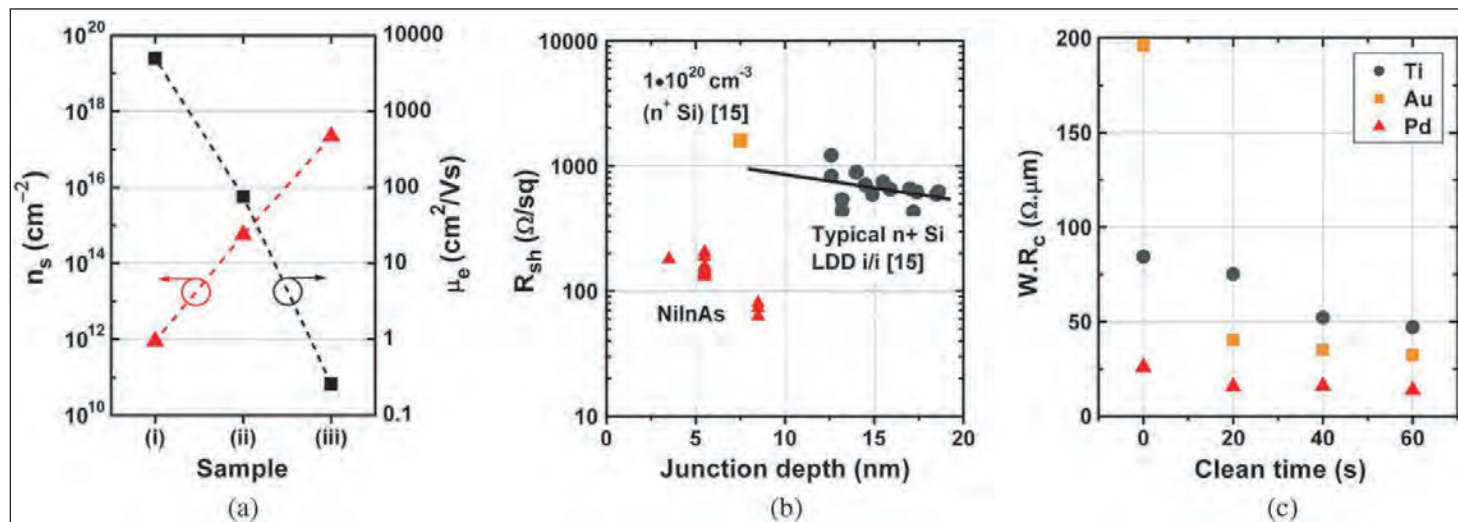


Figure 2. (a) Sheet carrier concentration n_s and electron mobility (μ_e) (i) for undoped InAs of 10nm thickness, (ii) with 6nm deposited Ni, and (iii) after formation of nickelide of 8.5nm thickness. (b) R_{sh} vs junction depth: comparison of measured nickelide R_{sh} with typical published Si implant low-doped drain (LDD) S/D extension R_{sh} . Also shown is (box profile) theoretical R_{sh} for 7.5nm junction depth with $1 \times 10^{20}/\text{cm}^3$ -type dopant activation in Si LDD. (c) $W \times R_c$ vs in-situ clean time for three different contact metals: titanium (Ti), gold (Au), and palladium (Pd). W is the width of the TLM contact (150μm).

for a 6nm Ni blanket was achieved with a 350°C RTA process. The resulting NiInAs junction had a depth of about 8.5nm (Figure 1b).

Hall measurements on the pure InAs channel and the nickelide material were performed (Figure 2a). These gave values for carrier density, mobility and sheet resistance (Table 1). The researchers comment: "The observed carrier density and mobility after RTA suggest that the nickelide is metallic. This metallic S/D is a potential solution to the 'source starvation' problem for III-V NMOS proposed in [M. V. Fischetti et al, IEDM Tech. Dig., p109, 2007] caused by low density of states in S/D regions."

The etch rate of the NiInAs material under hydrochloric acid solution was negligible. Pure nickel with the same solution etches at the rate of 3nm/second. A similar response to such an etch process had been found previously in NiInGaAs. The researchers comment: "It is clear from the atomically abrupt and smooth interface shown in the TEM (Figure 1b), from the comparison with Si R_{sh} data in Figure 2b and from the

availability of a selective wet etch to Ni, that nickelide would make an excellent S/D and extension material for III-V MOSFETs."

Various metal contact processes were tried. The best contact was achieved using an in-situ sputter clean and 10nm palladium metal evaporation. This achieved a transmission line model (TLM) contact resistance of 15Ω·μm before, and down to 5.1Ω·μm after, annealing.

A system with NiInAs and palladium contact metal achieved sheet resistance values of 97Ω/square and 5.1Ω·μm, giving a specific contact resistance of $2.7 \times 10^{-9} \Omega\text{-cm}^2$. The total parasitic resistance due to the metal contact and source/drain extension (R_{ext}) was estimated at 25Ω·μm for an ITRS 12nm device with a 23nm contact length and 7nm spacer length.

The researchers believe the contact scheme could be implemented as a self-aligned silicide-like process. ■

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MOCVD produces high-performance mHEMTs on silicon substrates

HKUST achieves performance comparable to devices produced using MBE and III-V substrates.

Hong Kong University of Science and Technology (HKUST) has produced high-performance gallium indium arsenide (GaInAs) metamorphic high-electron-mobility transistors (mHEMTs) on silicon substrates using metal-organic chemical vapor deposition (MOCVD) [Ming Li et al, IEEE Electron Device Letters, published online 7 March 2012].

The researchers sees the devices as “one of the most promising device candidates for future high-speed and low-power digital logic applications”. Further, “Seamless robust heterogeneous integration of high-performance GaInAs transistors on Si will help realize the ultimate vision of low-voltage high-speed III–V-based logic circuit blocks coupled with the functional density advantages provided by the Si CMOS”.

Previous high-performance mHEMTs on Si have been produced using molecular beam epitaxy (MBE), which is less attractive as a mass manufacturing technique. Such devices offer an order of magnitude improvement in energy–delay product, with performance parameters comparable with mHEMTs produced on gallium arsenide

(GaAs) or indium phosphide (InP) substrates.

The new devices show similar performance over a range of parameters (Table 1). The researchers comment: “To our best knowledge, these results are the best reported for MOCVD-grown mHEMTs on Si.”

The HKUST epitaxial structures were grown on exact (001)-oriented silicon substrates using Aixtron’s AIX-200/4 system (Figure 1). The GaInAs channel and aluminum indium arsenide (AlInAs) barrier layers were lattice matched to InP. The metamorphic buffer was grown using alternating low- temperature (LT) and high-temperature (HT) steps.

The mHEMT devices were mesa-isolated with ohmic source/drain contacts consisting of nickel/germanium/gold/germanium/nickel/gold. The source–drain spacing was 3µm.

Silicon nitride was deposited using plasma-enhanced CVD and a gate length of 100nm was defined. Various wet etching steps were performed to create a T-gate structure with its foot on the AlInAs barrier layer. The Schottky gate contact consisted of titanium/platinum/gold.

Hetero-structure	Sub.	Growth	Mob.	Lg (nm)	Gm (mS/mm)	f_T (GHz)	f_{max} (GHz)	Date	Ref.
In _{0.52} AlAs/ In _{0.53} GaAs	GaAs	MBE	N/A	100	750	154	300	2004	[9]
In _{0.52} AlAs/ In _{0.53} GaAs	GaAs	MBE	9100	150	750	140	240	2003	[10]
Al In _{0.50} As/ GaIn _{0.53} As	Si	MOCVD	4540	1µm	587	32	44	2008	[7]
In _{0.7} GaAs/ In _{0.52} AlAs	Si	MBE	10000	80	1200	302		2010	[6]
Al In _{0.51} As/ GaIn _{0.53} As	Si	MOCVD	7500	100	767	210	146	2011	This work

Table 1. Comparison of AlInAs/GaInAs HEMT performance with various production techniques.

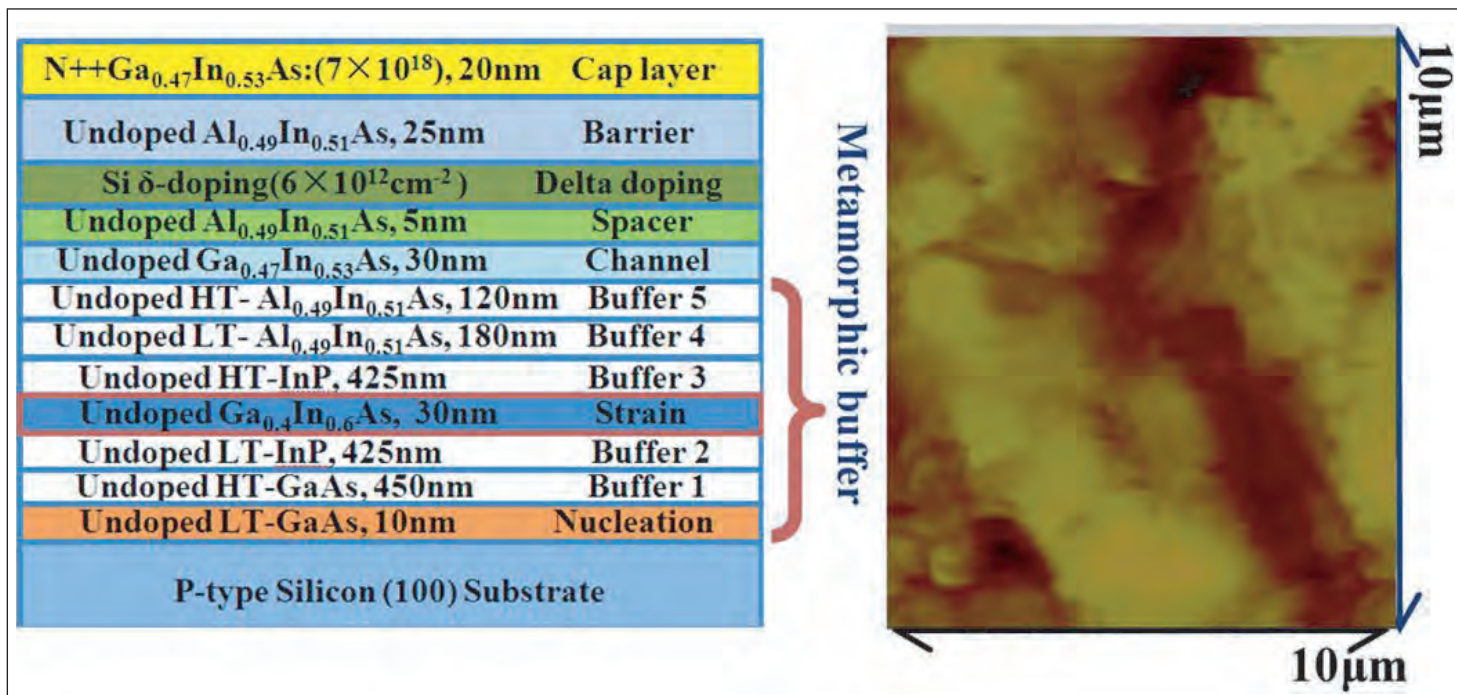


Figure 1. Nominal structure of mHEMT device on Si substrate and atomic force microscope (AFM) image of 10µm x 10µm scan area of buffer structure on Si substrate.

The gate width was 400nm.

The maximum extrinsic transconductance of the resulting device was 767mS/mm. The threshold voltage was negative, -0.45V, giving depletion/normally-on behavior. Below threshold, at -1.2V gate potential, the current was less than 0.32mA/mm at 1V drain bias. The gate leakage current of 0.12mA/mm at a gate potential of -3V and a drain bias of 1V was lower than previous work, due to the high resistivity of the multi-stage metamorphic buffer scheme.

The frequency performance of the device was tested

in the range 0.1–39.1GHz, giving extrapolations for the cut-off frequency (f_T) of 210GHz and for the maximum oscillation frequency (f_{max}) of 146GHz.

The researchers comment that they expect enhanced RF performance with improved fabrication techniques. "These results are very encouraging toward the manufacturing of high-performance metamorphic devices on Si substrates by MOCVD," they say. ■

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All-ternary InAlAs/InGaAs DHBT high frequency and breakdown performance

University of Manchester achieves record cut-off frequency of 140GHz for all-ternary double-heterojunction bipolar transistors.

The UK's University of Manchester has produced all-ternary indium aluminum arsenide/indium gallium arsenide (InAlAs/InGaAs) double-heterojunction bipolar transistors (DHBTs) that achieve simultaneous high breakdown voltages (5.5V) and cut-off frequencies (140GHz) [R Knight et al, Semicond. Sci. Technol., vol27, p045017, 2012].

Single-heterojunction devices can achieve higher cut-offs of 550GHz, but have poorer breakdown behavior. Good breakdown characteristics are needed for high-power or precision mixed-signal performance. Higher breakdowns of 4.0–4.5V and high cut-offs of 560GHz have been achieved in the USA with indium phosphide/indium gallium arsenide (InP/InGaAs) DHBTs produced

Layer	Material	Thickness (Å)	Doping (cm ⁻³)
Cap	In _{0.53} Ga _{0.47} As	800	2 × 10 ¹⁹ (n)
Emitter 1	In _{0.52} Al _{0.48} As	800	2 × 10 ¹⁹ (n)
Emitter 2	In _{0.52} Al _{0.48} As	500	5 × 10 ¹⁷ (n)
Spacer	In _{0.53} Ga _{0.47} As	100	nid
Base	In _{0.53} Ga _{0.47} As	281	4.2 × 10 ¹⁹ (p)
Spacer	In _{0.53} Ga _{0.47} As	500	nid
p-n dipole doping	In _{0.53} Ga _{0.47} As - In _{0.52} Al _{0.48} As	2 × 100	5 × 10 ¹⁸ (pn)
Collector	In _{0.52} Al _{0.48} As	1000	nid
Collector 2	In _{0.52} Al _{0.48} As	500	1 × 10 ¹⁹ (n)
Sub-collector	In _{0.53} Ga _{0.47} As	4500	1 × 10 ¹⁹ (n)
Buffer	In _{0.52} Al _{0.48} As	300	nid
Substrate	InP		Semi-insulating

nid = no intentional doping.

Table 1. Epitaxial structure of DHBT.

Company	Type	Emitter width (μm)	f_t (GHz)	f_{max} (GHz)	BV_{ce0} (V)
Ommic	InP	1.5	180	220	7
GCS	InP	1	150	150	7
Triquint	GaAs	2	40	60	14
WIN	GaAs	1	65	80	9
UoM	InP	1	140	95	5.5

Table 2. Commercially available InP and GaAs DHBTs. Last line is University of Manchester's device.

using sub-micron electron-beam or deep ultraviolet lithography.

The University of Manchester (UoM) device uses micron-scale optical lithography. The team has worked in the past few years on the InAlAs/InGaAs combination to overcome current-blocking affects that arise from a large discontinuity between the base-collector conduction bands, compared with InP/InGaAs-based devices. The team has developed designs with composite collector and doping interface dipole structures to achieve this aim. In particular, they have avoided the use of more complex (and hence more costly to manufacture) quaternary InAlGaAs material structures.

The Manchester work was supported by European defense electronics company Selex Galileo and the UK Electro-Magnetic Remote Sensing Defence Technology Centre (EMRS DTC). Partial funding also came from the UK Science and Technology Facilities Council (STFC) as part of the Square Kilometre Array (SKA) radio telescope program.

The epitaxial structure (Table 1) was grown on 3" iron-doped InP substrates using solid-source molecular beam epitaxy (SS-MBE) in a Riber V90H system. The growth temperature was a low 420°C in order to limit the diffusion of the beryllium doping from the p-type base layer. The n-type doping was achieved using silicon. The layers were lattice matched to the substrate so that InAlAs layers had 52% In molar fraction, and InGaAs layers 53%, except for base grading

from 53% at the collector junction to 46% at the emitter junction. Triple-step mesas were etched, allowing access to the emitter, base and collector regions with ohmic palladium/titanium/palladium/gold contacts. Further interconnects were non-alloyed titanium/gold deposited on benzocyclobutene (BCB) passivation. The base metal layer incorporated an air-bridge structure to minimize base-collector capacitance.

A 1 μm x 5 μm device gave a current gain of 42, an offset voltage of 350mV, power handling of 10mW, and current density of 1mA/ μm . The breakdown voltage for 100 μA collector current was 5.5V.

The peak RF performance was achieved at 4.2mA collector current and a collector-emitter voltage of 2V. The unity-gain cut-off (f_t) and maximum oscillation (f_{max}) frequencies came at 140GHz and 95GHz, respectively.

The researchers compared their device with those available commercially (Table 2). Although the Manchester device does not exceed the current performance of the commercial products, the researchers are hopeful that with "further epitaxial design work and investment to reduce device geometries, this material system may prove to have RF performance useful for high-frequency power applications". The new DHBT is also "the start of a UoM InAlAs-InGaAs BiFET and MMIC fabrication process."

The researchers conclude: "The demonstration of the frequency performance whilst achieving large breakdown voltage of 5.5 V coupled with the ease of processing makes the reported all-ternary InGaAs-InAlAs DHBTs attractive candidates for a number of high-power MMICs and BiFET applications." ■

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The frequency performance whilst achieving large breakdown voltage of 5.5V coupled with the ease of processing makes the reported all-ternary InGaAs-InAlAs DHBTs attractive candidates for a number of high-power MMICs and BiFET applications

First RF power operation report for AlGaN barrier HEMT on diamond

Japan's NTT makes devices that achieve breakdown voltage of 165V and power density of 2.13W/mm at 1GHz.

NTT Basic Research Laboratories in Japan has demonstrated "for the first time" RF power operation of aluminum gallium nitride (AlGaN) barrier high-electron-mobility transistors (HEMTs) epitaxially grown on diamond [Kazuyuki Hirama et al, IEEE Electron Device Letters, published online 2 March 2012].

The attraction of diamond as a substrate is the higher thermal conductivity (up to 22W/cm-K), allowing greater heat dissipation than alternatives such as sapphire (0.5W/cm-K), silicon (1.5W/cm-K) or even silicon carbide (4.0W/cm-K). Heat dissipation is particularly important in high output-power-density devices. Although molecular beam epitaxy (MBE) has previously been used to create nitride semiconductor HEMTs on diamond that demonstrated small-signal performance at 21GHz gain cut-off (f_T), power operation and high breakdown voltage had not been reported until the new NTT work.

The NTT devices were grown on 5mm x 5mm 0.3mm-thick IIa-type diamond (111) substrates using metal-organic chemical vapor deposition (MOCVD) — see Figure 1. The 'type' represents the amount of nitrogen impurity in the diamond structure. For type IIa, the amount of nitrogen is less than 1016/cm³. Reducing the amount of nitrogen increases thermal conductivity: for type IIa, the thermal conductivity is

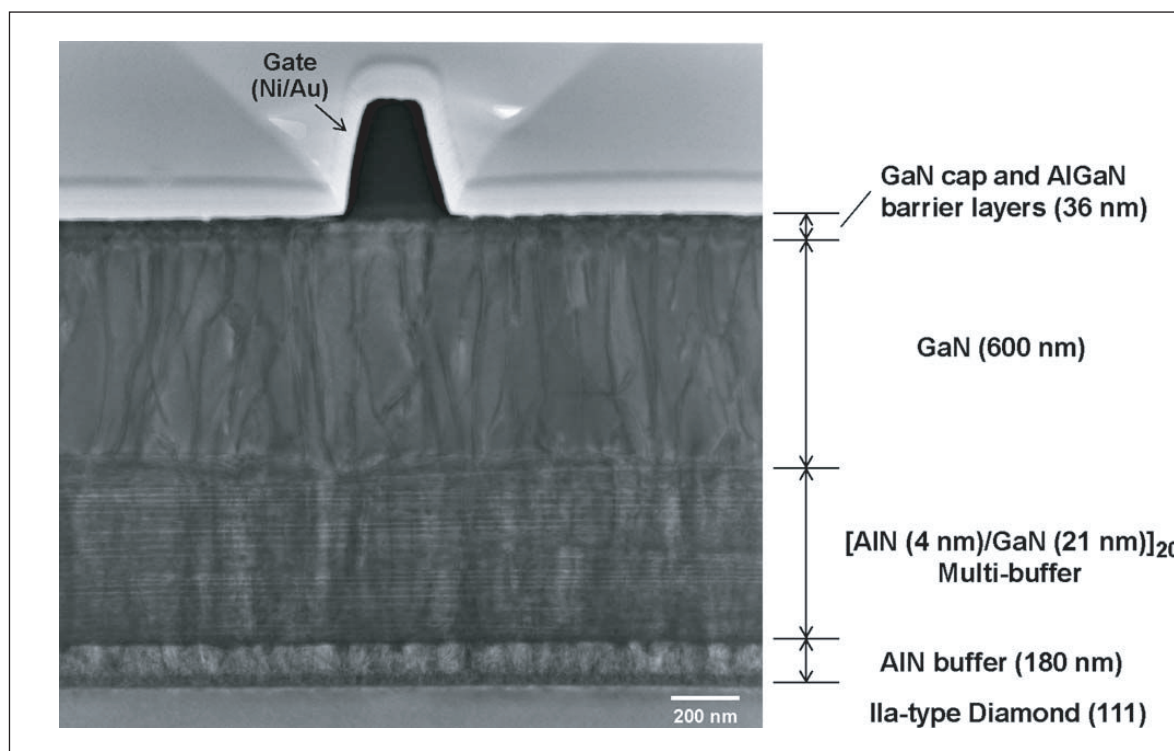


Figure 1. Cross-sectional bright-field TEM image of the AlGaN/GaN HEMT structure epitaxially grown on diamond (111) substrate. The multi-buffer region consists of 20 repeats of the structure shown. The 32nm AlGaN barrier had 33% aluminum content.

more than 22W/cm-K, compared with 10–18W/cm-K for type Ib diamond (N concentration up to 3×10^{19} /cm³).

No passivation layer was applied to the HEMTs. The threading dislocation density in the thick GaN layer was estimated at 8.4×10^9 /cm², which is comparable to the values for devices grown on sapphire substrates. X-ray diffraction analysis gave an estimate for (tensile) strain in the thick GaN layer of –0.01%. This low strain avoided crack formation.

The ohmic source/drain contacts consisted of titanium/aluminum/nickel/gold. The Schottky gate consisted of nickel/gold. The two-finger gate length was 0.4μm. The width was 100μm or 400μm. The source/drain separation was 5μm. The gate was placed centrally within the gap.

The maximum drain current was 770mA/mm and the off-state breakdown voltage at -6V gate potential (V_{BD}) was 165V. The researchers comment: "This V_{BD} is the highest ever reported for AlGaIn/GaN HEMTs on diamond, and also comparable to V_{BD} of typical AlGaIn/GaN HEMTs with gate-drain spacing of about 2 μ m and without a field-plate structure."

By halving both the maximum drain current and off-state breakdown voltage to give the bias points for A-class amplifier operation, the researchers estimate a potential output power density of 16W/mm.

The transconductance of 160mS/mm is lower than that achieved for devices produced on silicon carbide or silicon substrates. This is attributed to relatively low mobility of the two-dimensional electron gas (2DEG) channel (780cm²/V-s) and the relatively thick (36nm) barrier/cap layers.

Comparison with the DC performance showed little drain current collapse under pulsed operation, unlike with normal nitride semiconductor HEMTs. There was also less self-heating of the device.

The frequency performance showed a maximum available gain (f_T) of only 25GHz, and maximum oscillation (f_{max}) of 18GHz. Nitride semiconductor HEMTs produced on other substrates have achieved hundreds of gigahertz values for these parameters. The researchers comment that the low transconductance impacts the frequency performance. Also, the use on a non-T gate would probably increase the gate resistance.

A power sweep at 1GHz gave maximum output power of 2.13W/mm, maximum power gain of 28dB and power-added efficiency (PAE) of 46%. The bias point was 50mA drain current, 50V drain voltage, and -1.6V gate potential. The maximum output power fell short of the expected value of 3.13W/mm. This was attributed to impedance mismatch between the device and load of the testing system.

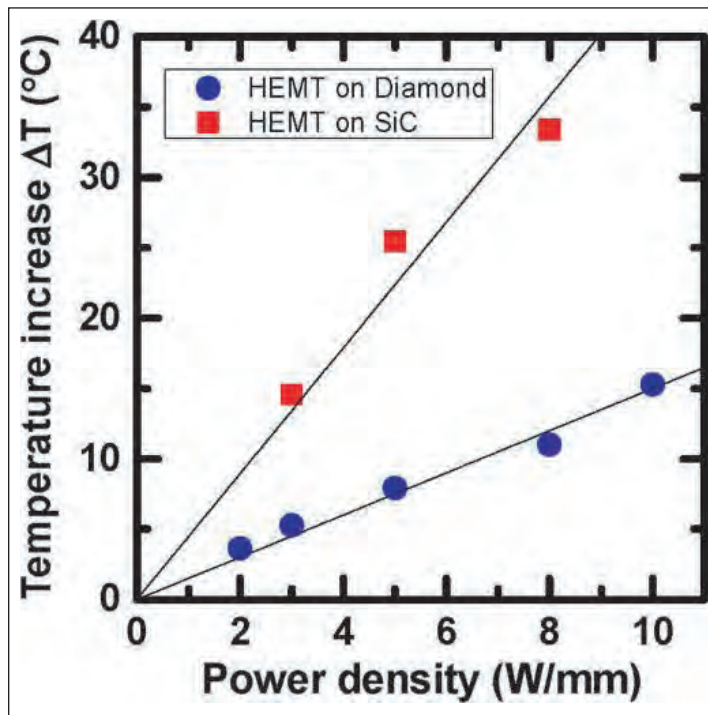


Figure 2. Power density dependence of temperature increase on diamond and silicon carbide.

The thermal performance of devices on diamond was compared with that of devices on silicon carbide, using infrared thermography (Figure 2). The thermal resistances derived from the slope of temperature increase with power density were 1.5K-mm/W for the diamond device and 4.2K-mm/W for the silicon carbide device. The type IIa diamond substrate also performed much better than a previously reported device on higher-nitrogen-content type Ib diamond that had a resistance of 4.1K-mm/W. ■

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Watt-level QCL emission at 3.3 μm without antimony

ETH-Zürich achieves short-wavelength quantum cascade laser operating at 350K using strain-compensated InGaAs/InAlAs on InP.

ETH-Zürich's Institute for Quantum Electronics has produced short-wavelength (3–4 μm) quantum cascade laser (QCLs) without using antimony (Sb) as part of the material structure [A Bismuto et al, *Semicond. Sci. Technol.* vol27, p045013, 2012]. Watt-level emission was obtained at 3.3 μm at room temperature, and pulsed operation lasing was achieved beyond 350K.

Using antimony in the lasing material has allowed QCLs to be created in this spectral range with low current threshold and low power consumption.

However, the growth of aluminum gallium indium arsenide antimonide (AlGaInAsSb) combinations can be difficult to achieve using most processes developed for high-performance laser operation.

Structures such as AlSb/GaAs/InAs/AlInSb on GaSb substrate have been used for short-wavelength QCLs. The laser operation is continuous wave (cw) at room temperature, based on interband cascade transitions. However, these devices suffer from relatively low slope efficiencies and high thermal degradation, as represented by low characteristic temperatures (less than 50K for both threshold current and slope efficiency).

The researchers see QCL devices as potential coherent light sources for the mid-infrared 'first atmospheric window' that falls in the 3–5 μm range. A large number of gases can be detected through light absorption levels, such as methane, nitric oxide, carbon monoxide,

carbon dioxide, formaldehyde etc. Further, stretching modes of C–H, N–H and O–H bonds fall in this range. These absorption levels can be several orders of magnitude larger than the overtone and combination bands that fall in the near infrared. The higher absorption should allow the measurement of extremely low concentrations using simpler, more compact systems.

Other possible applications include metrology, industrial control and clinical diagnostic systems.

However, QCLs designed for this range of wavelengths suffer from a number of problems. Some of these are due to the electronic band structure of the usual compound semiconductor materials. Other problems include interface roughness and material strain control.

The ETH team has focused on developing a non-Sb system of strain-compensated layers of InGaAs/InAlAs

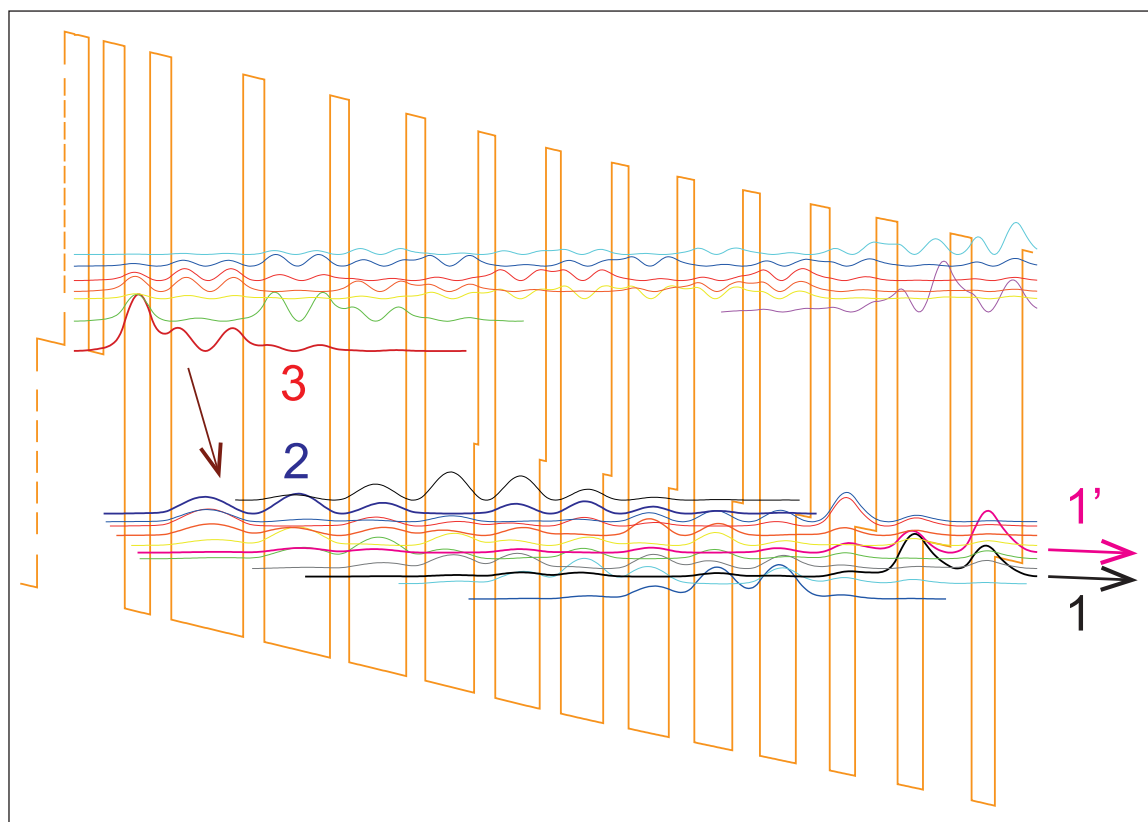


Figure 1. Conduction band diagram of one period of the active region at an average field of 120kV/cm. Calculated moduli squared of the relevant envelope wavefunctions are shown.

on indium phosphide (InP) substrates. The thickness of the barriers and wells had to be tuned so that strain levels and band offsets could be maintained. The strains for AlAs barriers and $\text{In}_{0.72}\text{Ga}_{0.28}\text{As}$ wells are +3.54% and -1.34%, respectively. These strain targets put constraints on the layer thicknesses. In this system, the AlAs thickness is restricted to about a third of that of the InGaAs well.

In order to ease these constraints, an InAlAs/AlAs composite barrier was developed. The growth process for InAlAs/AlAs (4.7nm/1.6nm) superlattices was first optimized, x-ray analysis suggesting that a growth

temperature of 493°C was optimum. In fact, for the developed QCLs, the AlAs was restricted to less than 1nm to avoid excessive strain in the individual barriers due to the higher complexity of laser structures as opposed to simple superlattices.

The QCL structures were grown on InP substrates. X-ray analysis indicated that the strain was perfectly balanced between +3.5% compressive strain in the AlAs barriers and -1.3% tensile stress in the InGaAs wells. The overall strain was about 0.1%.

The active region of the device consisted of 30-period cascade repetitions (Figure 1) sandwiched between 200nm InGaAs confinement layers. Suitably doped cladding layers of InP and InGaAs were added. The material was formed into ridge-waveguide laser diodes using wet chemical etching. Electrical insulation was provided by silicon dioxide. The top contact was titanium/platinum/gold. The device was thinned to 180µm before application of the bottom contact of germanium/gold/nickel/gold.

The researchers report on the performance: "Watt-level emission is observed at room temperature and the laser performance is comparable to what was observed for Sb-containing QCLs." The characteristic temperatures for thermal degradation of threshold current and slope efficiency (the increase in laser power output with current) are 70K (T_0) and 100K (T_1), respectively.

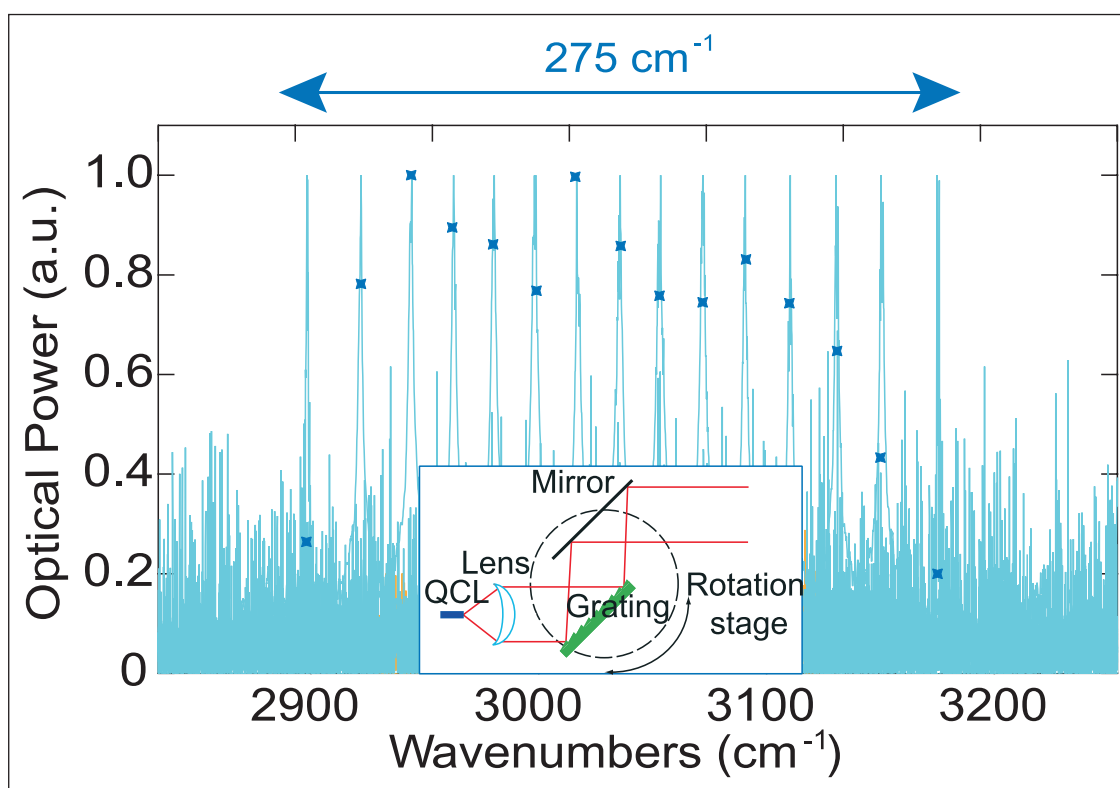


Figure 2. Tuning behavior with corresponding peak optical output power of the external-cavity QCL at various wavelengths. Measurements were taken at 288K at a duty cycle of 1.5% (15ns, 1MHz) at different currents. Schematic sketch of external-cavity QCL setup operated in Littrow configuration.

With a Littrow external cavity, a 3mm-long 15µm-wide device produced single-mode emissions tunable in the range 3.15–3.4µm (Figure 2).

With a view to continuous-wave performance, the researchers have also begun the development of buried heterostructure (BH) QCLs. First-order distributed feedback (DFB) gratings were defined using holography on the 200nm InGaAs confinement layer above the active region. The 80nm grating depth was wet etched. The grating was then buried in the n-InP cladding layer. Ridge widths were created between 3µm and 6µm, again using a wet etch. Lateral electrical insulation was supplied by iron-doped InP deposited on the side of the ridges.

These devices are not satisfactory as yet, although single-mode emission is observed at 250K. The researchers found significant leakage current and ageing effects. The leakage problem is attributed to use of the BH structure and, in particular, high-aluminum-content material. Voids in the Fe-InP insulating layers are also observed. New etching processes are being developed to overcome this problem.

The researchers believe that careful optimization of the active-region medium could open up the whole first atmospheric spectral region. One possible route to this could be through heterogeneous cascade structures. ■

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Double dielectric on nitride semiconductor LED boosts output power by 25%

Korean researchers show how a combination of silicon dioxide and aluminum oxide layers offers anti-reflective and passivating effects.

Researchers based in Korea have used double dielectric layers on nitride semiconductor light-emitting diodes (LEDs) to boost output power by up to 25% through anti-reflective and passivation effects [Chung-Mo Yang et al, IEEE Electron Device Letters, published online 2 March 2012]. The research was a collaboration between Kyoungpook National University and Samsung LED Company.

The epitaxial layer structure was grown on patterned sapphire substrates using metal-organic chemical vapor deposition (MOCVD). The active region consisted of indium gallium nitride (InGaN) multi-quantum wells (MQWs) with gallium nitride (GaN) barriers. The region was designed to emit at 460nm (blue) wavelength.

In further processing (Figure 1), the electrodes were then created, first by etching down to the n-type layer and then depositing and annealing (500°C) a 5nm/5nm nickel-gold transparent contact on the p-type layer. Thick bonding pads of titanium/gold were then produced.

The fabrication was then completed by depositing the double dielectric of 5nm aluminum oxide (Al_2O_3) by plasma-enhanced atomic layer deposition (ALD) and 50nm silicon dioxide (SiO_2) by plasma-enhanced CVD. A Fresnel analysis suggested that the optimum layer thicknesses to maximize the output power would have

The double dielectric layer device benefits from improved light extraction through the index of refraction of the SiO_2 layer widening the angles at which light can emerge from the device, along with improved electrical performance from reduction of competing non-radiative surface recombination of electrons and holes due to the Al_2O_3 passivation

an Al_2O_3 layer of 20nm followed by 50nm SiO_2 . However, such a double-layer would suffer from undesirable reverse current effects that increase as the passivation thickness increases. At normal incidence, it is estimated through a Fresnel analysis that the 50nm/5nm $\text{SiO}_2/\text{Al}_2\text{O}_3$ structure should allow 10% more light to be transmitted compared with a device without dielectric.

Various passivation layer combinations were tested for LED output power (Figure 2). The double dielectric layer results in about 25% higher output power compared with the unpassivated LED. The double dielectric layer device benefits from improved light

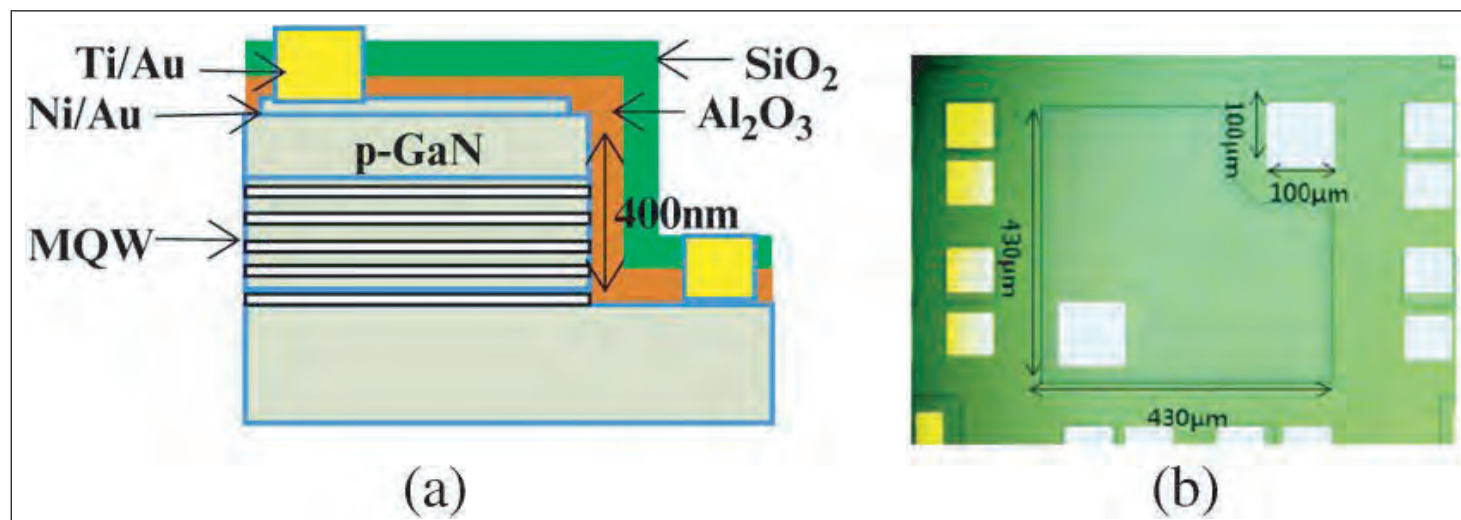


Figure 1. (a) Schematic of the LED configuration. (b) Fabrication of the 430µm x 430µm real LED chip.

extraction through the index of refraction of the SiO_2 layer widening the angles at which light can emerge from the device, along with improved electrical performance from reduction of competing non-radiative surface recombination of electrons and holes due to the Al_2O_3 passivation.

Parallel conduction through unpassivated surfaces lowers the apparent turn-on voltage of devices. The voltages at 20mA forward current were 3.31V, 3.33V, 3.39V and 3.99V for the unpassivated, the Al_2O_3 -passivated, the SiO_2 -passivated, and the $\text{SiO}_2/\text{Al}_2\text{O}_3$ -passivated LEDs, respectively.

Al_2O_3 passivation also reduced reverse leakage current at -5V by two or three orders of magnitude from $-1.9 \times 10^{-8}\text{A}$ (unpassivated) and $-7.14 \times 10^{-9}\text{A}$ (SiO_2 passivated) to $-3.46 \times 10^{-11}\text{A}$ (Al_2O_3).

Another positive effect of Al_2O_3 passivation is reduced trap state densities, which are estimated to be $2.6 \times 10^{11}/\text{eV}\cdot\text{cm}^2$ for the Al_2O_3 passivated device, compared with $6.2 \times 10^{12}/\text{eV}\cdot\text{cm}^2$ for the SiO_2/GaN inter-

face. The lower trap density decreases the amount of competing non-radiative recombination. ■

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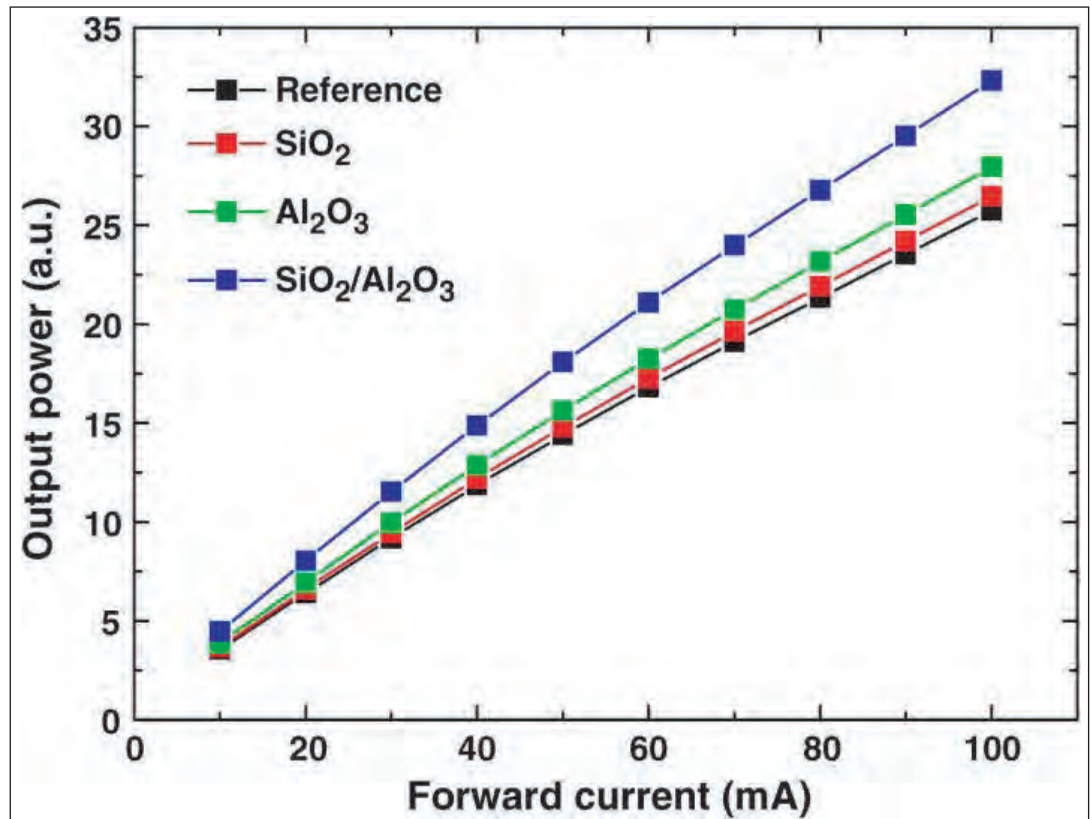


Figure 2. Output power characteristics of unpassivated, SiO_2 -passivated, Al_2O_3 -passivated, and $\text{Al}_2\text{O}_3/\text{SiO}_2$ -passivated LEDs. The output power of the $\text{Al}_2\text{O}_3/\text{SiO}_2$ -passivated LED is about 25% higher than that of the unpassivated LED.

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Transparent conduction for nitride LEDs

Mike Cooke reports recent developments in transparent conducting materials.

Transparent materials that conduct electricity are clearly desirable for the many new applications that combine light emission/absorption with electronics such as flat-panel displays and touch screens. In the compound semiconductor world, solar cells and light-emitting diodes would also benefit from the use of such materials.

In nitride LEDs, efficiency droop effects at high current injection mean that there is an advantage to making the current as uniform as possible across devices [see March/April issue, page 100]. Bare p-type gallium nitride (GaN) semiconductor has a lower conductivity, tending to restrict the current path to regions near the metal electrodes/pads. This creates a non-uniform current density across the device.

One approach for transparent conduction is to use very thin layers of metal. However, as metal thins it also becomes less conductive. Heavily doped wide-bandgap oxides, such as alloys of indium oxide (In_2O_3) and tin oxide SnO_2 , or zinc oxide (ZnO) are also transparent conductors. In fact, indium tin oxide (ITO) is widely used for flat-panel displays. Unfortunately, there are supply and consequent pricing concerns with the mass usage of indium. Instead, zinc oxide is being developed as a potential lower cost alternative across a number of applications.

In the past decade, graphene has emerged as another contender for such applications. In this article, we explore some recent developments in transparent conducting materials for LED applications.

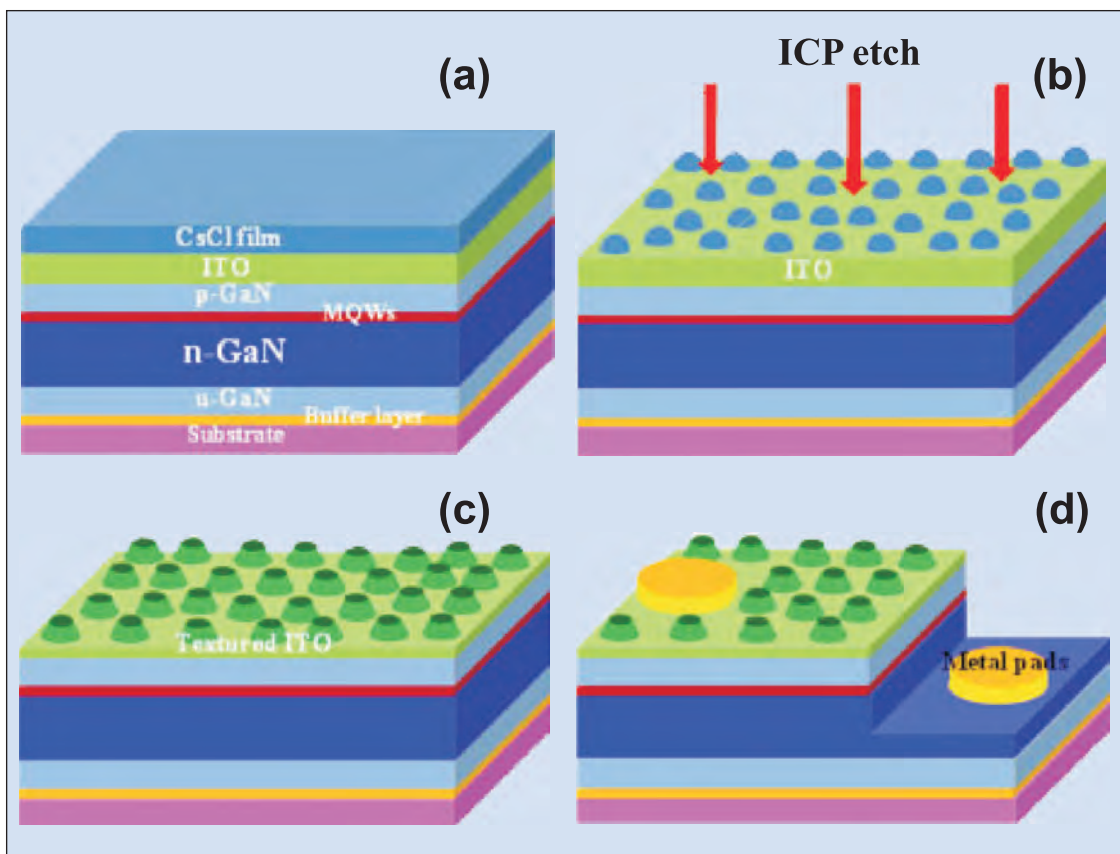


Figure 1. Schematics of Chinese Academy of Sciences fabrication process: (a) cesium chloride film deposition, (b) ICP etching, (c) nanoislands on the ITO layer, and (d) metal pad fabrication.

Nano-textured ITO

It is often helpful to light extraction to texture surfaces. This is because light is reflected back into the LED at interfaces between materials with different refractive indices, such as GaN/air or ITO/air. Researchers in China have used self-assembled cesium chloride (CsCl) nanospheres as a cost-effective mask for nano-texturing ITO layers on nitride semiconductor LEDs to improve light extraction by up to 23.4% [Yiyun Zhang et al, *Jpn. J. Appl. Phys.*, vol51, p020204, 2012].

The researchers were based at Chinese Academy of Sciences' institutes of semiconductors (Semiconductor Lighting Technology Research and Development Center) and of high-energy physics in Beijing. Researchers from the same facilities had previously attempted to use CsCl nanospheres to nano-texture the p-type GaN layer of nitride LEDs directly, but found that the process

often degraded the electrical performance of devices.

In the new work, conventional LED structures were grown on sapphire using metal-organic chemical vapor deposition (Figure 1). The active layer consisted of an 8-period multi-quantum well (MQW) with InGaN wells and GaN barriers.

A 300nm ITO transparent conducting layer was electron-beam deposited on the top p-GaN layer of the LED. This was followed by thermal evaporation of CsCl onto the ITO — various thicknesses of this layer were tested to optimize the process.

Exposure of the CsCl layer to water vapor caused the material to 'self-assemble' into 'nanospheres'. The spheres were randomly distributed on the wafer surface ($1.6\text{--}0.13 \times 10^9/\text{cm}^2$). The average diameter of the spheres (450–900nm) is controlled by the CsCl film thickness (50–150nm), relative humidity, and development time. In fact, the 'spheres' were not spherical but rather approximately hemispherical — a 700nm-wide island had a height of around 300nm.

The wafer was then subjected to inductively coupled plasma etching to pattern the ITO surface. The CsCl residue was then removed by soaking in deionized water. This etch process textured the ITO surface into truncated-cone nanoislands.

LEDs were constructed from the resulting material by etching mesas and applying chromium/platinum/gold metal layers on the p- and n-type contact layers.

All the treated ITO surfaces showed improved light output power at 350mA over a planar device (Figure 2). The largest improvement of 23.4% came from the 700nm nanosphere

etched surface. Improvements for 450 and 900nm nano-sphere treatments were 6.8% and 13.1%, respectively.

The researchers comment: "Obviously, there is an optimal size of the cesium chloride nanospheres. When the cesium chloride nanospheres are too large, the light

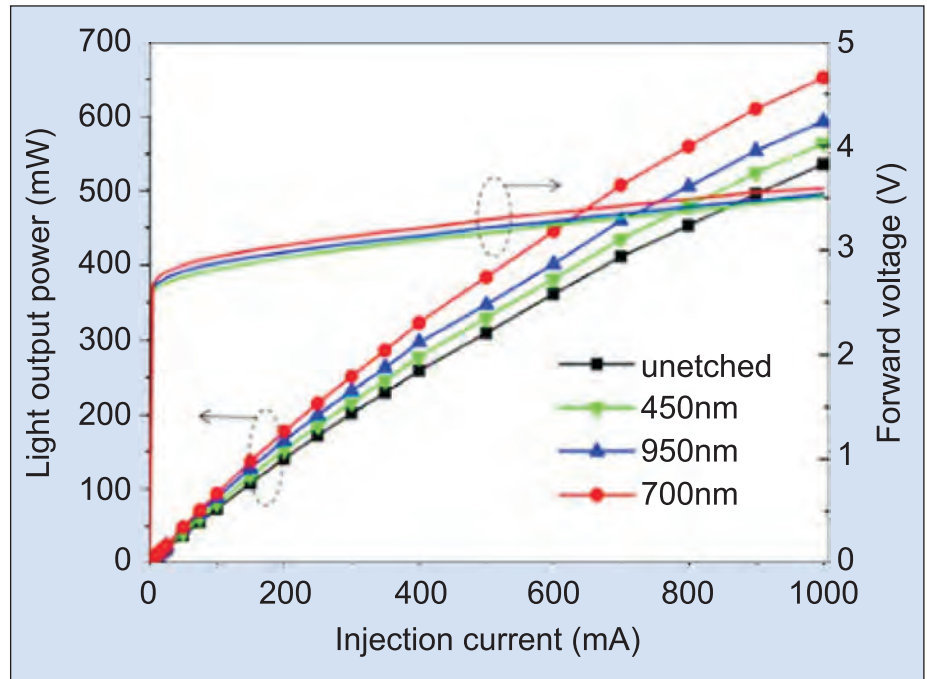


Figure 2. Light output power and forward voltage vs. current for LEDs produced by Chinese Academy of Sciences using different cesium chloride nanosphere sizes.

scattering occurring at the interface between the ITO layer and the air will be reduced because of the fewer nanoislands fabricated on the ITO layer. On the other hand, too small cesium chloride nano-spheres cannot entirely cover the ITO layer, which strongly affects the surface morphology of the etched ITO layer."

An important further consideration is that the treatment has little impact on electrical performance, as seen in the very similar current–voltage curves (Figure 2). This allows the researchers to conclude that the electrical performance of the LEDs is not damaged by the etch process. However, there is a slight increase in forward voltage of 0.1V in the best light output power device from 700nm nanospheres. This could be due to the

Contact	Mg-doped p ⁺ -GaN	10nm
Hole injection	Mg-doped p-GaN	50nm
Electron blocking (EBL)	Mg-doped p-GaN/p-AlGaIn (15% Al)	16nm/16nm
Active	3x(GaN/InGaN) (15–20% In)	20nm/3nm
Electron injection	Si-doped n-GaN	1μm
Substrate	(10 $\bar{1}\bar{1}$) bulk GaN	

Figure 3. Epitaxial structure used for UCSB/CNU LEDs.

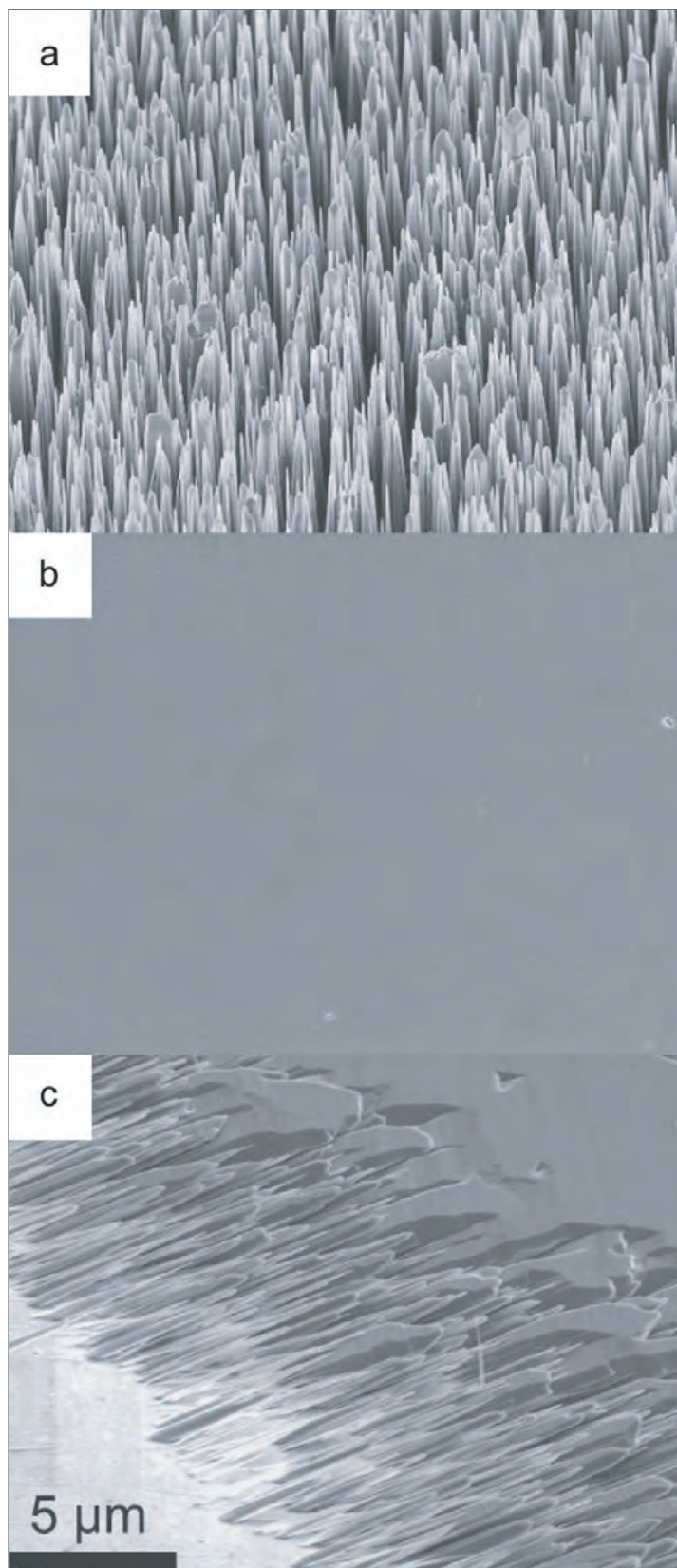


Figure 4. Representative SEM images showing the UCSB/CNU ZnO morphology resulting from identical growth conditions on (a) (0001) and (b) $(10\bar{1}\bar{1})$ GaN substrates. An uncoalesced region of the same $(10\bar{1}\bar{1})$ film from (b) is shown in (c).

surface being too rough to form good ohmic contacts on the ITO layer.

Zinc oxide

Researchers in the USA and Korea have been developing zinc oxide (ZnO) as a transparent conducting material for use with LEDs constructed from $(10\bar{1}\bar{1})$ semipolar nitride semiconductor material [Jacob J. Richardson et al, Appl. Phys. Express, vol4, p126502, 2011].

The use of semipolar or even nonpolar III-nitrides is designed to overcome polarization field effects that arise spontaneously and in strained piezoelectric conditions such as the quantum-confined Stark effect (QCSE). These fields are strongest along the standard c-direction of the nitride semiconductor lattice.

The University of California Santa Barbara (UCSB) has been researching semipolar and nonpolar devices for some time. The Korean researcher, Jun-Seok Ha, came from Chonnam National University (CNU), Republic of Korea.

The UCSB/Chonnam team grew their devices on $(10\bar{1}\bar{1})$ bulk GaN substrates supplied by Japan's Mitsubishi Chemical Corp. Atmospheric-pressure metal-organic chemical vapor deposition (MOCVD) was used to grow multiple films of various alloys involving indium, aluminum and gallium nitrides (InAlGaIn — see Figure 3).

The ZnO transparent layer was grown using a low-temperature aqueous solution (pH 12 ammonia with dissolved ZnO). The substrates were suspended in the aqueous solution for 18 hours at 90°C.

Unlike previous work with c-plane GaN, the researchers found that they did not need separate nucleation or 'seeding' steps or solution additives to modify the morphology. For the c-plane growth these extra steps/additives avoid the formation of needle structures, rather than the desired smooth coalesced film (Figure 4). Further study of the sample holder region (Figure 3c) suggested that the growth—even on the $(10\bar{1}\bar{1})$ —GaN starts as needles pointing in the c-direction, but that these needles then coalesced to form a smooth film.

Thicker layers of ZnO were applied in multiple steps. The first layer was annealed at 500°C in oxygen–nitrogen (20% O₂) gas for 15 minutes to improve adhesion of subsequent layers. Without this annealing step, the entire film of thicker layer ZnO would occasionally delaminate.

LEDs were then created using standard processes such as chlorine plasma etch to the n-type layer, forming 2mm x 0.5mm mesas, and electron-beam deposition of the contact metals. The backside of the wafer was roughened to reduce light reflection at the sapphire–air interface. The singulated chips were packaged in a vertical stand transparent LED architecture.

Pulsed measurements (1% duty cycle, Figure 5) gave light output power of 27mW at a current density of 2A/cm², and 276mW at 35A/cm². The maximum

external quantum efficiency (EQE) reached 48% at $1\text{A}/\text{cm}^2$. At the highest current density of $35\text{A}/\text{cm}^2$, this had fallen to 27.5%.

The researchers comment: "The light output and EQE of the device using the ZnO were lower than results previously published for a similarly packaged ($10\bar{1}\bar{1}$) device using an ITO current-spreading layer."

The team points out that, due to the smallness of the substrate available, they were unable to compare their ZnO-covered device with one using ITO. The difference in performance with the earlier experiment could be down to a difference in quality of the substrates or in run-to-run process variations in the MOCVD growth of the epitaxial material, they say.

Monolayer graphene

Another group of Korean and US researchers has compared the performance of graphene with ITO as a transparent conducting electrode (TCE) on the p-contact of nitride semiconductor LEDs [Tae Hoon Seo et al, Jpn. J. Appl. Phys., vol50, p125103, 2011].

This research involved Chonbuk National University, University of Michigan (UM), and Sungkyunkyun University (SU), and used monolayer graphene grown on copper foil. Earlier last year, a different team of researchers from Korea University, Korea Electronics Technology Institute and US Naval Research Laboratory reported the use of few-layer graphene as TCE for UV applications (www.semiconductor-today.com/news_items/2011/NOV/KU_0711111.html).

One particular attraction for graphene is that it transmits light of shorter wavelengths beyond the 300–400nm ultraviolet range where ITO cuts off. Comparisons between the light transmittance of graphene and 250nm ITO on aluminum oxide in the wavelength range 400–800nm gave values of more than 90% (up to nearly 97%) and ~80%, respectively. Below 400nm (the UV region), graphene continued to transmit about 90% of light, while ITO became opaque around 300nm.

One drawback of graphene is that due to its thinness it is more resistive than ITO. This means that the forward voltage at 20mA of the graphene contact LED was 5.87V, compared with 3.4V for the ITO-based device. Despite this, the light output power was 25% greater in the graphene LED at 20mA (Figure 6). The power loss of the graphene contact does begin to impact performance around 80mA, causing early saturation of device performance.

The researchers expect further efficiency enhancements in GaN-based LEDs that use graphene due to the intensive research in graphene material. This research is expected to

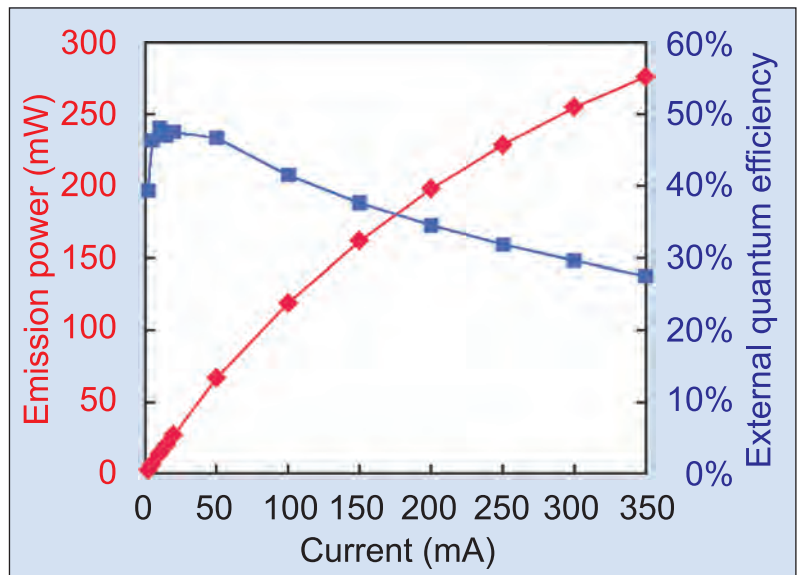


Figure 5. Light emission power and external quantum efficiency of UCSB/CNU semipolar ($10\bar{1}\bar{1}$) LED using an epitaxial ZnO current-spreading layer deposited from low-temperature aqueous solution. Measurements were performed under pulsed current conditions (1% duty cycle).

allow enhanced electrical properties such as control of the graphene work function and reduction of sheet resistance.

The LED structures were grown on sapphire using MOCVD. The active layer was a five-period InGaIn/GaN quantum well/barrier structure. The p-GaN layer was 200nm thick. The n-GaN layer was 2 μm thick, grown on 2 μm GaN buffer and 25nm GaN nucleation layers.

The high-quality monolayer graphene was produced using chemical vapor deposition on 70 μm copper foil. After a preparatory flow of hydrogen to reduce oxide on the copper (2.5 hours), the carbon source of methane was introduced (30mins). To transfer the

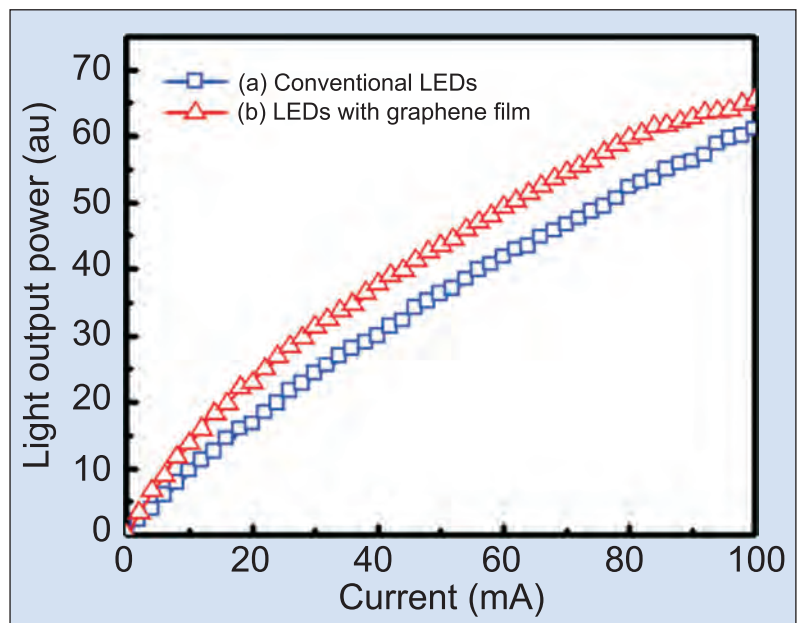


Figure 6. Light output of CNU/UM/SU LEDs versus current.

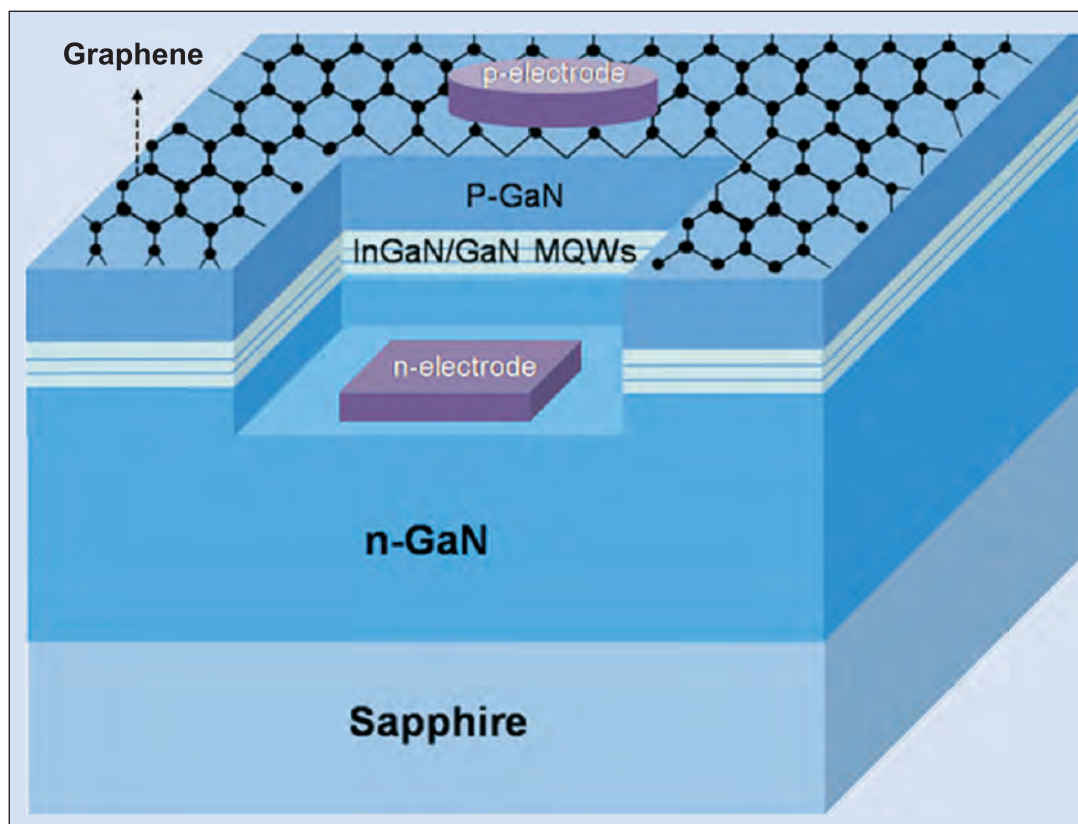


Figure 7. Schematic of CNU/UM/SU GaN-based LEDs with graphene film.

graphene, a poly(methyl methacrylate) (PMMA) film was spin-coated on the graphene. The copper was then (wet) etched away. The graphene was then applied to the GaN surface and the PMMA removed by annealing at 500°C in a hydrogen/argon mix for 30mins.

Although FCA is usually considered an infrared phenomenon, the UCSB/UM research suggests that it can also be significant in the visible range. FCA is an indirect process involving additional processes such as coupling to lattice vibrations/phonons. The additional

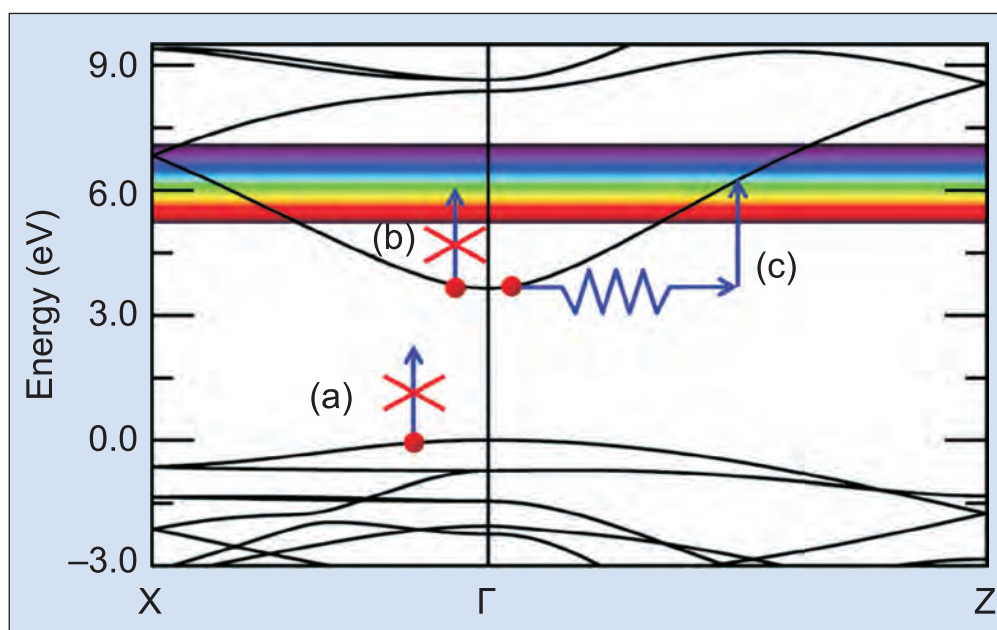


Figure 8. UCSB calculation of band structure of rutile SnO_2 , illustrating free-carrier absorption. Visible light does not carry enough energy to excite carriers across the band gap (a) or to excite free carriers directly to the next conduction-band states (b). But extra momentum provided by a phonon enables indirect free-carrier absorption (c) for any visible or infrared wavelength. States in energy range of the visible spectrum are indicated.

The LEDs (Figure 7) were formed by creating a mesa, removing the graphene film in the n-electrode region using an ash and then plasma etching the nitride semiconductor material down to the n-type layer. The electrodes for the n- and p-layers were chromium/gold. Devices with 250nm ITO transparent conduction layers were also produced for comparison.

University of California Santa Barbara and University of Michigan have been researching the theoretical reasons for the UV cut-off in tin oxide [H. Peelaers et al, Appl. Phys. Lett., vol100, p011914, 2012]. The team sees free-carrier absorption (FCA) as being the fundamental source of optical loss giving a transparency limit.

process is needed to conserve quasi-momentum in the conduction band (Figure 8). The work is based on first-principles density functional and perturbation theory.

In particular, the researchers see an absorption enhancement at short wavelengths (Figure 9), but before direct inter-band transitions are allowed. The tin oxide bandgap is about 3.6eV (344nm). Indium oxide has a similar value. However, these bandgap values are the least energy difference between the valence and conduction bands and do not represent dipole allowed transitions. The dipole allowed gap in tin oxide is 4.3eV (288nm). The researchers comment: "The absorption enhancement at shorter wavelengths cannot be described by simpler approaches such as the Drude model and is a clear prediction of our first-principles approach."

On the basis of their calculations, the researchers believe that electron-phonon scattering is the dominant mechanism in the 300–6000nm wavelength range, so long as the electron concentrations are under $10^{20}/\text{cm}^3$. At higher concentrations, scattering from ionized donors becomes significant in FCA. The absorption increases towards the UV and IR communication ends of the spectrum by up to 5x and 20x, respectively.

“Direct absorption of visible light cannot occur, because the next available electron level is too high in energy. But we found that more complex absorption mechanisms, which also involve lattice vibrations, can be remarkably strong,” says Hartwin Peelaers, a postdoctoral researcher and the lead author of the paper.

Graphene-nanorod hybrid

Researchers in Korea have combined graphene (Gr) and zinc oxide nanorods (ZNRs) in a nitride LED transparent conducting layer (TCL) [Jung Min Lee et al, Appl. Phys. Lett., vol100, p061107, 2012]. The effect is to increase light emission, along with improving the electrical current injection performance of the device. The research was an academic-industrial collaboration between Hanyang University (HU) and LG Display Co Ltd.

At 2.8V forward bias, an LED with Gr TCL demonstrated 4x the light intensity of a device without Gr, and 2x the injection current. Adding ZNRs gave a further 66% light output.

The researchers comment: “Our hybrid approach, which combines the key advantages of both 1D nanostructures and 2D Gr, could open up advanced and new design opportunities in high-performance optoelectronic devices resulting in optimal performance and functionality.”

The base for the new device structure was a traditional InGaN LED with a trident-shaped p-electrode frame (Figure 10) to which a layer of graphene was applied. The graphene was produced by methane-based chemical vapor deposition on copper and

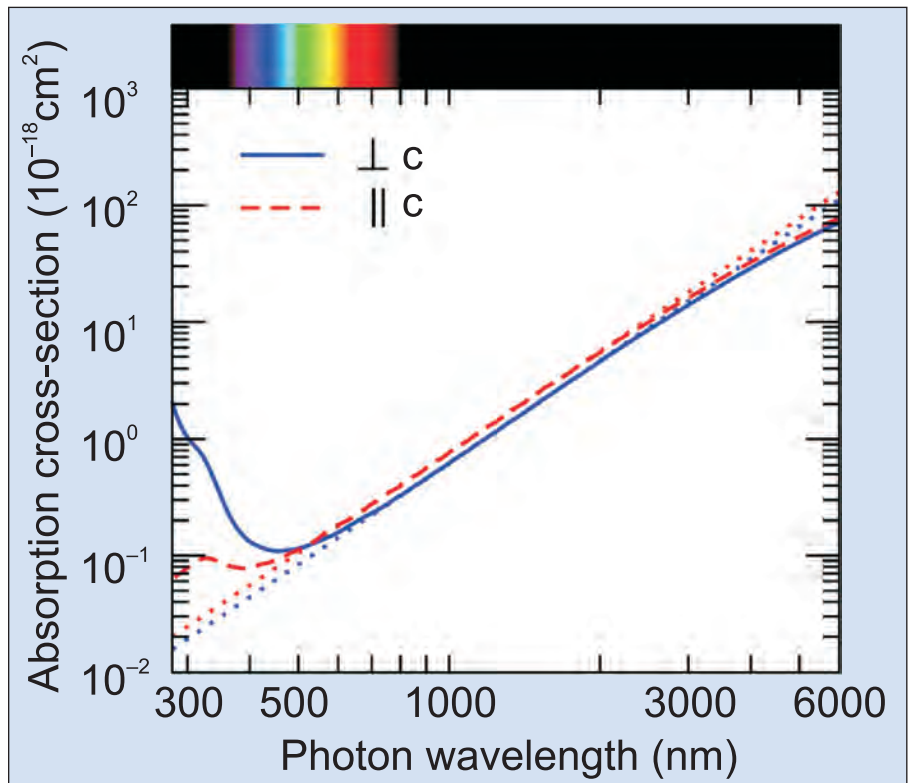


Figure 9. UCSB calculation of phonon-assisted free-carrier absorption in SnO_2 for light polarized perpendicular (solid line) or parallel (dashed line) to c-axis of the rutile structure. The dotted lines are fits to a simple model based on a Fröhlich electron coupling to longitudinal optical phonons. The visible spectrum is shown at the top of the graph as a reference.

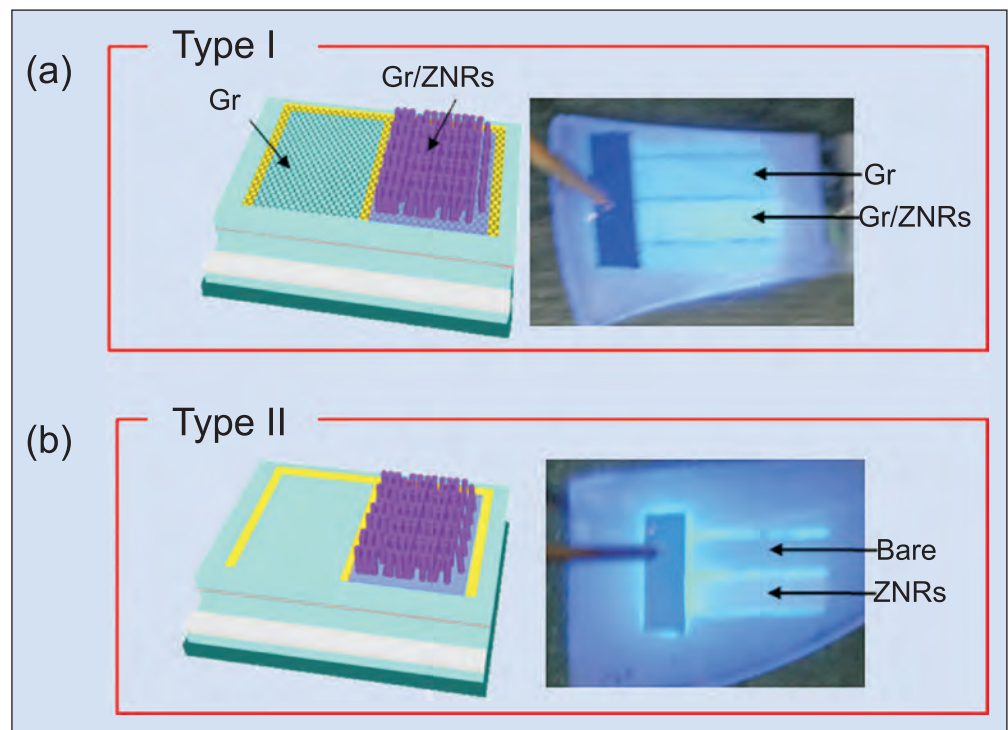


Figure 10. Schematic diagrams and photographs of HU/LG type I and II LEDs. (a) The schematic of type I LED with Gr and Gr/ZNR window electrodes along with a photograph of the resulting device. (b) The schematic of the type II LED with bare and ZNR window electrodes along with photograph of resulting device.

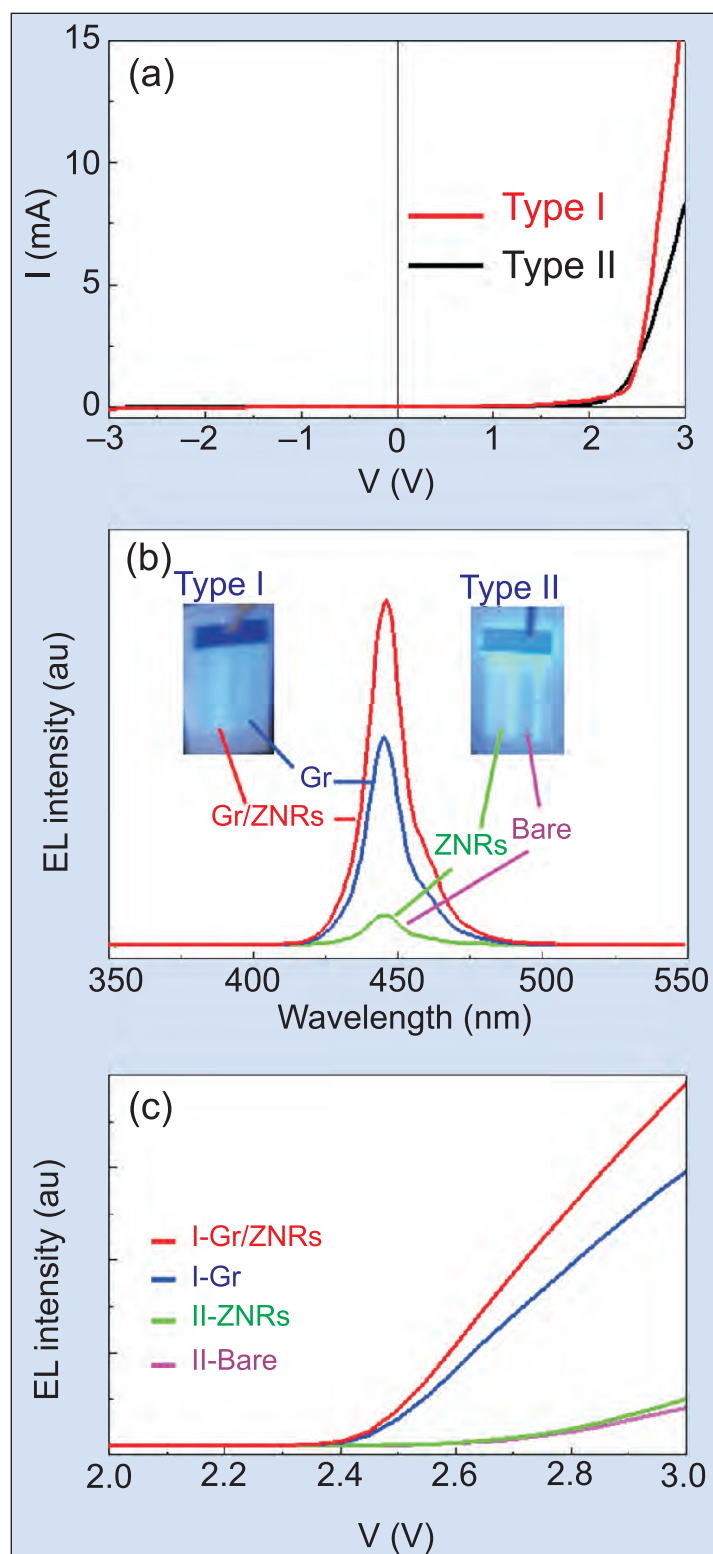


Figure 11. (a) Current–voltage (I–V) curves of HU/LG type I and II LEDs. (b) EL spectra of the type I and II GaN LEDs with four different top window electrodes (I-Gr, I-Gr/ZNRs, II-bare, and II-ZNRs) recorded at an applied voltage of 2.8 V. (c) EL intensity vs. voltage curves of GaN LEDs with different window electrodes.

transferred to the LED surface. ZnO nanorods were then grown selectively on the graphene using a low-temperature hydrothermal process in aqueous solution.

Optical experiments on the graphene and ZNR–graphene hybrid films suggested transmittances of 97% and 90% in the visible spectral range, respectively. The contact resistance was improved by including a very thin annealed layer of 1nm/1nm nickel/gold (Ni/Au) film before the ZNR–graphene hybrid film. The specific contact resistivity was reduced from $5\Omega\text{-cm}^2$ to $0.5\Omega\text{-cm}^2$ by the Ni/Au inclusion.

In all, four types of TCLs on the p-electrode were produced: a bare control, a ZNR-only film, a graphene film, and the ZNR–graphene hybrid. These were doubled up on two devices: ‘type I’ containing Gr-only and Gr–ZNR hybrid layers, and ‘type-II’ with bare and ZNR layers.

Scanning electron micrograph (SEM) inspection of the ZNR–graphene hybrid gave an average diameter for the near-vertical ZNRs of 50nm and an average height of $3\mu\text{m}$. The hexagonal cross-section of the rods was taken as indicating high crystal quality. There was also observed a thin 50nm ZnO film immediately above the graphene and below the NRs. This thin layer is believed to act as a seed layer for the rods.

The turn-on voltages of the devices are around 2.5V (Figure 11a). At -3V reverse bias, the leakage current is $7\times 10^{-5}\text{A}$. Under higher forward bias, the graphene-containing devices (‘type-I’) carry more current due, it is thought, to more efficient current spreading by the graphene and thin metal layers.

Electroluminescence occurred around the blue-violet wavelength of 446nm (Figure 11b). When driven at 2.8V, the current of the graphene-containing devices was double that of the non-graphene devices (‘type-II’).

In terms of light emission, the devices with graphene transparent contact exhibit up to 4x the amount of light intensity. Part of the improvement is attributed to reduced current crowding, giving more uniform illumination across the device. The improvement comes despite the estimated optical transmittance reduction of 20% due to the presence of the metal layers between the nitride contact and the graphene layers.

Adding the ZNRs, increases the light intensity a further 66% over the graphene-only device. This improvement is attributed to multiple photon scattering and the more gradual change in refractive index between the GaN layer and air. ZNRs have also been used to improve light extraction with ITO TCLs, giving a 57% boost with well-aligned rods and 34% for poorly aligned structures.

The better performance of ZNRs on graphene is attributed to the chemical stability of graphene. With ITO layers, the ZNR hydrothermal process attacks the TCL, slightly degrading its electrical properties.

The researchers also point to the better thermal properties of graphene for conducting heat away from the LED, improving performance. ■

Mike Cooke is a freelance technology journalist who has worked in semiconductor and advanced technology sectors since 1997.

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www.camchem.co.uk

The Fox Group Inc

(see section 3 for full contact details)

Intelligent Epitaxy Technology Inc

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5 Deposition materials

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MA 02464, USA
Tel: +1 617 965 5511
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www.microchem.com

Power + Energy Inc
(see section 10 for full contact details)

Praxair Electronics
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8 Wafer processing equipment

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Veeco Instruments Inc
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9 Materials & metals

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11 Process monitoring and control

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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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www.wepcontrol.com

12 Inspection equipment

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www.jawoollam.com

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www.suss.com

15 Assembly/packaging materials

ePAK International Inc

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Gel-Pak

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www.gelpak.com

Wafer World Inc

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16 Assembly/packaging equipment

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18 Chip foundry

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Fax: +44 141 579 3040
www.compoundsemi.co.uk

United Monolithic Semiconductors

Route departementale 128,
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Fax: +33 169 33 02 92
www.ums-gaas.com

19 Facility equipment

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www.marlerenterprises.net

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Fax: +1 412 471 9427
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Fax: +1 604 320 1734
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22 Used equipment

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TECDIA Inc

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24 Consulting

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25 Resources

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www.b2match.com/isicpeaw2012

3–6 June 2012

23rd Conference on Crystal Growth and Epitaxy — West (2012 AACGE-west)

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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

13–14 June 2012

euroLED 2012

NEC Birmingham, UK

E-mail: info@euroled.org.uk

www.euroled.org.uk

17–19 June 2012

2012 IEEE Radio Frequency Integrated Circuits Symposium (RFIC 2012)

Montreal, Canada

E-mail: tina.quach@ieee.org

www.rfic2012.org

17–21 June 2012

Optical Society of America (OSA) Advanced Photonics Congress, including Integrated Photonics Research, Silicon, and Nano-Photonics (IPR 2012)

Cheyenne Mountain Resort, Colorado Springs, CO, USA

E-mail: info@osa.org

www.osa.org/Meetings/optics_and_photonics_congresses/Advanced_Photonics_Congress

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Montreal, Canada

www.ims2012.org

19 June 2012

Nanoscale Plasma Processing

Southampton, UK

E-mail: process.news@oxinst.com

www.oxford-instruments.com/products/etching-deposition-growth/promotions/seminars

19–21 June 2012

Photonics Festival in Taiwan

Taipei World Trade Center, Taiwan

E-mail: exhibit@mail.pida.org.tw

www.optotaiwan.com/en

20–21 June 2012

Semiconductor Asia 2012

Shanghai, China

E-mail: sa@cdmc.org.cn

www.semiconductorasia.com

21 June 2012

Optoelectronics Industry Development Association (OIDA) workshop:

'Photonic Integration for Advanced Modulation Format Transmission at 100Gb/s and Beyond — Status of the Industry and Challenges Ahead' (co-located with the OSA's Advanced Photonics Congress)

Cheyenne Mountain Resort, Colorado Springs, CO, USA

E-mail: OIDAinfo@osa.org

www.oida.org/home/events/photonic_integration_workshop

24–29 June 2012

International Conference on Extended Defects in Semiconductors (EDS-2012)

Aristotle University of Thessaloniki, Greece

E-mail: eds-2012@physics.auth.gr

<http://eds-2012.physics.auth.gr>

4–5 July 2012

UK Semiconductors 2012 Conference and Exhibition

University of Sheffield, UK

E-mail: info@uksemiconductors.com

www.uksemiconductors.com

10–12 July 2012

SEMICON West 2012

Moscone Center, San Francisco, CA, USA

E-mail: semiconwest@xpressreg.net

<http://semiconwest.org>

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www.theledshow.com

12–16 August 2012

SPIE Optics + Photonics 2012

San Diego Convention Center, CA, USA

E-mail: customerservice@spie.org

<http://spie.org/optics-photonics.xml>

12–17 August 2012

Defects in Semiconductors: Gordon Research Conference

University of New England, Biddeford, ME, USA

E-mail: Evan.Glaser@NRL.navy.mil

www.grc.org/programs.aspx?year=2012&program=defects

22–24 August 2012

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KINTEX, Seoul, Korea

E-mail: led2100@naver.com

www.korealed.org

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29–31 August 2012

IEEE's 9th International Conference on Group IV Photonics (GFP 2012)

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E-mail: r.bankowski@ieee.org

www.gfp-ieee.org

2–6 September 2012

9th European Conference on Silicon Carbide & Related Materials (ECSCRM 2012)

St Petersburg, Russia

www.ecscrm-2012.org

6–9 September 2012

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