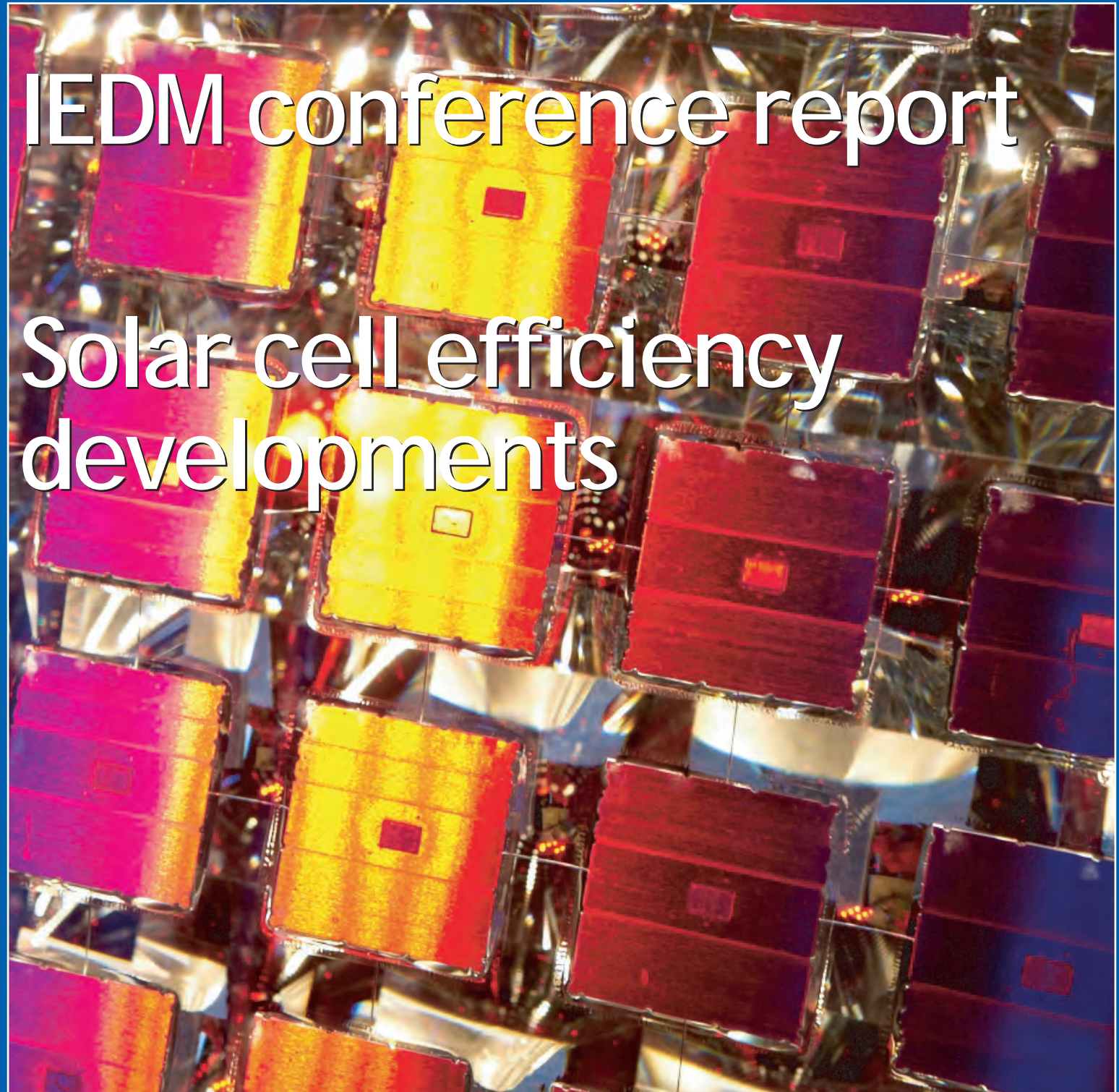


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COMPOUNDS & ADVANCED SILICON

Vol. 7 • Issue 10 • December 2012/January 2013 www.semiconductor-today.com



IEDM conference report

Solar cell efficiency developments

IQE buys Kopin Wireless • Zephyr Photonics launches foundry
Photop and Aegis merge • Global Solar cuts staffing by 70%

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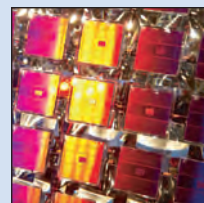
p34 KLA-Tencor has launched its ICOS WI-2280 fourth-generation wafer inspector for LED and adjacent markets.



p42 Seoul Semiconductor's new MJT LED chip has cells connected by multi-junction technology, enabling fixture-level performance of 100lm/W.



p56 Lithuania's President at the official opening of Brolis Semiconductors' MBE and laser diode production facility.



Cover: Arrays of concentrator photovoltaic cells. France's Soitec has opened its North American CPV module manufacturing facility in San Diego after completing on schedule an upgrade to install fully automated equipment and processes in a project representing an investment of over \$150m. **p70**

III-Vs on silicon work reported at IEDM, while thin-film PV challenges silicon efficiencies

As always, December's annual International Electron Devices Meeting (IEDM) presented cutting-edge developments in microelectronics by major players. As in recent years, this included — increasingly — not only conventional silicon-based technologies but also III-V (InGaAs) and germanium (Ge) materials, targeted at high-mobility channels for CMOS-compatible MOSFET device structures (see page 102). In addition, on page 100 we cover a report of monolithic indium arsenide (InAs) high-mobility channels on silicon, using a gallium antimonide (GaSb) buffer layer to avoid antiphase domains due to the lattice mismatch. Also, on page 98, we cover research on InGaAs-channel n-MOSFETs on germanium-on-insulator substrates (for integration with Ge p-MOSFETs on a common platform) that are said to have performance comparable to MOSFETs on indium phosphide (InP) substrates.

Regarding business news, January saw the acquisition by epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK of the Kopin Wireless compound semiconductor epiwafer manufacturing division of Kopin Corp of Taunton, MA, USA (page 17). As well as expanding its wireless market share (in particular for MOCVD-grown HBTs), IQE also gains Skyworks Solutions Inc of Woburn, MA (which has a long-standing supply agreement with Kopin) as a customer ("guaranteeing a significant proportion of Skyworks' business"). It also gains a possible boost to Asian business via Kopin Taiwan Corp. This follows IQE's acquisition last June of the in-house molecular beam epitaxy epiwafer manufacturing unit of RF Micro Devices Inc of Greensboro, NC, USA.

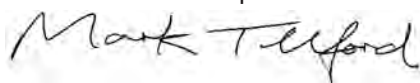
In the solar sector, the shakeout in copper indium gallium diselenide (CIGS) thin-film photovoltaics continues. Beijing-based Hanergy (claimed to be China's largest privately owned renewable energy firm) has finalized its acquisition of US Silicon Valley based CIGS solar panel maker MiaSolé. Meanwhile, Global Solar Energy Inc of Tucson, AZ, USA, which makes flexible CIGS solar modules, has implemented cost cuts — including slashing staffing by 70% (mainly manufacturing its roofing product line) — while it seeks a buyer for the firm (see page 78).

Nevertheless, the firms that are surviving the consolidation in this sector continue to make technical progress. Tokyo-based Solar Frontier — the largest maker of CIS (copper indium selenium) photovoltaic modules — has achieved record efficiency of 19.7% for cadmium-free, thin-film solar cells using the mass-production process of sputtering followed by selenization (see page 80). However, since the record was achieved using cells measuring 0.5cm² cut from a 30cm x 30cm substrate (rather than specifically developed small-area cells), the firm reckons it can also surpass the 20.3% efficiency record set using the co-evaporation process.

Most recently, Empa (the Swiss Federal Laboratories for Materials Science and Technology) has raised its efficiency record for copper indium gallium (di)selenide (CIGS) solar cells on flexible polymer substrates to 20.4%, exceeding the record of 20.3% cells on glass substrates (page 77). This also equals the efficiencies for polycrystalline silicon wafer-based solar cells, demonstrating the scope of thin-film PVs to cut dollars per Watt further.

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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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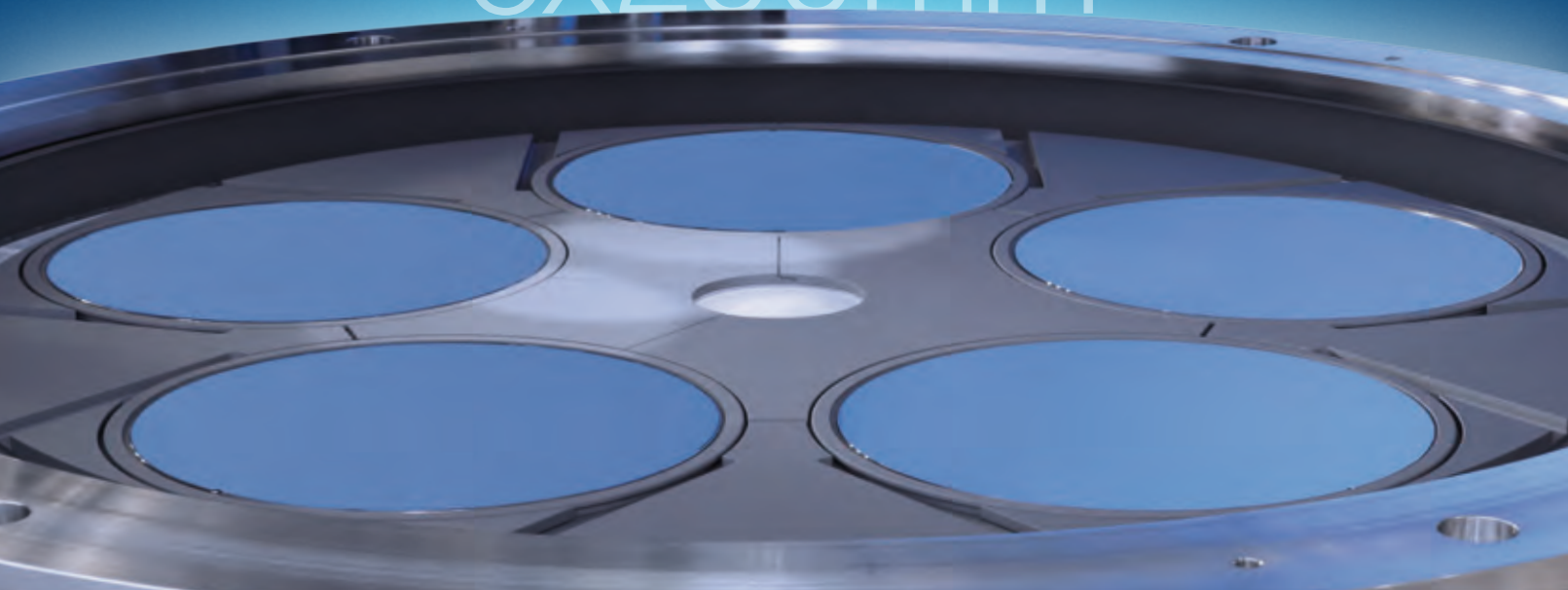
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Photonic integrated circuit market to grow at 26% from \$150m to \$1547.6m by 2022

APAC to grow at 35.9%, superseding North America as market leader

According to the report 'Photonic Integrated Circuit (IC) & quantum computing Market-By Application (optical fiber communication, Optical Fiber sensors, Biomedical, Others), Integration (Hybrid, Module & Monolithic), Components, Raw materials (LiNbO₃, silica on silicon, SOI, GaAs, InP), & Geography — Forecasts (2012–2022)' published by MarketsandMarkets, total market revenue is expected to increase at a compound annual growth rate (CAGR) of 26.3% from \$150.4m in 2012 to \$1547.6m by 2022.

Based on raw materials consisting of lithium niobate, silica-on-silicon, silicon-on-insulator, indium phosphide and gallium arsenide, photonic integrated circuits (planar lightwave circuits or integrated optoelectronic devices) have revolutionized the optical network industry, says the market research firm. Deployed primarily in optical fiber communications, the ability of PIC-based products to process a large amount of data at huge speeds makes them a key contributor to boosting transmission capacity. PICs have hence changed the dynamics of the optical network industry by increasing optical performance and reliability while reducing physical system size, power consumption and heat dissipation. Currently, 500Gb/s PICs have been developed to deliver high-capacity transmission while optimizing power, cooling, space and operational simplicity.

The main players in the PIC industry are the US-based firms Infinera Corp, NeoPhotonics Corp, Oclaro, Luxtera, Kotura and OneChip Photonics, which have played a significant role in changing the market dynamics. Leading players have developed monolithically integrated indium phosphide (InP)-based PICs.

For example, Infinera has introduced 500Gb/s PICs (for use in long-haul flex coherent super-channels) with the main features being simplicity, scalability, efficiency and reliability. NeoPhotonics has developed a PIC-based optical line terminal (OLT) transceiver, designed to lower the overall cost of fiber-to-the-home (FTTH) network installation. The report also covers developments such as NeoPhotonics acquiring Santur Corp in October 2011 and Oclaro acquiring Opnext, as well as several other acquisitions, mergers, new product launches, and agreements.

In addition to optical fiber communications, PICs are being developed for other applications, categorized as optical sensors, quantum computing and biomedical. Optical sensors applications include defense, aerospace, energy, transportation, medicine and other emerging fields. Quantum computing is forecasted to be commercialized by 2017, before

growing rapidly at a rate of 139.6% from 2017 to 2022, as the technology is expected to completely revolutionize the computing industry. In the biomedical field, InP-based application-specific PICs are being used for the diagnostic analysis of opaque skin tissue, principally using the techniques of optical coherence tomography (OCT) or Raman scatterometry.

Presently, the market leaders are developing medium and large PICs capable of incorporating 100–1000 components/functions in a single InP-based monolithic chip. However, the emergence of silicon photonics has changed market dynamics, as it has enabled large-scale production of PICs at low cost, notes the market research firm.

The report describes the various types of integration techniques used to fabricate PICs (including module, hybrid and monolithic) across North America, Europe, Asia-Pacific (APAC), and the rest of the world (ROW).

It also throws light on the PIC market according to various geographical regions (North America, Europe, Asia-Pacific, and ROW). Currently, with a market share of 49%, North America is the biggest market for PICs (particularly in data-centers and wireless area network applications for optical fiber communications), followed by Europe and APAC. However, APAC is the largest player in access network applications for optical fiber communications. So, due to the prolific growth of data-centers and access networks in that region, it is expected that APAC will emerge as the PIC market leader by 2022, growing at a CAGR of 35.9% from 2012 to 2022, concludes the report.

www.marketsandmarkets.com

The market leaders are developing medium and large PICs capable of incorporating 100–1000 components/functions in a single InP-based monolithic chip. However, the emergence of silicon photonics has changed market dynamics, as it has enabled large-scale production of PICs at low cost

LED lighting revenue to double to \$5.8bn in 2015 ...but total packaged LED market to fall towards end of decade

Global packaged LED revenue will decline in the second half of this decade, according to market analyst firm IMS Research in its 'Packaged LED – World – 2012 Report'.

With many LED end-markets already saturated, lighting will be the main driver of growth this decade, says the firm. The 2012 LED market is forecast to be about \$10.9bn, with \$2.9bn in lighting and \$8bn in all other applications. By 2015 this is forecast to reach \$13.5bn, with \$5.8bn in lighting (doubling in three years) and \$7.7bn in other areas (slightly less than now).

However, IMS Research expects shipments of LED lamps to remain relatively flat from 2015 onwards. "This is mainly due to fewer replacements being required each year due to the longer life-time of CFL and LED lamps reducing the overall market," explains IMS analyst Stewart Shinkwin.

With price erosion set to remain in double-digit figures, the LED lighting sector, as component packaged

LED revenue, is forecast to contract towards the end of the decade.

With no other markets expected to grow significantly, the total packaged LED market is expected to fall towards the end of the decade (as revenue) once the general lighting market has peaked. This outlook could, however, change if adoption is slower than predicted over the next three or four years. In this alternative scenario, growth would be slower initially but could be maintained for a longer period throughout the decade.

Other important issues that IMS considered in the long-term forecast are how low can the price of an LED really fall, and exactly how much the rate of lumens/watt improvements will slow in the second half of the decade as fundamental limits are reached.

The TV sector is the second largest market for packaged LEDs, and is forecast to grow slightly from 2012 (\$2.0bn) to 2016 (\$2.4bn), as LED adoption rates increase throughout

the time period just enough to overcome price erosion and the reduction in the number of LEDs required for a given area. LCD panel shipments are also forecast to increase slightly, while there is also the trend towards larger screens (a trend that has been ongoing for a number of years).

However the number of LEDs required for a given size screen has also been decreasing faster than had been previously expected. For example, in first-quarter 2012 the low-cost TVs that were introduced used half the number of LEDs for a given area and, although overall LED TV penetration increased as a result, the average number of LEDs per LCD TV actually fell from 175 in fourth-quarter 2011 to 137 in first-quarter 2012. This trend cannot continue at the same rate forever, and innovations may cause more LEDs to be used in some cases. However, the overall trend is for a slow decline.

www.ledmarketresearch.com

Declining pricing, softening demand and uncertain economy still troubling optoelectronics market ...but product development remains a bright spot

Rapidly declining pricing, softening demand and a still uncertain global economy are creating challenges for manufacturers at all stages of the optical industry supply chain, according to the Strategy Analytics GaAs and Compound Semiconductor Technologies Service (GaAs) viewpoint 'Compound Semiconductor Industry Review July – September 2012: Optoelectronics, Materials and Equipment'.

Most firms that manufacture equipment, material and devices for LEDs, optoelectronic devices and photovoltaic devices are seeing declining revenue and income, or outright losses, adds the report, which summarizes technology, product, contract, financial and

employment announcements in the July-September 2012 quarter from firms such as Soitec, Aixtron, AXT, Hitachi Cable, JDSU, Finisar, Oclaro, Emcore, GigOptix, IQE, Kopin, Cree, OpNext, First Solar and Spire.

But despite declining financials at many of these companies, the report concludes that product development activities remain strong, with the announcement of several new LED and higher-data-rate optical components.

"With a few notable exceptions like Dowa, First Solar and Cree, most of the other companies in this report struggled to increase revenue and income," notes Eric Higham, director of the Strategy Analytics GaAs and Compound

Semiconductor Technologies Service (GaAs). "Companies in the LED and equipment market are trying to address rapidly declining prices in conjunction with declining demand, and they are finding it difficult to increase revenue and income in this environment," he adds.

"Companies in the optical component segment of the supply chain are developing products for higher-data-rate networks, but most of the equipment orders at the front-end of the optical supply chain are going to research institutions rather than production expansions," comments Asif Anwar, director of the Strategy Analytics Strategic Technologies Practice (STP).

www.strategyanalytics.com

LED production value to grow by 12% in 2013

LED production value is expected to hit \$12.4bn in 2013, representing a 12% year-on-year growth, according to a report from LEDinside.

Handset applications and LED lighting product demand are expected to be the key sales drivers to spur corresponding LED demand. Yet, given that the oversupply issue will not be eased in the near term, LED manufacturers are expected to aggressively deploy the technology into new applications as well as consolidating with peers in order to secure sales and enhance profitability.

Handset and tablet PCs are identified as being a new sales driver for LEDs. Japanese and Korean vendors have started integrating 4.75" panels into their established technology portfolio in panel production, with the Japanese vendors in the lead through the introduction of smart-phones featuring a 5" high-resolution panel with 443ppi resolution.

LEDinside estimates that LED market value for smart-phone applications will hit \$710m in 2013, based on its forecast of an estimated 870m smart-phone shipments. Due to the consistent migration to bigger screen size with higher resolution, some smart-phones are expected to increase LED demand for backlighting from 6–8 up to 10 (per screen).

Further, rising demand for tablet

PCs and handsets with bigger panels and higher resolution is expected to fuel corresponding LED sales growth. Demand for camera flashes or other types of flashlight in handsets will also drive the upwards sales trends as camera specifications improve.

LEDinside further expects that the volume of LEDs for use in TV backlights will grow by 30–50% in 2013, driven by TV vendors' demand for brighter, higher-resolution panels. The growth is expected to compensate the weak LED backlight demand amid negative sales impact from a slow economy and high panel inventory within the Chinese market.

With the LED backlight market expected to expand in 2013, the rising market share of 50–60" TV sizes should spur corresponding LED demand. Most current large-size (50–60") edge-lit LED TVs incorporate an average of 130–150 LEDs. The advances of LED and LGP (Light Guide Plate) technology, which in turn requires fewer LEDs, is not expected to greatly hit overall LED demand as the (expected) rise in shipments of large-size LED TVs will continue to drive demand growth.

Also, new 'direct'-type and 'slim direct'-type LED TV models are due to be available in 2013. Vendors from China, Japan and Taiwan have already launched ultra-high-definition

'4K2K' panels (actually with 3840 x 2160 pixels) recently, in order to please consumers with better image quality in larger panel sizes.

Overall, LED lighting price competition will continue through 2013. "Demand for LED lighting is consistently growing worldwide, despite some temporal drawbacks such as the European debt crisis and the recent election of new Chinese leaders that discourage large-scale projects," says LEDinside. "In Europe, demand for LED lighting has started to emerge since the European Commission banned the sale of incandescent light bulbs after the end of 2012. In Taiwan, more LED street-lamp developments are also bringing new sales to local vendors."

While demand is picking up generally, LEDinside has concerns about the sector's relatively lean profitability. The report concludes, "Vendors are believed to be launching more competitive solutions to address market trends on the one hand while deploying into other areas on the other hand, in an attempt to offset the fierce price competition pressure. Besides the handheld devices markets, other sectors of interest include domestic and industrial lighting, plant lighting, freezer lighting."

www.LEDinside.com

Matthew Peach, contributing editor

LTE smartphone shipments to triple in 2013

LTE smartphone shipments will triple from 90.9 million units in 2012 to 275 million in 2013, yielding a record year for 4G technology, according to Strategy Analytics.

"Major countries driving LTE growth next year will include the USA, UK, Japan, China and South Korea," says senior analyst Neil Shah.

"Multiple operators, such as Verizon Wireless, Everything Everywhere and NTT Docomo, are aggressively expanding their LTE networks. Key vendors leading the push into LTE smartphones will include Apple, Samsung, LG, Nokia, HTC,

Motorola, Blackberry, Huawei, ZTE and Pantech. Popular models will include Apple's iPhone 5 and Samsung's Galaxy S3," he adds.

"2013 will be the year of 4G. LTE smartphone shipments worldwide will exceed a quarter-billion units for the first time," notes executive director Neil Mawston. "Multiple operators and multiple phone vendors will be launching dozens of LTE models across numerous countries worldwide. LTE has quickly become a high-growth, high-value market that no operator, service developer, component maker or device vendor

can afford to ignore," he adds.

"The LTE smartphone market has become highly valuable and we believe it will eventually attract new entrants seeking a slice of the 4G pie, such as Amazon or Mozilla," comments analyst Linda Sui.

"However, we caution possible new entrants like Amazon will not find it easy to break into the fiercely competitive LTE smartphone market, and they will need breakthrough products that are strongly differentiated in areas such as design, price or services."

www.strategyanalytics.com

Integrated antenna tuners adopted for smartphones

GaAs, CMOS and RF MEMS technologies vie for emerging market

Compact, integrated antenna tuners shipped into several popular smartphones in 2011, but this represented just the first of a wave of such tuners from Peregrine Semiconductor, RF Micro Devices and others, according to the report 'Outlook for Active Antennas & Tunable Components in Cellular Phones' from Strategy Analytics. The report reviews the prospects for tunable RF components, comparing the different approaches and suppliers, and provides an upbeat forecast of the market through 2017.

"Mobile devices that support 4G, 3G and 2G in multiple bands have complex RF front-ends, with com-

promises in antenna performance that can degrade calls, as Apple learned last year," says Christopher Taylor, director of the Strategy Analytics RF & Wireless Components market research service. "Tunable components can reduce dropped calls and improve battery life, while simplifying the cellphone," he adds.

"Antennas with tunable impedance match will emerge as an important piece of the cell-phone RF front-end, and we expect antenna specialists including Ethertronics and Skycross, in combination with front-end component suppliers including Skyworks, RFMD, Avago Tech, TriQuint and Murata, to compete

aggressively in this segment using GaAs, CMOS, RF MEMS and voltage-dependent dielectric variable capacitor technologies," says Eric Higham, director of the Strategy Analytics GaAs and Compound Semiconductor market research service.

"The new 'antenna tuner' product category will bring success to some new entrants such as WiSpry and inevitably shake up the existing order among cell-phone RF front-end component vendors," forecasts Stephen Entwistle, VP of the Strategy Analytics Strategic Technologies group.

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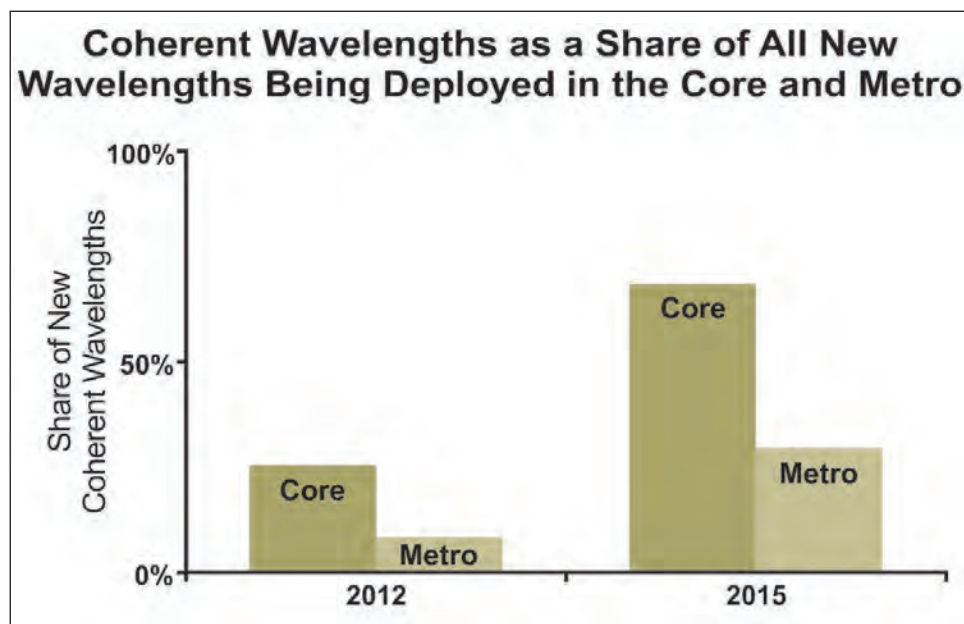
Coherent 100G to take over core networks

Market research firm Infonetics Research released excerpts from its '40G/100G and ROADM Deployment Strategies: Global Service Provider Survey', which details the plans of operators transitioning optical transmission and switching equipment to higher-speed 40G and 100G wavelengths.

"The debate between 40G and 100G in WDM [wavelength division multiplexing] networks is over, so for our latest 40G/100G and ROADM [reconfigurable optical add-drop multiplexer] deployment strategies survey we focused on identifying how the rollout of 100G will take place and to what degree networks will migrate to coherent technology and ROADMs," explains Andrew Schmitt, principal analyst for optical at Infonetics. "Operators participating in our study expect coherent 100G to take over most core networks by 2015 and even make some minor inroads into the metro," he adds.

Highlights of the survey include the following:

- Among survey respondents, by 2015 coherent wavelengths will account for 68% of deployments in



Among Infonetics' survey respondents, by 2015 coherent wavelengths will account for 68% of deployments in the core and 29% in the metro, and 100G will rise from just 5% of deployed wavelengths in 2012 to 37% in 2015.

(Graphic: Infonetics Research)

the core and 29% in the metro, while 100G will rise from just 5% of deployed wavelengths in 2012 to 37% in 2015.

- Carriers have mixed opinions on the future of various metro 100G approaches, including direct-detect 100G, pluggable coherent, and

advanced modulations such as 16-QAM.

- ROADMs are now a major part of optical networks, with ROADM nodes and degree counts set to surge by a factor of more than two, reckons the report.

www.infonetics.com

Solar module production costs to fall as low as \$0.48/W in 2017

Cost of CIGS modules to match crystalline silicon, but cadmium telluride remains the low-cost leader

The solar industry is reeling from overcapacity, and supply is outstripping demand by two to one, according to the report 'Module Cost Structure Update: Path to Profitability' from Lux Research. The industry needs to drive costs lower in order to overcome diminished subsidies and regain profitability, says the firm.

Module prices have fallen over the last four years to a low of \$0.70/W, but the cost of goods sold (COGS) for modules has not reached this level, resulting in substantial losses for most module manufacturers.

"With pressure from competitors, customers and policy-makers to drop prices even further, manufacturers need to drive costs down to survive and thrive during the com-

ing years of growth in the demand market," says Ed Cahill, Lux Research associate and lead author of the report.

Lux Research conducted a cost and sensitivity analysis, examining the impacts of drivers like low-cost manufacturing locations, high efficiency, increased capacity utilization, and higher production yields on module COGS. The analysis found that:

1. Copper indium gallium (di)selenide (CIGS) has the greatest potential to cut cost. COGS will fall across the board between 2012 and 2017, but the rate of decline will be the steepest for CIGS thin-film modules, which can shave \$0.14/W off the cost to \$0.64/W.
2. Cadmium telluride (CdTe)

remains the low-cost leader.

Despite the travails of its main champion First Solar, CdTe thin-film modules will remain the cheapest solar option in 2017, at \$0.48/W, down from the current \$0.67/W. 3. Efficiencies are the key driver. Manufacturing location has the greatest potential influence on COGS, but overcapacity makes opening new facilities in low-cost countries unlikely. Consequently, increasing module efficiencies will make the most difference, up to \$0.09/W for mc-Si and \$0.21/W for CIGS.

The report 'Module Cost Structure Update: Path to Profitability' is part of the Lux Research Solar Components Intelligence service.

www.luxresearchinc.com

RF power amplifier sales for wireless infrastructure to top \$2.4bn

Asia-Pacific region to remain focus, accounting for 75% of RF power semiconductor devices

Although 2012 turned out to be an off year for RF power amplifiers and devices for wireless infrastructure, the market still held its own, says market analyst firm ABI Research in its report 'RF Power Amplifiers'. This year should be viewed as a breathing space before both segments resume stable and moderate growth after an explosive 2011.

The Asia-Pacific region (including Japan) continues to account for more than 75% of the RF power semiconductor devices sold into the mobile wireless infrastructure segment. "For the foreseeable future the Asia-Pacific region, particularly China, will remain the most important region and focus for RF power

amplifiers and high-power RF devices for wireless infrastructure," says research director Lance Wilson.

Despite the downturn in 2012, RF power amplifier sales for wireless infrastructure will still top \$2.4bn and RF power device sales will be more than \$600m, forecasts ABI.

LTE will become an increasingly important factor in both of these businesses even though the rollout has not been as rapid as the industry would like, says the firm. Nevertheless, it is already worldwide in scope. "Although LTE has not significantly impacted RF power amplifier and device sales as of yet, it is going to bolster RF power sales in the wireless infrastructure space

from 2012 on," reckons Wilson.

The continuing overall need for wireless data remains an important driver for the overall market for both RF power amplifiers and RF power devices, concludes ABI.

The report 'RF Power Amplifiers' examines evolving design parameters and materials, price versus performance, and the interdependent relationship of RF power semiconductors to RF power amplifiers. Quantitative forecasts are presented through 2017 for both segments. The findings are part of ABI's 'Macro Basestations' and 'High-Power RF Active Devices' Research Services.

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Multi-junction CPV cells
HBTs pHEMTs BiFET/BiHEMTs

RFMD's Kevin Kobayashi named 2013 IEEE Fellow

RF Micro Devices Inc of Greensboro, NC, USA says that RFMD fellow Kevin W. Kobayashi has been named a fellow of the Institute of Electrical and Electronics Engineers by the IEEE board of directors.

The IEEE grade of fellow was conferred on Kobayashi in recognition for his "extraordinary contributions to monolithic microwave integrated circuits (MMICs)". Less than 0.1% of the total IEEE voting membership is recognized each year by the IEEE's board for elevation to fellow.

"Kevin is an outstanding engineer with an extraordinary record of accomplishments," comments RFMD's CEO & president Bob Bruggeworth. "His extensive industry knowledge and deep expertise across multiple technologies are valuable assets to RFMD and to our customers," he adds.

Kobayashi is the principle author of 130 technical publications and the inventor of 48 US patents. Noteworthy are his inventions

improving the broadband linearity and dynamic range of fundamental MMICs such as the Darlington pair, Gilbert cell, Doherty, cascode, and distributed amplifier topologies.

RFMD says his early work on GaAs MMIC technology established the foundation for many of the first HBT, HEMT and MESFET MMIC insertions in national space satellite systems and for the first commercial GaAs HBT MMIC products for the wireless industry. He was early to recognize the benefits of GaAs HBT for RF and microwave applications, and first to design a microwave GaAs HBT Darlington feedback amplifier, later helping to commercialize it into a high-volume product.

Kobayashi's contributions to MMICs span multiple compound semiconductor and silicon technologies. According to RFMD, he helped to prove the viability of monolithic GaAs BiFET-type solutions in challenging microwave designs. He

also demonstrated the advantages of InP HBTs for millimeter-wave and fiber-optic applications, later inventing a wide-dynamic-range transimpedance amplifier (TIA) currently deployed in an industry-leading 40Gbps InP receive optical subassembly (ROSA). More recently, Kobayashi has been engaged in the development of GaN MMICs, having achieved record low noise and wideband linearity, which is expected to enable future radio architectures. One of his HEMT-HBT MMIC demonstrations (the world's first) is displayed in the MTT (Microwave Theory and Techniques) historical exhibit, along with a GaAs HBT MMIC that he developed.

Kobayashi serves on several IEEE conference committees and has been an associate editor of the Journal of Solid-State Circuits, applying his RF and microwave experience in technical reviews of emerging silicon RF, millimeter-wave and fiber optic ICs.

Absorptive high-isolation GaAs pHEMT SPDT RF switch

RFMD says that its new RFSW6124 is a GaAs pHEMT single-pole double-throw (SPDT) RF switch featuring a symmetric design for high isolation (of 70dB at 2GHz).

The RFSW6124 uses a non-reflective architecture that terminates ports in the 'off' state and provides

an enable pin for an 'all-off' state (for both RF1 and RF2 ports). Control of the switch is both 3V and 5V positive logic-compatible. The third-order input intercept point (IIP3) is 58dBm at 5V.

Operating at 50–6000MHz, typical applications include cellular base-

stations and other communications systems requiring high linearity and power-handling capability, such as cellular, 3G and LTE infrastructure; wireless backhaul; high-performance communications systems; and test equipment.

www.rfmd.com

Integrated front-end modules for WiFi applications

RFMD says that its new RFFM8xxx series provides complete integrated solutions in single front-end modules (FEMs) for WiFi systems.

Operating frequencies are 2.4–2.5GHz for the RFFM8202 and RFFM8204 and 4.9–5.85GHz for the RFFM8502.

The RFFM8202 incorporates a power amplifier (PA), low-noise amplifier (LNA) with bypass mode, power detector, single-pole triple-throw (SP3T) switch, and filtering. The RFFM8204 incorporates a PA, SP3T switch, power detector and

filtering. The RFFM8502 incorporates a 5GHz PA, SP2T switch, LNA, and power detector.

Output power (P_{OUT}) is 19dBm for the RFFM8202 and RFFM8204 (11g OFDM 2.5% EVM; 21dBm meeting the 11b spec mask) and 17.5dBm for the RFFM8502 (11a, OFDM at 2.5% EVM).

Both inputs and outputs are matched to 50Ω. The products are able to support a wide voltage supply range.

Able to meet the demands of the evolving WiFi market, applications

include: cellular handsets; mobile devices; tablets; consumer electronics; gaming; netbooks/notebooks; TV/monitors/video; smart energy.

With each device provided in a low-profile (2.5mm x 2.5mm x 0.45mm) 16-pin QFN package (suited for SiP and CoB designs), the small form factor and integrated matching minimizes the layout area and slashes the number of external components. This simplifies the total front-end solution by reducing the bill of materials, system footprint, and manufacturability cost.

RFMD unveils highly integrated FEM for smart-energy/advanced metering infrastructure and ISM-band applications

At the 2013 Consumer Electronics Show (CES) in Las Vegas (8–11 January), RF Micro Devices Inc of Greensboro, NC, USA unveiled a highly integrated front-end module (FEM) for smart-energy/advanced metering infrastructure (AMI) applications.

RFMD claims that its single-chip RFFM6403 FEM delivers industry-leading performance, reduces customer design time and speeds customer time-to-market in smart-energy/AMI applications operating in the 405–475MHz frequency range, as well as for portable battery-powered equipment and general 433/470MHz ISM-band systems.

The feature-rich RFFM6403 integrates a transmit high-power path with a +30.5dBm power amplifier (PA) and Tx harmonic output filtering, a transmit bypass through path

with Tx harmonic output filtering, and a receive path with a low-noise amplifier (LNA) with bypass mode. The FEM also features a low-insertion-loss/high-isolation SP3T switch and separate Rx/Tx 50Ω ports, simplifying matching and providing input and output signals for both the Tx and Rx paths.

The RFFM6403 is designed for AMI systems operating with high efficiency requirements and a minimum output power of 30dBm. In the receive path, the Rx chain provides 16dB of typical gain with only 5mA of current and an excellent noise figure of 1.7dB. The high level of integration and the form factor (6mm x 6mm x 1mm) minimize product footprint at the customer device while reducing external component count and associated assembly costs.

RFMD launches 5GHz WiFi module for 802.11ac notebook and mobile equipment applications

RFMD has launched the highly integrated RFFM4501E front-end module (FEM) for 802.11ac notebook and mobile equipment applications.

The firm says that its newest WiFi FEM meets or exceeds the system requirements for 802.11ac connectivity in the 5.150–5.850GHz frequency band and is optimized to support multiple applications, including notebooks, mobile routers, and low-power customer premises systems.

The RFFM4501E integrates a +17.5dBm (80MHz MCS9) power amplifier (PA) at 3.3V, a low-insertion-loss/high-isolation single-pole two-throw (SP2T) switch, harmonic filtering, and a low-noise amplifier (LNA) with

bypass mode, for equipment manufacturers seeking to adjust receive sensitivity. The receive chain provides 12.5dB of typical gain with only 12mA of current and a noise figure of just 2.5dB. Separate Rx/Tx 50Ω ports simplify matching and provide input and output signals for both the transmit and receive paths.

The RFFM4501E is optimized to mate with the 802.11ac chipset of a leading semiconductor company.

RFMD says that the ultra-small form factor (3mm x 3mm x 1.1mm) and high level of integration of the RFFM4501E shrink the product footprint, reduce external component count, minimize assembly costs, and speed time-to-market.

www.rfmd.com

IN BRIEF

Three-stage WiFi PA modules for 802.11b/g/n applications

RFMD has launched the RFPA520x series of three-stage WiFi power amplifier (PA) modules, designed for 802.11b/g/n applications. Other applications include: consumer premise equipment (CPE); picocells and femtocells; data-cards and terminals; wireless access points, gateways, routers and set-top box applications; and industrial, scientific & medical (ISM)-band transmitter applications.

Each module is a highly integrated solution with minimal external components, eliminating the need for any external matching components and greatly reducing layout area, bill of materials (BOM), and manufacturing costs for the customer application, says RFMD.

Fabricated with an indium gallium phosphide (InGaP) HBT process, the PAs have high linear output power (27dBm, 5V <3% dynamic EVM, for the RFPA5200; and 29dBm, EVM = 3%, 11n MCS7 HT40 for the RFPA5201) while maintaining high power-added efficiency (PAE) of 21% for the RFPA5200 and 18.5% for the RFPA5201. Gain is 33dB for the RFPA5200 and 33.5dB for the RFPA5201. Both modules have input and output matched to 50Ω, and an integrated power detector, biasing, harmonic filtering, and enable pin.

The RFPA5200 is supplied in a 4mm x 4mm x 1mm, 10-pin laminate package and the RFPA5201 in a 14-pin, 7mm x 7mm multi-chip module (MCM).

Both parts are available now in production quantities. Pricing in 5000-unit quantities begins at \$1.26 each for the RFPA5200 and \$2.64 each for the RFPA5201.

TriQuint's filters capture 4G smartphone design wins

RF front-end component maker and foundry services provider TriQuint Semiconductor Inc of Hillsboro, OR, USA, has gained design wins for its new high-performance acoustic wave filters in 4G smartphones from manufacturers including Samsung, LG, HTC and Motorola Mobility.

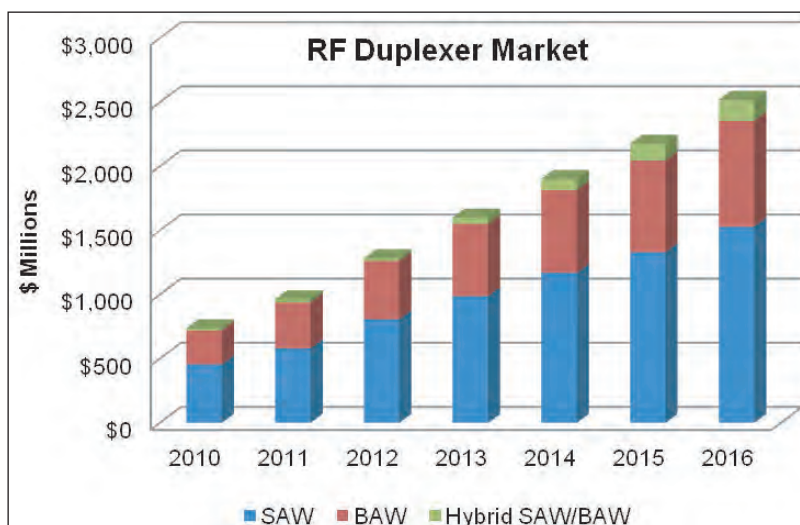
LTE deployments are driving demand for high-performance filters in multiband smartphones, says the firm. High-end smartphones house a growing number of cellular and Wi-Fi bands to support 2G/3G/4G voice and data services, as well as global roaming. In addition, the global spectrum crunch is leading governments around the world to squeeze new bands for 4G wireless services next to pre-existing bands, often with minimal guard bands. Advanced filter technology is needed to mitigate the resulting interference issues.

"We've achieved significant advancements in acoustic wave technology, thanks to three decades of filter innovation and our extensive manufacturing expertise," says Tim Dunn, VP of Mobile Devices. "We're one of the very few high-volume suppliers that can meet the demanding performance requirements for the most stringent LTE filter bands," he adds. "In the years ahead, deployments of next-generation LTE Advanced will spur even more demand for TriQuint's high-performance filters to reap the benefits of carrier aggregation."

Filters, duplexers and switches account for nearly half of the total \$6.4bn RF market, says TriQuint. As LTE networks continue to deploy, passive content in smartphones, tablets and other mobile devices will continue to grow. To supply the growing demand, TriQuint increased manufacturing capacity by 40% in 2011.

"The market for RF duplexers alone will reach \$2.5bn in 2016," says Yoshiyasu Andoh, president of market research firm Navian.

"The wide use of WCDMA and



The RF duplexer market for cellular terminals will reach \$2.5bn in 2016, driven by the growth of WCDMA and deployment of LTE networks. (Source: Navian Inc.)

increasing number of LTE bands is driving demand for duplexers at a significant rate. As RF complexity increases, we expect to see further integration of passives components such as filters and duplexers with active components like power amplifiers and switches."

Demand for high-performance filters is growing rapidly, as LTE networks deploy and Wi-Fi becomes ubiquitous. New 4G frequency bands are usually assigned next to pre-existing bands for Wi-Fi and Bluetooth services, often with minimal guard bands. TriQuint's bulk acoustic wave (BAW) and temperature-compensated (TC-SAW) technologies help enable simultaneous voice and data for 4G smartphones that operate on many different frequency bands, often in multiple regions of the world, says the firm. Since 2006, TriQuint has

CDMA, and 3G bands. Some new 3G and 4G WCDMA duplexers and filters are best served by TC-SAW, which reduces temperature drift for more challenging specifications. For example, TriQuint uses TC-SAW to support Band 13, Band 20 and Band 26 duplexers.

BAW is ideal for many of the new LTE bands above 1.9GHz, delivering superior performance with lower insertion loss, steeper slopes and excellent rejection. BAW excels in applications where the uplink and downlink separation is minimal and when attenuation is required in tightly-packed adjacent bands, says the firm. TriQuint harnesses the advantages of BAW technology to serve the following bands: Band 3, Band 7, Band 25, Band 38, Band 40 and Band 41, as well as Wi-Fi co-existence filters.

www.triquint.com



TriQuint's acoustic wave filters, used in multiple brands of smartphone.

shipped more than 2 billion SAW filters and nearly 1 billion BAW filters. SAW filters are well suited for most frequencies up through 1.9GHz, such as standard GSM,

TriQuint launches smallest linear EDGE transmit module for smartphones and other mobile devices

RF front-end component maker and foundry services provider TriQuint Semiconductor Inc of Hillsboro, OR, USA, has launched what it claims is the smallest linear EDGE transmit module, simplifying RF design for smartphones, tablets and other mobile devices.

Designed using TriQuint's InGaP HBT technology with CuFlip assembly (proving reliability, temperature stability and ruggedness), the latest addition to the QUANTUM Tx family of transmit modules enhances performance and delivers a smaller, more affordable solution compared to discrete devices, the firm says. Nearly 35% smaller than previous generations, the QUANTUM Tx TQM6M9085 integrates nine discrete parts into a compact 5.25mm x 6mm package, saving board space for compact mobile



The new QUANTUM Tx TQM6M9085 linear EDGE transmit module.

devices. It also has 45% power-added efficiency, providing longer battery life and more hours of operating time for mobile device users.

The TQM6M9085's high-gain linear operation at low DC power makes it suitable for next-generation devices requiring high efficiency.

The integrated module also features additional switch ports to support more frequency bands, delivering more design flexibility for smartphones, feature phones and low-cost voice-only phones.

The fully matched SP8T WEDGE transmit module that provides 2G RF power amplification, power control and 3G band switching. By eliminating the need to optimize matching between the amplifier and the switch, it helps accelerate customers' time to market compared to discrete solutions, says TriQuint. The firm adds that the module provides state-of-the-art GSM/EDGE efficiency, reduces overall bill-of-materials (BOM) count, and allows a flexible single phone board layout to support up to four bands of WCDMA/LTE operation.

www.triquint.com

TriQuint launches dual matched wideband low-noise amplifiers with very low noise, high linearity and balanced output

TriQuint Semiconductor Inc has released two new dual matched GaAs pHEMT low-noise amplifiers (LNAs) that are suited to balanced high-performance RF design configurations.

The devices consist of a single monolithic GaAs E-pHEMT die and integrate adjustable bias circuitry (for drain current and voltage) as well as automatic bias shut-down capability, allowing use in both time division duplex (TDD) and frequency-domain duplex (FDD) applications.

The integrated LNAs are highly linear and offer very low noise figures and high output. The TQP3M9039 operates at 700–1000MHz with a noise figure of 0.5dB (at 830MHz) and OIP3 of 38.8dB. The TQP3M9040 operates from 1500–2300MHz with a noise figure of 0.62dB (at 1950MHz) and OIP3 of 39.8dB. Both devices have P1dB RF output power of 21dBm,



TriQuint's new TQP3M9039 and TQP3M9040 dual matched GaAs pHEMT low-noise amplifiers for base-station applications.

and operate from a single positive supply (4.35V for the TQP3M9039 and 4.4V for the TQP3M9040, at 57mA).

The dual-amplifier structure enables operation in a balanced configuration. At 830MHz in a balanced configuration, the TQP3M9039 LNA provides 18dB gain, 20.7dBm IIP3 and 0.6dB noise figure. At 1.95GHz in a balanced configuration, the TQP3M9040 LNA provides 18dB

of gain, 22dBm IIP3, and a noise figure of 0.67dB.

Housed in RoHS-compliant, industry-standard 4mm x 4mm QFN packages, the devices do not require a negative supply for operation and are bias adjustable for both drain current and voltage.

The new TQP3M9039 and TQP3M9040 LNAs are currently in production. Samples are available now.

www.triquint.com

Skyworks enabling smallest 4G LTE datacards

Skyworks Solutions Inc of Woburn, MA, USA, which manufactures analog and mixed-signal semiconductors, says that its newest family of antenna switch modules are powering the world's smallest 4G LTE datacards from wireless communications equipment and network provider ZTE Corp of Shenzhen, China.

Skyworks is partnering with ZTE on solutions that enable high-speed Internet access without the need for a fixed-line Internet connection or public WiFi hotspot, says Bradley C. Byk, senior VP, worldwide sales.

Already available in Asia and

Europe, the ZTE MF823 datacard offers fast and easy Internet connectivity. Using Qualcomm's second-generation LTE chip platform, the datacard is only 13mm thick (nearly one third the size of first-generation LTE datacards). Average power consumption has also been greatly reduced (using one third less power and improving radiating properties with what is claimed to be the lowest working temperature in the industry). The datacard has also been optimized in terms of high bandwidth, low delay and high communication rate to reduce dropped calls and data.

With this latest design win, Skyworks continues to expand its partnership with ZTE across multiple platforms (including the Grand Era V985 smartphone, the Vodafone-branded Smart Tab V71 and V11 tablets and two TD-SCDMA smartphones launched with China Unicom).

Skyworks' devices, which combine switching functionality for multiple LTE bands along with integrated GSM harmonic filters and control circuitry, are also supporting several new smartphone and tablet platforms from other leading OEMs.

www.skyworksinc.com

Skyworks adds support for Windows 8 smartphones

Skyworks says that it is powering several smartphone platforms that are leveraging Microsoft's new Windows 8 operating system.

With the addition of this latest OS, Skyworks' products are now enabling all major smartphone and tablet operating systems. Recent Windows 8 smartphone launches that Skyworks is supporting include HTC's 8S and 8X (which are using the firm's SkyHi and LTE front-end solutions and switch technology) and several other mobile devices from a leading handset OEM.

Skyworks is supporting multiple smartphone makers as they launch innovative devices to meet the growing worldwide demand for an array of music, photo-sharing and

streaming video capability, says Bradley C. Byk, senior VP, worldwide sales.

"Skyworks' extensive product offering and agnostic technology approach give us the unique ability to meet our customers' diverse needs," he claims, "including driving ultra-fast download speeds and enabling extremely clear calls even in poor reception areas."

With the addition of this latest [Windows 8] operating system, Skyworks' products are now enabling all major smartphone and tablet operating systems

Skyworks' SkyHi modules deliver what is claimed to be best-in-class power-added efficiency performance for many existing data-intensive mobile platforms, helping to extend battery life. The SkyHi solutions are also optimized for all CDMA, WCDMA and LTE mobile devices such as handsets, tablets and data cards, given their unique over-voltage protection and integrated daisy-chain coupler, which reduce bill-of-material costs and printed-circuit board space, it is claimed. The firm says that its portfolio of switches is available in many different configurations, including broadband, high power, high isolation, low insertion loss, reflective, non-reflective and silicon on insulator (SOI).

Skyworks launches HBT drive amplifier in 2mm x 2mm QFN package for cellular infrastructure

Skyworks has launched a highly efficient, broadband, 13dB gain, gallium arsenide heterojunction bipolar transistor (HBT) drive amplifier in a small 2mm x 2mm QFN (quad flat, no lead) package.

The SKY67130-396LF draws less than 23mA at 3.3V, while achieving +39dBm OIP3 (output third-order

intercept point), providing a high linearity solution. On-die active bias design ensures consistent performance and unconditional stability, the firm claims.

The cost-effective solution is suited to cellular infrastructure applications such as tower-mounted amplifiers, remote radio units, repeaters, and

base stations, as well as WLAN and ISM-band applications at 2.45 and 0.9GHz, that require a highly efficient driver amplifier or low-power power amplifier with moderate noise figure and low VSWR (voltage standing wave ratio).

Samples are available, and pricing depends on quantities.

IQE acquires Kopin's III-V assets for \$75m; institutional share placing raises £16.5m

Kopin focusing on display products as IQE boosts wireless market share

Epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK has acquired the Kopin Wireless compound semiconductor epiwafer manufacturing division of Kopin Corp of Taunton, MA, USA (including its leased manufacturing facility there), plus its 90.2% controlling interest in Kopin Taiwan Corp (KTC) in Hsinchu.

IQE is paying Kopin \$75m in cash: an initial consideration of \$60m plus a deferred consideration of \$15m on the third anniversary of completion (16 January 2016).

Kopin supplies III-V products plus microdisplays for mobile applications (including smartphones, tablet PCs, military thermal weapons sights and wearable computers). Its Kopin Wireless business uses MOCVD epiwafer technology to make heterojunction bipolar transistor (HBT) materials for power amplifiers (PA) used in mobile communications devices. Kopin began producing III-V HBTs on gallium arsenide substrates in 1996.

IQE says the acquisition significantly extends its market share in wireless industry supply and delivers a market-leading position in MOCVD HBTs. It also says it builds on its risk-mitigation strategy in wireless — adding Skyworks Solutions Inc of Woburn, MA (which has a long-standing supply agreement with Kopin Wireless, with a current contract running until end-2013) as a major customer (guaranteeing a significant proportion of Skyworks' business).

Kopin Wireless also supplies HBT wafers to Taiwan's Advanced Wireless Semiconductor Company (AWSC), which provides foundry services to Skyworks. Kopin estimated that, in 2012, 28% of its total revenue of \$131.1m were derived from sales of GaAs products to Skyworks. Other significant customers include RF Micro Devices Inc of Greensboro, NC and TriQuint Semiconductor Inc of Hillsboro, OR, USA.

IQE says Kopin's Taiwan facility adds to its global manufacturing footprint, providing a strong position to access the growing Asian semiconductor market.

Kopin Wireless generated revenue of \$66.5m (with EBITDA of \$11.2m) in 2011, and \$44m (with EBITDA of \$7.5m) in the nine months to 29 September 2012. Net assets are expected to be about \$42m.

The \$75m acquisition will be financed partly through a new banking facility with HSBC Bank plc for \$40m (repayable in 20 quarterly instalments of \$1m from 31 March 2013, plus \$16m on 30 June 2015 and \$4m on 31 December 2017).

Also, a placing with institutional investors of 56,900,961 new ordinary shares (about 8.82% of the group's enlarged share capital following admission) at a price of 29 pence each has raised about £16.5m. The placing price represents a discount of about 0.85% to the 29.25 pence closing mid-market price of IQE's shares on 9 January (the last practicable date before the announcement). About £12.5m (\$20m) of the placing proceeds will go towards the initial consideration. The remaining £4m will be used for general corporate purposes and acquisition and placing expenses.

Organic cash flow should provide cash for the deferred consideration of \$15m payable in January 2016.

"This acquisition is our third key transaction in the past 12 months," says IQE's CEO Drew Nelson. "It significantly enhances our scale and provides us with a highly complementary product line in the wireless space," he adds. "The transaction marks another major step forward in our risk-mitigation strategy, whilst significantly boosting

our wireless market share. At the same time, it delivers excellent opportunities for additional business growth, particularly in Taiwan and from there into the Asian semiconductor market," Nelson continues.

"This transaction will be a key driver of significant earnings and cash generation and also brings substantial financial and scale benefits," Nelson reckons. "This will enable the group to make significant cost savings from fiscal-year 2014 onwards."

In a trading update for full-year 2012, IQE says that it expects revenue of £87-88m, with earnings before interest, tax, depreciation and amortisation (EBITDA) of £16-17m and net debt as at end-December 2012 of £15.5m. The firm reckons that the acquisition will be earnings enhancing from 2013 onwards. Also, due to its expanded global footprint and increase in scale, IQE expects annual cost synergies of at least £7m from 2014. As part of the plan to achieve this, one-off exceptional costs should be about £3m in 2013 and £2m in 2014.

Kopin says that the divestment will enable it to focus exclusively on continued commercial development of its Golden-i mobile communications technology platform, as well as on its microdisplay products. "Over the past 17 years, our III-V technology has contributed significantly to the operational success of Kopin and to advances in the wireless handset market," says Kopin's president & CEO Dr John C.C. Fan. "However, while the III-V product line is successful we have made the strategic decision to focus on our Golden-i technology... shareholders will be more effectively served by having the company focusing its resources on expanding the commercial development of Golden-i and our display product line."

www.iqep.com
www.kopin.com

IN BRIEF

M/A-COM launches small-package directional power detectors

M/A-COM Technology Solutions has launched a new line of small-package directional detectors for power monitoring in point-to-point radios, aerospace & defense systems, radar, IMS, VSAT, and electronic warfare (EW) applications.

Housed in a miniature, surface-mount 1.5mm x 1.2mm lead-less plastic package, the detectors require a small bias current of less than 0.5mA for proper performance with a DC offset of 100mV. Despite the small size, the package can still be handled with standard pick & place assembly equipment. The detectors are fabricated using an established GaAs process, featuring full passivation for performance and reliability.

The 2–6GHz MACP-010561 has directivity of 16dB, insertion loss of 0.25dB, input return loss of 23dB and output return loss of 24dB; the 6–18GHz MACP-010562 has directivity of 19dB, insertion loss of 0.30dB, input return loss of 18dB and output return loss of 20dB; and the 10–30GHz MACP-010563 has directivity of 16dB, insertion loss of 0.50dB, input return loss of 16dB and output return loss of 17.5dB.

“With integrated low-loss directional couplers and built-in temperature compensation circuits, these detectors provide an easy way to monitor the power of a signal travelling in a specific direction along a transmission line,” says product manager Tom Galluccio.

Production quantities and samples of the new devices are available from stock.

www.macomtech.com

Anadigics launches small-cell wireless infrastructure power amplifier

RF component maker Anadigics Inc of Warren, NJ, USA has launched the AWB7129 small-cell power amplifier (PA), which is optimized for Band 8 WCDMA and LTE applications, including picocells, enterprise-class femtocells, and high-performance customer premises equipment (CPE).

Based on the firm’s patented InGaP-Plus technology, the AWB7129 small-cell PA is optimized for WCDMA, HSPA, and LTE small-cell base stations operating in the 925-960MHz frequency band. The PA delivers 15% efficiency to minimize power requirements. With linearity of -47dBc ACPR @ $\pm 10\text{MHz}$ offset (10MHz LTE channel bandwidth), $+24.5\text{dBm}$ linear output power, and 30dB gain, the AWB7129 provides high-throughput data rates with a wide coverage area, says the firm. The AWB7129 is provided in a compact, low-profile 7mm x 7mm x 1.3mm surface-mount package with integrated RF matching to reduce PCB space requirements.

“Mobile data use is rapidly rising as users transition from feature phones to smartphones, and attachment rates of 3G/4G functionality to tablets, notebooks,



and gaming devices increase,” says Glenn Eswein, director of product marketing for infrastructure products. “Cost-effective, high-performance small-cell base stations, such as picocells and femtocells, are designed to help carriers meet this growing demand for wireless data, especially in dense geographic locations and campus environments,” he adds. “Anadigics’ small-cell power amplifiers are optimized for these applications by enabling manufacturers to develop wireless infrastructure solutions with exceptional throughput and range.”

Engineering samples of the AWB7129 are available now for qualified programs.

Anadigics receives ZTE’s Best Comprehensive Performance Award

Wireless communications equipment and network provider ZTE Corp of Shenzhen, China has awarded Anadigics Inc of Warren, NJ, USA its 2012 Best Comprehensive Performance Award for its “technological leadership, quality excellence, and superior service”.

Anadigics supplies ZTE with 3G and 4G power amplifiers. Anadigics’ commitment to world-class performance was also recognized during ZTE’s recent Supplier Day event in Shenzhen China.

Anadigics previously also received ZTE’s Best Comprehensive Performance Award in 2011. “These awards not only validate the tremendous performance, technology, and quality advantages that we offer, but also exemplify the strength of the relationship forged between Anadigics and ZTE,” comments Michael Canonico, Anadigics’ senior VP of worldwide sales.

www.zte.com.cn

www.anadigics.com

Microsemi launches 5GHz power amplifier for fifth-generation Wi-Fi applications

Microsemi Corp of Aliso Viejo, CA, USA (which designs and makes analog and RF devices, mixed-signal integrated circuits, FPGAs and customizable SoCs, and complete subsystems, based on silicon, gallium arsenide and silicon carbide) has launched a 5GHz LX5509 power amplifier (PA) for IEEE 802.11ac (fifth-generation Wi-Fi) wireless access points and media devices.

The firm claims that the LX5509 is the first commercially available PA that can transmit at similar power levels in both IEEE 802.11n and IEEE 802.11ac networks, allowing optimum system performance by extending the high-data rate-range.

"Our new PA is the second in a series of devices we are introducing to accelerate the proliferation of the next-generation Wi-Fi standard," says Amir Asvadi, VP & general manager of Microsemi's Analog and Mixed Signal group. "We will continue to focus on strengthening our 802.11ac portfolio with industry-leading solutions and partnering with world-class WLAN manufacturers to deliver circuits that provide the highest system performance."

LX5509 features a standardized pin-out, which enables customers to (without layout changes) later upgrade the performance level in their systems with higher-power 5GHz PAs that are currently in development at Microsemi.

The LX5509's features also include: linear output power of 19dBm for IEEE 802.11ac 256-QAM 80MHz (EVM < 1.8% @3.3V) and 20dBm for IEEE 802.11n 64-QAM 20MHz (EVM < 3% @3.3V); 28dB OFDM power gain; 50-ohm input and output match (eliminating the need to optimize output matching on the PCB); an integrated harmonic filter and output detector; as well as a temperature-compensated on-chip

output power detector with wide dynamic range.

The LX5509 is packaged in a 4mm x 4mm quad flat no-lead (QFN) package and is available for sampling.

Microsemi's 802.11ac solution offerings also include the LX5586, the first monolithic silicon germanium (SiGe) RF front-end (FE) device. The firm recently

announced that this works in conjunction with Broadcom's BCM4335 combo chip for mobile platforms.

The firm also offers a broad portfolio of IEEE 802.11a/b/g/n solutions including power amplifiers, low noise amplifiers, front-end modules and reference designs co-developed with leading WLAN chipset manufacturers.

www.microsemi.com



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RFaxis launches CMOS single-chip/single-die 802.11ac RF front-end integrated circuits

Fabless semiconductor firm RFaxis Inc of Irvine, CA, USA, which designs RF semiconductors and embedded antenna solutions for the wireless connectivity and cellular mobility markets, has started sampling its RFX5010 5GHz 802.11ac RF front-end IC (RFeIC) to strategic customers and reference design partners.

RFX5010 is the latest addition to the firm's pure CMOS-based single-chip/single-die RFeIC product family that supports Wi-Fi applications across all existing and newly added protocols, including IEEE 802.11b, g, a, n and ac, for both 2.4GHz and 5GHz frequency bands. It provides more than 30dB gain and 15dBm output power at antenna with -35dB EVM for 802.11ac MCS9 with 256-QAM modulation and 80MHz channel bandwidth.

The device is pin-compatible with the firm's 11a/n RFeIC, the RFX5000, which is in production and slated for volume shipment in Q1/2013. RFaxis will also soon be launching a new, higher-power 802.11ac RFeIC that is pin-compatible with RFX5010 and RFX5000, and will be targeting the 802.11ac AP, wireless router and outdoor hotspot markets.

Built upon RFaxis' patented single-chip/single-die RFeIC architecture and new design innovations, our engineering team has delivered a pure-CMOS RFeIC with full 802.11ac support

"We recognize the Wi-Fi industry's rapid move towards 11ac products that offer users enhanced wireless experience with higher data throughput, extended operating range and longer battery life," says chairman & CEO Mike Neshat.

"Built upon RFaxis' patented single-chip/single-die RFeIC architecture and new design innovations, our engineering team has delivered a pure-CMOS RFeIC with full 802.11ac support," he adds. The 802.11ac RF front-end solution is offered at a price point substantially lower than existing legacy 802.11a/n front-end solutions, he claims.

RFaxis will showcase the RFX5010 and additional new products, including its dual-band/dual-mode CMOS RFeIC, at the 2013 International Consumer Electronics Show (CES) on 8-11 January in Las Vegas.

www.rfaxis.com

RFaxis' CMOS RFeICs power Zylux's wireless Home Theater Systems

Fabless semiconductor firm RFaxis Inc of Irvine, CA, USA, which designs RF semiconductors and embedded antenna solutions for the wireless connectivity and cellular mobility markets, says that its CMOS radio-frequency front-end integrated circuits (RFeICs) are powering the latest generation of wireless sound bar and subwoofer systems made by Taiwan's Zylux Acoustic Corp, a designer of consumer electronics and loud-speaker systems.

Designed for home theater enthusiasts, Zylux products feature RF modules made by Atmel (formerly Ozmo Devices) that use the RFaxis RFX5000 5GHz RF front-end with Ozmo2000 chipset for 802.11a 5GHz Wi-Fi Direct models, as well as modules made by Freesystems that use RFaxis' RFX2402C 2.4GHz RF front-end paired with the MuChip FS2219 wireless audio system-on-chip

(SoC).

"The home entertainment market continues to be a growing sector," says RFaxis' chairman & CEO Mike Neshat. "The maturity of the home theater systems requires technologies like ours to enable home-area networks (HAN) to go beyond file transfer and Internet access to more complicated operations such as multimedia streaming," he adds. "High-fidelity and high-definition audio streaming over proprietary RF connections and Wi-Fi Direct are an on-going trend."

"RFaxis' technology has enabled us to offer our customers high-performance and high-reliability wireless audio products at very competitive prices," notes Wyatt Briant, president of Zylux America. "Their technology offers innovation, high-quality, high-scale, and cost-effective solutions for our RF front-end needs."

RFX5000 is a fully integrated, single-chip, single-die CMOS RFeIC that incorporates all the RF functionality needed for a typical IEEE 802.11a/n WLAN system operating in the 4.9-5.85GHz range. Similarly, the RFX2402C incorporates all RF front-end functionality needed for 2.4GHz IEEE 802.11b/g/n WLAN applications. The RFaxis RFeIC architecture integrates the power amplifier (PA), low-noise amplifier (LNA), transmit & receive switching circuitry, the associated matching network, and the harmonic filter, all in a CMOS single-chip device.

A live demonstration of a 2.1 wireless surround sound wireless subwoofer and sound bar system was showcased by RFaxis at the 2013 International Consumer Electronics Show (CES) in Las Vegas (8-11 January).

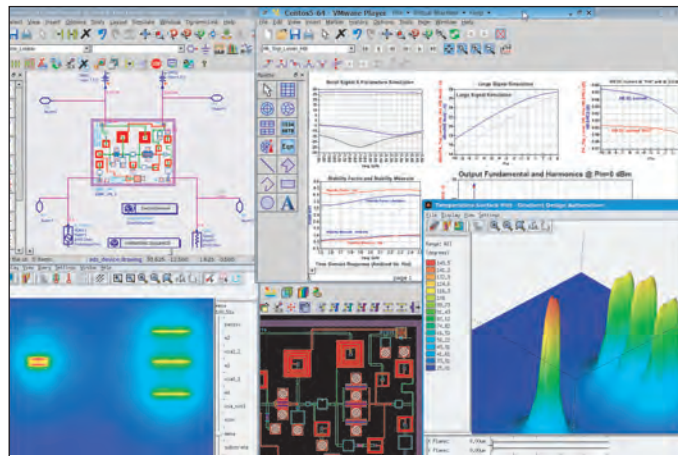
www.zyluxacoustic.com
www.rfaxis.com

Agilent ships new ADS EDA software to advance single-, multi-technology design of RF power amplifiers

Agilent Technologies Inc of Santa Clara, CA, USA says it is shipping Advanced Design System 2012, its flagship RF and microwave EDA software platform. The software features new capabilities that improve productivity and efficiency for all applications that the system supports as well as breakthrough technologies applicable to GaAs, GaN and silicon RF power-amplifier multi-chip module design, says the firm.

The capabilities now available to new and existing ADS users include:

- User interface enhancements designed to improve design efficiency and productivity, such as dockable windows for quickly accessing frequently used dialog boxes.
- Updated Load Pull and Amplifier DesignGuides, which offer mismatch simulation and make it easy to see amplifier performance at a specific output power level or a specific amount of gain, respectively.



Screenshot of Agilent's ADS2012 EDA software.

- Dramatically improved integration with EMPro, which enables 3D electromagnetic component designs to be saved as database cells for use directly in ADS.
- A new ADS electro-thermal simulator that incorporates dynamic temperature effects to improve accuracy in 'thermally aware'

circuit-simulation results.

- Multi-chip module electromagnetic simulation setup and finite-element method (FEM) simulation of different technologies to analyze electromagnetic interactions between circuits and interconnects, wire bond and flip-chip solder bumps in typical multi-chip RF power

amplifier modules.

- Model support for Agilent's artificial neural network-based NeuroFET model (extracted by Agilent's IC-CAP device modeling software) to enable more accurate FET modeling and simulation results.

www.agilent.com/find/eesof-ads-downloads-and-trials

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IN BRIEF

Digi-Key to distribute GeneSiC's products

Global Internet-based electronic components distributor Digi-Key Corp of Thief River Falls, MN, USA has agreed to distribute worldwide the silicon carbide technologies of GeneSiC Semiconductor Inc of Dulles, VA, USA, which develops SiC and silicon-based devices for high-temperature, radiation and power grid applications.

Founded in 2004, GeneSiC's SiC products play a role in conserving energy in high-power systems, running faster, cooler and more efficiently (making them suitable for increasing efficiency in energy-harvesting applications).

"Digi-Key was the missing piece to our distribution program," says GeneSiC's chief business development officer Michael DiGangi.

"This agreement enhances GeneSiC Semiconductor's ability to seed the market with our brand of silicon carbide high-voltage, high-temperature, and first-of-their-kind (1N8XX SiC diode/2N76XX SiC transistors) mil-standard products."

GeneSiC claims to have the largest portfolio of commercial SiC diodes, offering a best-in-class SiC switch — the super junction transistor (SJT) — which aims to revolutionize insulated-gate bipolar transistor (IGBT) and field-effect transistor (FET) designs for those seeking higher performance.

GeneSiC claims its silicon high-voltage rectifiers have the best forward voltage on the market. While others have abandoned this market, it is claimed, GeneSiC has been investing in new products.

"Adding suppliers as committed to innovation as GeneSiC Semiconductor affirms our commitment to providing the newest, state-of-the-art products," says Mark Zack, VP, Global Semiconductor Product at Digi-Key.

www.digikey.com

www.genesicsemi.com

International Rectifier appoints chief operations officer; creates role of executive VP GaN Technologies

Power semiconductor device maker International Rectifier Corp (IR) of El Segundo, CA, USA has appointed Gary Tanner as executive VP & chief operations officer.

Reporting to president & CEO Oleg Khaykin, Tanner will be responsible for continued implementation of the firm's operational transformation strategy. He succeeds Mike Barrow, who will now lead the firm's efforts to commercialize its gallium nitride on silicon (GaN-on-Si) technology.

"As we position IR for the next phase of growth, the execution of our operational transformation strategy and the successful launch of our GaN technology platform will be two of our major focus areas," says Khaykin. "Both Gary and Mike have outstanding track records in the semiconductor industry and I am confident in their leadership and management capabilities to drive two of our most critical initiatives."

"I look forward to working with IR's talented operations team to continue implementing our operational transformation strategy," says Tanner. "We believe that doing so will allow us to re-size our operations, reduce costs, effectively scale the business during an up-cycle and significantly reduce the downward margin pressure during a down cycle."

With over 35 years of semiconductor industry experience, Tanner most recently served as CEO at Zarlink Semiconductor Inc (acquired by Microsemi Corp in October 2011). Previously, he was COO, responsible for increasing operational efficiency and streamlining operations. Tanner joined Zarlink in 2007 as senior VP of worldwide operations via the acquisition of Legerity, where he was head of operations. Before Zarlink, Tanner worked for nine years at Intel Corp, where he held various positions managing domestic and international manufacturing operations. Prior to Intel, he held

management positions in fab operations at National Semiconductor, Texas Instruments and NCR.

Tanner has a Bachelor of Science degree in Technical Management from Regis College.

"The company has made a significant investment in developing GaN technology over the past nine years," says Khaykin. "As we move from the R&D phase to production, we are putting one of our most senior and talented executives in charge of this strategic initiative to ensure the successful commercialization of this revolutionary new technology," he adds. "Mike joined IR in 2008 as executive vice president & chief operations officer and was the principal architect of IR's operational transformation strategy. I thank

The company has made a significant investment in developing gallium nitride technology over the past nine years

Mike for his leadership and contribution to IR's growth over the past four years and look forward to his continued leadership as the executive vice president of GaN Technologies. In his

new role Mike will be responsible for all aspects of GaN, including process and product development, product marketing, and manufacturing."

"We have a highly talented GaN technology team, a large library of intellectual property, and have successfully validated our GaN technologies with Tier 1 customers," notes Barrow. "The next step is for us to fully commercialize this exciting new platform," he adds. "IR is already a market leader in silicon power management technologies and it is my goal to extend this lead and open up new opportunities with our GaN technologies."

www.irf.com



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ISO9001:2000, Certificate No.: FM 26963
ISO14001:2004, Certificate No.: EMS 502245

HexaTech wins \$2.2m ARPA-E contract to develop smart-grid power semiconductor technology

AlN substrate maker to establish epi techniques for 20kV power devices

HexaTech Inc of Morrisville, NC, USA has received a \$2.2m award from the US Department of Energy (DOE) Advanced Research Projects Agency – Energy (ARPA-E) to enable the development of “new power semiconductor technology for the modernization of our electrical power grid”.

HexaTech was spun off from the Department of Materials Science of North Carolina State University in 2001 with a transfer of technology — developed by co-founders Dr Zlatko Sitar (president & chief technology officer) and Dr Raoul Schlessler (VP development) — to produce single-crystalline bulk aluminium nitride (AlN) substrates for both electronic and optoelectronic devices. Subsequently, in late 2005, the firm raised \$8.9m in a Series A round of financing led by Intersouth Partners of Durham, NC and joined by H.I.G. Ventures, Sevin Rosen Funds and NC IDEA.

In 2007, HexaTech won a \$2m Advanced Technology Program (ATP) grant from the US Commerce Department’s National Institute of

Science and Technology (NIST) as part of a \$3.28m, three-year project (starting in November) to develop high-efficiency deep ultraviolet LEDs for use as a high-energy UV light source to kill micro-organisms in drinking and waste water. Since then, HexaTech raised \$300,000 in debt financing in January 2010, followed by a further \$3.1m in a round that closed this July. Including a further \$500,000 in debt financing in August, HexaTech has raised more than \$17m in total since the firm was founded.

HexaTech’s AlN technology has now been identified by the Department of Energy as a “transformational, breakthrough technology with significant technical promise”.

Using very low-dislocation-density single-crystal AlN substrates, HexaTech aims to develop novel doping schemes and contact metals for AlN/AlGaN with high Al content. “The development will enable a significant step toward producing 20kV AlN-based Schottky diodes (SBD, JBSD) and transistors (JFET,

MOSFET),” says director of engineering Dr Baxter Moody. “The ARPA-E contract has opened the door for the material development and research to demonstrate AlN high-voltage, high-efficiency power conversion capability,” he adds. For power systems and grid-scale power conversion applications, high-efficiency AlN-based power devices will offer a significant reduction in size, weight, and cooling, reckons HexaTech.

Power semiconductor devices at this level are not currently available on the market, the firm says. Experimental devices based on silicon carbide technology are being developed. But, compared to SiC, AlN should enable power electronics with a 10x improvement in performance. Based on AlN’s wide-bandgap material properties, the critical field is 6x larger, the on-resistance will be lower, and the resulting power device area will be smaller for a comparable power level, the firm concludes.

www.hexatechinc.com

TriQuint claims record GaN circuit reliability

At the Defense Manufacturing Conference (DMC) in Orlando, FL in late November, TriQuint Semiconductor of Hillsboro, OR, USA announced what it claims is record gallium nitride circuit reliability, exceeding previous industry standards.

TriQuint says its new GaN benchmark supports highly reliable integrated RF solutions that use less power, are compact, and serve wide frequency ranges. Any RF system can benefit from reduced maintenance and longer operational lifetimes arising from increased reliability such as commercial and defense RF infrastructure, broadband communications, first-responder radios and space-based applications, the firm adds.

“The achievement supports our foundry services and helps us accelerate product development,” says James L. Klein, VP & general manager for Infrastructure and Defense Products. “We are delivering more products and services than ever before.”

The TQGa25 process, qualified to operate up to 40V, has achieved a mean time to failure (MTTF) of over 10 million hours at 200°C and over 1 million hours at 225°C. TriQuint says the reliability milestone was achieved with its newly released Generation II 0.25µm GaN-on-SiC process that it uses for GaN product solutions and foundry services.

TriQuint achieved its new GaN performance through in-house

development programs. The new reliability also supports the objectives of the firm’s Defense Production Act (DPA) Title III contract for GaN-on-SiC monolithic microwave integrated circuits (MMICs), funded by the US Department of Defense Tri-Services laboratories (Air Force, Army and Navy). TriQuint is also reducing manufacturing cycle times and increasing yields while making other GaN enhancements that work hand-in-hand with DPA Title III goals.

Manufacturing enhancement are designed to support greater affordability of next-generation AESA (active electronically scanned array) radars, new electronic warfare systems and commercial applications.

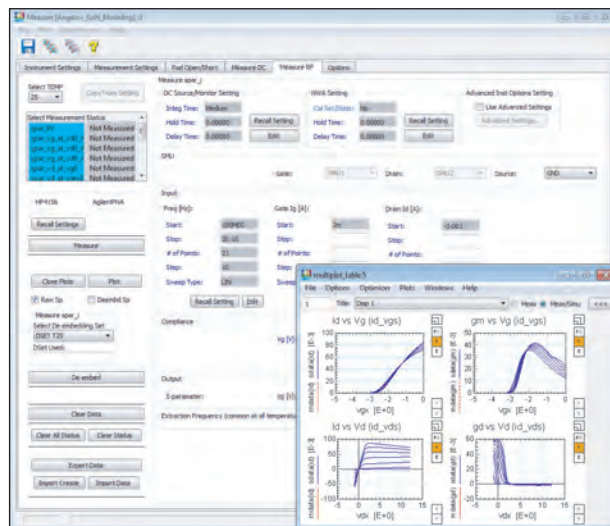
www.triquint.com/defense

Agilent launches IC-CAP platform with Angelov-GaN modeling software

Agilent Technologies Inc of Santa Clara, CA, USA has introduced the latest release of its Integrated Circuit Characterization and Analysis Program (IC-CAP) high-frequency device modeling software platform. With IC-CAP 2013.01, a key improvement is turnkey extraction of the Angelov-GaN model, the industry-standard compact device model for gallium nitride devices.

GaN technology is becoming commonplace in high-power RF communication circuits and automotive electronic components, says Agilent. However, modeling GaN-based devices is challenging due to the impact of trapping and thermal effects on the device's electrical characteristics. Existing GaAs models have been used as a first attempt to model GaN devices, but they are not accurate enough, says Agilent. The Angelov-GaN model, developed by professor Ilcho Angelov at Chalmers University of Technology, is quickly establishing itself as the industry's solution to this problem.

Agilent's W8533 Angelov-GaN extraction package, which is part of the IC-CAP platform, was developed in conjunction with industry partners and validated on real GaN processes. It provides a dedicated software environment that allows users to perform the necessary measurements and extraction of the Angelov-GaN model. Typical DC and network analyzers are supported for making DC and S-parameter measurements and de-embedding. A convenient interface lets users execute a step-by-step extraction flow to obtain the model parameters. A turnkey flow provides quick start modeling of GaN devices. The package also enables complete customization to optimize the flow to different tech-



IC-CAP Angelov-GaN Extraction Package.

nology flavors of GaN processes. Simulations are performed using Agilent's Advanced Design System. IC-CAP 2013.01 also features a new Python programming environment that is up to 100 times faster for tasks such as parameter extraction, data analysis, instrument control and interface responsiveness. It enables better code organization and provides an extensive set of libraries for math, instrument control and statistical analysis. Python programs are interoperable with existing programs, ensuring compatibility with ongoing IC-CAP projects.

Other new features in IC-CAP 2013.01 include support of SmartSpice simulations and support for gain compression and two-tone intermodulation distortion measurements with Agilent's PNA-X network analyzer. This is a critical capability since nonlinear device characterization is essential to verifying model accuracy in real applications. Another part of the platform, IC-CAP WaferPro (a powerful automated on-wafer measurement solution), now features usability and user interface enhancements to facilitate test-plan development.

IC-CAP 2013.01 will be available for download in January at www.agilent.com/find/eesof-iccap-downloads-and-trials

IN BRIEF

Cambridge Centre for Gallium Nitride orders Power+Energy hydrogen purifier

Power+Energy Inc (P+E) of Ivyland, PA, USA, which provides palladium-membrane-based hydrogen purifiers for the compound semiconductor and energy industries, has received an order for a PE9000C Series purifier from the Cambridge Centre for Gallium Nitride at the University of Cambridge. The micro-channel palladium purifier will be used in a new Aixtron MOCVD reactor to purify hydrogen for gallium nitride (GaN) research, says the firm.

"We require the highest purity gases for our advanced GaN research, which is why we have chosen the palladium membrane technology in the 9000C Series purifier," says professor Sir Colin Humphreys, director, Cambridge Centre for Gallium Nitride.

The compact 9000C Series removes oxygen, moisture and carbon contamination to parts-per-trillion levels to assure a stable process regardless of source gas quality or flow rate.

www.gan.msm.cam.ac.uk

Distributor for Japan appointed

P+E has appointed Fuse Technonet Co. Ltd as its exclusive distributor for Japan. Fuse was established in 1996 to provide equipment for gas and fluid control to support semiconductor, environmental and energy company manufacturing. Fuse has offices in Tokyo, Itami-shi and Higashi-Kurume-shi. The firm will provide sales, technical support and service for P+E's complete line of gas purifiers and other products.

www.fusetechno.co.jp

www.powerandenergy.com

IN BRIEF

Praxair raises prices

Praxair Inc of Danbury, CT, USA has notified clients in the USA, Canada and Puerto Rico of rises in prices (from 1 January, or as contracts permit) as follows:

- Nitrogen, oxygen, and carbon dioxide — up to 15%;
- Argon and hydrogen — up to 20%;
- Helium — up to 30%;
- Facility fees or monthly bulk product charges and cylinder rental rates — up to 15%; and
- Hardgoods — up to 15%.

Adjustments are due to "persistent supply/demand imbalances for some products in the USA and Canada, combined with increases in the cost of feedstock and other raw materials". Also, US energy costs continue to rise, driven by state renewable energy requirements and associated utility transmission and distribution upgrades.

www.praxair.com

Vienna University of Technology orders two Riber MBE reactors

Riber of Bezons, France has sold two Compact 21 MBE systems to Vienna University of Technology for its material research laboratory.

The firm says that its Compact 21 3"-wafer systems are designed for research on compound semiconductors for microelectronics or optoelectronics applications. It adds that MBE growth technology was chosen in this case as such a platform is optimal when the highest-performance, most complex semiconductor

heterostructures are needed.

The two new systems will enable Vienna University of Technology to increase his research capacities for new III-V and metal-based structures. To extend its research capabilities and to grow 'incompatible' material structures, the two MBE systems are connected together to maintain a full ultrahigh-vacuum (UHV) environment throughout MBE processing.

www.tuwien.ac.at/en

System sold for II-VI-based IR sensor growth

Riber has sold an MBE 412 system to a US firm for growing IR imaging sensor materials for ground- and space-based astronomy".

The MBE412 is optimized for use where the highest performance for complex heterostructures

layers is required, says Riber.

The order is repeat business, adds the firm, and will enable the customer to further increase its activities involving new infrared sensor materials and structures.

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Matheson's COO becomes CEO; Kroll now chairman

Matheson of Basking Ridge, NJ, USA, which is a subsidiary of Taiyo Nippon Sanso Corp (TNSC), says that chairman & CEO William J. Kroll has transferred to the role of executive chairman of the board. President & chief operating officer Scott Kallman has been appointed as president & CEO.

As the largest subsidiary of Japan's Taiyo Nippon Sanso Corporation Group (the world's fifth largest supplier of industrial, specialty, and electronics gases), Matheson is a single source for industrial, medical, specialty and electronic gases, gas handling equipment, purification systems, engineering and gas management services, and on-site gas generation.

Kroll has been chairman & CEO of Matheson for nine years and, under his leadership, Matheson has more than tripled its revenues. He will continue to lead the firm's board and corporate auditing functions,

and will continue to serve as a member of the board of directors for Taiyo Nippon Sanso Corp.

Prior to joining Matheson in 2001 for a second time, Kroll served as executive vice president of Business Development at Emcore, where he was instrumental in taking that company public. He played a key part forming joint ventures and making acquisitions. His most notable accomplishments were the formation of GELcore, the joint venture in solid-state lighting with General Electric Lighting; the joint venture with Uniroyal Technology Corp. in the formation of Uniroyal Optoelectronics, a maker of light emitting diode chips; and the joint venture with Union Miniere in the use of Germanium substrates for III-V devices.

"This leadership transition will allow me to focus on capitalizing on growth opportunities and synergies afforded by close coordination with TNSC," says Kroll. "I am looking

forward to working with newly appointed TNSC chairman Hiroshi Taguchi to help move the TNSC Group forward on the global stage."

In his expanded role, Kallman will continue to lead Matheson's operations and customer-facing divisions, while also assuming responsibility for corporate administration, human resources, legal services, business development, information technology, R&D, marketing, and finance.

"Kallman joined Matheson in 2005, running the industrial side of the business, and since then he has made several significant improvements in the areas of safety, quality, and customer focus, serving recently as chief operating officer," says Kroll. "Scott is the right person to take Matheson to the next level as we seek to advance the company as a world leader in the industrial, specialty, and electronics market segments."

www.mathesongas.com

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Dynax orders first Aixtron MOCVD system in China dedicated to GaN electronic device production

Deposition equipment maker Aixtron SE of Herzogenrath, Germany has received its first purchase order for a Close Coupled Showerhead (CCS) CRIUS MOCVD system from Dynax Semiconductor Inc of Kunshan, Jiangsu province, east China.

Aixtron reckons it will be the first system in China dedicated to the manufacturing of gallium nitride (GaN)-based electronic devices.

The system will be used to grow GaN and related nitride epitaxial layers on silicon carbide (SiC) and silicon (Si) substrates for microwave and power devices. After installation and commissioning the system is now ready to produce GaN epiwafers.

Founded in 2011, Dynax was the first commercial firm in China to be

focused on the design and manufacturing of GaN electronic devices. It produces devices for the electronic, data communications, automotive, and motor control markets.

"High-power and high-efficiency GaN electronic devices are the key components for next-generation power management and data communications," says Dynax's president & CEO Dr NaiQian Zhang.

"The Aixtron reactor is a proven system for this application".

"The Dynax technical team already has extensive experience with Aixtron's CCS technology," notes Dr Frank Wischmeyer, Aixtron's VP & program manager Power Electronics.

"We are looking forward to supporting the customer with our expertise

on accelerating the GaN power device market introduction in China."

Compared to conventional silicon devices, GaN electronic devices provide superior performance in high frequency (RF) and power electronic applications in terms of efficiency and power density. Two major challenges however have to be met: due to the strong lattice mismatch between GaN and foreign substrates, GaN has to be grown in a special process. To compete with silicon devices, manufacturing costs have to be as low as possible which requires state-of-the-art MOCVD technology to provide high uniformity and reproducibility.

www.aixtron.com

GaN-on-Si(001) HEMT growth aided by LayTec's EpiCurve TT in-situ growth monitoring

LayTec AG of Berlin, Germany says that at October's International Workshop on Nitride Semiconductors (IWN 2012) in Sapporo, Japan, Jonas Hennig of Germany's Otto-von-Guericke Universität Magdeburg reported on high-performance gallium nitride high-electron-mobility transistor (HEMT) structures on Si(001) with highly optimized inter-layers to control stress and defect density. According to Hennig, in-situ growth monitoring using LayTec's Epi-Curve TT helped greatly with strain engineering.

The reflectance measurements (at three wavelengths) in Figure 2 demonstrate pronounced Fabry–Perot oscillations at 950nm (blue) and 633nm (red) in correlation with smooth development of curvature, showing the high quality of the GaN. Also (see Figure 1), during growth of interlayers, when the temperature (in red) is being brought down, an abrupt increase in curvature (black) can be seen.

The three combined reflectance

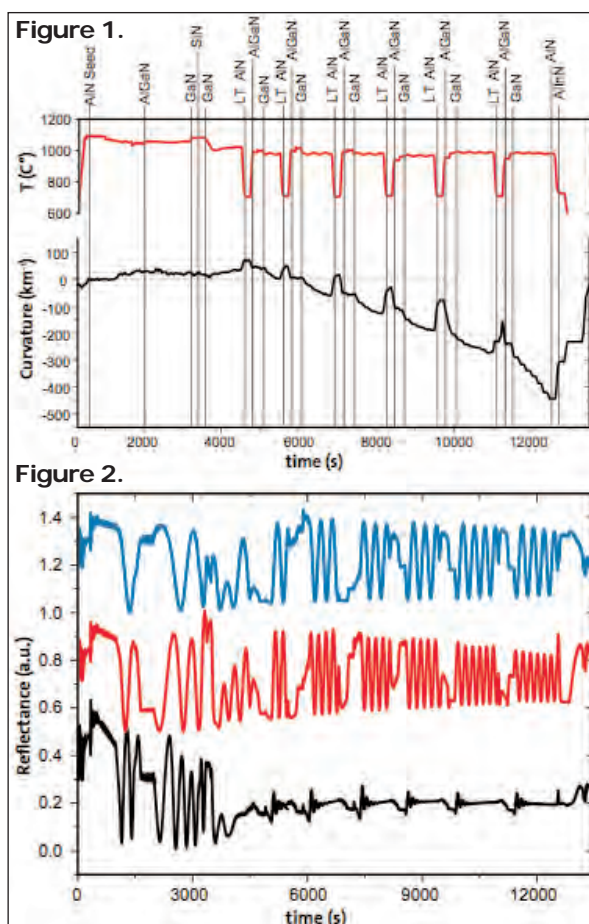


Fig. 1: In-situ measurements of temperature (red) and curvature (black) during GaN on Si(001) growth.

Fig. 2: In-situ reflectance measurements at three wavelengths: blue - 950nm, red - 633nm, black - 405nm.

signals help to determine the growth rates and adjust the growth parameters. Also, the 405nm reflectance (Figure 2 - black) provides information on the structural interface quality.

The work at Otto-von-Guericke University (and other institutions that use LayTec's in-situ tools for silicon applications) shows that GaN/Si quality can be greatly improved by advanced curvature monitoring combined with multiple wavelength reflectance, says LayTec.

www.laytec.de

Veeco hosts Chinese LED makers at MOCVD User Meeting

Epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA says that more than 80 LED manufacturing customers recently attended its metal-organic chemical vapor deposition (MOCVD) User Meeting in Guangzhou, China. Representatives from most of China's top LED makers attended the meeting, which was held in conjunction with China SSL, one of the largest annual events in the solid-state lighting industry.

"China has demonstrated significant progress to drive policies that stimulate end-market demand for LED lighting products," comments Tim Liu, Veeco's Vice President & Greater China Country Manager. "Worldwide adoption of LEDs is growing steadily and our goal is to make sure our customers are best prepared for the lighting ramp by delivering production-proven systems that maximize productivity and yield, while reducing costs."

www.veeco.com



China's top LED makers attended Veeco's MOCVD User Meeting in Guangzhou, China, to discuss manufacturing challenges and learn solutions to maximize productivity and yield while driving down costs.

Deli opts for Veeco MOCVD systems for new LED manufacturing facility ramp-up

Veeco Instruments says that newly formed and privately held company Guangdong Deli Optoelectronics Co Ltd (a subsidiary of Wenzhou-based DELIXI, which makes electric power transmission and distribution appliances) has ordered multiple TurboDisc K465i MOCVD systems for its high-brightness light-emitting diode (HB-LED) manufacturing ramp.

Based in the high-tech development zone of Jiangmen, Guangdong, China, Deli's new production facility which will open in spring 2013. "We chose Veeco over its competitors because of

the company's demonstrated market leadership in MOCVD and production-proven technology," says Deli's president Mai Qinghua. "Veeco's systems will provide us the lowest cost of ownership," he reckons.

"Our tools have supported many of China's LED leaders, so we look forward to providing this new customer with state-of-the-art equipment, engineer training and excellent support and service," says Jeff Hawthorne, Veeco's senior vice president, MOCVD.

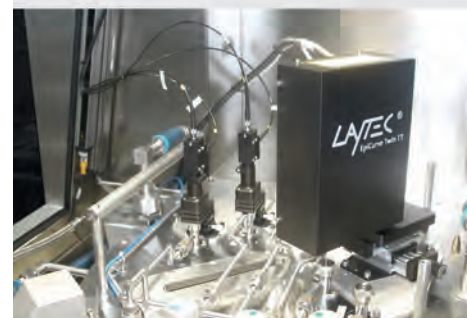
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 Knowledge is key

IN BRIEF

Plasma processing workshop at MIT

Oxford Instruments Plasma Technology (OIPT) says that its first workshop held at MIT's Microsystems Technology Laboratories (MTL) in December addressed the latest research and technologies in plasma etch and deposition, via technical presentations and discussions focusing on the latest innovations.

"Talks presented a huge amount of very useful information, allowing our students and researchers to learn more about atomic layer deposition and plasma processing," says Dr Vicky Diadiuk, associate director, Operations, MTL.

Topics included: ALD processing and applications; an overview of plasma etch, PECVD & TEOS processes, as well as MEMS & nanoscale applications.

www.oxford-instruments.com

SEMI-GAS introduces multi-cylinder system for bulk gas delivery

SEMI-GAS Systems, a division of Applied Energy Systems Inc of Malvern, PA, USA, is now offering a multi-cylinder bulk specialty gas system for high-flow gas processes. MegaCyl, part of the Megaturion line of bulk gas source systems, suits areas where logistics or local regulations preclude the use of bulk gas containers, says the firm.

MegaCyl uses 4 to 18 standard gas cylinders (or more) to create one consolidated bulk gas delivery system. The MegaCyl source system is designed to supply NH₃, HCl, H₂Se and other hazardous process gases at flow rates up to 500slpm. Optional manifold and cylinder heaters are incorporated to facilitate liquid-to-gas phase change and to sustain higher gas flow rates.

"MegaCyl is an excellent solution for our customers located in areas where logistics inhibit the purchase, transport or storage of tonner and

other bulk gas cylinders," says Jim Murphy, SEMI-GAS Systems' division manager. "MegaCyl utilizes banks of standard-sized gas cylinders to sustain our customers' high flow rates, when larger bulk gas packages aren't a viable option."

MegaCyl safely dispenses high-flow hazardous process gases and completes purge routines automatically. Cylinder switchover is fully automatic as well. System conditions are continuously monitored and recorded on a detailed alarm log, through an ergonomically positioned color touch-screen. Each gas cylinder is independently monitored, weighed and potentially shut-down.

Constructed of welded 11-gauge steel with heavy cast-aluminium cylinder brackets, MegaCyl features self-closing, self-latching doors and 1/4" thick windows as well as integrated UL-approved fire sprinklers.

www.semi-gas.com

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www.oxford-instruments.com/plasma



Ultratech acquires assets of Cambridge Nanotech

Lithography and laser-processing tool maker adds ALD to expand nanotech portfolio into new markets

Ultratech Inc of San Jose, CA, USA, which designs and manufactures photolithography and laser-processing systems used to make semiconductor devices and high-brightness LEDs (HB-LEDs), has acquired the assets of Massachusetts-based Cambridge Nanotech Inc.

Spun off from Harvard University's Gordon Lab in 2003, Cambridge Nanotech makes atomic layer deposition (ALD) equipment, with hundreds of system installed in research and manufacturing worldwide.

Ultratech says that, with the acquisition, it is expanding its nanotechnology and intellectual property (IP) portfolio with ALD technology to provide solutions for new layers within the electronics industry and entry into new markets, such as

biomedical and energy.

Due to the increasing interest in nanoscience, ALD has emerged as a critical technology for depositing precise nanometer-thin films, says Ultratech. Typical applications require the manufacture of very precise nanometer-thin, pinhole-free and conformal thin films on many shapes and geometries. The firm hence expects that the technology will be in demand in volume manufacturing environments and in particular for micro-electro-mechanical systems (MEMS), implantable devices in the biomedical sector, and batteries and fuel cells in the energy arena. ALD is an enabling technology and provides coatings and material features with significant advantages to other existing techniques, it adds.

"As a global leader in experimental ALD solutions, Cambridge has developed a portfolio of valuable technology and systems," says Ultratech's chairman & CEO Arthur W. Zafiropoulos. "We plan to integrate the intellectual property acquired from Cambridge Nanotech into Ultratech and include the ALD systems in our nanotechnology product group," he adds. "By increasing our IP and expanding our nanotechnology portfolio to new levels, we expect to generate a new revenue stream in existing and new markets... We expect that this acquisition will enhance our short-term as well as our long-term growth expectations."

www.ultratech.com

www.cambridgenanotech.com



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Temescal's Auratus process enhancement methodology optimizes electron-beam metalization

Ferrotec Corp (a supplier of materials, components and precision systems and a manufacturer of electron-beam evaporative coating systems) of Livermore, CA, USA says that its Temescal Division (which makes electron-beam-based evaporative coating systems) has made a process breakthrough in electron-beam metallization for lift-off compound semiconductor applications.

The firm says that its Auratus deposition process enhancement methodology improves wafer-coating processes dramatically, producing near-perfect uniformity and increased precision across a wide range of metals, while delivering up to 40% reduction in material consumption (resulting in cost savings on process materials like gold and platinum compared to traditional box coaters).

Traditionally, electron-beam evaporation takes place inside box-shaped stainless-steel vacuum chambers, using a high-voltage electron beam to vaporize materials such as gold or platinum. After the material has been vaporized, it forms a flux cloud above the electron-beam gun, resulting in a thin-film coating condensing on the wafers held in an assembly in the upper part of the chamber. However, traditional deposition methods have not fully optimized the vapor cloud in terms of maximizing efficiency in lift-off process collection. With the new Auratus methodology, vapor cloud utilization is optimized, says the firm.

"With the Auratus process enhancement methodology, we have re-envisioned electron-beam deposition, with an emphasis on

multiple metal uniformity and collection efficiency," says Temescal's managing director Gregg Wallace.

Auratus is a proprietary optimization methodology for lift-off electron-beam evaporative coating that incorporates patent-pending technology to achieve uniformity, precision, and collection efficiency. It enables Temescal customers to coat wafers with near-perfect uniformity, resulting in more consistent, better quality products and fewer defects. It also has the capability to increase the effective deposition rate, enabling increased throughput, adds the firm.

Temescal's Auratus process enhancement methodology is only available on select Temescal systems. Contact Temescal for qualification.

www.temescal.net

Inspectrology expands Europe & Asia operations with rep deals with France's Eumetrys and Singapore's Excellis

Inspectrology LLC of Sudbury, MA, USA, which manufactures the IVS optical overlay metrology product line, has signed agreements to be represented in Asia by Excellis Pte Ltd of Singapore and in Europe by Eumetrys SAS of Gaillac, France.

Founded in 1980 from a project at MIT's Lincoln Laboratory, IVS was purchased by Schlumberger in 1997 and spun off as Soluris in 2003. In 2006, Soluris was purchased by Nanometrics. Inspectrology was formed in 2008 by IVS engineers devoted to the advancement of the IVS metrology platform, focusing on the 75–200mm-wafer-based market.

"Having acquired the rights to the IVS product line in September, it was critical for our business to quickly scale to a world-wide service organization," says Inspectrology's VP of marketing & finance Paul Knutrud. With a focus on MEMS, compound semiconductor, LED and

other challenging processes, the IVS system is positioned to meet the needs of fabs running at 75–200mm wafer sizes. "Working with the experienced engineers at Excellis and Eumetrys has allowed us to ramp quickly and efficiently to meet our customer's needs," he adds.

"We have consolidated our stock in Singapore and are already installing new equipment for a customer in Singapore," says Excellis' managing director Martin Lau.

"Our customers are seeing the attention to service we are now able to provide them." Excellis' business portfolio consists of equipment servicing, used equipment trading, and distributor of semiconductor consumable parts.

"Our customers reported to us they are very excited about the new support structure," comments Eumetrys' CEO Yannick Bedin, the

long-time technical support manager for the IVS products, who formed the firm in November to fill the need for European customer support for the IVS system.

"The IVS tools have always been great workhorse tools," he adds. Eumetrys aims to work closely with Inspectrology to focus on response time and customer satisfaction for the IVS product line in Europe. The European region has important potential for expansion of the metrology marketplace, the firm reckons. Eumetrys says that it is qualified to both support the existing customer base and to enable expansion of the product line in Europe, with a focus on MEMS, compound semiconductor, LED, and high-value semiconductor systems at 200mm wafer sizes and below.

www.inspectrology.com

www.eumetrys.com

www.excellis.com.sg

Hidden launches MS Spectral Overlap Evaluator iPad app

Hidden Analytical Ltd of Warrington, UK has introduced its Overlap Evaluator iPad app reference tool for users of mass spectrometers in vacuum science and processing, and for researchers using real-time gas analysis systems.

The evaluator enables the user to create a mass spectral overview of multiple fragmentation spectra to identify the mass peaks with least spectral interference. It is therefore most suited to species monitoring, and includes a quick mass peak look-up table from a library of common gas and vapour species.

Based on the Hidden QGA quantitative gas analysis system software, up to 16 gas and vapour species can be added to an analysis 'setup'. On adding the gases and vapours of interest, the MS overlap evaluator automatically provides a simulated analysis and displays the unique mass peaks together with any spectral overlaps. A spectral viewer is included to provide a histogram display of the simulated spectrum of the selected analysis.

The concentration levels for each component in the simulation mix can be adjusted, to provide a representative simulated mass spectrum of the users selected gas and vapour mixture.

The MS spectral overlap evaluator is available free to download from the Apple app. store.

www.HiddenAnalytical.com

QuantumClean acquires Advent Cleaning Technology

QuantumClean of Dublin, CA, USA, which provides high-purity outsourced process tool parts cleaning, surface treatment, refurbishment, analytical and engineering services to the semiconductor, solar and LED industries, has acquired semiconductor parts cleaning business Advent Cleaning Technology Inc of Carrollton, TX.

QuantumClean says the acquisition enhances its regional cleaning capabilities and adds quartz fabrication and repair to its portfolio of semiconductor parts refurbishment services.

Advent is recognized for its customer orientation and quality focus, says Scott Nicholas, CEO & president of QuantumClean's parent firm Quantum Global Technologies. "Advent is a perfect fit with QuantumClean's strategy to continually increase its value to its semiconductor wafer fabrication, OEM and OPM customers through the offering of greater capabilities and convenience," he adds.

With the Advent acquisition, QuantumClean now operates 15 Advanced Technology Cleaning Centers and three ChemTrace microcontamination analytical laboratories in seven countries employing nearly 1000 staff providing high-purity parts cleaning and analytical services.

www.adventclean.com

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KLA-Tencor launches ICOS WI-2280 fourth-generation wafer inspector for LED and adjacent markets

Process control and yield management solutions provider KLA-Tencor Corp of Milpitas, CA, USA has launched its next-generation LED patterned wafer inspection tool. Designed specifically for defect inspection and 2D metrology for LED applications, the ICOS WI-2280 can also provide enhanced inspection capabilities and increased flexibility for micro-electro-mechanical systems (MEMS) and semiconductor wafers spanning 2-inches to 8-inches in size.

Built on its WI-22xx platform (of which there are now more than 80 tools installed in the field), the ICOS WI-2280 is KLA-Tencor's fourth-generation LED wafer inspection system. Compared with the existing WI-2200 and -2250 models, the new WI-2280 model delivers enhanced sensitivity with increased throughput for reduced cost of ownership.

Additionally, the tool supports the handling of whole wafers in carriers as well as diced wafers in both hoop ring or film frame carriers to accommodate multiple media with minimal equipment changeover time. This is especially relevant in China and Taiwan, notes Jaydeep Khedhar, director of marketing, Growth & Emerging Markets (GEM), where 2" hoop rings are widely used but have been a challenge for the WI-2200 and -2250 (while film frame carriers are used for solid-state lighting applications). In addition, in Taiwan want to change over the wafer size, adds Khedhar.

The new system also features an enhanced rule-based binning defect classification and recipe qualification engine. This enables faster yield learning during production ramps, as well as improved process control and process tool monitoring strategies, KLA-Tencor says.

"Increasingly, LED manufacturers are demanding improved detection and classification of yield-relevant defects of interest, which enables



KLA-Tencor's new ICOS WI-2280 system.

them to take faster corrective actions to improve their yields at higher inspection throughput," says Jeff Donnelly, group vice president, Growth and Emerging Markets. "There is also a growing need to boost productivity by enabling faster production recipe creation," he adds.

Compared with the ICOS WI-2250, the WI-2280 allows increased tool productivity, with throughput up by 25%, says Khedhar.

This is especially important, he adds, as the increase in die size for higher-power LEDs is leading to more complex, dense device structures, which are consequently more prone to having defects.

"The ICOS WI-2280 addresses critical market requirements — ultimately enabling LED manufacturers to achieve better lumens per watt

and lumens per dollar performance," states Donnelly.

In addition to LED application environments, the MEMS, semiconductor, compound semiconductor and power device markets can also leverage the WI-2280 tool for: back-end-of-line and post-dicing outgoing quality control or binning; front-end-of-line patterned

wafer inspection for baseline yield improvement, rework, excursion control or overlay; and 2D surface inspection and metrology. Although LEDs currently comprise the biggest application, Khedhar sees these other applications developing in the next one or two years.

As part of KLA-Tencor's LED portfolio, the ICOS WI-2280 works in conjunction with the firm's Candela LED unpatterned wafer inspection system and Klarity LED automated analysis and defect data management system, providing comprehensive end-to-end inspection coverage. In addition, existing WI-2200 and -2500 tools in the field can be upgraded to WI-2280 spec.

All tools are backed by KLA-Tencor's global, comprehensive service network.

www.kla-tencor.com

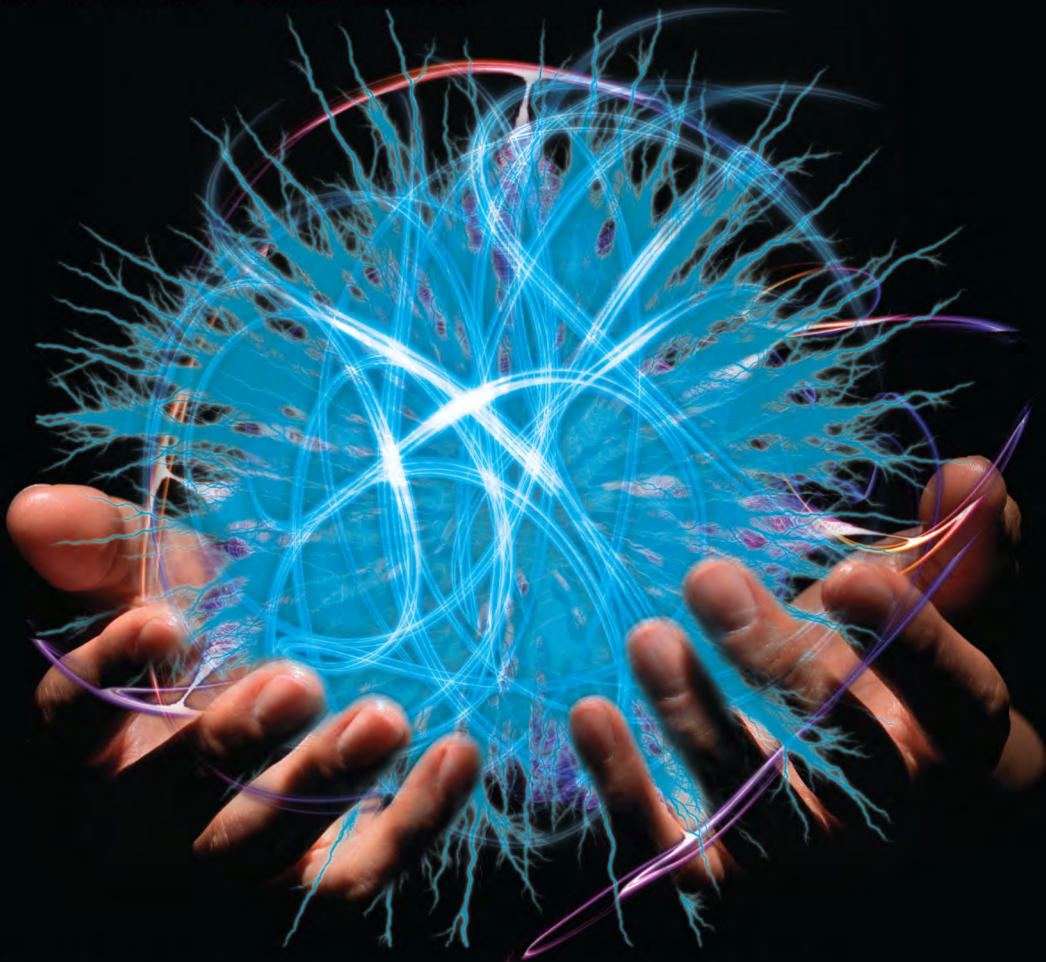
Building on the performance of the ICOS WI range, the WI-2280 includes:

- highly flexible optical modes with dedicated image processing, enabling a high defect capture rate and recipe robustness against a varying process background;
- unique defect classification, delivering faster time to information;
- an advanced recipe tuning engine with best known methods,

allowing faster recipe qualification;

- enhanced metrology capability, offering additional yield-relevant actionable data with no impact to throughput;
- front-end to back-end-of-line connectivity analysis capability, delivering a single platform for defect source analysis; and
- an easy-to-use inline or offline reclassification engine, enabling post-inspection yield improvements for enhanced productivity.

Hold Your Ground



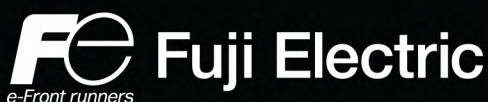
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IN BRIEF

Rubicon awarded patent for ultra-flat, high-throughput wafer lapping

Rubicon Technology Inc of Bensenville, IL, USA, which makes monocrystalline sapphire substrates and products for the LED, RFIC, semiconductor and optical industries, says that the US Patent and Trademark Office (USPTO) has allowed its patent application 'Ultra-Flat, High-Throughput Wafer Lapping Process', which covers its process for performing grinding and polishing to achieve consistent, ultra-flat and defect-free surface quality for the high-volume production of large-diameter sapphire wafers.

Rubicon says its customers in the LED and SoS/RFIC markets have very demanding requirements for the quality of sapphire wafers used in their applications. The patent addresses the quality and flatness challenges inherent in the production of sapphire wafers at larger diameters.

The patented lapping process enables high levels of flatness and quality while maintaining the highest levels of throughput in the production of large-diameter sapphire wafers, says Rubicon. As wafers are lapped and polished, the platens facing the wafers become worn and deformed, leading to the deterioration of wafer quality. In the patented process, the platens are continuously self-conditioned and self-optimized to maintain high performance.

"This patent underscores our dedication to improving the large-diameter sapphire manufacturing process and improving the leading technology platform for the high-throughput production of high-quality large diameter sapphire wafers for our customers," says president & CEO Raja M. Parvez.

www.rubicon-es2.com

GT expect revenue down 10% in Q4, and 23% below guidance for 2012

GT Advanced Technologies Inc of Nashua, NH, USA (a provider of polysilicon production technology as well as sapphire and silicon crystalline growth systems and materials for the solar, LED and other specialty markets) says that it expects revenue of \$95–102m in fourth-quarter 2012 (down about 10% on Q3's \$110.1m). For full-year 2012, revenue should total \$726–733m (23% below the guidance of \$925–975m reiterated in September), with about 62% of 2012 revenue from polysilicon, 31% from sapphire, and 7% from photovoltaics (PV).

The firm expects to take a charge of \$80–90m related to the write-down of the majority of its DSS (Directional Solidification System) inventory and other inventory-related charges. Excluding this charge, gross margin should be 34–36% in Q4/2012 and 38–40% in 2012.

The firm is also evaluating potential impairment related to goodwill, long-lived assets & other intangibles for the PV business that could impact Q4/2012. Excluding this, operating expenses should be \$49–51m in Q4/2012 (including \$23–25m in R&D), and \$151–153m in full-year 2012 (including \$71–73m in R&D).

On a non-GAAP basis, GT expects a loss per share (on a fully diluted basis) of \$0.05–0.10 in Q4/2012 and \$0.77–0.82 in 2012, excluding the inventory charges and any impairment charges, as well as restructuring charges (of about \$4.2m), stock compensation expense, contingent consideration, non-cash interest expense, amortization of intangible assets and acquisition expenses.

Capital expenditures should be \$5–7m in Q4/2012 and \$41–43m in 2012. During Q4/2012, cash & cash equivalents should fall from \$479.2m to something over \$400m (including total debt of about \$300m).

Order backlog is expected to fall from \$1.5bn to \$1.2bn at the end of Q4. Based on current market conditions and uncertainty related

to the delivery timing of certain orders in backlog, GT expects that about 25% of this backlog is at risk.

The firm will report final Q4 and full-year 2012 results in February.

For 2013, GT's preliminary outlook indicates revenue falling to \$500–600m, with only about 1% from the PV segment, and 42% from polysilicon and 57% from sapphire. Gross margin should fall to 35–37%. Operating expenses are expected to be \$152–158m (including \$75–80m for R&D).

"Our outlook reflects the soft market conditions and very tight lending environment in the solar and LED industries that we serve, as well as the overall challenging macroeconomic environment," says president & CEO Tom Gutierrez.

"We have taken actions to size our business in accordance with the environment and expect to remain profitable in 2013," he adds.

At the end of October, GT said that it was streamlining global operations to better align its cost structure with market conditions and enhance its ability to pursue strategic growth initiatives. This includes the consolidation of existing business units into a single Crystal Growth Systems (CGS) group and cost-reduction actions (including a reduction in staffing of about 25% that is expected to cut annualized expenses by about \$13m).

After capital expenditure of just \$11–13m in full-year 2013, non-GAAP earnings per share (on a fully diluted basis) should be \$0.25–0.45. Nevertheless, the year-end cash balance should still fall to \$225–275m.

"While current market conditions are unlikely to improve over the next 12 months, we remain confident about our long-term future, and we expect to exit this downturn as a stronger more diversified company with market-leading positions in several growth industries," concludes Gutierrez.

www.gtat.com

GT completes restructuring with streamlining of operations and new functional structure

GT Advanced Technologies Inc of Nashua, NH, USA (a provider of polysilicon production technology as well as sapphire and silicon crystalline growth systems and materials for the solar, LED and other specialty markets) says that it is transitioning to a functional organizational structure from its prior business unit organization as it continues to streamline operations and position the company for growth once the markets it serves start to recover (as announced last November).

Under the new structure, sales, service and worldwide operations will be centralized under the leadership of Dan Squiller, who will continue to report to president & CEO Tom Gutierrez. Dave Keck, formerly general manager, polysilicon and photovoltaic equipment, will lead sales and service across all businesses, reporting to Squiller. Jeff Ford, VP of DSS business development, will continue to have responsibility for GT's DSS (Directional Solidification System) business, leveraging his industry knowledge and experience to ensure that GT continues to support its DSS customer base as the firm transitions to next-generation photovoltaic (PV) technologies.

The firm's R&D initiatives in next-generation solar, Hyperion ion implant exfoliation and sapphire will be managed under Dr Vikram Singh, executive VP, Advanced Systems Development. In addition, Singh remains responsible for all central engineering support services as well as business development and prod-

uct management for the Hyperion and next-generation solar platforms. Chief technology officer Dr P.S. Raghavan will continue to lead technology development for silicon carbide (SiC) and gallium nitride (GaN) applications. As a result of the functional realignment, the business unit general manager positions have been eliminated and Cheryl Diuguid (formerly general manager of the sapphire business) has left the firm.

As previously indicated, the firm is scaling back its merger & acquisition (M&A) program in 2013.

Hence, the role of chief strategy and new business officer is being eliminated and David Gray Ph.D. will leave the firm effective 25 January. CEO Tom Gutierrez will drive strategic development initiatives.

"The new functional structure reflects GT's continued efforts to streamline our operations and align our business with current market and business conditions," says Gutierrez. "It further minimizes duplication of resources and provides us with a very efficient platform to grow from in 2013," he adds.

As part of the reorganization of resources, the firm is shifting final development and beta build activities for its HiCz (continuously fed Czochralski growth) product to its facility in Merrimack, NH, and will be idling its HiCz materials pilot manufacturing facility in St. Louis, MO. As a result, the firm will layoff about 35 employees in St. Louis. These employees will be provided severance pay, health and dental benefits and outplacement services.

GT says that it remains committed to the commercialization of the HiCz platform, a next-generation PV furnace that will produce N-type silicon wafers to help make more efficient solar cells. It expects to be ready to offer the HiCz product by mid-2013 but, given current market conditions in the PV industry, orders for the new-generation systems may not occur until 2014 when the industry begins to recover. Several HiCz pullers are already installed and operating in Merrimack, where most of the HiCz R&D team is based.

GT is seeking a strategic partner to purchase the St. Louis operation. The 67,000ft² leased facility currently has HiCz tools installed, representing a capacity of 50MW/~250MT output/~12.5 million wafers per year. The facility is designed to support twice as many tools as are currently installed.

The firm estimates that the idling of the St. Louis facility will reduce its annualized expenses by about \$15m (excluding restructuring charges). The savings related to this action were anticipated and reflected in the 2013 guidance range provided on 18 December. In addition, GT expects to incur restructuring and non-cash asset impairment charges in Q4/2012 and in 2013 related to this action. The firm is evaluating the timing and amounts of the charges and expects to provide further details on these when it reports 2012 earnings results in February.

www.gtat.com

Rubicon closes \$25m secured revolving credit facility

Rubicon Technology Inc of Bensenville, IL, USA, which makes monocrystalline sapphire substrates and products for LED, RFIC, semiconductor and optical markets, has closed a three-year \$25m secured revolving credit facility with Silicon Valley Bank.

"This undrawn credit facility bolsters Rubicon's strong liquidity position," says chief financial officer William Weissman. "It is prudent to establish this additional financial flexibility for the future," he believes.

Rubicon currently has no debt. The terms and conditions of the credit facility will be described in the firm's filings with the US Securities and Exchange Commission (SEC).

www.rubicon-es2.com

BluGlass completes A\$2.35m institutional placement

Proceeds to be used to commercialize RPCVD technology for LED and solar applications

On 7 December, BluGlass Ltd of Silverwater, Australia allotted and issued 11,766,025 new fully paid ordinary shares to institutional investors at a price of A\$0.20 each (a discount of about 11% on the closing price on 28 November of \$0.22, and a 28% discount to the volume weighted average price of shares traded since BluGlass' proof-of-concept announcement on 22 November).

This followed settlement of its placement, announced to the Australian Securities Exchange (ASX) on 3 December. The placement

raised \$2,353,205, or US\$2.45m (before costs).

In addition, shareholders on BluGlass' register on 30 November with registered addresses in Australia and New Zealand were also given the opportunity to apply for a parcel of new shares in BluGlass valued at A\$2500, A\$5000, A\$7500, A\$10,000, A\$12,500 or A\$15,000 (subject to any scale-back determined by BluGlass' directors) at the same issue price, without incurring brokerage or transaction costs, via a shareholder share purchase plan (SPP).

The purpose of the new placement and SPP is to provide funds for:

- the commercialization of BluGlass' RPCVD technology for LED applications;
- further development for solar cell applications;
- match funding, should BluGlass be successful with its application for a grant under the Clean Technology Innovation Program of the Australian Government's AusIndustry initiative; and
- general working capital requirements.

www.asx.com.au

Preliminary results reported on RPCVD-grown p-GaN

Improved blue LED efficiency targeted for low-temp process

BluGlass says that it has succeeded in its initial laboratory experiments in developing p-type gallium nitride (p-GaN) material (essential for the top layers of a nitride LED).

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

The firm has now used its low-temperature RPCVD technology to create the p-GaN layer on a commercially grown metal-organic chemical vapor deposition

(MOCVD) 456nm-wavelength blue multi-quantum well structure.

In preliminary testing on the sample using a 0.5mm-diameter p-type indium contact, light output was measured with a UV detector positioned under the wafer, calibrated at the wavelength of the light emission.

At a drive current of 20mA and a voltage of 4.7V, light output was 270µW (emitted at a wavelength of 458nm, with a full width half

The firm has now used its low-temperature RPCVD technology to create the p-GaN layer on a commercially grown MOCVD 456nm blue MQW structure

maximum of 19nm). At 50mA and 5.5V, output was 1.23mW (emitted at 456nm, with a full width half maximum of 18nm) — the current was applied continuously for over an hour without any loss of function of the device.

At its recent annual general meeting (AGM) of shareholders, BluGlass outlined that it was looking to demonstrate p-GaN and identified a number of steps in order to demonstrate improved LED efficiency with a low-temperature process. "While these results are preliminary, they represent highly encouraging progress, ahead of our expectations towards our next major milestone to prove that a low-temperature technology can improve the efficiency of an LED," says CEO Giles Bourne.

BluGlass receives \$2.3m R&D tax credit

Further to its announcement on 17 April confirming its eligibility to receive a rebate on R&D activities in 2012, BluGlass' subsidiary EpiBlu (formed in 2010 as a joint venture with SPTS Technologies Ltd of New-

port, UK) has received a \$1,626,027 tax credit from the Australian Tax Office. Parent firm BluGlass has also received an additional \$709,930. Total tax rebates hence amount to \$2,335,957 (before costs).

"This is a significant cash injection for BluGlass and it will greatly assist the company in the commercialization of its groundbreaking technology," says CEO Giles Bourne.

www.bluglass.com.au

Mentor Graphics enhances measurement and characterization hardware and simulation software for LED auto-lighting developers

Mentor Graphics Corp of Wilsonville, OR, USA says it has made significant advances to its T3Ster+TeraLED measurement and characterization hardware, as well as its FloEFD software simulation products, to meet the needs of lighting developers using arrays of LEDs in headlights, taillights and other transportation industry applications. According to the firm, the product improvements will enable developers to efficiently manage the heat and condensation developed by these arrays, thus improving their reliability and life. In addition, with T3Ster and TeraLED hardware's ability to measure both thermal and optical characteristics of single LEDs and full arrays, proper light quality and color can be achieved.

The FloEFD product has been extended with a dedicated LED module, which enables thermal simulation of the most advanced LED products along with the capa-

bility of predicting their 'hot lumens', i.e. their total emitted luminous flux at their operating temperatures. This capability is provided through an LED model library whose elements are characterized directly from physical tests by the Mentor T3Ster+TeraLED combined thermal and radiometric/photometric LED testing solution. In addition, the FloEFD LED models support radiation absorption in semi-transparent solids, such as the head or taillight lens.

"LEDs shipped to use in headlamps are forecast to grow significantly from 10 million units in 2012 to 78 million units in 2018," says Jamie Fox, lighting and LEDs research manager for IMS Research. "The quality, lifetime and reliability requirements in the automotive sector are very high, higher than most other LED sectors."

"The use of LEDs in the transportation industry is expanding

rapidly, led by Europe but now also prevalent in the US and Asia," says Erich Buerger, general manager of Mentor Graphics' Mechanical Analysis Division. "We have serviced this industry for several years now but larger, hotter and more complex shaped arrays are driving us to enhance our FloEFD, T3Ster, and TeraLED products to stay ahead of our users' needs," he adds. "These enhancements will ensure that the industry is able to advance while maintaining high product reliability and achieving faster times to market."

To accommodate larger LED arrays, Mentor now provides a 50cm diameter sphere, in addition to its 30cm, on its TeraLED product to measure optical performance. A 50cm sphere is large enough to hold LEDs used in headlights and taillights producing up to 7500lm, with cooling for up to 50W of heat dissipation.

<http://go.mentor.com/autolight>

GE Lighting acquiring lighting fixture maker Albeo

GE Lighting of Cleveland, OH, USA has agreed to acquire Albeo Technologies Inc of Boulder, CO, a privately held LED fixture maker established in 2004.

"The addition of Albeo Technologies' immensely talented team and its award-winning LED fixture portfolio enhances GE Lighting's ability to serve as a trusted advisor to enterprise customers around the world," reckons GE Lighting's president & CEO Maryrose Sylvester. "This acquisition is a big boost for GE customers moving aggressively toward an all-LED building envelope in new construction and retrofits, including retail, commercial and industrial high-bay applications."

GE offers commercial, industrial and municipal customers a range of legacy lighting solutions and LED

systems for architectural, indoor, outdoor, signage, retail and transportation applications.

Albeo's LED systems — high-bay, low-bay, linear, surface mount and under cabinet fixtures — are used in commercial, warehouse, industrial, cold-storage, office, data-center, food processing, parking garage, school, sporting and correctional settings. Its solutions have helped to illuminate a range of 'all-LED' facilities, including one of the world's 10 largest data centers. Albeo's products have been recognized with 16 independently judged awards, including six from the US Department of Energy.

"Joining GE vastly expands the universe of customers with access to our breakthrough LED solutions and it profoundly empowers our

research and product development capability," says Albeo's co-founder & CEO Jeff Bisberg.

GE says that, through the acquisition, it accelerates its ability to offer customers a more complete and integrated LED solution. "Some of our biggest customers told us they wanted a GE-quality solution for high bay," notes Sylvester. "This acquisition accelerates our development of cutting-edge technologies that brings customers the energy-efficient solutions they need. That's what customers get at the end of the day—a refined, highly modular and scalable platform."

Albeo's products are available via distribution channels and now via GE's global distribution network.

www.albeotech.com

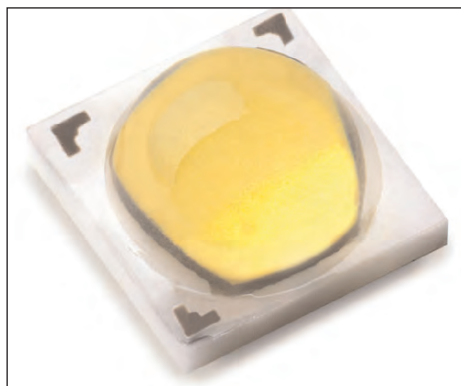
www.gelighting.com

LUXEON T LED delivers performance and precise beam control for directional & efficacy-driven applications

Building on its innovations of hot testing and 'Freedom from Binning', LED maker Philips Lumileds of San Jose, CA, USA has launched LUXEON T, its next-generation illumination-grade LED which is tested and specified at 85°C to ensure in-application performance with tight color control, to within 3-step MacAdams (SDCM).

Optimized for efficacy and supported by what is claimed to be an industry-leading low forward voltage of 2.7V and the lowest thermal resistance of 3 Kelvin per Watt, Lumileds reckons that the LUXEON T allows the highest possible system efficacy and the flexibility to reduce the number of emitters, without compromising on high color rendering index (CRI) across the full correlated color temperature (CCT) range of 2700–5000K.

"With its high efficacy and luminance, LUXEON T is ideal for directional applications such as MR16



Lumileds' new LUXEON T LED.

and PAR retrofit lamps," says product line director Kathleen Hartnett. "LUXEON T is able to deliver high center-beam candle power (CBCP) and precise optical control, which are required to deliver the narrow beams desired for these systems."

LUXEON T delivers luminous efficacy of up to 140 lumens per watt at a drive current of 350mA (at 85°C) in neutral white at a CCT of 5000K and a CRI of 80 (minimum) from a

compact 3.7mm x 3.7mm package. Lumileds says that the performance is realized through more tightly controlled epitaxial growth (delivering what is claimed to be leading wall-plug efficiency and hot cold factor), new phosphors to enhance conversion efficiency, and package optimization (for light extraction and the lowest thermal resistance).

LUXEON T is now available in five different CCTs (2700K, 3000K, 3500K, 4000K and 5000K), all specified at high CRI (80 minimum). In addition to the 80-CRI range, LUXEON T is also available with a typical CRI of 95 and exceptional red rendering (R9) of 90, making it suitable for the professional lighting market. To enable system-level performance improvements in outdoor and industrial applications (including high-bay, street and roadway lighting), in January the LUXEON T will be extended to the 70 CRI range.

www.philipslumileds.com

Lumileds restructures Future Electronics distribution agreement

Lumileds has restructured its long-standing distribution agreement with Future Lighting Solutions (a division of Future Electronics) to allow both firms to create additional partnerships.

"Our restructured agreement allows us to continue our collaboration with a long-term, trusted

and successful partner," says CEO Pierre-Yves Lesaichere. "We are able to serve the needs of our growing customer base and carry on our widespread expansion into new target markets." Lumileds can now distribute and sell its LED products through additional partners in various regions. Future Lighting

Solutions can distribute other suppliers' solid-state lighting lines.

"Future Lighting Solutions will now have the opportunity to expand our portfolio of products in order to address the needs of our lighting customers," says Gerry Duggan, executive VP, Future Electronics.

www.futurelightingsolutions.com

New distributor relationships for EMEA & Greater China

After restructuring its distribution channels, Philips Lumileds has added new distributors for the first time in nearly two decades, driven by the needs of a rapidly growing customer base and to allow the continued, widespread expansion of its products and solutions into new markets.

Enhancing its Europe, Middle East & Africa presence, Lumileds has appointed Avnet company Silica

(the third largest semiconductor distributor in EMEA, with over 600 staff and 39 branch offices) as its pan-European distribution partner.

For Greater China (China, Hong Kong and Taiwan), Lumileds has formed three new distribution partnerships, with Avnet Memec, WT Microelectronics and Yosun Group.

Each new distribution partner will have full access to the products, services and people at Lumileds

says CEO Pierre-Yves Lesaichere.

"Silica, the Yosun Group, Avnet Memec, and WT Microelectronics are now able to provide their customer base with access to the world's most comprehensive portfolio of application-specific LED solutions."

www.silicalighting.eu

www.em.avnetasia.com

www.wtmec.com

www.yosungroup.com

Soraa launches industry's first fixture validation program

Soraa Inc of Fremont, CA, USA, which develops solid-state lighting fabricated on 'GaN on GaN' (gallium nitride on gallium nitride) substrates, has launched 'Works with Soraa', the lighting industry's first fixture validation program. Lighting fixture makers Tech Lighting, Focal Point, Hevi Lite, and Dream-scape Lighting have joined Soraa to kick off the program.

Incompatibility between LED lamps and fixtures designed for traditional light sources — incandescent, halogen or fluorescent — is one of the biggest hurdles facing the lighting industry, says Soraa. The Works with Soraa program aims to foster strong collaboration between the firm and fixture makers, so fixture and lamp combinations can be rapidly validated for mechanical, thermal and electrical compatibility. The program will hence facilitate faster time-to-market for new fixtures and lamps. Specifiers can then specify, and customers can purchase and install, these validated combinations with confidence.

"The Works with Soraa program will benefit all stakeholders in the lighting industry — lighting designers, architects, contractors, installers and end-users — by providing certainty about fixture and LED lamp compatibility," reckons Soraa's CEO Eric Kim.

"Furthermore, this program will enable fixture manufacturers to quickly offer a world-class LED solution, while focusing on what they do best... It's all about enabling flexibility and choice without compromising performance and quality."

"For LED lighting to gain greater acceptance in the lighting design community, it is critical that we solve the LED lamp and fixture compatibility issue," says Chip Israel, president architectural lighting design firm Lighting Design Alliance, who encourage other fixture manufacturers to join the program "as we are desperate for this information".

"For too long, many in our industry have used the word LED 'replacement' lamp far too loosely," says Tech Lighting's president Joshua Weiss. "We are excited to partner with Soraa because we can say with confidence that their MR16 lamps are true replacements both in output and quality of light. At the same time, they exceed the definition of 'replacement' on numerous other criteria and serve as the perfect long-lasting, energy efficient complement to our fixtures," he adds.

"Focal Point is excited to work with Soraa as they are the first LED lamp supplier that is taking a proactive approach to ensuring

compatibility between lamp and luminaire," says Michael Thornton, VP of marketing at Focal Point.

"Working together ensures that the thermal requirements of the Soraa lamp perform within specification when used in select Focal Point luminaires. We look forward to validating additional Focal Point luminaires in the future using Soraa lamps."

"Its unique thermal heat-sink, with an exact MR16 bulb shape, make it a perfect retrofit LED replacement lamp," comments John Baldasti, CEO of Hevi Lite Inc. "The lamp is true to the color and output of a standard halogen MR16 lamp," he adds.

"The Works with Soraa program allows us to validate the compatibility of our products with the Soraa lamp — simplifying the end-users' lamp and fixture choice," notes Victor Kelmelis, VP of Dreamscape Lighting Mfg Inc. "Soraa was very helpful during our initial fixture testing and we plan on validating many of our products in the future."

Validated fixtures will be listed on Soraa's website, cross-referenced with lamps with which the fixtures were tested. Similarly, fixture makers will list validated fixtures in their catalogs and website, cross-referenced with the Soraa lamps tested.

www.soraa.com/solutions

Soraa sponsors lighting industry's first PlugFest event

Soraa sponsored the lighting industry's first PlugFest in conjunction with the Illuminating Engineering Society of New York City (IESNYC) at their annual Control This! event on 5 December.

"Incompatibility between LED lamps and fixtures with existing control gear and dimmers designed for traditional light sources — incandescent, halogen, or fluorescent — is one of the biggest hurdles facing the lighting industry today," said Paul Gregory, founder & president of architectural lighting design firm Focus Lighting Inc of New York City.

"PlugFests are a mainstay of high-tech industries, and Lighting PlugFest at Control This! is destined to revolutionize the way lighting practitioners and OEM vendors of LED lamps, fixtures, transformers, and dimmers test the interoperability between products from different manufacturers and accelerate the growth of the entire industry," said Control This! co-chair Meg Smith, senior project manager, Philips Lighting Solutions and Services.

Soraa managed and ran the testing using a custom-built panel consisting of an array of commonly used transformers and dimmers and its

12V_{AC} LED MR16 lamps, and also accommodated participating firms' transformers, dimmers and 12V_{AC} LED lamps or fixtures. A video of how the panel works is available at: www.youtube.com/watch?v=pmw_9k8IM-8&feature=plcp.

"Manufacturers benefit because Lighting PlugFest addresses compatibility — an obstacle to widespread LED lamp adoption; designers benefit because they can specify with confidence; and end users benefit because they will know that product combinations work," said Soraa's CEO Eric Kim.

www.controlthis.org

Seoul Semiconductor's MJT series LEDs enable fixture-level performance of 100lm/W

Seoul Semiconductor says that it is accelerating sales of its MJT (Multi Junction Technology) series LEDs, which uses the firm's integrated Acrich technology. An advantage of the MJT series is that its 5630 and 3528 packages offer LED lighting manufacturers easier production with the standard (module) size and enable fixture-level performance luminous efficacy of up to 100 lumens per watt.

Unlike the conventional method that requires complicated circuitry to connect multiple LED chips, the MJT series is designed to operate at various voltage levels, allowing operation at high voltage levels using only one LED chip with cells connected by multi-junction technology. Using one LED chip, rather than multiple LED chips, reduces the failure rate, and an optimized chip design helps to achieve the 100lm/W fixture-level luminous efficiency.

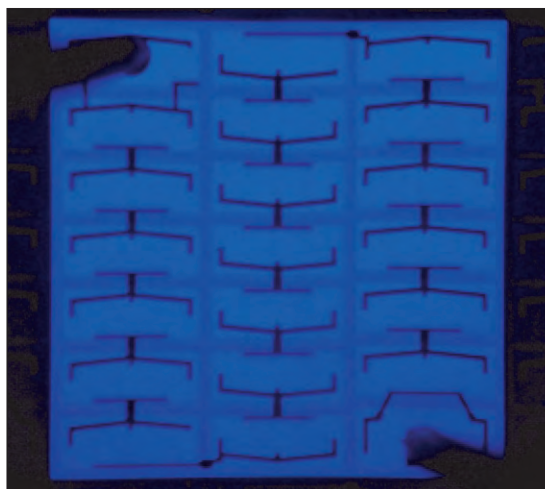


Photo of MJT LED chip.

Seoul Semiconductor says that lighting fixtures that use the MJT

The MJT series is designed to operate at various voltage levels, allowing operation at high voltage levels using only one LED chip with cells connected by multi-junction technology

series require the least amount of circuitry to be highly compatible with conventional dimmers.

"Since the high price of LED lighting is a major hindrance to extending the LED market, LED lighting designers make an effort to develop higher-performance and lower-cost LED lighting for end users to reduce payback periods," says Seoul Semiconductor's John Bae. "The MJT series meets those demands, so

10 millions of MJT series has been already offered monthly to the top global major lighting manufacturers .

Seoul Semiconductor's MJT series runs at 19V, 22V and 32V and offers a wide range of color temperatures (2700–6500K). The LEDs are also optimized for general LED lighting such as A19 lamps, PAR lamps and down-lights.

www.seoulsemicon.com

Verbatim to launch halogen-replacement lamps based on Seoul Semiconductor's nPola LED chip technology

South Korean LED maker Seoul Semiconductor Co Ltd says that, to address demand for LED lamps that more closely approximate the characteristics of halogen lighting, Verbatim is to launch a new range of LED-based products based on its patented nPola technology. Verbatim has been introducing a growing portfolio of high-performance LED lamps to the lighting market since 2010.

For GaN epitaxial growth, 'nPola' uses gallium nitride (GaN) substrates from Verbatim's parent company Mitsubishi Chemical Corp, replacing sapphire or silicon carbide (SiC) substrates. Consequently, nPola minimizes defects in the LED chip's active layer and allows current densities 5–10 times higher than conventional chips,



Verbatim MR16 LED lamp using Seoul Semiconductor's nPola technology.

says the firm. This results in 5–10 times brighter light output from the same size of chip.

Verbatim LED lamps with nPola technology were presented at Lighting Japan (16–18 January). With mass production due to begin in March, Verbatim's initial launch of nPola-based LED lamps focuses on MR16 form factors, initially targeting 50W MR16 halogen equivalency.

Seoul Semiconductor says that the combination of high light output and beam characteristics that closely resemble halogen lamps should allow lighting designers and contractors to replace halogen lighting with high-performance, energy-efficient LED products in both new design and retrofit environments.

SSC and Verbatim plan to continue to work together to develop LED lighting products.

www.verbatim.com

Taiwan's LED makers form LED Lighting Industry Alliance

According to a report from Taipei Times' Helen Ku, on 24 December over 30 Taiwan-based LED makers launched the LED Lighting Industry Alliance as a continuation of the LED Street Lighting Industry Alliance, which was established in 2011 with the assistance of the Industrial Technology Research Institute (ITRI).

LED manufacturers such as Everlight Electronics Co, Lextar Electronics Corp, Formosa Epiptaxy Inc, and Unity Opto Technology Co are members of the alliance, which aims to facilitate communication between alliance members and make recommendations to government concerning the LED industry.

According to ITRI, the LED lighting industry's compound growth rate is forecast to reach 32% between 2010 and 2020, with the global LED lighting market worth as much as USD72.74bn by 2020. China is forecast to be the biggest LED lighting market.

Tan Chang-lin, CEO of TSMC Solid State Lighting Ltd, forecasts rapid growth in the LED lighting industry in 2013, driven by solid-state lighting. He estimates that sales of LED-backlit products will remain flat in 2013, but LED lighting devices will grow by at least by 30% year-on-year.

www.taipeitimes.com/News

Plessey's MAGIC HB-LEDs win Elektra Award's Solid-State Lighting Application Category

Plessey Semiconductors Ltd of Plymouth, UK says that its new MAGIC (MANufactured on GaN ICs) high-brightness LEDs (HB-LEDs) have won the Solid-State Lighting Application Category of the Elektra Awards 2012. Winners were unveiled at the European Electronics Industry Awards ceremony in London.

"LEDs are the next key phase of the drive to reduce carbon usage but widespread adoption has been held back by the high product costs and the low level of the light output," says Plessey's chief operating officer Barry Dennington. "Our MAGIC technology solves both these problems opening the way for LED lighting to become widespread and help cut energy bills. We have invested millions of pounds in our MAGIC manufacturing lines in Plymouth that are ramping up to volume production this year," he adds.

MAGIC HB-LEDs are manufactured on standard silicon substrates — using industry-standard, high-volume processing — at a much lower cost



than existing LED technologies based on sapphire or silicon carbide (SiC) substrates. The firm's technology uses gallium nitride (GaN) on 6" silicon substrates. It uses a much thinner GaN layer, at only 2.5µm compared to 6–8µm in other GaN-on-Si technologies. This means less deposition time, so that the firm can do multiple production cycles in 24 hours to achieve higher throughputs and lower costs.

For its next-generation products, Plessey aims to integrate its MAGIC HB-LED products with its range of sensor and power technologies to provide smart lighting solutions.

www.plesseysemiconductors.com

IN BRIEF

Future Lighting Solutions inks global distribution agreement with LG Innotek

Future Lighting Solutions of Montreal, Canada (a division of Future Electronics) and South Korea's LG Innotek (an affiliate of LG Group) have agreed a strategic global distribution agreement to introduce LG Innotek's entire portfolio of LED lighting solutions to the market.

"We are excited about LG Innotek's exceptionally strong portfolio of LED products, aggressive technology road map, and unparalleled quality manufacturing capabilities for the general illumination market," says Gerry Duggan, executive VP of Future Electronics. "This will further strengthen our proficiency in serving our customers' growing demand for best-in-class LED lighting solutions."

"This agreement will significantly increase the availability of our products around the world as well as help us continually broaden our product line to offer the right solution for different lighting scenarios," says Harry Kang, VP of the LED Business Division at LG Innotek.

"By joining forces with Future Lighting Solutions, we will be better able to equip lighting OEMs with the products and tools they need to put more LED-based lighting products on store shelves," he adds.

Earlier in December, Future Lighting Solutions and LED maker Philips Lumileds announced that they had restructured their long-standing exclusive distribution agreement to allow both companies to create additional partnerships.

www.FutureLightingSolutions.com

Luminus ships UV Slim LED package production units

Luminus Devices Inc of Billerica, MA, USA, which makes PhlatLight (photonic lattice) LEDs for solid-state lighting applications, says that its new UV Slim LED packages (which began sampling in May) have begun shipping as production units.

Designed specifically for high-density linear arrays, UV Slim LED devices provide the maximum UV energy of any single-die UV LED available, claims the firm. In addition to superior performance, higher reliability, and greater energy efficiency over traditional UV mercury lamp technology, the devices also

improve workplace safety and lower environmental impact by eliminating harmful byproducts such as ozone and mercury, it adds.

"Customers can tightly align the UV Slim LEDs together in order to generate the highest-power-density UV LED line source available, which is especially useful for line-curing applications," says Mike Lim, director of Global Industrial and New Business.

Designed with graphic arts printing in mind, the UV Slim devices also provide the traditional advantages of Luminus' 'Big Chip' LED

technology, including improved thermal power density and simpler support system architecture, along with delivering greater wall-plug efficiency than traditionally sized LED dies, the firm claims.

The new CBT-120-UV-C14 UV Slim LEDs have a single monolithic 12mm² die that emits directly into air. They are available in a NIST-traceable power output range of 11–13.3W.

The UV Slim LEDs are available worldwide through distribution partners Avnet, Digi-Key, EBV Elektronik, Marubun and Mouser.

www.luminus.com

Luminus selected as a GoingGreen Silicon Valley Global 200 winner

At its seventh annual GoingGreen Silicon Valley (27–28 November) event in San Francisco, media network AlwaysOn honoured Luminus as a GoingGreen Silicon Valley Global 200 winner, signifying "leadership amongst its peers and game-changing approaches and green technologies that are likely to disrupt existing and entrenched players in traditional technology". Luminus was specially selected by the AlwaysOn editorial team and industry experts worldwide based on a set of five criteria: innovation, market potential, commercialization, stakeholder value, and media buzz.

"GoingGreen highlights the importance of green technology and the positive impact that LEDs can have on our energy usage and our environment, and through this our company plans to encourage the widespread use of LEDs to save energy, reduce costs, provide better lighting solutions, and create a cleaner global environment," said Luminus' CEO Keith T.S. Ward.

The 200 winning companies were selected from among thousands of domestic and international technology companies nominated by investors, bankers, journalists, and green-tech industry insiders.

The AlwaysOn editorial team conducted a rigorous three-month selection process to finalize the 2012 list.

"This year's GoingGreen Global 200 displays a maturity in the green technology industry that makes it very attractive to both investors and innovators," comments AlwaysOn's founder & editor Tony Perkins. "The strength of these companies lies in their ability to nurture innovative ideas and see them through to successful, sustainable, and profitable businesses."

www.aonetwork.com

PhotonStar LED seals intellectual property licencing & design services supply deal

LED lighting solutions designer and manufacturer PhotonStar LED Group plc of Romsey, Hampshire, UK has signed its first licensing agreement for its next-generation chip design patents, as well as an associated design services supply agreement, with a "leading LED chip maker".

PhotonStar's IP platform consists of 15 patent families covering LED chip design, optimal low-cost packaging, advanced colour mixing and

control. The LED chip patents dating back to 2008/9 are now mostly granted in Europe and progressing through the international phase. The firm recently received its first Chinese patents and continues to further develop its chip IP.

The non-exclusive patent license agreement is expected to have an impact on PhotonStar's revenues in 2014, when the resulting LED chips are to be brought to the market by the manufacturer.

"Licensing our LED chip design IP to third parties will be a key part of our business going forward, and will be a clear demonstration of the substantial value in our IP," says CEO James McKenzie. "This agreement is a major validation of our LED chip design approach and is expected to produce LED chips with extremely high levels of chip light extraction, making them some of the lowest-cost and most efficient chips available."

www.photonstarled.com

SemiLEDs' revenue rebounds by 12.7%; losses cut

Demand rising as Enhanced Vertical LED products qualified

For its fiscal first-quarter 2013 (to end-November 2012), LED chip and component maker SemiLEDs Corp of Hsinchu Science Park, Taiwan has reported revenue of \$6.2m, down 8% on \$6.7m a year ago but up 12.7% on \$5.5m last quarter (after a severe 40% dip from a high of \$9.2m the previous quarter).

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

"As more of our customers have qualified our EV [Enhanced Vertical] products, the demand of our LED chips and LED components has increased," says chairman & CEO Trung Doan. "We are seeing pockets of demands while the overall LED market is still weak," he adds.

Gross margin was -53%, compared with -12% a year ago, impacted mainly by a drop in average selling prices and excess capacity charges for the firm's LED chips.

R&D expenses have been cut further, from \$1.5m last quarter to \$1.2m. Selling, general & administra-

We are seeing pockets of demands while the overall LED market is still weak. We continue to manage cost, inventory and spending

tive expenses have also been cut, from \$4.1m last quarter to \$3.7m.

On a non-GAAP basis, net loss has almost been halved, from \$16.6m last quarter (which included \$7.5m due to impairment of long-lived assets) to \$8.6m, although this is still worse than \$7.1m a year ago.

Cash used in operating activities was \$3.3m (cut from \$5.2m last quarter and \$3.5m a year ago). Capital expenditure has been cut from \$5.8m a year ago to \$1.7m. Total cash burn has therefore been cut from \$9.3m a year ago and \$6.5m last quarter to \$4.9m. During the quarter, cash and cash equivalents fell further, from \$47.2m to \$39.3m.

"We continue to manage cost, inventory and spending with a focus on profitable LED sectors to achieve our positive cash flow goal," notes Doan.

CFO replaced by deputy controller; permanent replacement sought

SemiLEDs says that, on 2 January, David Young resigned as its chief financial officer.

Subsequently, on 4 January, the board of directors appointed Timothy Lin to serve as interim CFO while it conducts a search for a permanent replacement. Young has agreed to provide transition assis-

tance to the firm for a period of time.

Lin has been deputy controller since joining the firm in October 2010. Previously, he was a senior manager at Ernst & Young (Taiwan) from October 2009 to October 2010 and a manager at Deloitte & Touche (Taiwan) from June 2006 to October 2009.

Lin's monthly base salary is NT\$200,000 (about US\$6900). He is also eligible for a year-end bonus equivalent to 2 months of his then average base salary, subject to the achievement of performance targets determined by the chief executive officer.

www.semileds.com

SemiLEDs boosts brightness of blue EV-LED chips by 10%, allowing cool-white efficacy of 130lm/W

SemiLEDs has announced power improvements to its EV-LED family of products (launched last June), allowing single-chip emitters to achieve luminous efficiency of more than 130lm/W.

SemiLEDs says recent improvements to both the epitaxial quality and chip process of its EV family of LED chips have allowed a 10% increase in blue chip brightness and an 8% reduction in forward voltage (V_f) in mass production. This can

enable users to achieve luminous efficiency of more than 130lm/W (in a cool-white LED) and 110lm/W (in a warm-white LED). Measurements were taken at a drive current of 350mA.

SemiLEDs says that, with its Enhanced Vertical (EV) technology, it has been able to increase brightness and reduce defects through new advances in epitaxial and process technology. Production monitoring has shown an increase of 10% in

brightness distribution and improved leakage current yield. The EV technology not only increased the luminous output but also enabled a down shift of the V_f distribution by 8%, increasing efficiency by 6–8% at 350mA.

SemiLEDs reckons the improvements make its chips suitable for demanding directional applications such as street lighting, tunnel lighting and indoor retail lighting.

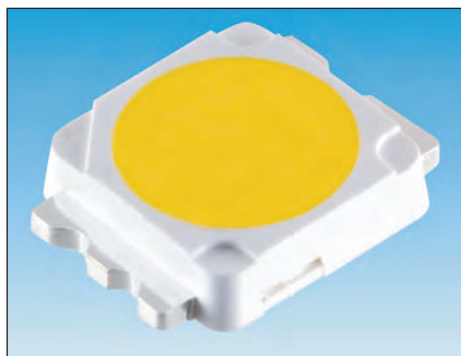
www.semileds.com

Toshiba starts selling GaN-on-Si packaged white LEDs

Bridgelux collaboration yields 1-Watt LED with production capacity of 10 million units per month

Tokyo-based semiconductor maker Toshiba Corp has begun mass production of white LED packages that, it is claimed, offer a cost-competitive alternative to existing LED packages for general-purpose and industrial LED lighting.

LED chip fabrication is typically done on 2–4" wafers based on costly sapphire substrates. But, since January, Toshiba has collaborated on white LED chip development with Bridgelux Inc of Livermore, CA, USA (which makes LED solid-state light sources specifically for the lighting industry). In May, Toshiba said that, through combining its 200mm silicon wafer processing and manufacturing technology with Bridgelux's crystal growth and LED chip structure, a prototype gallium nitride on silicon (GaN-on-Si) LED chip had been developed. The firms have hence



Toshiba's 1W GaN-on-Si white LED.

developed a process for manufacturing GaN LEDs on 200mm silicon wafers, which Toshiba has brought to a new production line at Kaga Toshiba Electronics Corp (a discrete products plant in northern Japan).

Toshiba says that deployment of GaN-on-Si technology for LED chip production has allowed it to replace sapphire substrates and to produce

chips on much more cost-competitive silicon substrates. Mass production of packages using the new line's output started in December. The new 6.4mm x 5.0mm x 1.35mm 1-Watt TL1F1 series GaN-on-Si LEDs generate a light flux of 112lm (at a drive current of 350mA). Planned production capability is 10 million units per month.

Toshiba says that the low power consumption and long life of white LED lighting is winning widespread adoption in applications including general-purpose lighting and TV backlighting. The global market was 700bn yen (US\$8.5bn) in 2011 and is expected to almost double to 1250bn yen (\$15.2bn) in 2016. Toshiba targets product development and global sales, aiming to secure a 10% share of this market in 2016.

www.toshiba-components.com

Bridgelux launches array platform for designing solid-state lighting

Bridgelux has introduced its Vero LED array, a lighting platform that simplifies design integration and manufacturing and aims to give designers a more flexible LED lighting solution. Vero involves three main innovations: a new higher-flux-density LED array; an increase in lumens per watt by up to 20% over existing Bridgelux arrays; and a simplified assembly process that streamlines manufacturing and improves overall system reliability, says the firm.

The Vero platform should allow manufacturers to reduce electronic and optical component inventories while broad input current ranges allow designers to optimize products on efficiency, cost and light output.

"The Vero product is manufactured using highly automated processes to reduce cost and can be easily upgraded for the smart applications of the future," says chief sales & marketing officer Jim Miller. "The

Vero array offers our customers the manufacturing and design capabilities they need to open up new design possibilities while ultimately driving faster adoption of LED lighting."

While Bridgelux has been increasing the efficiency of its LEDs over the past five years, the firm has also been developing chip on board (COB) technology, engaging in a complementary effort to reduce the cost of the packaging and other systems around the LEDs. Vero is the next step in that evolution.

The Vero platform provides complete application coverage from four form factors, delivering the light output and color temperatures required for retail, hospitality, commercial, industrial, residential and outdoor lighting applications. The arrays will initially be available with performance ranging from 800lm in warm white (3000K) up to 20,000lm in cool white (5000K) with multiple CCT and CRI options,

including the 97 CRI Decor product.

With significant advances in luminaire design flexibility, Vero offers a light emitting surface (LES) area with higher flux densities than earlier Bridgelux array designs. It is engineered to be driven reliably at much higher currents than previous offerings to further increase performance and reduce cost. These new features combine to allow luminaire designers to develop smaller, sleeker designs and to deliver narrow beam angles for spot and track applications facilitating high-contrast-ratio lighting designs.

Vero is compatible with a wide range of standard drivers and optical components. Electrical connection may be established via solder pads or by using a solderless on-board connector provided by Molex.

Vero is being evaluated by customers and will be commercially available in first-quarter 2013.

www.bridgelux.com

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Cree reaches milestone with 200 lumen per watt LED

Cree Inc of Durham, NC, USA has introduced XLamp MK-R LEDs. The new LEDs leverage the firm's SC³ Technology next-generation LED platform, based on silicon carbide (SiC) technology, to deliver up to 200 lumen per watt (at 1W, 25°C).

The MK-R LED has a 7mm x 7mm footprint with a 6mm optical source and delivers up to 1600 lumens at 15W, 85°C. Characterized at 85°C, it is available in 2700–7000K color temperatures and offers minimum color rendering index (CRI) options of 70, 80 and 90 (at selected color temperatures).

"An LED with this level of performance can accelerate the development

of high-output lighting applications," says John Edmond, Cree co-founder & director of advanced optoelectronics.

MK-R LEDs make the next generation of 100+ lumens-per-watt systems possible for high-lumen applications, including outdoor and indoor directional applications, such as halogen replacement lamps. Available in EasyWhite color temperatures, MK-R LEDs provide what is claimed to be the industry's best color consistency for designs that use only one LED. For systems that use multiple LEDs, MK-R enables manufacturers to use fewer LEDs while still maintaining light output

and quality, translating to lower system cost.

"The high efficacy of the MK-R LED means that we can drive the LED harder for more light output without creating heat issues," says Nicola Vendrame, CEO of Linea Light group. "In addition, the MK-R LED has the right combination of size, color consistency and optical control to enable the next generation of performance in our indoor directional luminaires," she adds.

Cree XLamp MK-R LED samples are available now and production quantities are available with standard lead times.

www.cree.com/mkr

Cree introduces Driver Compatibility Program for LED modules

LED chip, lamp and lighting fixture maker Cree has launched a Driver Compatibility Program, providing LED lighting manufacturers with a list of drivers that are compatible with Cree LED modules, as verified through evaluation and testing by Cree. By leveraging the technology and features of third-party drivers, the program aims to enable lighting manufacturers to quickly address the requirements unique to various countries, further differentiate their products, and address more applications.

The first-of-its-kind program allows Cree to extend its LED module warranty to the use of Cree's LED module with a compatible third-party LED driver. The warranty was previously limited to using a Cree LED module with a Cree driver.

"For driver manufacturers, the program provides access to Cree's customers and products, expanding their market and enabling them to better serve lighting manufacturers," says Mike Watson, Cree's senior director marketing,

LED components. "For lighting manufacturers, the program provides greater design flexibility and enables a shorter design cycle to get products to market faster," he adds.

Cree has kicked off the Driver Compatibility Program with a range of compatible drivers for the LMH2 LED module, and plans to extend it to other LED products later this year.

To submit a driver for consideration, visit www.cree.com/submitdrivers.

www.cree.com/dcp

LM16 LED lamp to replace 50W halogen MR16 lamps

Cree has launched its LM16 LED lamp, which it claims uses up to 80% less energy and is designed to last up to eight times longer than traditional 50W halogen MR16 lamps.

The LM16 LED lamp uses only 9W of input power. With typical commercial usage of 16 hours per day and the national average \$0.12 per kWh electric costs, lighting-related HVAC impact and re-lamp maintenance reductions, many upgrade installations can pay for themselves in less than a year.

Cree claims the LM16 lamp delivers the best center beam candlepower

for 25° beam angles, suiting a wide spectrum of applications in retail, hospitality and residential settings.

"The Cree LM16 LED lamp will let companies instantly upgrade outdated halogen lighting without any sacrifice in performance and/or any change-out problems," says Roger Lane, principal with LAMPS Inc.

"Cree's revolutionary design provides optimal control of the beam angles to direct the light exactly where it's needed. They've effectively eliminated surface glare and have even added a pleasant touch of backlight that is soft on the eyes

while saving energy."

The LM16 50W halogen equivalent delivers 620 lumens (consuming only 9W) and the 35-watt halogen equivalent delivers 425 lumens (consuming 7W). The new lamps are designed to provide a minimum of 25,000 operating hours, reducing the need to replace lamps. The 50-watt equivalent is dimmable to 5% on a broad range of dimmers and transformers. The new LM16 LED lamp is available in three beam angles: 17° spot, 25° flood and 40° wide flood.

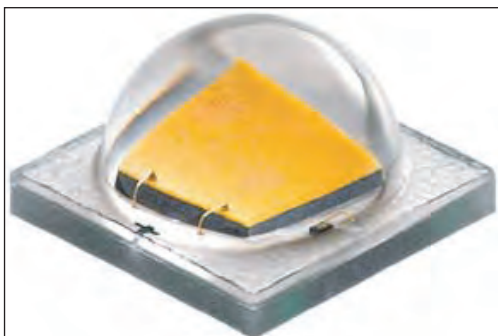
www.cree.com/lm16

Cree launches brightest, highest-performing, single-die LEDs; XM-L2 delivers 186lm/W

Cree Inc of Durham, NC, USA has announced commercial availability of its XLamp XM-L2 LED, which delivers luminous efficacy of up to 186 lumens-per-watt at a drive current of 350mA (at 25°C), a level of performance claimed to be available only in a lab setting just three years ago.

Built on Cree's SC² Technology next-generation LED platform, which leverages the firm's silicon carbide (SiC) technology, XM-L2

LEDs double the lumens-per-dollar and deliver 20% more lumens-per-watt over the original XM-L LED (enabling lighting manufacturers to use fewer LEDs to deliver a better



lighting system for lower cost). The XM-L2 delivers 1198 lumens at 116 lumens-per-watt efficacy at 3A, 25°C.

Designed for very-high-lumen applications (such as indoor, high-bay and outdoor lighting), XM-L2 LEDs are compatible with existing XM-L designs and leverage the 5mm x 5mm XM footprint, allowing XM-L2 LEDs to be incorporated into existing XM LED designs (shortening the fixture design cycle and improving time-to-market).

The XM-L2 LED offers the unique combination of very high efficacy and high drive currents, delivering what is claimed to be an unprecedented 1198 lumens at 116lm/W efficacy at 3A (25°C). The XM-L2 is the eighth product built on Cree's SC² Technology platform, which leverages Cree's silicon carbide technology, features advancements in LED chip architecture and phosphor, and uses a new package design.

"The XM-L2 LED efficiently delivers hundreds of lumens per LED, allowing us to significantly reduce the number of LEDs in our designs," says Steve Walczak, director of engineering at Sternberg Lighting. "By using fewer LEDs, we can simplify design and production, ultimately reducing cost without sacrificing light output or quality for our end customers."

Characterized at 85°C, the XM-L2 LED is available in 2700–6200K color temperatures and offers minimum CRI options of 80, 85 and 90. Also, since the XM-L2 is a successor product to XM-L LEDs, the application of ENERGY STAR qualification requires only 3000 hours of XM-L2 LED LM-80 data, instead of the normal 6000 hours. The XM-L2 LED is also UL-recognized and features a level-4 rating.

XLamp XM-L2 LED samples are available now, and production quantities are available with standard lead times.

www.cree.com/xml2



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www.EVGroup.com



Cree boosts XSP Series LED Street Light output by more than 35%, enabling new applications

LED chip, lamp and lighting fixture maker Cree Inc of Durham, NC, USA says that it is extending its XSP Series LED Street Light portfolio to deliver municipalities improved performance at more affordable price points. The new XSP2L LED street light increases lumen output by over 35% compared to the original XSP luminaire. The XSP2L is suitable as a replacement for high-pressure sodium and

metal-halide fixtures up to 400 watts, the firm says.

Delivering better performance and lower cost per lumen, the XSP Series LED Street Light has what is claimed to be an industry-leading 10-year warranty and a calculated L₇₀ lifetime of more than 100,000 hours, as well as a thermal management system that improves overall performance. The result is a luminaire that delivers up to 30%

more lumens per dollar, it is reckoned.

"Cree is committed to helping communities significantly lower their energy costs and maintenance expenses," says Greg Merritt, vice president, lighting at Cree. "The latest Cree innovation makes LED street lighting available for higher-performance applications with compelling payback."

www.cree.com/xsp

Cree launches highest-efficacy LED downlight

Cree has launched its LR6-10L six-inch LED downlight, which delivers 1000 lumens of light with a color rendering index (CRI) of 90+ while achieving luminous efficacy of 90 lumens per watt.

Combining the high efficacy and high-quality light of Cree TrueWhite Technology with an integrated driver to enable energy savings (of up to 50% compared to incumbent CFL technology or 30%

compared to competing LED products), the LR6-10L uses only 11W of power, suiting use in new or retrofit commercial applications, says the firm.

"The latest Cree LR6 downlight showcases what's possible with LED lighting," says Greg Merritt, VP, lighting at Cree. "When you consider the industry-leading efficacy, energy savings and long lifetime, I see no reason to specify a CFL or

incandescent downlight again."

The fixture is available in color temperatures to match existing installations of incandescent, halogen and fluorescent technologies (2700K, 3000K, 3500K and 4000K). Featuring a 10-year warranty and dimmable to 5% on a broad range of dimmers, the LR6-10L LED downlight is also ENERGY STAR qualified.

www.cree.com/lrseries

GE Lighting appoints president & CEO for EMEA

GE Lighting of East Cleveland, OH, USA has named Agostino Renna as president & CEO of GE Lighting Europe, Middle East and Africa (EMEA). Reporting to GE Lighting president & CEO Maryrose Sylvester, he succeeds Phil Marshall, who has led GE Lighting Europe, Middle East and Africa since 2008 but has left GE Lighting to pursue a position outside the firm.

GE Lighting offers commercial, industrial, municipal and residential customers a range of legacy lighting solutions and LED systems for architectural, indoor, outdoor, signage, retail and transportation applications.

"Agostino Renna's experience, leadership and significant sales and marketing background make him an outstanding person to continue



Agostino Renna.

the transformation of the Lighting business in the region," believes Sylvester.

"Agostino has demonstrated outstanding management qualities and has

the ability to sharpen our strategic focus to lead GE Lighting Europe, Middle East and Africa to achieve strong, sustained growth in 2013 and beyond."

Most recently Renna was VP, Growth and Market Strategy for GE-Canada, with responsibility for the long-term growth and market positioning of all GE's businesses in Canada.

Prior to joining GE, Renna spent 14 years at Johnson Controls Inc, where he worked in Canada, the USA and Europe. He held leadership roles in sales, marketing, strategy and general management, culminating with a position leading Johnson Controls' Energy Solutions division for Europe, the Middle East and Africa based in Brussels, Belgium.

Renna was born in Montreal, Quebec and has a degree in Mechanical Engineering from McGill University. Speaking four languages fluently, he is a regular speaker at conferences and roundtables that focus on addressing global energy challenges. While in Belgium, Renna was an Executive in Residence at the Vlerick Leuven Gent Management School.

www.gelighting.com



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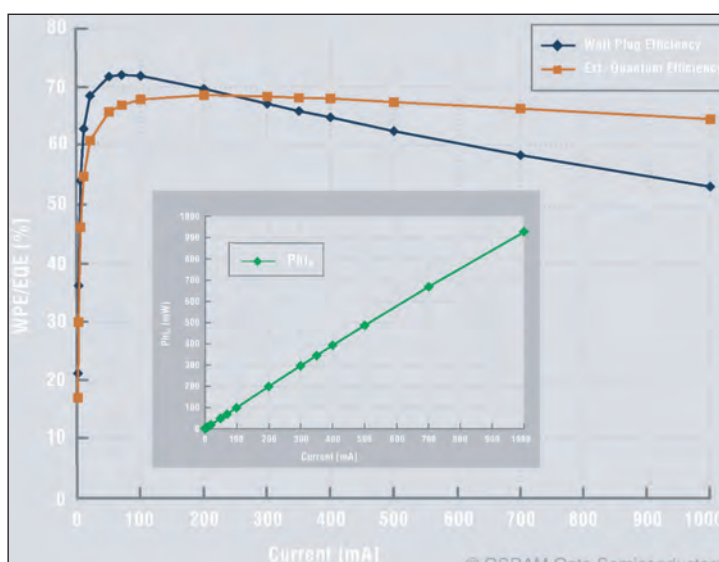
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Osram's prototype LED chip sets record 72% efficiency for infrared illumination

Using its latest thin-film technology, Osram Opto Semiconductors GmbH of Regensburg, Germany has developed a 1mm² infrared LED chip prototype that has achieved what is claimed to be record efficiency of up to 72% at an operating current of 100mA.

This wall-plug efficiency (WPE, the ratio of radiated power to electrical input power) was measured at room temperature at a DC current up to 1A. At 930mW from an operating current of 1A, the light output power under laboratory conditions is 25% higher than that of any chips currently on the market, the firm claims.

The prototype 1mm² infrared chip also has a high external quantum efficiency (EQE) that remains around 65% for operating currents up to 1A. The 850nm wavelength suits infrared illumination applications, particularly for surveillance tasks and use with CCTV cameras. There are also potential safety applications in the automotive sec-



The 1mm² IR chip has wall-plug efficiency of up to 72% and a high external quantum efficiency (remaining around 65% up to 1A).

tor, such as pre-crash sensors and illumination sources for night-vision systems.

"The way in which the efficiency and brightness have been increased can be transferred from 850nm to other wavelengths," says

Markus Bröll, project manager for the development of IRED chips. "This means that it will be possible to create highly energy-efficient solutions for infrared lighting in the future." Fewer components will be needed in multi-chip applications, he adds, saving both money and energy.

The results of the development

work are now being implemented stage by stage. The new chip is expected to go into series production by mid-2013. Future infrared LEDs can be made even more energy efficient, it is expected.

www.osram-os.com

Osram's Oslon SSL LEDs installed in China coal mine

Osram Opto says that 19,500 of its Oslon SSL series LEDs have been installed in 975 lamps in the 63.1km² Xishan Duerping coal mine in Shanxi Province (China's 'home of coal'). Replacing fluorescent lamps, the LED lamps enable energy savings of 61% (from 427,050kW-hr down to 170,820kW-hr annually), as well as reducing maintenance requirements and accident rates, the firm reckons, yielding annual saving of over RMB220,000 (about €28,000).

Osram Opto notes that, as a low-reflectivity, low-contrast, high-temperature and highly corrosive environment, the coal mine is one of the most difficult lighting applications. But, with the use of LEDs in place of traditional incandescent lamps, coal mine lighting has become less challenging.

The 20W LED lamps come in two designs: round-shaped ones for general lighting in the coal mine; and square-shaped ones for long-distance lighting in the tunnels. Due to the low reflectivity in coal mines, light output needs to be much higher. With a luminous flux of 104lm (warm white) to 130lm (cool white), the Oslon SSL suits this application, reckons the firm.

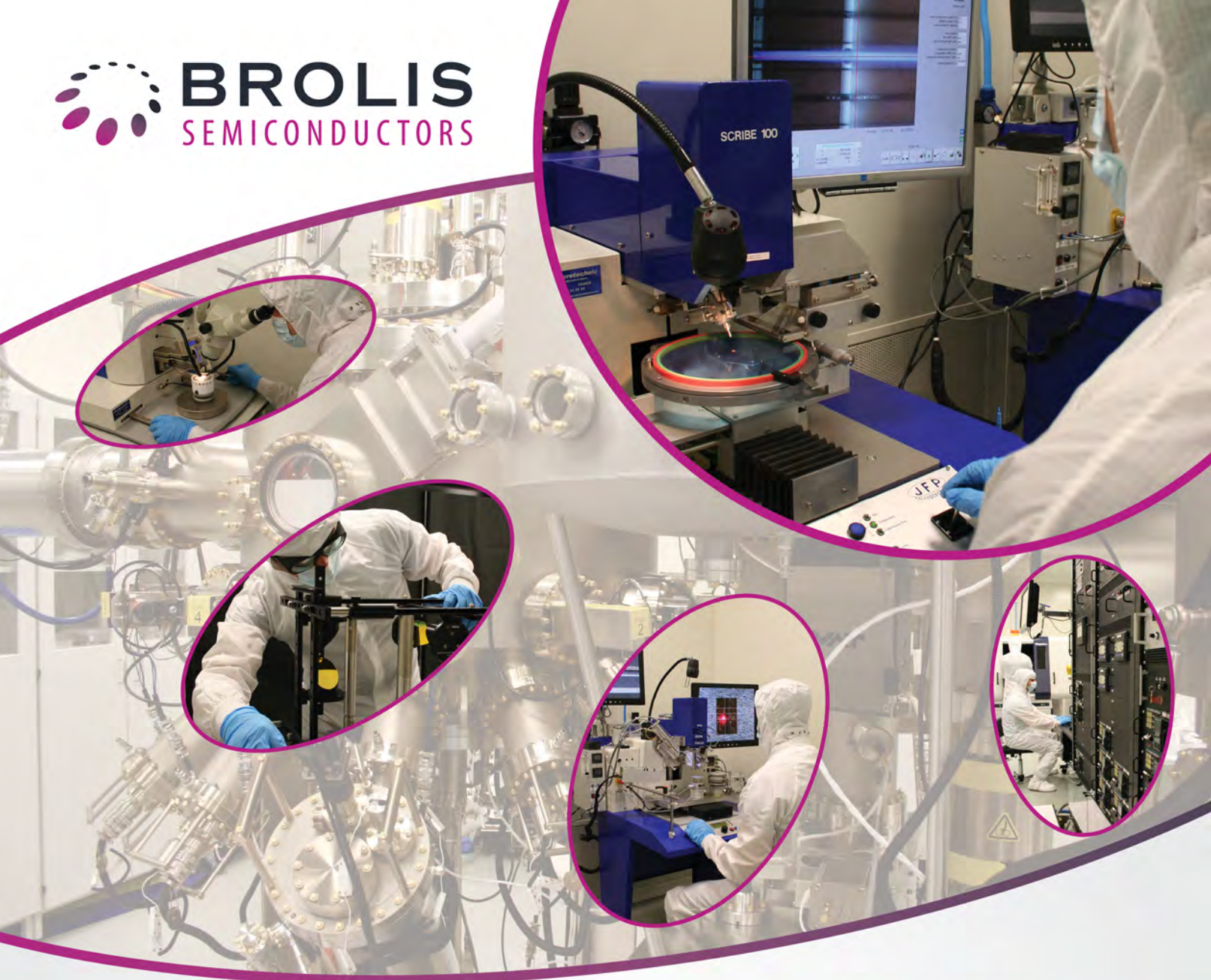
"The light output of these LEDs is high enough for good designs," says Zhong-hua Li, chairman of Shenzhen General Technology Co Ltd, which makes the lamps. "The average luminance is 82 lux, compared to 45 lux of the previous incandescent lamps," he adds.

"The use of LEDs in coal mine lighting is definitely taking off," reckons Kai-chong Cheng, senior

marketing director APAC at Osram Opto Semiconductors Asia Ltd.

"As LEDs do not use any glass envelope and cannot break, we hope the use of these LED lamps will reduce hazards for the people who work underground."

Also, compared with up to 3000 hours for an incandescent bulb, the LEDs can provide useful light for over 50,000 hours, extending the maintenance interval from three months to a year. According to a study by the USA's National Institute for Occupational Safety and Health (NIOSH), most accidents (53%) happen during the maintenance and repair of light bulbs or light fixtures. The longer life and glass-envelope-free packaging of LEDs can hence reduce exposure to these hazards.



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Siemens to spin off 80.5% of Osram

Transition to semiconductor lighting prompts sell-off; Siemens shareholders vote in January; Osram cut further 4700 staff

Engineering, electronics and high-tech giant Siemens AG of Munich, Germany has announced its intention to spin-off 80.5% of its subsidiary Osram (the world's second biggest lighting manufacturer, whose subsidiary Osram Opto Semiconductors GmbH of Regensburg, Germany makes light-emitting diodes). The plan requires approval of at least three-quarters of voters at Siemens' Annual Shareholders' Meeting on 23 January.

If approved, the transaction will see Siemens shareholders receiving one Osram share for every 10 Siemens shares held. Siemens says it also intends to remain an almost 20% shareholder in Osram (holding a 17% stake, with Siemens Pension Trust holding a further 2.5%).

An intrinsic part of this massive reshuffle of two of the world's largest technology brands is that lighting giant Osram will cut another 4700 jobs (12% of its workforce) by 2014, as the firm — alongside the wider lighting industry — tries to deal with global markets' legislation- and technology-led transition from traditional lighting sources (such as incandescent and fluorescent) to solid-state technologies.

"Given the accelerated transformation of the lighting market to semiconductor-based products,

[we are] pushing forward our corporate reorganization," Osram said.

The job cuts will mostly be achieved through plant sales. However, Osram said that staffing levels will be increased in future-oriented business fields, which will partly compensate the adjustments in the traditional business. The measures of the entire program are to result in cumulative gross savings of about €1bn by 2015. The total costs in the period from now until 2014 will amount to a "mid-three digit million [euro] figure".

A notable development in Germany will be the establishment of a center of excellence for LED-based product manufacturing processes at Osram's facility in Augsburg, although much of the LED investment will be made outside the country, including at its recently established Chinese plant.

"Osram will invest a low three-digit million euro figure over the coming years in its LED assembly plant in the Chinese province of Jiangsu," said the firm. "Currently in the final completion stage, 1700 employees will manufacture products for key segments of the Chinese market and entire Asian region. The region will already account for around half of the global general lighting market in five years' time."

In early 2012, Osram had already initiated a comprehensive corpo-

rate program, which in principle focuses on processes and structures, operational activities as well as the further development of the corporate culture. Before the latest job cuts were announced, some 1900 jobs had already been cut worldwide in fiscal 2012, of which 300 were in German locations.

Osram says that these measures in Germany and internationally are aimed at plants with products at the end of their product life cycle or the closure of smaller plants with lower sales. At the same time, the firm is aiming to restore profitability with efficient structures in production, research & development, sales as well as in central functions.

"We are entering the digital lighting age. Compared to traditional products, the depth of our added value in LED-based products will be significantly reduced," commented Wolfgang Dehen, CEO of OSRAM Licht AG. "Consequently, the personnel increase in the future fields will only partially compensate for the change in the traditional business."

On 7 December, Osram aims to publish the prospectus for its public listing of shares, which it targets for after the spin-off from Siemens.

www.siemens.com

www.osram.com

Matthew Peach, Contributing Editor

Daylight awarded patent for quantum cascade laser-based beam-combining technique

Daylight Solutions Inc of San Diego, CA, USA, which makes molecular detection, spectroscopic imaging and high-power illumination systems based on quantum cascade lasers (QCLs), has received its 16th US patent relating to its quantum cascade laser (QCL) based technology. The patent involves combining beams from individual QCL sources to create a single beam of greater

combined power and/or a multiple wavelengths. The technique is valuable in applications where high power or a combination of different wavelengths is necessary. One application is infrared counter-measures (IRCM), where mid-infrared lasers are used to protect aircraft from heat-seeking missiles.

"Daylight Solutions continues to receive significant patents relevant

to both our core technology and our broad range of applications," says CEO & chief technology officer Dr Timothy Day. "The company has now been awarded 16 patents with over 400 claims."

Daylight Solutions says that it is currently in discussions with several Fortune 100 companies to license its technology.

www.daylightsolutions.com

OPEL subsidiary ODIS produces integrated laser device using POET monolithic optoelectronic platform

OPEL Technologies Inc of Toronto, Ontario, Canada says that its US affiliate OPEL Defense Integrated Systems (ODIS Inc) of Storrs, CT has produced an integrated laser device, achieving a key milestone in its Planar Optoelectronic Technology (POET) process, which enables high-performance devices fusing optical and electronic devices together on a single chip.

The firm reckons that, by allowing the production of components with increased speed, density, reliability and lower costs, POET offers the semiconductor industry the ability to push Moore's Law to the next level, overcoming existing silicon-based bottlenecks, and potentially changing the roadmap for a range of applications such as smartphones, tablets and wearable computers.

OPEL says that, after years of development, it has succeeded in fabricating the first Vertical Cavity Laser (VCL) using ODIS' patented POET GaAs III-V technology. It adds that incremental progress over the years has led to what many consider to be the next phase of semiconductor development, i.e. surpassing the capabilities of CMOS technology for the next generation of high-speed low-power applications, CMOS technology advances are now widely believed to have reached a saturation point.

The new laser can serve as the basis for chip-to-chip interconnection and complements other devices already demonstrated by ODIS, including HFETs, optical thyristors, pulsed lasers, and super-radiant light-emitting devices (which can all be monolithically fabricated via the POET process).

"Dr Taylor and the ODIS team have chosen to achieve the most difficult laser first and have done so under extreme duress," notes OPEL's executive director Peter Copetti. "This is not just an endorsement of the ODIS team but also of the POET process itself," he adds.

"Re-set of our milestone timelines by approximately 8 weeks because of equipment repair caused by Hurricane Sandy is obviously a disappointment to everyone involved, but we believe it is merely a bump in the road," Copetti continues.

"In the long run, it should have no material impact on monetizing POET," OPEL's chief scientist Dr Geoffrey Taylor adds that, "POET remains on track with its vision of full monolithic integration and its applications in microprocessing".

POET merges optical devices into the growth and fabrication that supports complementary HFET analog and digital functions. The n-channel and p-channel FETs take advantage of the high mobilities inherent to strained quantum wells. Simultaneously, the quantum wells provide the active emitter for lasers and amplifiers and the active absorber for detectors and modulators.

The intimate connections between diverse device types enables novel gate designs that dramatically reduce the power consumed in optoelectronic (OE) and electro-optic (EO) conversion, it is claimed. The VCL also has the small footprint needed for dense circuit layout and enables vertical connections from anywhere in the circuit plane to fiber or to other stacked chips. Further, the same VCL structure enables both in-plane and edge-emitting operation, based on proprietary OE designs. The firm reckons that availability of the integrated VCL can change the architecture and design for future complementary integrated circuits.

Future technology development aims to lower threshold current, increase output power and optimize the in-plane version of the VCL. Also, the complementary transistor circuit capability will be enhanced by reducing feature size to the 100nm scale, incorporating ODIS' new self-aligned contact technology. With transistor cutoff frequencies of about 38GHz for a 0.7µm gate,

scaling is expected to produce 260GHz transistors with commensurate improvements in circuit speed.

In the near-term, POET is expected to include an optical interface as a single chip to connect existing CMOS processors. The optical interface chip integrates the laser, modulator, modulator driver, detector, receiver amplifiers, serializer/deserializer, clock & data recovery, and phase-locked-loop circuits monolithically.

The longer-term solution looks to replace CMOS gates with POET complementary HFET gates. POET processors would provide their own optical output and also perform the optical receive function, hence the need for a separate interface chip would no longer be required.

"This is a key milestone in our acceleration of POET for commercial application," notes OPEL's CEO Leon M. Pierhal. "OPEL now has all components in place for on-chip integration of photonic circuits in the same semiconductor framework as electronic circuits," he adds.

"Hurricane Sandy's effect was felt at ODIS' R&D facility at the University of Connecticut," continues Pierhal. "Equipment damage within the facility caused by Sandy made the recovery from the storm and the completion of the VCL extremely difficult," he adds. "Damage inflicted on the delicate equipment must now be effectively and permanently addressed in order to continue with POET's milestone achievements. A rebuild and retrofitting period of 6-8 week is being planned for December and January, which will delay the rollout planning process."

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

www.odisinc.com

IQE secures its first £1m laser epiwafer order for communications technology

Epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK has received its first single order valued at more than £1m for advanced laser wafers, to enable a new generation of fiber-optic communications devices.

The order is to be delivered during first-half 2013, with further significant follow-on orders expected, driven by strong demand in China for data-center applications and

infrastructure build out. The wafers will be produced at IQE's Cardiff manufacturing facility using its 100mm InP platforms.

IQE says that optical interconnects are on the brink of rapid growth, driven by strongly increasing demand for 'big data' applications across data centers, fiber-to-the-home (FTTH), backbone interconnection of 4G/LTE base-stations and active optical cable (AOC) inter-

connects between computers and peripheral consumer electronic devices, replacing existing copper USB2 cables.

"This latest order for a new range of low-cost, high-performance optical fiber components marks a key milestone in the adoption of optical interconnects for a range of high-volume applications," says IQE's president & CEO Dr Drew Nelson.

www.iqep.com

Brolis' MBE and laser diode production facility opened

In December, Brolis Semiconductors of Vilnius, Lithuania officially opened its MBE and laser diode production facility. Established by brothers Augustinas Vizbaras, Kristijonas Vizbaras and Dominykas Vizbaras in 2011, the firm specializes in mid-infrared type-I GaSb lasers and MBE, manufacturing epitaxial wafers for antimonide and arsenide materials for thermal imaging focal plane arrays, CPV and custom devices.

The ceremony was led by Lithuania's President Dalia Grybauskaitė, who gave an opening speech, followed by speeches by Brolis' co-founders (the Vizbaras brothers); TU Munich professor Markus-Christian Amann; Prime Minister Andrius Kubilius; and Sarunas Siugzda, managing partner of venture capital fund LitCapital. Brolis set up the plant in 9 months, with total investment of about €5m.

"Talented young people are coming back to Lithuania to create business. This is the best proof that business conditions are improving in our country," said Grybauskaitė. "Such a company is an inspiring example of innovative and viable business model. Not only it creates jobs but also makes our country competitive," she added.

"We have been putting maximum efforts in the last couple of months to finish the facility on time. However, the hardest work and most difficult challenge is still ahead of us.



The President of Lithuania Ms Dalia Grybauskaitė, with the Vizbaras brothers to her left and TU Munich's professor Markus-Christian Amann on her right.

Our next nearest goal is to bring the first batch of our R&D laser diode products by the end of February and this is where our efforts are being directed at the moment. We hope that in the next few years we will be able to grow and to establish ourselves as a reliable supplier for mid-infrared optoelectronic components and epi-material in the global market," said CEO Dominykas Vizbaras.

Using cash from LitCapital and the EU's Structural Funds, total investment was 14 million litas (€4m).

CEO Dominykas Vizbaras said the firm had been considering three potential sites for the plant (includ-

ing the USA and Germany) before choosing Lithuania. "It can be done in the easiest and most cost-effective way here [in Lithuania]. The European Investment Fund's (EIF) JEREMIE initiative made it possible for new business funding tools to develop in the last four years. Support from EU structural funds was very significant," Vizbaras said.

The next goal is to deliver the first R&D laser diode products by late February. The firm will develop a long-wavelength laser technology in 2012–2015.

LitCapital has provided up to €1m in investments for the first stage of development. The fund has acquired a majority stake in the firm from its founders.

Brolis plans to develop lasers for use in plastics, welding, night-vision systems, laser radars, search & rescue, and defense. It says it has already attracted interest from several US and European high-tech firms that have expressed intentions to buy products.

www.brolis-semicon.com

EC-funded BRIDLE project aims to boost high-power diode lasers for industrial applications

Consortium targets 2kW source with 40% efficiency from 100µm-diameter fiber

A consortium of companies and research institutes from five European countries has joined forces to improve the brightness of high-power direct-diode laser systems.

Having started in September, the three-year project 'BRIDLE' (Brilliant Industrial Diode Laser) is receiving funding of about €3m from the European Commission's FP7 Theme 3 'Information and Communication Technologies' program.

Coordinated by DILAS Diodenlaser GmbH of Mainz, Germany, the consortium includes researchers from the UK's University of Nottingham, Germany's Fraunhofer Institute for Laser Technology ILT in Aachen and Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik (FBH) in Berlin, the Laboratoire Charles Fabry (a joint research unit between Institut d'Optique Graduate School and France's CNRS), and the industrial partners Modulight Inc of Tampere, Finland and Bystronic Laser AG of Niederörs, Switzerland.

BRIDLE makes use of a modular, scalable and upward compatible approach, employing advanced technologies and beam combination architectures, to yield a diode laser source that delivers output power exceeding 2kW from a 100µm-diameter, NA<0.15 optical fiber with a power conversion efficiency of >40%.

The consortium aims to develop novel diode-laser mini-bars, targeting a 3x higher brilliance compared to commercially available broad-area emitters, with dense and coarse spectral multiplexing schemes pursued for power scaling. In addition, coherent beam combining techniques (which phase-couple bars to produce nearly diffraction-limited output) will be investigated.

During the project, a sequence of increasingly brilliant demonstrators will be developed, each targeting a specific industrial application. Manufacturability and cost down-scal-

ing issues are also being addressed by integrating micro-optical beam shaping and beam combination into the production process.

www.bridle.eu

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IN BRIEF

The Optoelectronics Company debuts laser diode modules

The Optoelectronics Company Ltd of Henham, Bishops Stortford, UK, which makes and distributes components including Opnext (Oclaro) laser diodes, Panasonic lenses and Optowell VCSELs, has launched its own range of laser diode modules designed for OEMs, end-users and systems integrators.

The new range combines an Opnext (Oclaro) laser diode with externally adjustable optics, a Panasonic aspherical glass lens, electronics and a rugged modular anodized aluminium housing to provide a laser source suitable for use in industrial, commercial and medical applications such as inspection, alignment and sensing.

The modules are compact CW visible or infrared lasers producing an elliptical beam. They offer a combination of low noise and output stability and are available at five lasing wavelengths (635nm, 639nm, 660nm, 830nm, 852nm) at powers of up to 75mW.

Mechanical dimensions are 12mm diameter x 53mm length.

With an operating voltage of 3–6V_{DC} and a broad ambient temperature operating range of –10°C to +50°C, the modules are static, surge and reverse-polarity protected and RoHS compliant. Electrical connections are via external flying leads.

The firm claims the modules require less power, generate less heat, have longer lifetimes and are smaller than other laser sources.

Custom lasing wavelengths (from 405nm to 852nm) and power options are available, as is laser engraving (e.g. of a customer's part number). Both standard and custom configurations provide OEMs, end-users and systems integrators with complete laser solutions.

www.oe-company.com

EU project MIRAGE to develop optical interconnect technology for terabit data links

Assembly processes based on 3D integration to blend silicon, glass and III-V photonics with CMOS silicon electronic drivers

MIRAGE — a new project supported by the Seventh Framework Programme (FP7), Information and Communication Technologies (ICT) of the European Commission (EC) — was launched recently to develop next-generation optical interconnect technology for terabit data links.

Focusing on optical rack-to-rack and board-to-board interconnects, the three-year research project brings together seven academic and industrial partners in the optical value chain. Headed by Greece's National Technical University of Athens, partners also include the Aristotle University of Thessaloniki in Greece; nanoelectronics research institute Imec of Leuven, Belgium; UK-based OptoScribe Ltd; Austriamicrosystems AG; and Aachen-based AMO GmbH and Technische Universität München in Germany. The project's budget is €4.17m, including €3m from the EC.

Today the internet is morphing into a content-centric network with billions of users demanding ubiquitous, instant access to vast amounts of data. In this new networking paradigm, the hot spots are the data centers, where the bulk of the information is residing. These data centers may consist of hundreds or even thousands of servers interconnected with each other. The content providers are in a constant race to increase this interconnection speed to improve the delivery of the data to the end user.

MIRAGE's aim is to increase the optical interconnect speed, which currently tops at around 140Gb/s per link, and bring it to the terabit realm. To do so, the program will tackle the issues that still have to be solved to develop technology suitable for commercial adoption.

For example, it will look into high-speed VCSELs (vertical-cavity surface-emitting laser), low-energy electronic drivers, a flexible motherboard technology that allows new functionalities such as wavelength multiplexing, multi-level modulation and multi-core fibre coupling, and ways to introduce new degrees of parallelization into the optical interconnects. In addition, project partners will develop new assembly processes based on 3D integration of electronic and optical components to effectively blend silicon, glass and III-V photonic elements with CMOS silicon electronic drivers.

As part of the project, Imec's associated lab at Ghent University will develop the dedicated high-speed low-power VCSEL driver array and the transimpedance amplifier (TIA) array. In these IC designs, Imec will focus on the close integration and matching of the drivers with the corresponding VCSEL/photodiode arrays. Its team aims to co-optimize the electronic circuits, parasitic elements, interconnects and optical-electronic-optical component parameters to take advantage of the various new technologies developed by the MIRAGE consortium.

In addition, imec will develop a methodology to simplify bonding the MIRAGE active add-ons to the silicon platform. Particularly for the VCSEL and photodiode bonding, tight alignment tolerances usually require costly equipment, whereas the large distance between VCSELs and waveguides necessitates the use of microlenses to account for beam divergence. MIRAGE will tackle these cost factors with a self-alignment assembly process based on microbumps.

www.imec.be

Invest in Photonics conference highlights opportunities

Organizers of Invest in Photonics, a two-day international convention on photonics venture capital (VC) investment, said that participation at the event increased "despite a tough investment decade in photonics".

The meeting in Bordeaux, France (host of the Laser Megajoule and a region recognized as a center for photonics) gathered industry leaders, investors, photonics specialists, market analysts and trade representatives from across Europe, the USA and Asia. They met with 19 key firms selected for the special funding session, raising attendance to 150 (up 20% on the prior event in 2010). Total funding targeted by selected companies also increased to €72m (\$90m), more than doubling earlier funding targets.

The photonics market is estimated to be worth €300bn (\$395bn) and is expected to reach €480bn (\$632bn) by 2015, according to SPIE, the international society for optics and photonics. The photonics industry now supports 1.7 million jobs. The market in Europe, consisting of about 5000 small- and medium-sized enterprises (SMEs) and 1000 research institutes, is estimated to be €60bn. In Europe, Germany leads with 20% of the market, followed by France and the UK with 14% each, according to European industry group Photonics 21.

"Invest in Photonics is the only venue that informs VCs about future applications in photonics," commented Invest in Photonics chairman Giorgio Anania, chairman of Cube Optics' board and former CEO of Bookham (now Oclaro). "The photonics industry will have a major impact on a range of industries. We bring the key players together to help make this happen."

Growth areas

Analysts and speakers from leading companies focused on three high-growth markets: consumer goods, clean-tech and healthcare, plus the evergreen hot topic of Asia. Subjects covered included: communication and data infrastructure in the

21st century, consumer devices, LED lighting, lasers, advanced displays and sensors, 3D IC packaging, micro-fabrication of glass and PCBs, and solar energy.

"Photonics is ubiquitous yet often invisible," said Steve Anderson, industry and market analyst for SPIE. "It is a light-based enabling technology that underpins just about everything from consumer devices to clean-tech and from communications to life sciences," he added.

"Smartphones, for example, are made using 13 different laser-based systems; they contain diverse photonics components and are enabled using fiber-optic technology. A significant number of commercially successful companies that rely on photonics technology do not associate themselves with the photonics industry."

Fiber lasers

Several delegates spoke about the market for lasers which, according to Anderson, continues to exhibit strong growth for certain types of products, in particular fiber lasers. These are being adopted faster than any other laser technology in history. For directed energy, lasers allow processing by the single unit (versus batch), enabling customization or adaptation to upstream process changes.

LEDs dominating

LED technologies currently represent half of the sales involved in backlighting in TVs and mobile devices. A 13% compound annual growth rate is expected over the next two years, from \$11.4bn in 2012 to \$17bn by 2018, according to Yole Development's report 'Status of the LED Industry'.

"The LED is unlike any other lighting technology in history," said Hans Nikol, vice president LED Innovation and Strategy at Philips Lighting. "Today, every light technology from the candle to fluorescent and halogen co-exists. We strongly believe that LED will wipe out previous existing lighting technologies."

Another emerging area of interest is integrated photonics – achieving with light what has been previously done with electronics. "Areas where photonics can provide solutions include the necessity to reduce the power consumption of running and cooling computer servers, as well as routers that are becoming increasingly more power hungry," noted Carl Zeiss France's president Pierre Billardon. "Other markets are reducing the cost of healthcare."

Solar power

Raffi Garabedian, chief technology officer at cadmium telluride solar module maker First Solar of Tempe, AZ, USA, pointed VCs to four areas offering investment potential: incremental technological developments that can improve the dominant platform technologies with minimal factory re-tooling; metrologies for improved quality and process controls in manufacturing; balance of system controls for low-cost power conversion; grid integration and controls; and prediction and forecasting – disruptive new photovoltaic technologies with the promise of low system costs and improved efficiency.

Intune Networks' chairman Ian Jenks said that, in a world moving to zettabyte communications, photonics will be important in solving problems associated with the need to develop new architectures that will be required to scale virtualized networks economically.

Asian focus

Analysts acknowledged the lead that many Asian companies have in certain areas of photonics, in particular citing AMO-LED display technology (where Samsung and LG are now well established) followed by several emerging firms from around Asia. China has the top capacity in LED reactors, despite only starting production in 2009. Participants voiced concerns about IP protection. Nevertheless, "China is a great business opportunity. Go there!" concludes Billardon.

www.invest-in-photonics.com

Matthew Peach, Contributing Editor

GigOptix's preliminary Q4 revenue down 21% Growth of 14% expected for full-year 2012, but staffing being cut by 10% to maintain profit in 2013

For fourth-quarter 2012, GigOptix Inc of San Jose, CA, USA (a fabless supplier of analog semiconductor and optical components enabling high-speed end-to-end information streaming over optical fiber and wireless networks) has reported preliminary revenue of about \$8m, including \$0.9m of previously unrecognized government contract revenue. This is down 21% on both Q4 guidance (provided at the end of October) and Q3 revenue of \$10.1m.

Factors that contributed to the lower-than-expected revenue in Q4 included weaker demand in markets that the firm currently serves, challenging macroeconomic conditions, and a push-out into first-half 2013 of some anticipated deployments within the optical product line.

"After 12 consecutive quarters of increasing revenues we are clearly disappointed that revenues for the fourth quarter of fiscal 2012 are below expectations," says chairman

& CEO Dr Avi Katz. Indeed, full-year 2012 revenue is expected to be about \$37m, up 14% on 2011's \$32.3m, due solely to organic growth as the firm did not enter into any mergers or acquisitions in 2012. "We view the revenue performance of the fourth quarter of 2012 as a temporary setback and not indicative of our future prospects," Katz adds.

Nevertheless, GigOptix says that, as it continues to focus on its adjusted EBITDA (earnings before interest, taxes, depreciation and amortization), it has taken immediate actions to adjust overall spending. These include reducing its global workforce by about 10% (primarily in support and administrative functions) and company-wide salary cuts of 5–25% (based on an individual's salary level). These actions are expected to result in about \$450,000 of quarterly cost savings, once the plan is fully implemented.

"We will use this opportunity to

further sharpen our business model and cost structure, enhance our operating efficiency, and deploy a leaner and more structured organization," says Katz. "We are confident these changes will deliver improved adjusted EBITDA in 2013," he adds. "While we are not in a position to provide specific financial guidance for fiscal 2013 at this time, our current outlook for the year is positive, based on customer feedback and the prospect for better conditions in the areas within the optical components market we currently serve, and new product deployments targeting the telecom, datacom, and consumer electronics markets."

GigOptix cautions that its anticipated revenue, and cost-reduction savings, are preliminary and based on the best information available. Revenue is subject to completion of audited financial statements for 2012.

www.gigoptix.com

Zephyr Photonics launches Semiconductor Fabrication & Foundry Services business unit

Zephyr Photonics Inc of Zephyr Cove, NV, USA, which manufactures harsh-environment, optical interconnect solutions (based on proprietary, wide-temperature VCSEL-based technology) for mission-critical intelligence, defense, aerospace, energy and industrial applications, has launched its Semiconductor Fabrication and Foundry Services (SFFS) business unit.

"Our Semiconductor Fabrication and Foundry Services business unit was formed to match the growing demands of fabless semiconductor companies and semiconductor companies with our growth, fabrication, testing and production capabilities," says CEO Tom Steding PhD.

"Zephyr Photonics currently provides time-critical device development,

testing and production services for a number of key industry customers."

Among Zephyr's resources at its vertically integrated 17,000ft² development and manufacturing facility is a 10,000ft² cleanroom, which includes epitaxial growth, device fabrication, testing and production equipment such as packaging and module assembly. The facility is accredited by DMEA as the only US Trusted optoelectronic foundry and IC supplier, and is ITAR compliant and ISO 9001:2008 certified. Zephyr says that its team combines more than 100 years of relevant experience.

Zephyr reckons that the development enables it to play a key fabrication role in enabling customers' innovation and improving their time

to market by leveraging its experience, in-depth knowledge, process libraries, IP and facilities.

"Our customers couldn't have been clearer, voicing their enthusiasm with our flexibility, responsiveness, time to market, and breadth of experience, which helps them to improve their own execution and downstream customer satisfaction," says Tim McAllister, VP of business development. "Our new business unit will grow to be a very important part of our overall corporate mission, to be a high-performance, specialized and trusted foundry partner," he believes.

Zephyr's SFFS is fully operational and is now ready to begin customer engagements.

www.zephyrphotonics.com

II-VI firms Photop and Aegis merge

Aegis and subsidiary AOFR's manufacturing transferred to Photop in Fuzhou

Aegis Lightwave Inc of Woburn, MA, USA and Photop Technologies Inc of Fuzhou, China (both subsidiaries of II-VI Inc of Saxonburg, PA) have merged under the Photop brand.

Founded in 2003 through a merger of four firms (involved in optic, laser, fiber-optic, and photonic crystal material products), Photop Technologies is a photonics designer and vertically integrated manufacturer of crystals & advanced optics, optical components and photonic products for communications, industrial and life science applications. In January 2010, the firm was bought by II-VI. As a vertically integrated manufacturer of engineered materials and optoelectronic components that makes products for diversified markets including industrial manufacturing, military and aerospace, high-power electronics, optical communications, and thermoelectronics applications, II-VI manufactures crystalline compounds including zinc selenide for infrared laser optics, silicon carbide for high-power electronic and microwave applications, and bismuth telluride for thermoelectric coolers.

Aegis Lightwave builds solutions for intelligent optical networks that are used for video, datacoms, telecoms and other fast-growing markets, delivering intelligent fiber-optic sub-systems to optical networking systems makers that enable service providers to deploy high-bandwidth video services such as high-definition TV, IPTV, and video-on-demand. In particular, the firm offers optical channel monitors designed for reconfigurable optical add-drop multiplexing (ROADM) applications in high-speed optical networks. Aegis became a subsidiary of II-VI in 2011.

Aegis Lightwave will now operate as Photop Aegis Inc of Woburn, MA (with additional R&D in Flemington, NJ). Aegis Lightwave subsidiary AOFR Pty Ltd in Canberra, Australia

— which makes fused fiber components (including those required for fiber lasers used in materials processing applications) and optical couplers (used primarily in telecom markets) — has been renamed Photop AOFR Pty Ltd.

The merger of Aegis and Photop is targeted at allowing the affiliates to better serve an expanding and global customer base with coordinated sales, marketing, applications engineering and product development activities using the firms' combined resources and complementary expertise. Their joint product portfolio will be presented as one Photop product portfolio, with each product carrying the same brand identity.

"We are excited about the ability to leverage Photop's strong brand identity to accelerate the sales of our market-leading optical channel monitors and fused fiber devices in the global market," comments Photop Aegis' general manager Chris Koeppen.

"We look forward to partnering with Aegis and AOFR to further develop our product portfolios and market penetration worldwide where Photop is rapidly becoming a leading player of optical components and photonic products dedicated to the markets of communications, industrial applications and life sciences," says Photop's CEO John Ling.

Photop Aegis and Photop AOFR have transferred their main manufacturing operations to Photop Technologies' facilities in Fuzhou. Based on the joint manufacturing and integrated operations, the firms have now completed a full merger with what is claimed to be little impact to its customer base. Photop reckons that, as a consolidated brand, it will be able to provide customers increasing levels of service and responsiveness.

www.photoptech.com

www.ii-vi.com/aegis-lightwave

IN BRIEF

Firecomms appoints Mid-Atlantic/Chesapeake sales rep for industrial automation, transportation and medical markets

Firecomms Ltd of Cork, Ireland, a manufacturer of fiber-optic solutions and optical transceivers (including its OptoLock technology, licensed worldwide) has appointed Colrud-Lowery (a representative of electro-mechanical and passive component manufacturers covering a six-state territory in the Mid-Atlantic/Chesapeake region) as a sales representative.

"We are very excited about the opportunity to help Firecomms expand its footprint in the plastic optical fiber market," said Colrud-Lowery vice president Jeb Bartle. "Firecomms is an energetic company with new products that should dovetail nicely with our marketplace."

"As our fiber optical transceivers are ideal for industrial automation, transportation and medical applications, we have sought a representative in the Mid-Atlantic/Chesapeake region that will effectively serve large businesses in these markets," says Lawrence Thorne, Firecomms' VP of sales & marketing, North America. "Due to its excellent reputation among both its customers and partners, we have chosen Colrud-Lowery to offer our OptoLock, LC, and new RedLink fiber optical transceivers to key customers in that region."

Firecomms recently announced an expansion of its line of fiber-optic transceivers. It now also offers an accompanying line of cable assembly solutions enabling quick field installations without extensive training.

www.colrud-lowery.com

www.firecomms.com

OneChip names VP of Product Development to extend PIC technology into data-center interconnect market

OneChip Photonics Inc of Ottawa, Canada, which manufactures optical modules and transceivers based on monolithic photonic integrated circuits (PICs) fabricated in indium phosphide (InP) for access networks and other mass-market broadband applications, has named Jonathan Boocock as VP of product development, responsible for the development of PIC-based passive optical network (PON) transceivers and bi-directional optical sub-assemblies (BOSAs). He will also lead efforts to extend the technology into the next-generation data-center interconnect (NG DCI) market.

"Jonathan knows what it takes to succeed in the very cost-sensitive, high-volume broadband access arena," says CEO Jim Hjartarson. "His experience in developing innovative optical communications solutions from the ground up will be crucial as we look to extend our unique PIC technology to the fast-growing data communications market."

Boocock has more than 25 years of industry experience, most recently as executive VP of engineering at BTI Systems Inc, where he managed development of the BTI 7000 Series Service Edge and Aggregation Packet Optical Plat-

form from its inception to its volume delivery to carriers worldwide.

Previously, he was a co-founder and member of the senior management team at Ottawa-based broadband access start-up Catena Networks (sold in 2004 for US\$487m to Ciena). Boocock also was a senior manager at Nortel Networks, where he led development of its World Line Card access product, which shipped in volumes of more than 12 million lines per year and has a deployed base of more than 200 million lines.

OneChip was first to develop fully integrated optical modules for the PON market, notes Boocock, adding that the firm's technology can greatly reduce the cost and footprint of optical modules and boost optical interconnect speeds to 40G, 100G and beyond.

On 21 May, OneChip announced that in second-half 2012 it planned to make available engineering samples of its PIC-based 40GBASE-LR4 and 100GBASE-LR4 receiver chips for partner testing. Following the release of its PIC-based receiver chips, it expects to also make available engineering samples of its 40GBASE-LR4 transmitter optical components and 100GBASE-LR4 single-chip transmitter PICs.

According to Boocock, OneChip will use the feedback that it receives from these initial 40G and 100G engineering sample designs to develop PIC-based optical modules – such as transmitter optical sub-assemblies (TOSAs) and receiver optical sub-assemblies (ROSAs) – which can be used to lower costs, boost performance and improve reliability in high-speed optical interconnect applications. The solutions would help to remove traffic bottlenecks in data centers and in campus and enterprise networks, the firm reckons.

Meanwhile, OneChip says it will continue to grow its Engineering team, focused on this effort.

"We have an opportunity, with our PIC technology, to make a significant impact in the PON market and the next-generation data-center interconnect market," Boocock reckons, "and we want to bring in additional engineering talent to supplement the strong team that we have in place."

To view a Q&A interview with Boocock and a video animation highlighting OneChip's 40GBASE-LR4 and 100GBASE-LR4 solutions, see:

www.onechipphotonics.com/company/OneChipVideos.htm

JDSU appoints Rex Jackson as CFO

Optoelectronic chip and module maker JDSU of Milpitas, CA, USA has appointed Rex Jackson as executive VP & chief financial officer, and Susan Spradley as senior VP & general manager of the Communications Test and Measurement business segment.

Jackson reports to president & CEO Tom Waechter, and has served as acting CFO since September. He joined JDSU two years ago as senior VP, Business Services, responsible for several corporate functions including Information Technology, where he drove operational

improvements. Previously, Jackson was executive VP & CFO at Symyx Technologies, leading its acquisition of MDL Information Systems and a subsequent merger with Accelrys. He was also acting CFO at Synopsys and held executive positions with Avago, AdForce and Read-Rite.

"Rex's strong performance as acting CFO and his deep knowledge of the company's strategy to drive profitable growth, combined with his prior experience as a public company CFO, make him an excellent choice for this key leadership position," says Waechter.

Reporting to CommTest's president David Heard, Spradley is responsible for developing and managing the communications test product portfolio. Her 20 years of telecoms industry experience include executive roles at Nokia Siemens Networks and Nortel. Appointed by the US President to the National Security Telecommunications Advisory Committee, she chairs the White House and National Science Foundation initiative 'US Ignite' to promote US leadership in developing applications and services for broadband and software-defined networks.

www.jdsu.com

Oclaro seals sales of thin-film filter business and interleaver product line

Initial cash proceeds of \$23m received

Oclaro of San Jose, CA, USA, which makes lasers and optical components, modules and subsystems for the optical communications, industrial and consumer laser markets, has completed the sale of the assets of its Santa Rosa thin-film filter business to Photop Technologies Inc of FuZhou, China, a subsidiary of II-VI Inc of Saxonburg, PA, USA (which manufactures crystalline compounds including zinc selenide for infrared laser optics, silicon carbide for high-power electronic and microwave applications,

and bismuth telluride for thermoelectric coolers). As part of the agreement, Oclaro also sold its interleaver product line to II-VI subsidiary Photop Konkent Inc (FuZhou).

Total consideration to Oclaro for the transactions is in the form of cash proceeds of \$27m (including \$23m received on 3 December, plus \$3m paid by 28 December, and \$1m to be held in escrow until 31 December 2013).

www.oclaro.com

www.ii-vi.com/photop-technologies

Oclaro raises \$23.2m in private offering

In mid-December, Oclaro closed a private placement of \$25m of Exchangeable Senior Secured Second Lien Notes (due 2018), sold to qualified institutional buyers.

The notes bear interest at a rate of 7.5% per year (payable semi-annually in arrears on 15 June and 15 December of each year, beginning 15 June 2013) and will mature on 15 June 2018.

Oclaro intends to use the net proceeds of about \$23.2m for general corporate purposes, including working capital. It may also use part of the net proceeds to acquire or invest in complementary businesses, products or technologies. The firm adds that its management will have significant discretion in applying the net proceeds.

Opnext merger litigation given preliminary approval

On 10 December, Oclaro said that the Superior Court of California in and for the County of Alameda had granted preliminary approval of its proposed settlement (disclosed in a filing to the Securities and Exchange Commission on 26 November) of four putative class actions challenging the proposed merger between Oclaro, Tahoe Acquisition Sub Inc and Opnext Inc. The merger was announced in March and approved by shareholders in July.

The defendants in each case are Opnext and the members of Opnext's board, the firm, and Tahoe Acquisition Sub Inc. Each action alleges that the Opnext

defendants breached their fiduciary duties to Opnext stockholders by entering into the merger agreement. Each action further alleges that the defendants aided and abetted those breaches of fiduciary duties.

Under the proposed settlement, the remaining plaintiffs agreed to settle these matters for additional disclosures only. Plaintiffs have agreed to limit their application for fees and costs to \$235,000. The parties also agreed that the two actions filed in the Delaware Court of Chancery challenging the merger would be dismissed. The proposed settlement is subject to final court approval in a hearing on 31 January.

IN BRIEF

DTN-X deployed platform for 100G national backbone

CenturyLink Inc has deployed Infinera's DTN-X platform on its nationwide fiber optic backbone.

The DTN-X delivers 500Gb/s FlexCoherent long-haul super-channels and integrates 5Tb/s of OTN switching per chassis, resulting in lower latency for mission-critical services while lowering the total cost of ownership of the transport network, says the firm. DTN-X hence provides CenturyLink with scalable, efficient, and reliable long-haul optical transport, Infinera says. The DTN-X enables CenturyLink to enhance its nationwide next-generation backbone transport network to support critical video, mobile, and cloud IP services, and extend its ability to deliver up to 100 Gigabit Ethernet services (GbE) to its data centers and customer facilities around the country.

CenturyLink first deployed Infinera's Digital Optical Network architecture in 2004 with the DTN platform, the industry's first optical transport solution powered by PICs. "Our experience with the Infinera DTN platform has demonstrated a system based on quality, ease of use, proven technology and reliability," says Matt Beal, CenturyLink's senior VP - corporate strategy, product development & chief technology officer. "We look forward to including the DTN-X as part of our next-generation network and achieving the same positive results as we have in the past," he adds.

"As operators upgrade existing networks to 100G or deploy new 100G networks, the DTN-X uniquely delivers the scale and efficiency required at the core of the world's largest optical networks," says Infinera's CEO Tom Fallon.

www.infinera.com

Infinera and Nissho demo first 8Tb/s super-channel transmission over dispersion-shifted fiber

Along with its Tokyo-based partner Nissho Electronics, 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 demonstrated its DTN-X platform delivering 8 Terabits per second (Tb/s) capacity using production-ready super-channels across 800km of ITU-T G.653 dispersion-shifted fiber (DSF).

The demonstration at the NET Frontier Center illustrates the value of 100Gb/s coherent optical technology in leveraging DSF assets for service providers, says Infinera. Deployed throughout Japan, DSF has proven to be a challenge in deploying high-capacity DWDM transport technology due to low chromatic dispersion in the C-band, making it difficult to achieve high-capacity optical transmission over long distance economically, adds the firm. Capacities have hence been severely limited and have had to use expensive L-band technology to achieve long-haul-quality performance from the DSF fiber.

Based on 500Gb/s photonic integrated circuits (PIC) and the second-generation FlexCoherent Processor (offering software-configurable coherent modulation), the DTN-X platform offers long-haul 500Gb/s super-channels featuring polarization mode dispersion (PMD) compensation.

The next-generation platform has now demonstrated it can transmit 8Tb/s of super-channel capacity on the C-band over 800km of challenging DSF fiber, says Infinera. This enables network operators to leverage existing fiber plant investments while also being able to operate the latest multi-Terabit, long-haul next-generation WDM transmission technologies, adds the firm. This same capacity extends to well over 2500km when using quadrature phase-shift keying (QPSK) modulation on the DTN-X with non-DSF fiber (in use in much of the world), highlighting the unique challenges of the DSF fiber in Japan.

Infinera also demonstrated the system's FlexCoherent capabilities, showcasing the ability to software-select different modulation formats including QPSK and BPSK (binary phase shift keying) to optimize both reach and capacity. Infinera says that the trial validates that service providers globally can deploy the latest high-capacity optical transport solutions on existing DSF fiber economically, continuing to leverage their current infrastructure. The demonstration also shows 100GbE service provisioned in less than 100 seconds, showcasing the simplicity of DTN-X and its ability to activate services much faster than conventional solutions, the firm claims.

"This test truly demonstrates the value of the DTN-X platform to

service providers with DSF assets," says comments Nissho's executive officer Kimitaka Sato. "In the past, service providers may not have been able to run even multiple 10Gb/s transmission over this kind of fiber. Infinera's solution proves that we can run the very latest super-channel technology at 8Tb/s on DSF," he adds.

"This trial is unique because it not only achieves world-class reach and capacity over a very difficult type of optical fiber, it shows how quickly capacity can be turned up for service providers today," claims Infinera's co-founder, executive VP & chief strategy officer Dave Welch. "This capability can be combined with our recently introduced Instant Bandwidth solution on the DTN-X to allow service providers to compete more effectively and achieve a success-based business model."

Infinera claims to be first to deliver 500Gb/s long-haul super-channels based on PICs and the FlexCoherent Processor, scaling transport capacity without scaling operational complexity. Shipping since second-quarter 2012, the DTN-X has received purchase commitments from 16 operators globally, including Cable&Wireless Worldwide, DANTE, PIPE Networks, Telefonica International Wholesale Carrier, Cyprus Telecommunications Authority and TeliaSonera International Carrier.

www.infinera.com

ESnet extends 100GbE capability with Infinera's DTN platform

Infinera's DTN platform has been used for the deployment of 100 Gigabit Ethernet (GbE) services on the Long Island MAN portion of the US Department of Energy's (DOE) Energy Sciences Network (ESnet).

Leveraging its existing Infinera digital optical network, ESnet will offer 100GbE services from DOE's Brookhaven National Laboratory to data centers in Manhattan and back

onto ESnet's nationwide network. Brookhaven is one of two facilities in the US making data from the Large Hadron Collider's ATLAS experiment available to the 44 US institutions participating in ATLAS.

ATLAS detects particles created by proton-proton collisions as part of the search for the Higgs boson particle. ESnet also provides a high-speed network serving tens

of thousands of the DOE's scientists and collaborators worldwide.

ESnet first deployed the Infinera DTN platform for an advanced network testbed, and then leveraged the platform to provide production network services over the dark fiber ring in Long Island. In November, Infinera and ESnet demonstrated transport Software Defined Networking on ESnet's testbed.

Infinera and ESnet claim first demonstration of SDN Open Transport Switch

In partnership with the US Department of Energy's Energy Sciences Network's (ESnet) Long Island Metropolitan Area Network (LIMAN) control-plane test bed, 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 claimed the telecom industry's first demonstration of a prototype Software Defined Network (SDN) Open Transport Switch (OTS).

Infinera says that the proof-of-concept demonstration shows the potential of Transport SDN, extending the concepts and benefits of SDN to the dynamic optical transport layer. The OTS concept is a lightweight virtual transport switch that may be deployed on optical transport systems to interface with a SDN controller via an extended version of the OpenFlow protocol. This approach has the potential to facilitate application-driven control over transport bandwidth services, including converged wavelength, OTN and packet transport technologies. By enabling multi-layer coordination and control, service providers will potentially be able to leverage Transport SDN to improve the utilization and efficiency of their network infrastructure, increase network resiliency, and deploy new services more rapidly while simplifying and automating operations, lowering the total cost of network ownership, says the firm.

In the demonstration, Infinera tested a prototype of the OTS running on its DTN platform, allowing ESnet's optical transport network to be configured by an SDN controller via the OpenFlow protocol. ESnet enhanced its SDN controller and demonstrated on-demand bandwidth Ethernet services including bandwidth elasticity for data-intensive science experiments at Brookhaven National Laboratory on

their LIMAN network, spanning from Manhattan, NY, to Upton, NY. The services were provisioned by a high-capacity bandwidth-on-demand application utilizing the SDN controller in three different transport network abstractions, including one based on Infinera's standards-based GMPLS control plane, showcasing the potential to deploy Transport SDN in networks with existing control planes in production.

To implement OTS and extend SDN to the transport layer, the contributing platforms that are used to build this layer must be able to virtualize the digital and optical resources. Infinera's Bandwidth Virtualization provides this abstraction by leveraging the integration of a standards-based GMPLS software control plane, integrated OTN switching and PIC technology, providing a massive, shareable and programmable pool of optical transport capacity. In contrast, claims Infinera, conventional optical transport systems are generally more static in nature, with limited or no integrated OTN switching, and do not easily support Transport SDN.

"The emerging era of data-intensive science demands the highest level of performance from the network. The ability for the network to scale and handle large data flows efficiently across a multi-layer network is an essential capability,"

The emerging era of data-intensive science demands the highest level of performance from the network. The ability for the network to scale and handle large data flows efficiently across a multi-layer network is an essential capability

says ESnet's chief technologist Inder Monga. "The type of bandwidth flexibility, automation and resource efficiency demonstrated in this test are critical to supporting the large-scale data transfer requirements of data-driven science research."

Brookhaven National Lab's networking team and researchers used this SDN platform to experiment with ultra-high-speed data transfer applications being developed for next-generation networks using RDMA over Ethernet protocols.

"Big data applications hosted at BNL and other DOE national labs routinely move petabytes of data over LAN and WAN and require the capability of fully utilizing the current and next generation of 100Gbps networks," says Scott Bradley, manager of Network Services at BNL. "Software-defined networks helps us to meet this challenge and allows us to implement and validate the data transport protocols/software intra-data centers and over WAN in the speed of 100Gbps and beyond."

"This pioneering demonstration is an important first step on the path toward enabling Transport SDN," says Chris Liou, Infinera's VP Network Strategy. "For service providers interested in deploying Transport SDN, we believe the OTS can play a key role in realizing many benefits, including simplified provisioning of bandwidth services in multi-tiered, multi-vendor, multi-domain environments, increased efficiency and utilization of network resources, and an open, programmable transport network for enhancing integration and automation with applications."

"SDN and OpenFlow are finding new applications in the market every day," says Dan Pitt, executive director of the Open Networking Foundation, which standardizes OpenFlow and promotes SDN.

www.infinera.com/go/SDN

Emcore reports revenue of \$47.5m, down 9% year-on-year but up 16% quarter-to-quarter

Previously flood-hit operations “now restored”

For its fiscal fourth-quarter 2012 (to end-September), Emcore Corp of Albuquerque, NM, USA, which manufactures compound semiconductor-based systems for fiber-optic and solar power applications, has reported revenue of \$47.5m, down 8.9% on the prior year's equivalent quarter but up 15.6% on fiscal Q3/2012.

The increase was primarily due to Fiber Optics revenue of \$30.1m, down 2.7% on Q4/2011 but 16.5% up on Q3/2012, driven by ITLA (integrable tunable laser assembly) sales. In addition, the firm's Photovoltaics division yielded revenue of \$17.4m, down 17.9% on Q4/2011 but up 14.2% on Q3/2012. Photovoltaics business accounted for 37% of total revenue (level with last quarter).

Consolidated gross margin was 9.7%, down from 10.7% last quarter and 19.2% the prior year. On a segment basis, Photovoltaics' gross margin was 22.2%, up from 13% the preceding quarter and 21% the prior year. Fiber Optics' gross margin was just 2.4%, down from 9.3% the preceding quarter and 18% the prior year, primarily due to higher excess and obsolete charges, work order variances for new product lines, and yield and other variances associated with manufacturing transfer from California to China and Thailand. Excluding these items, Fiber Optics gross margin would have been over 20%. “We expect our gross margins in the Fiber Optics segment to improve in future quarters as we complete the ramp-up of our product lines at our overseas locations,” commented chief financial officer Mark Weinswig.

Operating loss was \$6.3m, an improvement of \$2.5m on the preceding quarter and \$8.1m on the prior year. The firm noted that the quarter-on-quarter boost was

primarily due to the \$4m of insurance recoveries relating to the flooding at Thailand-based subcontract manufacturer Fabrinet, partially offset by higher severance-related costs from corporate restructuring.

After excluding certain non-cash and other infrequent transactions, non-GAAP net loss was \$6.6m, an additional loss of about \$2.6m on the prior year but a lower loss of \$0.9m on last quarter.

Considering its full-year fiscal 2012 performance, revenue was \$163.8m, down 18.5% on the prior year's \$200.9m. Fiber Optics revenue was \$96.2m, down 23.5% “primarily due to the Thailand flood in October 2011”. Revenue for the Photovoltaics segment was \$67.6m, down 10.2%, primarily due to lower sales to an [unnamed] international customer.

The firm commented that during fiscal 2012, lower fiber-optics revenues due to the impact from the Thailand flood resulted in higher manufacturing overhead as a percentage of revenue. Manufacturing of certain fiber-optics components was moved to company-owned facilities in the USA, which involved higher labor and other related costs. Instead of completely rebuilding all flood-damaged manufacturing lines, Emcore's management decided to realign the company's fiber-optics product portfolio and focus on business areas with strong technology differentiation and growth opportunities.

We expect our gross margins in the Fiber Optics segment to improve in future quarters as we complete the ramp-up of our product lines at our overseas locations

During fiscal 2012, management identified \$1.6m of inventory on order related to manufacturing product lines that were destroyed by the Thailand flood and will not be replaced. This expense was recorded within cost of revenues. Photovoltaics' gross margins fell year-on-year, primarily due to lower revenues with unfavorable product mix changes, as well as lower manufacturing yields on new products.

As of end-September, order backlog for Emcore's Photovoltaics segment totaled \$43.3m, down 6.3% on \$46.2m at the end of June. The order backlog as of end-September and end-June included \$1.9m and \$5.1m, respectively, of terrestrial solar cell orders from the Suncore joint venture. Emcore notes that product sales from its Fiber Optics segment are made in relation to purchase orders, often with short lead-times, and revenue from this segment is still limited by the rebuilding of production capacity.

“In the fourth quarter, Emcore sold assets relating to the terrestrial systems product lines to Suncore as part of the realignment strategy we discussed last quarter,” noted Weinswig in the subsequent analysts conference. “As we have said previously, while we believe in the long-term growth prospects of the space solar power business, our revenues in any given quarter may be a bit lumpy,” he added.

“Over the past few months, we have made significant strides in recovering from the crisis caused by the flooding in Thailand, including steps to streamline and focus our business through the sale of certain product lines,” noted Weinswig. “We look forward to showing the results of these actions over the next few quarters.”

Considering its business outlook Emcore stated, “On a consolidated basis, we expect revenue for our

first quarter 2013 (ending December 31, 2012) to be in the range of \$49–51m [up 5% sequentially], which includes revenue from our joint venture Suncore that was previously deferred."

CEO Hong Hou added, "The fundamentals of the business remain robust, and the outlook for the space programs remains promising. We have good visibility into our customer demand for the next 12 months and expect to book several high-value contracts in our space solar segment in the near term.

"Furthermore, we have increased our focus on operational efficiency in the Photovoltaics area, and those efforts are paying off. Product yield and productivity are improving, and we expect the trend to continue throughout the next several quarters. With the divestiture of the terrestrial systems business and the improvement in the space solar business, we'd expect more consistent operating results in the future periods.

"Our forecast fiscal year 2013 revenue for solar is expected to be at or near record level, and our profit margins are currently projected to show marked improvement over the 2012 results. Finally, for solar segment, it's widely recognized by the industry that Emcore maintains its technology lead in the next-generation solar cell and solar panel technology, commonly referred to as IMM [Inverted Metamorphic].

"We currently hold the world record for space solar cell efficiency, with demonstrated results of greater than 35% efficiency as compared to 29.5% that represents the current state of the practice. We plan to reintroduce IMM products to well-

We are increasing manufacturing capacity by 50% by adding more processing and testing equipment

known manufacturing in the year.

"During the September quarter, we achieved significant increase in revenue for our Fiber Optics business. This is due primarily to the increase in ITLA shipment for 40G and 100G coherent systems. The revenue from this product line in the September quarter exceeded the highest level pre-flood.

"As we announced in the last quarter, we are increasing manufacturing capacity by 50% by adding more processing and testing equipment, as well as shortening production cycle time. We are on track for increasing capacity and reaching that level by March 2013.

"With a completed recovery in the manufacturing capacity, we are moving to recapture the lost market share. We're very encouraged and confident by the recent order activities, which positions us for substantial ramp in the March quarter."

www.emcore.com

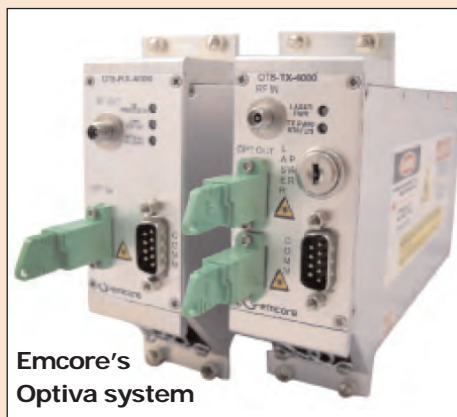
Matthew Peach, Contributing Editor

Emcore releases Optiva satcom-band microwave fiber-optic transmitters and receivers

Emcore has announced the availability of its Optiva satcom band microwave fiber-optic transmitters and receivers for satellite communications, RF antenna remoting and other high-dynamic-range microwave applications.

The new products supplement Emcore's existing Optiva ultra-wideband RF fiber-optic transport system by adding band-specific C, X, Ku, or Ka transmitter and receiver modules compatible with the firm's modular or flange-mount Optiva Platform configurations. The addition of the Optiva satcom band RF fiber-optic transport system further expands the existing Optiva platform that already supports 50MHz to 18, 22 or 40GHz broadband microwave transport, reference oscillators, IRIG, IF, L- & S-band, plus audio, video, data and Ethernet.

"By leveraging our existing ultra-wideband 50MHz–40GHz Optiva



Emcore's Optiva system

products as building blocks, Emcore is able to provide high-performance externally modulated RF-banded technology at directly modulated technology price points," says Frank Weiss, VP of Emcore's Advanced Systems Division. "Additionally, these new products support multiple format frequency transport in a single flexible platform for C, X, Ku, and Ka-band applications."

Using the firm's high-perform-

ance ultra-low Relative Intensity Noise (RIN) source laser technology and high-optical-input-power-capable photodiodes, the new system provides a high dynamic range of $>110\text{dB-Hz}^{2/3}$. The system features microprocessor-based transmitter and receiver control for laser and modulator bias, plus variable RF link gain which provides consistent high-performance and constant gain operation.

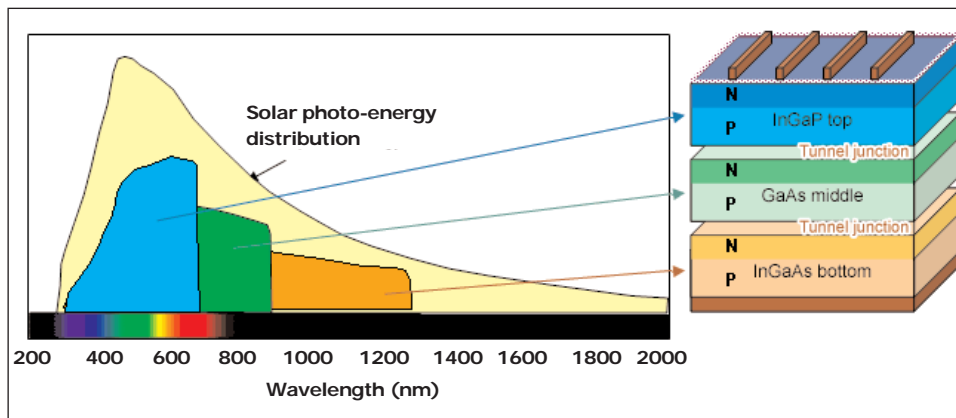
The standard Optiva transmitter provides a high-power optical output and operates at a nominal wavelength of 1550nm. Wavelength-selected lasers on the ITU grid are also available to support multi-channel DWDM applications. Additional advanced capabilities include Simple Network Management Protocol (SNMP) V.1, optical and RF amplification options, and RS-232 monitor & control with flexible user interface options.

Sharp claims record 37.7% efficiency for non-concentrator solar cell

Japan's Sharp Corp has achieved what is claimed to be record solar cell conversion efficiency (for research-level non-concentrator solar cells) of 37.7% using a triple-junction III-V compound semiconductor solar cell (in which three photo-absorption layers are stacked together) with a cell surface of about 1cm².

Sharp says that it achieved the breakthrough as a result of an R&D initiative promoted by Japan's New Energy and Industrial Technology Development Organization (NEDO) on the theme of 'R&D on Innovative Solar Cells' (in which Sharp has previously achieved triple-junction cell efficiency of 35.8% in 2009 and 36.9% in 2011, as well as 43.5% for a concentrator triple-junction cell, at 360-fold concentration, in June 2012). Measurement of the value of 37.7% was confirmed in September by Japan's National Institute of Advanced Industrial Science and Technology (AIST).

The basic structure of the latest triple-junction compound solar cell uses proprietary Sharp technology that enables efficient stacking of



Wavelength distribution of solar photo-energy and wavelength sensitivity of triple-junction cell for the InGaP, GaAs and InGaAs parts of the structure.

the three photo-absorption layers, with an indium gallium phosphide (InGaP) top layer, gallium arsenide (GaAs) middle layer and indium gallium arsenide (InGaAs) bottom layer, separated by tunnel junctions.

To achieve the latest increase in efficiency, Sharp capitalized on the new cell's ability to efficiently absorb light from different wavelengths. Sharp also increased the active area (the ratio of the effective light-reception area to the total surface area of the cell) for converting light into electricity through

optimal processing of the cell edges. These improvements led to higher maximum output levels for the solar cell and enabled Sharp to achieve the 37.7% efficiency.

Sharp's aim for the future is to apply the latest development to concentrator photovoltaic (CPV) power systems that use lenses to collect and convert sunlight into electricity. The firm also foresees many other practical applications for the cells, such as on space satellites and vehicles.

www.sharp-world.com

Azur Space reports CPV cell efficiency of 43.3% Record efficiency claimed for solar cell grown upright using MOVPE

Azur Space Solar Power GmbH of Heilbronn, Germany says that it has achieved solar energy conversion efficiency of 43.3% with its new multi-junction cell using 500-fold concentration.

This is claimed to be the highest efficiency ever reported for a solar cell grown upright using MOVPE (metal-organic vapour phase epitaxy). In October, Solar Junction of San Jose, CA, USA raised its own efficiency record for a commercial-ready production solar cell from 43.5% at 418 suns to 44% at 947 suns, but those cells were

grown using molecular beam epitaxy (MBE).

Azur Space develops, produces and supplies bare solar cells for space and terrestrial CPV customers. The firm has been active in the space solar cell market for over 40 years and has supplied solar cells for more than 400 satellites to date. Its range of products covers several types of silicon and III-V-on-germanium solar cells. Using materials and structures originally developed to supply power to telecom and Earth-observation satellites designed for scientific

research, reconnaissance or navigation, Azur Space is now demonstrating the performance of its solar cells for terrestrial applications.

The firm says that this new generation of solar cells is currently being brought to market. By using MOVPE technology (proven in mass production on germanium-based substrates) on 100mm and 150mm, Azur Space reckons that it can offer the highest-performing multi-junction cells on the best price-performance basis available in the market.

www.azurspace.com

NRL designs multi-junction solar cell aiming to raise efficiency record from 44% to beyond 50%

InAlAsSb lattice-matched to InP substrate raises direct bandgap from 1.4eV to 1.8eV

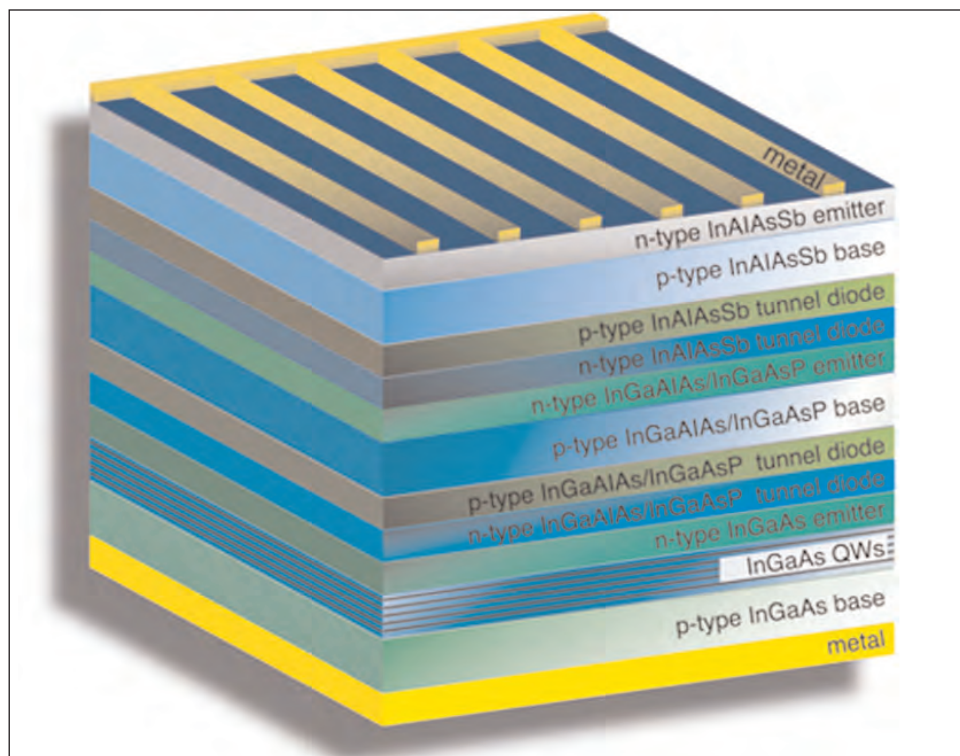
In collaboration with Imperial College London in the UK and MicroLink Devices Inc of Niles, IL, USA, researchers in the US Naval Research Laboratory's Electronics Technology and Science Division have proposed a novel triple-junction solar cell which they reckon has the potential to exceed 50% energy conversion efficiency (the current goal in multi-junction photovoltaic development).

"This research has produced a novel, realistically achievable, lattice-matched, multi-junction solar cell design with the potential to break the 50% power conversion efficiency mark under concentrated illumination," says NRL research physicist Robert Walters PhD.

"At present, the world-record triple-junction solar cell efficiency is 44% under concentration, and it is generally accepted that a major technology breakthrough will be required for the efficiency of these cells to increase much further."

In multi-junction (MJ) solar cells, each junction is tuned to different wavelength bands in the solar spectrum to increase efficiency. High-bandgap semiconductor material is used to absorb the short-wavelength radiation, with longer-wavelength parts transmitted to subsequent semiconductor layers with different energy bandgaps. In theory, an infinite-junction cell could obtain a maximum power conversion percentage of nearly 87%, says NRL. The challenge is to develop a semiconductor material system that can attain a wide range of bandgaps and be grown with high crystalline quality.

By exploring novel semiconductor materials and applying band-structure engineering, via strain-balanced quantum wells, the NRL research team has produced a design for a MJ solar cell that can achieve direct



Schematic diagram of a multi-junction (MJ) solar cell formed from materials lattice-matched to InP and achieving the bandgaps for maximum efficiency. (Photo: US Naval Research Laboratory)

band gaps from 0.7eV to 1.8eV with materials that are all lattice-matched to an InP substrate.

"Having all lattice-matched materials with this wide range of bandgaps is the key to breaking the current world record," adds Walters. "It is well known that materials lattice-matched to indium phosphide (InP) can achieve bandgaps of about 1.4eV and below, but no ternary alloy semiconductors exist with a higher direct bandgap."

NRL says that the primary innovation enabling this new path to high efficiency is the identification of InAlAsSb quaternary alloys as a high-bandgap material layer that can be grown lattice-matched to InP. Drawing from their experience with antimony (Sb)-based compounds for detector and laser applications, NRL researchers have modeled the band-structure of

InAlAsSb and showed that this material could potentially achieve a direct bandgap as high as 1.8eV. With this result, and using a model that includes both radiative and non-radiative recombination, the NRL scientists have created a solar cell design that is a potential route to power conversion efficiency of more than 50% under concentrated solar illumination, it is reckoned.

After being awarded funding for a US Department of Energy (DoE) Advanced Research Projects Agency-Energy (ARPA-E) project at the end of November, the NRL scientists — working with MicroLink and Rochester Institute of Technology of Rochester, NY — aim to execute a three-year materials and device development program to realize the new solar cell technology.

www.nrl.navy.mil

www.mldevices.com

Soitec opens \$150m San Diego factory to locally produce CPV modules

280MWp plant to make firm one of the top three solar module manufacturers in USA

Within a year after acquiring it from Sony Electronics Inc in December 2011, Soitec of Bernin, France has opened its North American concentrator photovoltaic (CPV) module manufacturing facility in San Diego after completing on schedule an extensive upgrade to install fully automated manufacturing equipment and processes in a project representing a total investment of more than \$150m. M+W US Inc (a subsidiary of global engineering and construction firm M+W Group) was the general contractor for facility construction.

Sited on 14.8 acres of land, the 176,000ft² manufacturing center produced its first module in October. The first phase (140MWp) of the production line is now operational, as initially planned. The factory has been designed to reach 280MWp in capacity at full production.

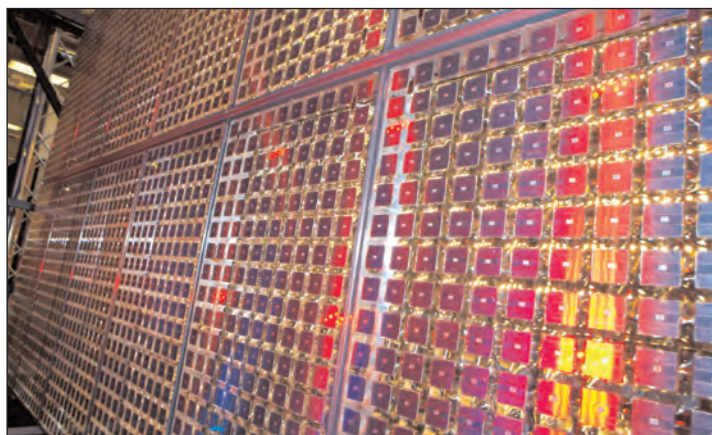
The CPV modules that are produced will support hundreds of MWp of contracts for utility-scale projects in California. In 2011, the California Public Utilities Commission (CPUC) approved 300MWp of power purchase agreements (PPAs) which are expected to use Soitec's Concentrix technology.

At the peak of construction, over 280 people were employed on site. At full capacity, the factory should create 450 jobs, including staff for the joint venture Reflexite Soitec Optical Technology LLC, which was formed in November 2011 with Reflexite Energy Solutions Inc of Avon, CT, USA (a global supplier of microstructured optical components for the solar power, lighting, instrumentation and display industries). The JV runs a manufacturing operation within the facility developing and making silicone-on-glass (SOG) Fresnel lens plates used in Soitec's CPV modules.



Soitec's chairman & CEO André-Jacques Auberton-Hervé (center), flanked by commissioner Timothy Simon of the California Public Utilities Commission (second left) at the official opening.

Soitec's CPV technology uses triple-junction photovoltaic cells mounted on a glass plate. Silicone-on-glass Fresnel lenses concentrate sunlight 500 times before it reaches these cells. A metal frame holds two glass plates to form the modules. By combining several modules on biaxial trackers (based on a proprietary algorithm automatically optimizing their position based on the path of the sun), energy generation is maximized throughout the day, says Soitec. With yields of 30%, the CPV modules achieve at least twice the performance of conventional photovoltaic



Arrays of Soitec's concentrator photovoltaic cells.

technologies, claims Soitec.

Soitec reckons that its new plant will make it one of the top three manufacturers of solar modules in the USA, as well as positioning it to support customers with a dedicated local team. "By producing high volumes of CPV modules at this facility, we are

now able to help California meet its renewable energy goals and further support the US market," said chairman & CEO André-Jacques Auberton-Hervé. "Soitec already manages six factories around the world, and this gives us strong expertise in industrial processes, manufacturing and quality systems," he added. "We have also installed CPV systems in 14 countries on four continents."

"The city, CleanTECH San Diego, the Regional EDC [Economic Development Corporation], University of California San Diego and SDG&E [San Diego Gas &

Electric Company] combined their resources to show Soitec that San Diego was as enticing as any other region in the desert Southwest," commented San Diego mayor Bob Filner at the facility's Grand Opening.

www.soitec.com



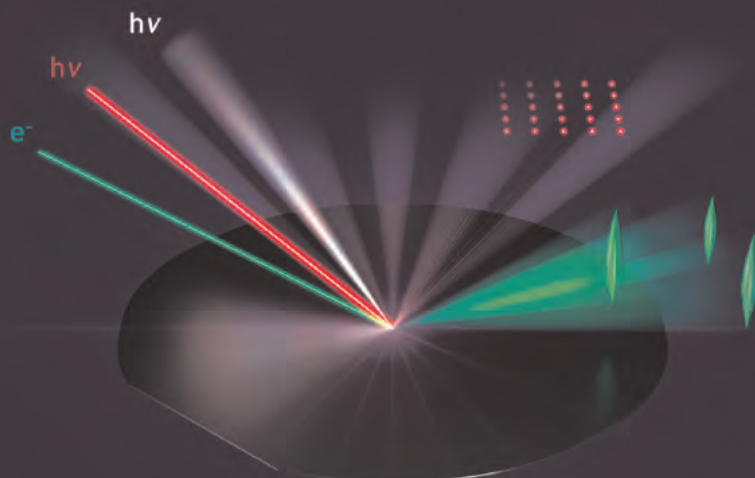
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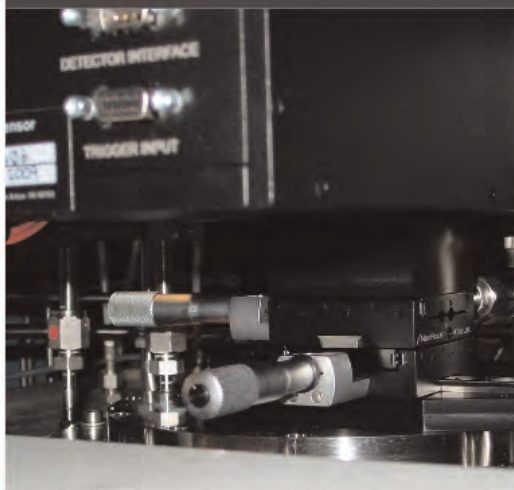
Real-Time Process Monitoring for MOCVD, MBE, Sputtering, and Thin-Film PV Deposition



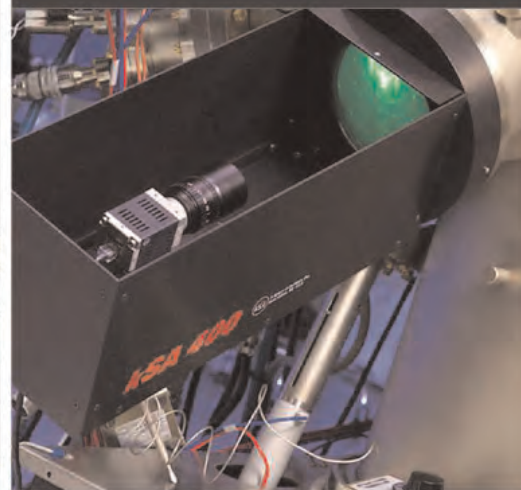
kSA BandiT Wafer Temperature



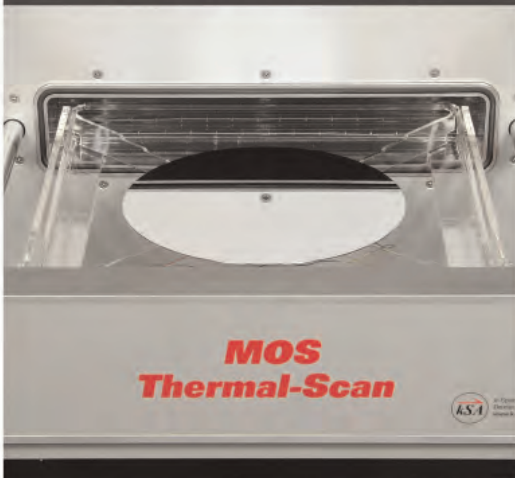
kSA MOS and kSA Mini-MOS Thin-Film Stress



kSA 400 Analytical RHEED



kSA MOS Ultra-Scan and Thermal-Scan Stress Mapping



kSA Rate Rat Pro Thickness & Deposition Rate



kSA BandiT PV Process Tuning



IQE completes Solar Junction process transfer milestones

Epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK says it has achieved several key technology transfer milestones representing significant progress in its commercial relationship with Solar Junction of San Jose, CA, USA, which manufactures III-V multi-junction solar cells for concentrated photovoltaics (CPV).

In February, IQE announced an exclusive manufacturing and technology transfer agreement with Solar Junction and laid out a series of milestones. These milestones were designed to culminate in the delivery of full three-junction (3J) structures to Solar Junction based on successful installation and commissioning of customized production-scale molecular beam epitaxy (MBE) tools, and subsequent technology transfer from Solar Junction. Completion of this was planned for fourth-quarter 2012.

IQE and Solar Junction have now completed these milestones and the delivery of full 3J wafers (using the transferred process) to Solar Junction. Commercial production is expected to begin in first-half 2013, initially with customer product qualification quantities, moving to volume production in second-half 2013.

Independently, Solar Junction has qualified its cells to full IEC (International Electrotechnical Commission) specifications with several customers, and is strongly engaged with all leading CPV systems houses.

"Our deal with Solar Junction earlier this year will significantly accelerate our well established CPV strategy and position us to become the key epiwafer supplier to the CPV market," reckons IQE's chief executive Dr Drew Nelson. "The combination of Solar Junction's core materials IP and technology, with its recently

improved world-record efficiencies of 44% [achieved in October], together with our own IP and manufacturing capabilities, provides a compelling route to significantly higher cell efficiency and cost-effective, high-volume production for the CPV industry. That combination is now all but complete, and we are on track to move to commercial volume production during 2013," he adds.

"As we approach the end of our financial year, we are also confident that we will meet our earnings expectations," Nelson continues. "The transformational deals completed with Solar Junction and RFMD earlier this year are highly complementary and position the group for accelerating growth in rapidly expanding markets."

www.iqep.com

www.sj-solar.com

Global Photonic Energy develops potential grid-parity solar cell

University of Michigan produces 20%-efficient, ultra-lightweight and flexible GaAs solar cell at potential \$0.45/W

At the 2012 Fall Meeting of the Materials Research Society (MRS) in Boston at the beginning of December, Global Photonic Energy Corp (GPEC) of Medford Lakes, NJ, USA — a developer of organic photovoltaic (OPV) technology that has research partnerships with the University of Southern California, the University of Michigan and Princeton University — said that it has demonstrated a thin-film solar cell that can potentially provide electricity at grid parity (the cost of traditionally provided electricity), it is claimed.

Dr Stephen R. Forrest of the University of Michigan said the breakthrough is the result of substantially reduced production costs, based on a patent-pending invention that reuses the same

gallium arsenide wafer multiple times to produce solar cells. This unlimited wafer reuse approach to conventional epitaxial lift-off technology (which typically leads to wafer damage, and hence only a very limited number — just one or two — of wafer reuses) has the potential to reduce the cost of a typical GaAs solar cell to below \$1 per Watt (peak), it is reckoned.

The development implies that "ultra-high-efficiency solar cells based on gallium arsenide can eventually produce electricity at or below grid parity," according to Forrest. "Using integrated solar concentrators and our adhesive-free, cold-weld bonding technology to plastic substrates, we estimate electricity could be produced as low as \$0.45 cents per Watt,

compared to traditional grid parity of \$1 per Watt."

"In addition to its dramatically reduced cost structure, this demonstration in the University of Michigan laboratories can be used for numerous applications because these high-efficiency solar cells, deployed on roll-up plastic sheets, are ultra-lightweight and flexible," says GPEC's president & CEO Dean Ledger. "These applications include use in off-grid locations, spot powering of vehicles, mobile military equipment and satellites." Ledger adds that GPEC will commercialize its technology through licensing of its intellectual property, becoming part of its foundational portfolio of more than 425 patents (issued and pending).

www.globalphotonic.com

Alta Devices announces reference designs for lightest, most efficient military mobile charging mats

Application to be extended to unmanned systems, consumer devices, automobiles

Alta Devices of Sunnyvale, CA, USA has announced reference designs for what it claims are the world's lightest and highest-energy-density flexible military charging mats.

Alta fabricates single-junction gallium arsenide (GaAs) photovoltaic cells in a micron-thick thin-film that it then lifts off the growth GaAs substrate (which can then be reused multiple times to amortize its high cost). The thin-film cell can then be placed on a flexible substrate.

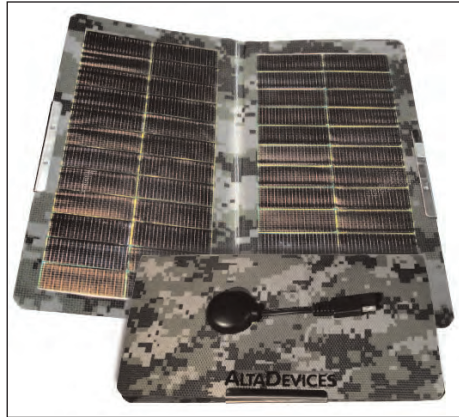
Founded in 2007, Alta has achieved records for single-junction solar cell and module energy conversion efficiency (under one sun), as validated by the US National Renewable Energy Laboratory (NREL).

The smallest of the new charging mat (providing 10 Watt) weighs just 4.1 ounces, has dimensions slightly larger than a sheet of paper (when unfolded), and can provide power to a soldier in the field without the need for an alternative fuel source. The 20 Watt mat weighs only 10 ounces, and generates up to 120 Watt-hours of energy per day. Both designs can be folded for easy storage and transportation.

The designs are compliant to MIL-810-G specifications for temperature, humidity, shock and other environmental stresses. The mats can be married to any type of battery charging connector.

According to the US Army Research Laboratory, a soldier's load can weigh 100 pounds, over a third of which are batteries. Alta's technology can reduce that battery weight by 70%, saving about 25 pounds of pack weight, it is reckoned, allowing troops to extend their mission without needing to be resupplied.

The technology that makes the military chargers possible will also be introduced in unmanned systems, consumer electronics, auto-



Alta Devices' 10W charging mat.

mobiles, and a variety of industrial, remote power applications. "We have come to rely on mobile machines and devices that always need a source of power whether it be the grid, batteries, or fuel," says president & CEO Chris Norris. "But in the next decade we will come to expect mobile power that is transparently available at all times," he adds.

In addition to being adopted by the military to improve the effectiveness of soldiers, Alta says that its mobile power technology is targeted at manufacturers of unmanned aerial vehicles (to increase flight times), at industrial suppliers in the mining and exploration markets (to provide remote power), at consumer electronics makers (to minimize recharging), and at the automotive industry (to provide supplemental power or to increase vehicle range).

"There are nearly limitless opportunities for always-available mobile power," reckons Norris. "We are initially targeting applications where the need is well understood and the opportunity is substantial," he adds. "Over time, we see huge markets being enabled by this kind of mobile power."

www.altadevices.com

IN BRIEF

Construction of Campo Verde Solar Project begins

First Solar has started construction of the 139MW Campo Verde Solar Project, sited near El Centro in Imperial County, CA, USA (for completion in 2013). The plant should create about 250 construction jobs, as well as over \$230m in new economic activity to the Imperial Valley.

On 18 December, the project gained approval from the Imperial Irrigation District (IID) for easements required to allow the project's transmission line to cross IID's Westside Main Canal. Earlier approvals included a decision to issue a Right of Way grant from the US Bureau of Land Management (BLM) and a Conditional Use Permit from Imperial County.

The project should generate enough electricity to power about 50,000 average California homes, displacing 80,000 metric tons of CO₂ per year (equivalent to taking 15,000 cars off the road).

"First Solar's project brings much needed jobs and economic development to the Valley at a time when it is sorely needed," says County Board president Ray Castillo. "The project also pays added tax revenue, funds for agricultural benefits and community benefits while helping the County diversify its economy. We've been working to attract projects like this for the past five or six years and are glad to see it's finally happening," he adds.

"First Solar is grateful to the IID, Imperial County, and the BLM for their support of this project," says First Solar's project development director James F. Cook. "Campo Verde is creating badly needed jobs and will help the county and state reach their renewable energy goals."

www.firstsolar.com

First Solar hires regional director for sub-Saharan Africa and MD of new South Africa operating subsidiary

First Solar Inc of Tempe, AZ, USA, which makes cadmium telluride (CdTe) thin-film photovoltaic (PV) modules, has appointed Johan Cilliers as regional director of business development for sub-Saharan Africa and managing director of its new South Africa operating subsidiary. Cilliers will be based in First Solar's new office in Cape Town and will report to Christopher Burghardt, VP of business development for Europe, Middle East and Africa (EMEA).

Cilliers has more than 25 years of energy industry experience in South Africa, and joins First Solar from Suzlon, where he was VP of sales & marketing in South Africa. Prior to Suzlon, he worked at General Electric, Siemens and Eskom in roles including market development, sales & marketing, project development, and financing.

"South Africa has great potential to be a sustainable market for solar energy, and Cilliers' quarter-

century of experience in the African energy industry and strong understanding of the Sub-Saharan Africa market will be invaluable as we work with our customers to help the region meet its energy and economic development needs," says Burghardt.

Cilliers earned a BS degree in chemistry from the University of Pretoria and a BS degree in energy from the University of Johannesburg.

www.firstsolar.com

First Solar partners with Zhenfa to supply 2MW of modules for thin-film PV demonstration project in China

First Solar has agreed that in first-quarter 2013 it will supply 2MW of modules to one of the approved solar projects of Beijing-based Zhenfa New Energy Science & Technology Co Ltd in Xinjiang province. The collaboration will create First Solar's first commercial demonstration project in China and provide a platform to showcase its photovoltaic (PV) technology.

"This agreement marks an important step forward in First Solar's efforts to support China's renewable energy goals," says Bruce Yung, managing director & VP of Business Development for First Solar in China. "This will be the first of many opportunities for collaboration between First Solar and leading Chinese companies, both within

China and globally," he expects.

Founded in 2004, Zhenfa New Energy is one of the largest providers of integrated PV power generation systems in China, with an installed capacity of 410MW by the end of 2011 and plans to increase to 1100MW by March 2013. In eastern China, the firm constructs fishing-solar complementing integrated power stations on coastal mud flats and fish ponds, and combines solar facilities with local agriculture; in western China, it helps to resolve desertification and increase incomes of local residents by developing PV power stations to gain both economic and social benefits. The self-adaptive single-axis solar tracking system, devel-

oped independently by Zhenfa, can increase the power generation system efficiency, the firm claims.

"By sharing experience, expertise and technologies we are creating a very strong combination. We look forward to exploring additional opportunities to work together to generate clean, renewable energy for China and the world," says chairman Zha Zhengfa.

"An important element of First Solar's business strategy is to work with Chinese partners to create shared value both in China and abroad," says Yung. "The agreement between First Solar and Zhenfa will serve as a positive example of win-win collaboration between leading renewable energy companies from China and the USA."

First Solar presents awards for outstanding supplier performance

First Solar has honoured its premier suppliers at a Supplier Recognition Day. About 160 of First Solar's top suppliers attended the event in Phoenix, where five were honoured with the firm's NOVA award for outstanding performance in 2012.

NOVA awards were presented to advanced materials supplier Morgan Crucible Company; Nippon Sheet Glass (NSG), one of the world's

largest glass companies; global logistics firm Expeditors International; Oryx Advanced Materials, a provider of thin-film deposition applications; and Rapid Manufacturing, a global manufacturer of custom cable/wire harnesses.

"Our suppliers play a critical role in fulfilling our mission to create enduring value by enabling a world powered by clean, affordable solar

electricity," says Shellie Molina, First Solar's vice president, Global Supply Chain. "We appreciate the exceptional efforts of these NOVA award recipients and the value they provide through the highest standards of quality, cost and performance."

First Solar estimates that its business supports about 33,000 supply chain jobs globally.

First Solar releases more efficient, 92.5Watt-rated FS Series 3 CdTe photovoltaic module

First Solar Inc of Tempe, AZ, USA — which manufactures thin-film photovoltaic modules based on cadmium telluride (CdTe) — has announced the release of its Series 3 FS-392 module, which is rated at 92.5 watts and maintains all the existing IEC (International Electrotechnical Commission) certifications and UL (Underwriters Laboratories) listings for the Series 3 family, including UL listing for 1000V systems.

"The FS-392 demonstrates the success of First Solar's R&D investment to drive higher and higher module conversion efficiencies into production," says Tom Kuster, VP of product management and system

technology. "This increase in module efficiency, coupled with our thin-film technology's real-world yield advantage when compared to crystalline silicon PV, results in higher energy density and lower levelized cost of energy (LCOE)," he adds.

First Solar says that one of the drivers of its modules' performance advantage over crystalline silicon solar modules is a lower temperature coefficient, delivering higher energy yields at elevated operating temperatures typical of utility-scale power plants in sunny regions.

www.firstsolar.com
/Innovation/Advanced-Thin-Film-Modules

Intermolecular and First Solar extend collaboration and licensing agreement

Intermolecular Inc of San Jose, CA, USA and First Solar Inc of Tempe, AZ, USA have entered into a two-year collaboration and licensing agreement focused on further increases to the conversion efficiency of First Solar's cadmium telluride (CdTe) solar cell technology.

Under the collaborative development program, First Solar and Intermolecular researchers will work together to develop disruptive new approaches to increasing the performance of CdTe solar cell technology using Intermolecular's proprietary High Productivity Combinatorial (HPC) platform. The program targets substantial gains in First Solar's module conversion efficiency beyond its previously announced roadmap.

"The combinatorial approach to material and process screening has shown promise to augment First Solar's already world-leading research and development capabilities in CdTe solar technology,

enabling better performance and faster time-to-market," says Raffi Garabedian First Solar's chief technology officer. "This program targets disruptive advances in our module performance which will be additive to our current roadmap... We are confident this effort will bear fruit in the coming years, combining with our other new R&D advances," he adds.

"Extending and expanding the collaboration with First Solar after working closely with them last year represents tremendous validation of our value proposition," says Sandeep Nijhawan, VP & general manager of Intermolecular's Clean Energy Group. "We look forward to be closely working with First Solar to further increase CdTe solar cell conversion-efficiency by leveraging our HPC platform and capabilities."

www.intermolecular.com
www.firstsolar.com

IN BRIEF

Module production costs to fall to \$0.48/W in 2017

The solar industry is reeling from overcapacity, and supply is outstripping demand by two to one, according to the report 'Module Cost Structure Update: Path to Profitability' from Lux Research. The industry needs to drive costs lower in order to overcome diminished subsidies and regain profitability, says the firm.

Module prices have fallen over the last four years to \$0.70/W, but the cost of goods sold (COGS) for modules has not reached this level, resulting in substantial losses for most module makers.

"With pressure from competitors, customers and policy-makers to drop prices even further, manufacturers need to drive costs down to survive and thrive during the coming years of growth in demand," says lead author Ed Cahill.

In a cost and sensitivity analysis (on the impacts of drivers like low-cost manufacturing locations, high efficiency, increased capacity utilization, and higher production yields on module COGS) Lux found that:

1. Copper indium gallium (di)selenide (CIGS) has the greatest potential to cut cost. Between 2012 and 2017, COGS will fall fastest for CIGS modules (down \$0.14/W to \$0.64/W).
2. Despite the woes of First Solar, cadmium telluride (CdTe) modules will remain the cheapest option in 2017, down from \$0.67/W now to \$0.48/W.
3. Efficiencies are the key driver. Manufacturing location has the greatest potential influence on COGS, but overcapacity makes opening new facilities in low-cost countries unlikely. Increasing module efficiencies will hence make the most difference, up to \$0.09/W for mc-Si and \$0.21/W for CIGS.

www.luxresearchinc.com

First Solar acquires project developer Solar Chile

Following a strategic working alliance formed in October 2011, First Solar Inc of Tempe, AZ, USA, which makes thin-film photovoltaic modules based on cadmium telluride (CdTe), has acquired Solar Chile, a Santiago-based solar development company in which Fundación Chile was an early investor. First Solar formed a strategic working alliance with Fundación Chile in October 2011.

Solar Chile has a portfolio of early-to mid-stage utility-scale photovoltaic (PV) power projects totaling about 1.5GW in Regions I, II, III and XV in northern Chile, including the Atacama Desert region, which offers the highest solar irradiance in the world.

"We have been very impressed by the quality of the Solar Chile team and the projects they are developing, and we believe that together we will bring even more value to the

Chilean market," says First Solar's CEO Jim Hughes. "Combining Solar Chile's market knowledge and promising project portfolio with First Solar's resources, technology and strong execution track record offers Chile a rapid and proven path to add significant solar generation capacity, helping to meet high energy demand and support economic growth."

"First Solar's acquisition of Solar Chile is a milestone of enormous significance to our country," says Fundación Chile's president Alvaro Fischer. "It highlights the tremendous potential that solar PV energy has to change the demography and the economy of northern Chile, opening it up to new opportunities beyond mining and fishing, into water desalinization, hydrogen production or large green data centers."

"Chile faces a growing energy

demand from its sustained economic growth," said Hernán Cheyre, executive VP of CORFO, the Chilean government's economic development agency. "Solar energy provides a sustainable and clean energy source that takes advantage of our outstanding clear skies and irradiance. The growth of the solar industry and the arrival of First Solar validates Chile's position as a regional hub for entrepreneurship and innovation."

Under the terms of the agreement, the five-person Solar Chile team is joining First Solar, and Fundación Chile will provide ongoing consultation services.

First Solar has a global development pipeline of projects under contract to utilities totaling 3GW, with 2GW under construction. It has constructed more than 600MW of PV power projects worldwide.

www.firstsolar.com

HILCOBID ONLINE AUCTION

TUES., FEB. 12TH THRU THURS, FEB. 14TH

Kodak

Online Bidding Begins:

Tues., Feb. 12th, 2013 at 8 AM EST

Online Bidding Ends:

Thurs., Feb. 14th, 2013 at Noon EST

Location

Rochester, NY

Preview Information

Preview by appointment only.

Please contact:

Chris Jock -

cjock@hilcobid.com

or 443-945-2315



Late Model Print Head and Ink Tank Pilot Production and R&D Assets in Clean Room Facility



- (2) Newport MRSI 175-AG Epoxy Dispensers, (2005)
- Newport MRSI 705 Dispenser and Die Bonder, (2011)
- PVA 350 Dispense System, (2011)
- Asymtek Automove Dispensing System
- XPO CT2-LZRZ Wafer Pick and Place, (2006)
- Leister Novolas WS CD Laser Welder, (2008)
- Keyence V9900 Class IV Laser Scribe, (2008)
- Sonitek S10 Thermal Presses, (2012)
- Sonitek TS500 Thermal Press, (2010)
- BTU TCA-183 5 Zone Reflow Oven, (2005)
- (3) Blue M SPX Thermal Convection Ovens, (2006)
- Shrink Sleever - Quadrel SL-100 Labeler & Conveyor with
- Benison ES-200 Heat Shrink Tunnel, (2011)
- (2) Branson Mini II Vibration Welders, (2006)
- Calvary Automation PO577 HiBar Filler Station, (2011)
- (2) Thermal Labelers w/ Domino Laser
- Thermotron SM16 Environmental Chamber, (2010)
- Inficon UL1000 Helium Leak Detector
- OGP Smartscope Quest 250 CMM
- (15) Mettler Toledo Balances
- Large Quantity of Electronic Test and Measurement and Lab Equipment
- Clean Room & Lab Furniture

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Empa raises efficiency record for flexible CIGS thin-film solar cells from 18.7% to 20.4%

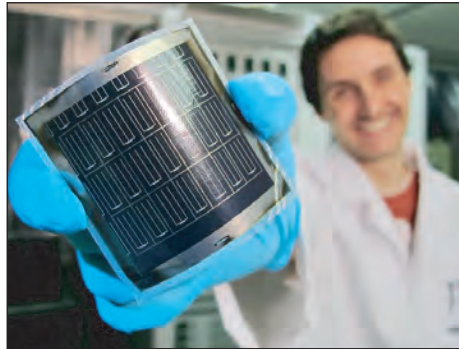
Exceeds record of 20.3% for CIGS cells on glass substrates and equals efficiencies for polycrystalline silicon cells

Led by Ayodhya N. Tiwari, a team of researchers in the Laboratory for Thin Film and Photovoltaics at Empa (the Swiss Federal Laboratories for Materials Science and Technology) has raised the energy conversion efficiency record for copper indium gallium (di)selenide (CIGS) thin-film photovoltaic solar cells on flexible polymer substrates to 20.4%, as independently certified by the Fraunhofer Institute for Solar Energy Systems (ISE) in Freiburg, Germany.

The lab has previously boosted the efficiency of flexible CIGS solar cells repeatedly, from 12.8% in 1999 (the team's first record) to 14.1% in 2005, then 17.6% in June 2010, and the team's existing record of 18.7% in May 2011.

Empa says that, to make solar electricity affordable on a large scale, scientists and engineers the worldwide have long been trying to develop a low-cost solar cell that is both highly efficient and easy to manufacture with high throughput. Tiwari's team has been investigating various thin-film solar cell technologies for some time.

The latest in the series of records has been achieved due partly to work by PhD students Adrian Chirila



Flexible CIGS solar cells on polyimide film developed at Empa.

and Fabian Pianezzi. The team has modified the properties of the CIGS layer (grown at low temperature) that absorbs light and contributes to the photo-current in solar cells.

Empa's new efficiency record for flexible solar cells now exceeds the record of 20.3% for CIGS solar cells on glass substrates. It also equals the highest efficiencies for polycrystalline silicon wafer-based solar cells. "We have now — finally — managed to close the 'efficiency gap' to solar cells based on polycrystalline silicon wafers or CIGS thin-film cells on glass," says Tiwari.

Empa says that thin-film, lightweight and flexible high-performance solar modules are attractive for many applications such as solar

farms, roofs and facades of buildings, automobiles and portable electronics, and can be produced using continuous roll-to-roll manufacturing processes that offer further cost reductions compared with standard silicon technologies (and hence they have the potential to enable low-cost solar electricity in the near future).

"The series of record efficiencies for flexible CIGS solar cells developed at Empa demonstrates that thin-film solar cells can match the excellent performance of polycrystalline silicon cells," says Empa's director Gian-Luca Bona. "Now it is time for the next step, the scale-up of the technology to cover large areas in a cost-efficient roll-to-roll manufacturing process with an industrial partner," he adds. For this purpose, Empa is collaborating with Flisom, a start-up company involved in the industrialization of flexible CIGS solar cells.

The research work has been supported over the years by the Swiss National Science Foundation (SNSF), the Commission for Technology and Innovation (CTI), the Swiss Federal Office of Energy (SFOE), and the EU Framework Programmes.

www.empa.ch

First Solar hires senior VP, project development

First Solar has appointed Tim Rebhorn as senior VP, project development. He reports to CEO Jim Hughes and will be responsible for global project development strategy and execution.

"Tim will play a crucial role in implementing First Solar's strategy to provide fully integrated photovoltaic power solutions in sustainable markets around the world," says Hughes. "He brings proven strengths in business development, mergers and

acquisitions, integration, value creation and strategy implementation."

Rebhorn has more than 30 years of experience in the power generation business as a senior executive in the gas, electricity, generation and distribution industry segments. Most recently, he was CEO of Quail Nuclear Specialty Services, an industrial construction firm supporting the nuclear power industry. Previously, he was managing director

of Resolutions Management, where he provided strategic support for clients in energy, steel, fuel cell, engineering and construction, petroleum and manufacturing industries. Earlier executive roles include Merrill International and Stewart & Stevenson. He began his career in the US Navy, where he served in the Naval Nuclear Propulsion Program and as a NATO Staff Planning Officer.

www.firstsolar.com

Global Solar implements cost cuts to preserve operations while acquisition offers and strategic options considered Workforce cut by 70%, focusing on roofing product line

Global Solar Energy Inc of Tucson, AZ, USA, which makes flexible copper indium gallium diselenide (CIGS) thin-film photovoltaic cells and modules, has implemented cost cuts as it continues to progress the previously announced sale process and to evaluate strategic options (as announced in June).

To "preserve operational and production flexibility", Global Solar

has reduced its workforce by about 70%, consisting primarily of staff dedicated to the firm's roofing product line. Key technical staff and management have been retained, as well as a production team focused on select customer orders.

"We continue to work toward a solution which will preserve Global Solar's industry-leading CIGS technology and production

capabilities," says the firm's CEO Dr Jeffrey Britt. "We have had a very strong level of investor interest, which has been predicated on Global Solar's high-quality products and technological strength," he adds.

Inquiries about the sales process should be directed to Chris LeWand (chris.lewand@fticonsulting.com) of FTI Capital Advisors LLC (FTICA).

www.globalsolar.com

Hanergy completes acquisition of MiaSolé

Beijing-based Hanergy Holding Group Ltd (claimed to be China's largest privately owned renewable energy firm) has finalized its acquisition of MiaSolé of Santa Clara, CA, USA, which was founded in 2001 to make copper indium gallium diselenide (CIGS) thin-film photovoltaic (PV) solar panels.

The strategic partnership follows a 9-month search by MiaSolé, which has already attracted over \$550m from investors including KPCB and Vantage Point. The acquisition also follows Hanergy's purchase last June from Q.Cells SE of Bitterfeld-Wolfen, Germany of its thin-film subsidiary Solibro GmbH, which produces CIGS PV modules under the brand name Q.SMART.

Hanergy's latest acquisition should boost MiaSolé's operations. Hanergy plans to ramp up MiaSolé's factory to full capacity. The plant's 100-plus staff in engineering, technology and manufacturing will be preserved and Hanergy expects to hire extra staff. It says it will also make sustained investment in MiaSolé's R&D.

The deal has regulatory approval from both the Committee on Foreign Investment in the United States (CFIUS) and Chinese authorities.

"Hanergy is committed to developing thin-film PV technology, providing turn-key solutions, and developing solar plants. The future of solar energy is thin-film technology," says

Hanergy's chairman Li Hejun. "This acquisition allows us to add a highly efficient flexible product to our portfolio. Hanergy's vision to lead CIGS technology globally, and its combined strength with Solibro and MiaSolé, now make for a diversified and compelling product, which will be offered to a global customer base," he adds.

"MiaSolé has advanced solar technology by developing the highest-efficiency and lowest-cost CIGS modules, but we needed to align with a strategic partner in order to deploy our technology across a larger global scale," says MiaSolé's CEO John Carrington. "I greatly appreciate and identify with Hanergy's unique business model, its focus on and belief in thin-film solar technology, and its vision of providing clean-energy solutions to the world," he adds. "Hanergy will secure our CIGS technology, which boasts the world's highest conversion efficiency, to complement its existing technologies and promote the company's leap-forward development in its global technological integration. MiaSolé will enjoy a fully optimized capital structure, enabling us to focus on R&D and capacity breakthroughs, and become more competitive by riding on Hanergy's global advantages."

Hanergy says that it previously decided to invest in the CIGS co-evaporation technology that

Solibro has developed over the last 25 years. After completion of the acquisition, Solibro will ramp up to annual production capacity of 100MW in Thalheim to supply Hanergy's European customers. Now, although MiaSolé's CIGS follows a different technological line, the two can share patents and thus improve conversion efficiency. MiaSolé has achieved record flexible PV efficiency of 15.5%. It is expected that CIGS efficiency will rise further to above 17% within 24 months, and that production cost will drop below \$0.50 per Watt within 24 months.

Established in 1994, Hanergy's thin-film PV production capacity has now achieved 3GW in total. The firm now has more than 8000 staff. The firm says that thin-film solar cells have the exclusive advantages of low material consumption, low energy consumption, and zero pollution. Thin-film solar cells can also be made on flexible substrates to form lightweight and flexible PV modules. Such flexible PV modules are easy to install, the firm adds, because no supporting holders are needed. They are hence greatly beneficial for application to non-bearing or limited-bearing roofs. Hanergy says it will therefore continue to focus on thin-film technology.

www.hanergy.com

www.MiaSole.com

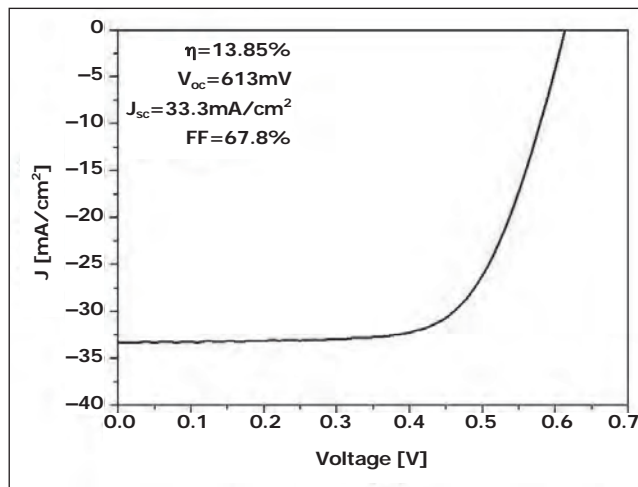
First PV cells from Solliance's CIGS facility yield 13.85% efficiency

TNO and Imec collaborating on boosting efficiency while establishing reference pre-pilotline process flow

At the new copper indium gallium (di)selenide (CIGS) facility of the Solliance collaboration platform in Eindhoven, The Netherlands, the first CIGS solar cells have been fabricated, demonstrating solar energy conversion efficiency of 13.85%. The result is expected to be the starting point for further improvements in the cell's efficiency, large-area uniformity and run-to-run variability. The facility will also be used for advancing Solliance's alternative thin-film photovoltaic (TF-PV) activities.

The alliance partners involved in Solliance include ECN (the energy research institute of The Netherlands), TNO (the Netherlands Organization for Applied Scientific Research in Delft), the Holst Center in Eindhoven (a joint research initiative of Imec and TNO), TU/e (Eindhoven University of Technology) and nanoelectronics research institute Imec of Leuven, Belgium. Solliance is supported by the Dutch province of North Brabant, which dedicated €28m to fund a large shared laboratory in Eindhoven (complementing the partner's labs, which are also available to the other partners).

Solliance works in cooperation with industry, both to fulfill its short-term needs and on mid- and long-term research programs. It focuses on three main thin-film technologies: thin-film silicon, copper indium gallium diselenide (CIGS), and organic photovoltaics (OPV). For these principal themes, Solliance is collaborating with industry at its facilities in Eindhoven as well as at Imec's facilities in Leuven. Solliance also concentrates on generic technologies vital to the thin-film PV industry, including testing, characterization and monitoring, laser technologies,



CIGS solar cell with 13.85% efficiency, fabricated in Solliance's new CIGS facility.

transparent conductive layers, monolithic interconnection, thin-film deposition techniques, roll-to-roll processing, and in-line monitoring.

Solliance's aim is to strengthen the position of the Eindhoven–Leuven–Aachen triangle (the ELAT region) as a world player in thin-film PV by joint use of infrastructure, alignment of research programs, and close cooperation with the solar TF-PV business community.

In September, the last tool of the CIGS solar base-line facility was installed and accepted at TNO in Eindhoven. A reference process flow has since developed, resulting in the first CIGS TF-PV cells fully made with the facility's equipment. The highest efficiency obtained by the first full run was 13.85%. This is similar to industrial CIGS modules (with an efficiency of 13–14%), but still below the laboratory record of 20.3% on a CIGS solar cell reported in August 2010 by Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg (Centre for Solar Energy and Hydrogen Research,

ZSW) in Stuttgart, Germany. Based on Solliance's result, further improvements in cell efficiencies are expected in the coming months through intensified collaboration between TNO and Imec in the CIGS facility.

The facility's main focus will be on improving the large-area uniformity and reducing the run-to-run variability of CIGS solar cell manufacturing. The stable and reproducible

reference process flow to be obtained will then serve as a baseline for developing improved cell concepts and for innovating process equipment for individual process steps. The facility possesses all the processing tools for a full CIGS solar cell flow on substrates up to 30cm x 30cm, and will be used as a pre-pilotline for testing cell and process equipment concepts.

Solliance's CIGS facility will also be used for the alternative TF-PV activities of Solliance, aiming to improve the solar cell efficiency of emerging copper zinc tin sulfide (CZTS) absorber TF-PV materials. This new absorber is expected to solve the availability problem of the In and Ga material of the CIGS absorber when these are used in high-volume manufacturing. The new CZTS absorber material consists of only Earth-abundant elements such as Cu, Zn, Sn, Se and S. Imec's thin-film solar cell activities, focusing on CZTS and organic PV, are integrated into the Solliance collaboration platform.

www.imec.be
www.solliance.eu

Solar Frontier achieves record 19.7% efficiency for CIS PV cell using sputtering and selenization

0.5cm² cell cut from 30cm x 30cm substrate; optimization targets 20.3% co-evaporation record

In joint research with Japan's New Energy and Industrial Technology Development Organization (NEDO), Tokyo-based Solar Frontier — the largest manufacturer of CIS (copper indium selenium) thin-film photovoltaic (PV) modules — has achieved record efficiency of 19.7% for cadmium-free, thin-film solar cells measuring about 0.5cm², as measured by the National Institute of Advanced Industrial Science and Technology (AIST). It has been ten years since the previous record of 18.6% was achieved in 2012 (by the CIS-21 collaboration).

The record was achieved using cells cut from a 30cm x 30cm substrate, rather than specifically developed small-area cells, demonstrating high potential for further increases, it is reckoned. Moreover, it used the same fabrication method to achieve the result as that used for mass-production: a process of sputtering followed by selenization.



Solar Frontier's CIS cells.

Solar Frontier has chosen this method over co-evaporation due to the greater efficiencies in mass production. The firm aims to surpass the existing energy conversion efficiency record of 20.3% set using the co-evaporation method.

"This new achievement in energy conversion efficiency indicates the high level of Solar Frontier's technology and the high potential of CIS technology," says Satoru Kuriyagawa, chief technology officer, Solar Frontier. "The CIS thin-film modules currently available from Solar Frontier have gained a reputation for high perform-

ance in actual power generation, as they are not easily affected by shadows or high temperatures. Now, even higher real-world performance can be expected by applying this new basic technology," he adds. "We will continue working to further enhance our technological capabilities with the aim of setting a world record for thin-film solar cells overall."

Solar Frontier's CIS modules are manufactured at its Kunitomi Plant in Miyazaki prefecture in southwestern Japan. Since the plant started commercial production in February 2011, it has steadily increased its production efficiency. Currently, the CIS modules produced there have a conversion efficiency that exceeds 13%, and the amount of electricity generated (kWh) per installed capacity (kW) exceeds that of other solar modules, it is claimed.

www.solar-frontier.com

Pioneer PV Solutions launches operations to provide off-the-shelf, compact microsolar solutions

Pioneer PV Solutions of the Los Angeles, CA, USA, a thin-film copper indium gallium (di)selenide (CIGS) microsolar company, has officially launched its operations. The firm aims to provide off-the-shelf compact solutions for rechargeable and DC power applications to an "under-served, multibillion dollar market segment" suffering from what is described as an inconsistent solar product supply chain.

"There is no question that the efficiency, durability, and quality of 'big solar' technologies has vastly improved over the past 20 years," says Vincent Kapur, VP of business development. "Yet off-the-shelf 'small solar' solutions are not ade-

quately matched to the needs of the wide variety of microsolar applications. They are often the result of a 'scrapyard legacy', where castoff crystalline-silicon cells are broken up and manually assembled into sub-optimal mini-modules, with little attention paid to quality control, reliability, and performance," he adds. "The economics of force-feeding the leftovers of traditional big solar technologies into small solar applications doesn't make sense anymore."

One of the largest emerging markets for microsolar-scale panels is lighting in the developing world, where some 1.4 billion people have extremely limited or nonexistent access to the electrical grid and in

many cases rely on inefficient and polluting kerosene lamps — or nothing at all, says the firm. A recent International Finance Corp study on solar off-grid lighting in seven Asian countries identified a potential market of 75 million households, which currently spend about \$2.2bn on kerosene annually, in India alone.

Pioneer PV is engaged with a number of OEM integrators on high-end, low-cost solar charging solutions for their product lines. It continues to pursue additional strategic funding to expand its market development efforts and finance the build-out of a dedicated thin-film microsolar production line.

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Dry etching of InP-based materials using a high-density ICP plasma system

Ligang Deng of Oxford Instruments Plasma Technology outlines how inductively coupled plasma technology can provide fast, accurate, low-damage etching of indium phosphide materials.

Dry etching is now widely used in the fabrication of optoelectronic and electronic devices involving III-V materials, due to the need for careful control of the critical dimensions of components. Fast etch rates, repeatability, uniformity, clean chemistries, vertical profile and low device damage are some of the most desirable aspects of the etching processes. Inductively coupled plasma (ICP) etching is ideally suited to these requirements, since it provides high ion densities and hence fast etch rates, while allowing separate control of ion density and ion energy (giving a low damage capability).

To meet these demands, Oxford Instruments Plasma Technology (OIPT) has developed a wide range of ICP etch processes for III-V semiconductors. This article focuses on etching processes for InP and related materials, discussing various etching chemistries and system requirements for different applications and providing an update of the latest new process developing results.

1. The ICP tool

The system used for these processes is Oxford Instruments Plasma Technology's PlasmaPro 100 ICP etcher (OIPT CS1 hardware). A schematic of the etch chamber is given in Figure 1 and the full system is shown in Figure 2.

RF power (13.56MHz) is applied to both the ICP source (up to 3000 Watts) and substrate electrode (up to 600 Watts) to generate the etch plasma. An electrostatic shield around the ICP tube is used to ensure that the ICP power is purely inductively coupled (i.e. 'true-ICP'), hence eliminating sputtering of tube material and minimizing unnecessary high-energy ion damage to devices. Ion energy at the substrate

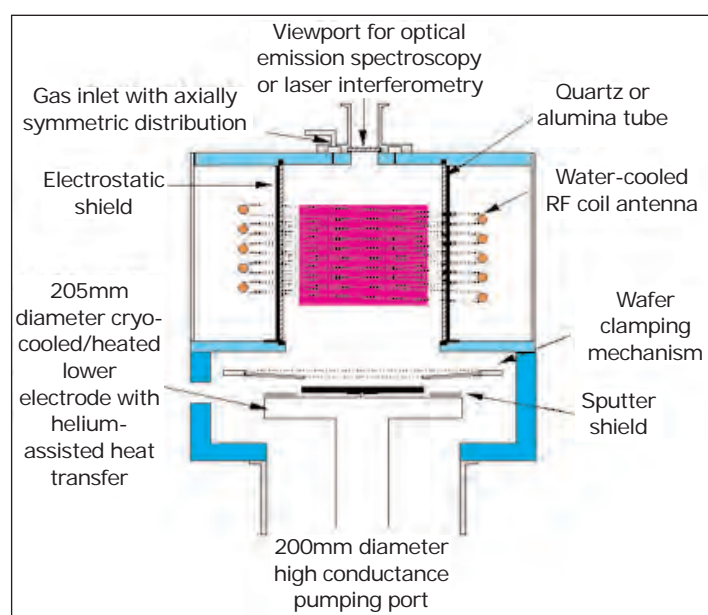


Figure 1. Schematic of PlasmaPro 100 ICP180.

is monitored by measurement of the DC bias generated on the lower electrode, and is controlled mainly by the RF power supplied to this electrode.

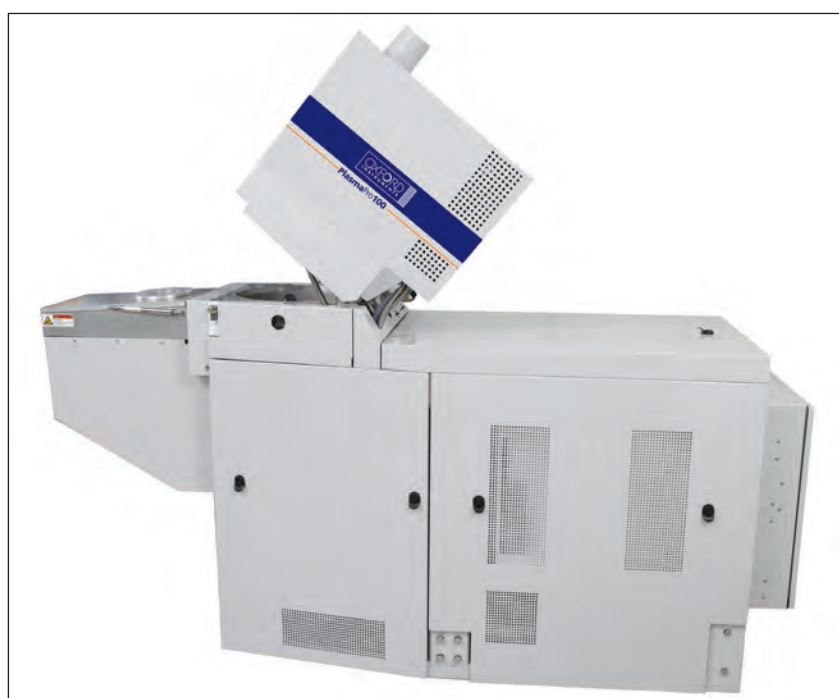


Figure 2. PlasmaPro 100 ICP180.

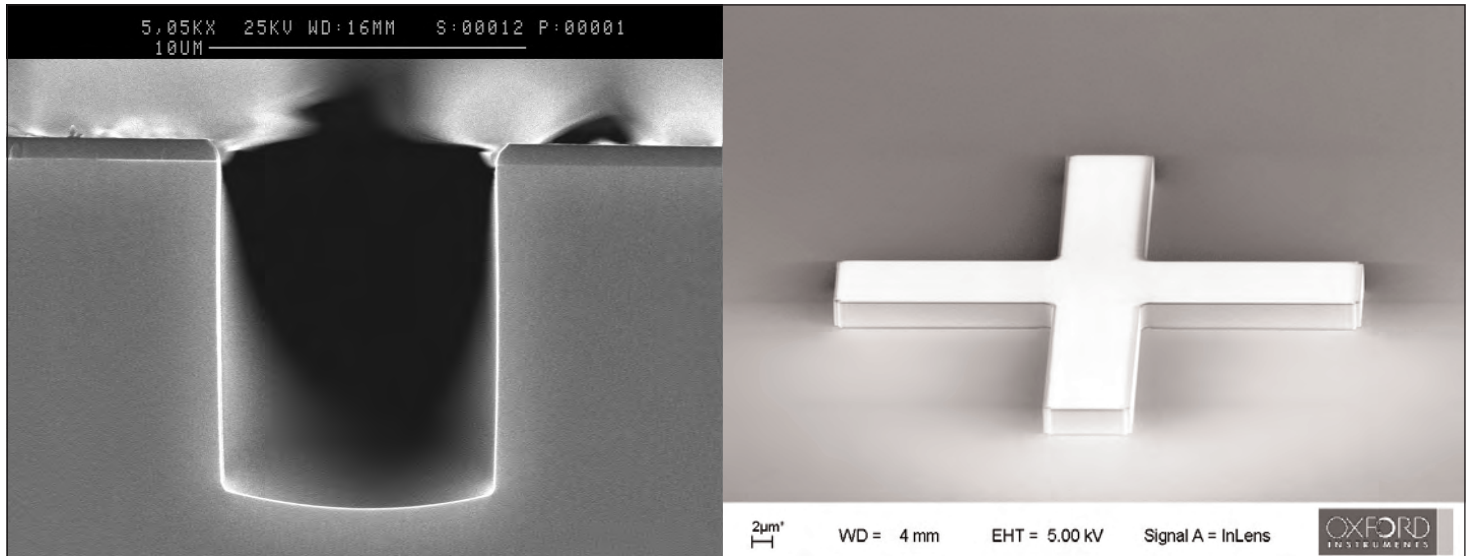


Figure 3. InP-based material etched using $\text{CH}_4/\text{H}_2/\text{Cl}_2$ process. Etch rates of $>1.5\mu\text{m}/\text{min}$ and selectivity of $>15:1$ is achieved.

Wafers are loaded into the chamber via a load lock to maintain good stability of chamber vacuum and hence repeatability of etching results.

The wafers being etched are either mechanically or electrostatically clamped to the temperature-controlled lower electrode. Helium is applied to the back of the wafers to provide good thermal conductance between the chuck and the wafer.

Through the use of electrical heater elements and a coolant circulating circuit, the PlasmaPro 100 ICP has control of substrate table temperature to an accuracy of $\pm 1^\circ\text{C}$ over a temperature range of -5°C to $+400^\circ\text{C}$. Substrate temperature has a marked effect on the etch result, as it controls the volatility of the etch species and hence influences the chemical component of the process, affecting not only etch rate, selectivity and profile but also surface roughness. The system can be operated over a pressure range from 1mT to 100mT, allowing accurate control process chamber pressure.

2. InP-based material etching

2.1 High-rate etching of waveguide and mirror facet

For high-rate etching of mirror facets and waveguides, the key requirements are fast etch rates to depths of up to $10\mu\text{m}$ and $5\mu\text{m}$ respectively, controllable etch depth, highly anisotropic profile, no notching at buried layers of InGaAsP (or similar), and smooth sidewalls and etched surface.

$\text{CH}_4/\text{H}_2/\text{Cl}_2$ chemistry is the most effective process for this kind of application. If the temperature of the wafer is allowed to increase to near 200°C , then the etch rate of the commonly

used CH_4/H_2 process increases. However, profile control becomes difficult due to increased undercutting. Addition of Cl_2 to this mixture allows highly anisotropic etch profiles, due to the low volatility of InCl_x . This therefore allows accurate profile control through adjustment of the CH_4/Cl_2 ratio. Etch rates of $>1.5\mu\text{m}/\text{min}$ and selectivity of $>15:1$ to SiO_2 or SiN_x masks can be achieved. Figure 3 shows a $10\mu\text{m}$ -deep mirror facet etched using this chemistry.

This chemistry has the advantage that it etches a wide range of materials, i.e. those containing In, P, Ga, As, Al, Sb etc, with low selectivity ($\sim 0.5\text{--}1:1$) between each other, hence etched profiles have no notching at interfaces between materials. It also produces less polymer contamination than the CH_4/H_2 chemistry due to the lower CH_4 content of this process and much faster etch rate. There is no additional wafer heating required, as the InP-based wafer is heated solely by the high-density plasma itself. With accurate control of the plasma parameters, process repeatability is better than $\pm 3\%$, and no wafer clamping is required.

This technique enables batch processing for high-throughput production applications (e.g. $4\times 2''$ wafers loaded per run), since the wafers can simply rest on a carrier plate and do not need to be individually clamped and helium cooled. Another variant of this process is the $\text{CH}_4/\text{Ar}/\text{Cl}_2$ chemistry, which has also

Table 1. $\text{CH}_4/\text{H}_2/\text{Cl}_2$ process performance summary.

	Etch rate (nm/min)	Selectivity to SiO_2	Etched profile	Etched surface and sidewall	Uniformity
Single 2" wafer	1500	15:1	$90^\circ \pm 1$	smooth	$< \pm 2.5\%$
Single 4" wafer	500	8	$90^\circ \pm 1$	smooth	$< \pm 4.0\%$
Batch $4\times 2''$ wafers	500	8	$90^\circ \pm 1$	smooth	$< \pm 5.0\%$

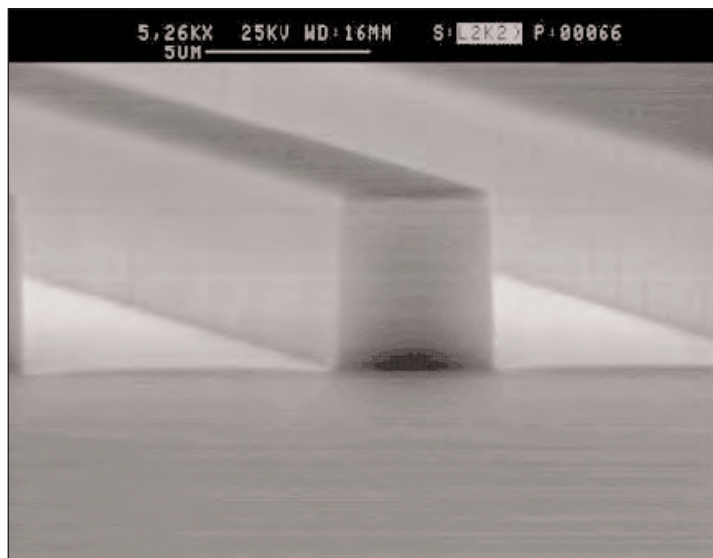


Figure 4. Cl_2/N_2 etched waveguide.

been shown to produce excellent etch results using this etch equipment.

However, often the demands of production dictate that the chamber must stay as clean as possible, ideally with no polymer deposition, even at the expense of the etch anisotropy and sidewall smoothness if necessary. This requires that the process does not contain CH_4 . A common approach is to use a Cl_2 -based etch chemistry with a heated electrode ($\geq 150^\circ\text{C}$, in order to effectively remove the InCl_x etch product from the wafer surface). Accurate wafer temperature control is recommended for this process. If the sample temperature rises excessively, the InCl_x evaporates from the surface easily and hence produces undercutting. On the other hand, at too low a temperature, InCl_x is non-volatile, resulting in slow etch rates, low selectivity and surface roughness. Often N_2 is added to increase the physical component of the etching and to passivate the surface, hence reducing surface roughness and improving profile control. Using this process, etch rates

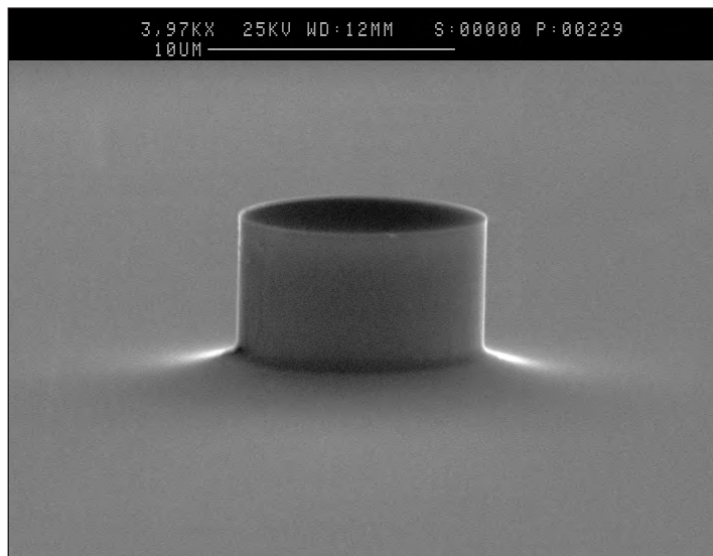


Figure 6. InP etches using photoresists as a mask.

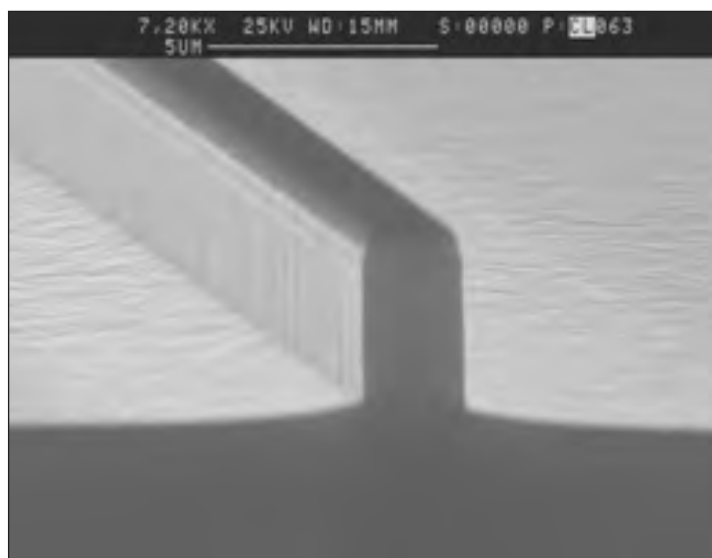


Figure 5. HBr waveguide etch.

of $>1\mu\text{m}/\text{min}$ and selectivity to SiO_2 of $>10:1$ have been achieved. Figure 4 shows a typical $5\mu\text{m}$ -deep etch result. This is a H^+ -free process, which may create less damage to the device, as H^+ often forms a passivation layer under the etched surface that may affect device performance.

The $\text{CH}_4/\text{H}_2/\text{Cl}_2$ and Cl_2/N_2 processes listed above can also be used to create device mesas, with either vertical or sloped profiles achieved by suitably adjusting process parameters.

An alternative technique that allows processing at

The HBr process can also etch InP with photoresist as a mask, since it requires lower temperature compared to Cl_2 chemistry

lower temperatures of $\sim 100\text{--}150^\circ\text{C}$ involves the use of HBr chemistry, since the etch product of InBr_x becomes volatile at a lower temperature than InCl_x . Figure 5

shows a typical $5\mu\text{m}$ -deep etch result at an etch rate of $0.8\mu\text{m}/\text{min}$ and a selectivity of $>10:1$ to SiO_2 . Again, good temperature control is recommended due to the sensitivity of etch results to wafer temperature.

The HBr process can also etch InP with photoresist (PR) as a mask, as shown in Figure 6, since it requires lower temperature compared to Cl_2 chemistry. Typically an etch rate of $>1\mu\text{m}/\text{min}$ and a selectivity of $14:1$ are achieved. This process required hard baking of the photoresist mask before etching in order to reduce photoresist burning. Advantages of this process include potential elimination of the use of hard masks and significantly reduced process complexity and cost.

A Cl_2/H_2 process has been developed recently. In this process, the lower electrode is set at room temperature. The wafer is placed on top of a carrier wafer without additional thermal contact, or wafer clamping. The etch mechanism is similar to that of the $\text{CH}_4/\text{H}_2/\text{Cl}_2$

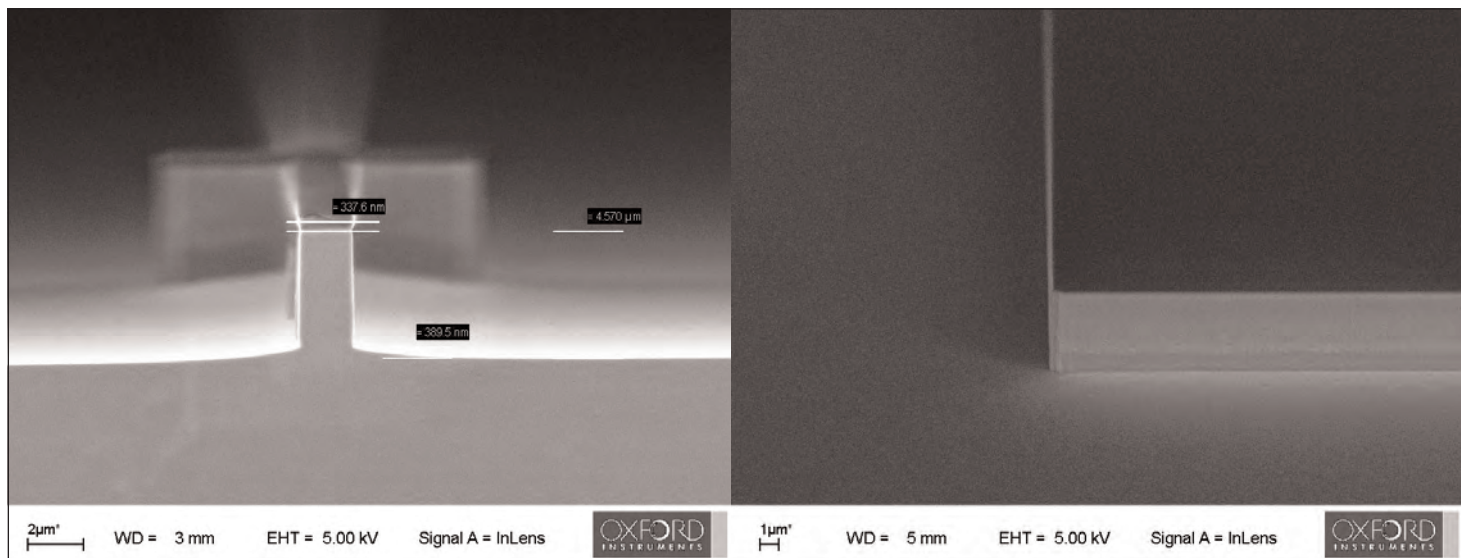


Figure 7. InP/InGaAs sample etched using Cl_2/H_2 process at room temperature.

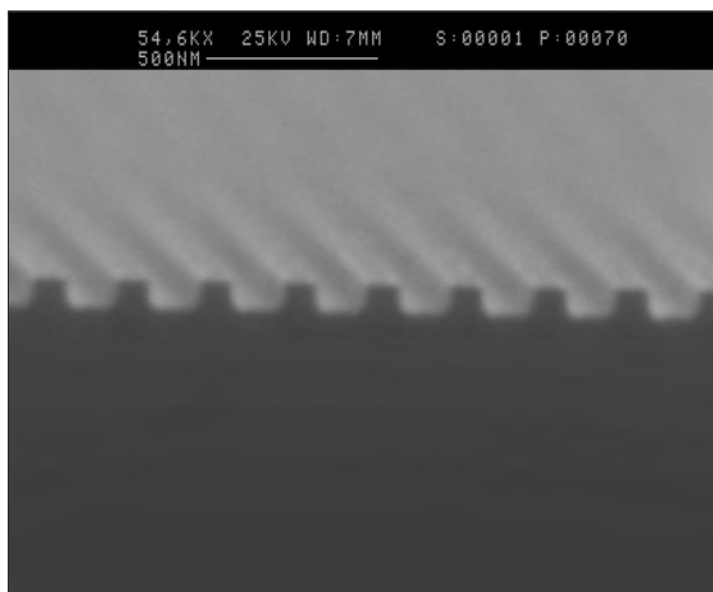


Figure 8 CH_4/H_2 grating etch.

process — the wafer is heated by the plasma itself. The advantage of this process is the absence of CH_4 , therefore no polymer deposits in the chamber. It is a clean and also environmental friendly process. In this process, the gas ratio of Cl_2/H_2 is very important. High gas ratio leads to a high etch rate but also gives an undercut etching profile. Figure 7 shows the results of Cl_2/H_2 etch in ICP mode. The etch rate is 850nm/min with selectivity to nitride mask of > 10:1.

2.2 InP grating etching or shallow etching

Although the CH_4/H_2 InP etching process can be replaced by faster, cleaner etch chemistries in ICP mode for the majority of applications, it is still widely used for InP DFB (distributed feedback laser) grating etching, due to the requirements of shallow and accurately controlled etch depth (typically < 200nm). Also, the frequent use of photoresist masks (often delicate e-beam resists) for grating definition requires room-temperature etching. In an ICP tool this process

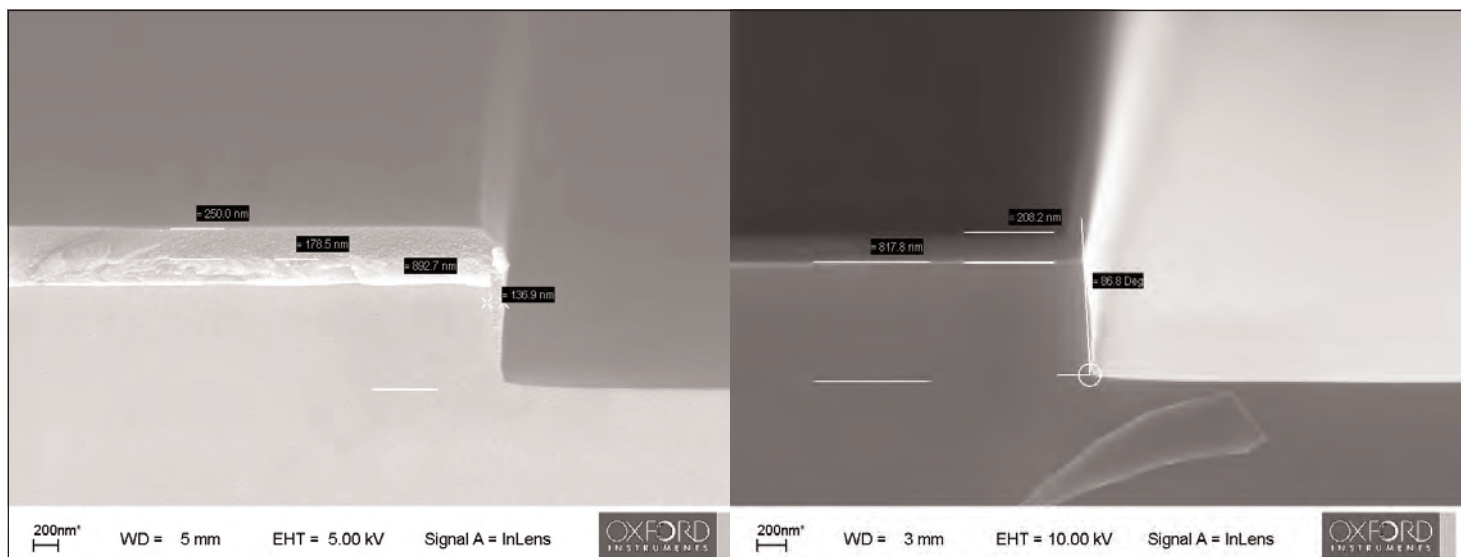


Figure 9. Shallow InP etch using CH_4/H_2 in RIE mode process: (a) single-step process showing some polymer deposit on etched top surface and sidewall; (b) two-step process, no more polymer residual on etched surface.

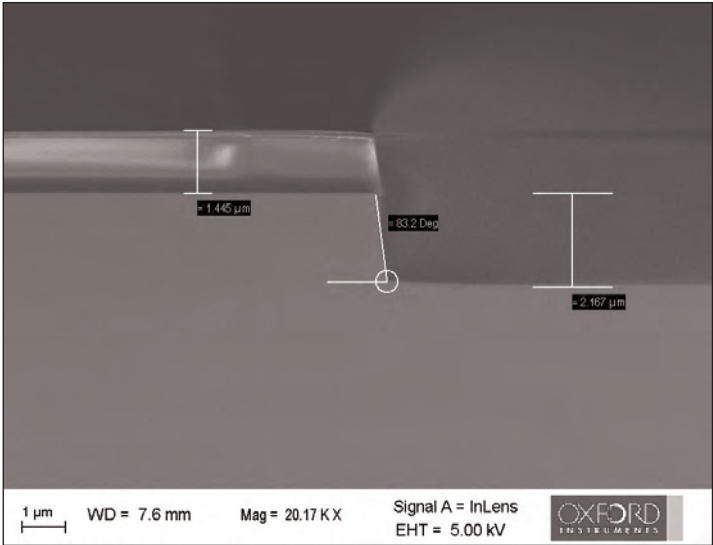


Figure 10: Single 3" wafer shallow InP etch using CH₄/H₂ in ICP mode process, photoresist as a mask.

is typically performed with no ICP power (i.e. only lower electrode power is applied), enabling a slow ‘RIE mode’ of etching. Figure 8 shows the result of a RIE-mode grating etch in an ICP tool to a depth of 100nm at an etch rate of 20nm/min.

CH₄/H₂ process in RIE mode is used for shallow InP etch (etched depth less than 1000nm). Since it is a room-temperature process, photoresist can be used as mask. However, CH₄/H₂ forms a large amount of polymer in the chamber and also forms a deposit at the etched top surface and sidewall. Often a short O₂ clean step is added into the process

following the etching in order to remove the residual polymer. Figure 9 shows the result of a RIE-mode shallow InP etch to a depth of less than 1000nm at an etch rate of 20~40nm/min.

Due to the slow etch rate, the throughput is low in the RIE-mode process. Therefore, sometimes CH₄/H₂ etching in ICP mode is required in order to increase etch rate.

Typically, using this type of chemistry to etch a single 3" wafer achieves an etch rate of 100nm/min, a selectivity to PR mask of >10:1, and a uniformity of ±3% with a profile >80°, as shown in Figure 10.

Working with Fraunhofer Heinrich Hertz Institute (FhG HHI) we have developed a batch process for three 3" wafers on a ICP380 tool. This process gives an etch rate of 100nm/min, a selectivity to PR mask of >10:1, and a uniformity of ±3% across wafer with a profile >80°, as shown in Figure 11 (profiles are taken at the centre and edge of the wafer/carrier).

As can be seen, there is excellent process uniformity and etch rate over the three wafers using this CH₄/H₂-based process chemistry. With an etch rate in the range of 100nm/min (10 times slower compared with chlorine-containing processes), it can be used for applications where accurate control of the etched depth is required while maintaining a reasonably short processing time.

Table2. CH ₄ /H ₂ process performance summary.					
	Batch size	Etch rate (nm/min)	Selectivity to photo-resist	Etched profile	Uniformity (cross-wafer or batch)
ICP CH ₄ /H ₂	1x 2"	125	>10:1	>80°	<±3%
	1x 3"	110	>10:1	>80°	<±3%
	3x3"	100	>10:1	>80°	<±5%
RIE CH ₄ /H ₂	1x2"	20	>10:1	>80°	<±2%
	1x3"	15	>10:1	>80°	<±3%
	3x3"	12	>10:1	>80°	<±4%

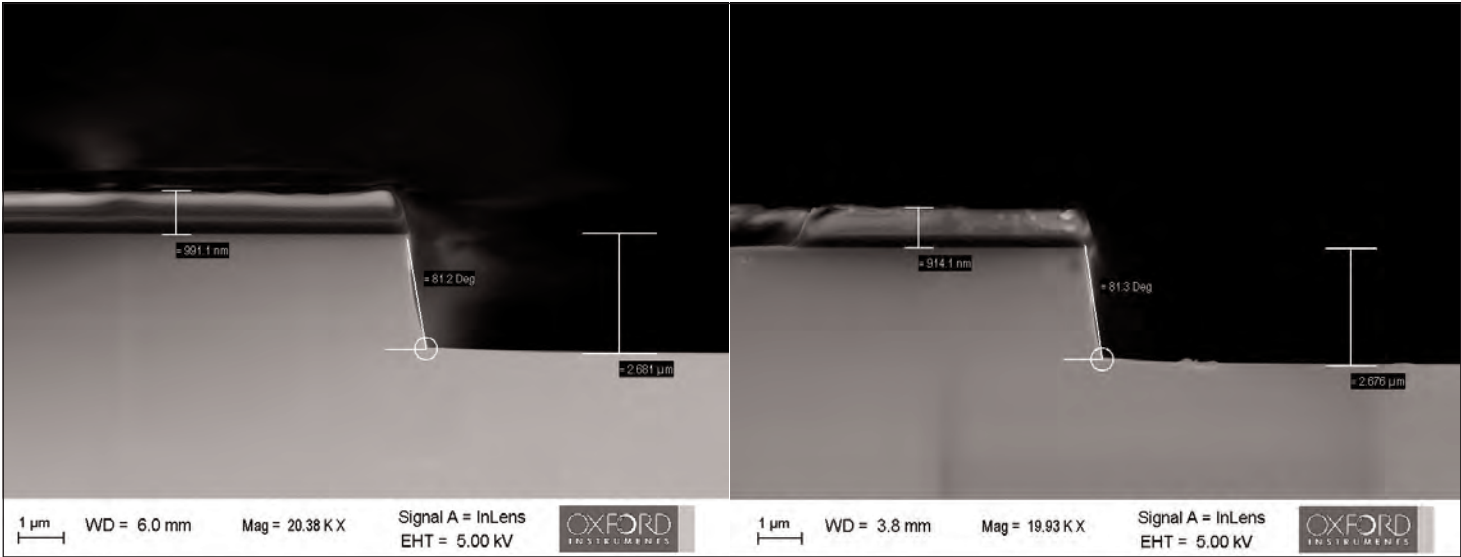


Figure 11 Batch 3x3"-wafer shallow InP etch using CH₄/H₂ in an ICP-mode process, with photoresist as a mask (with kind permission of FGH HHI.)

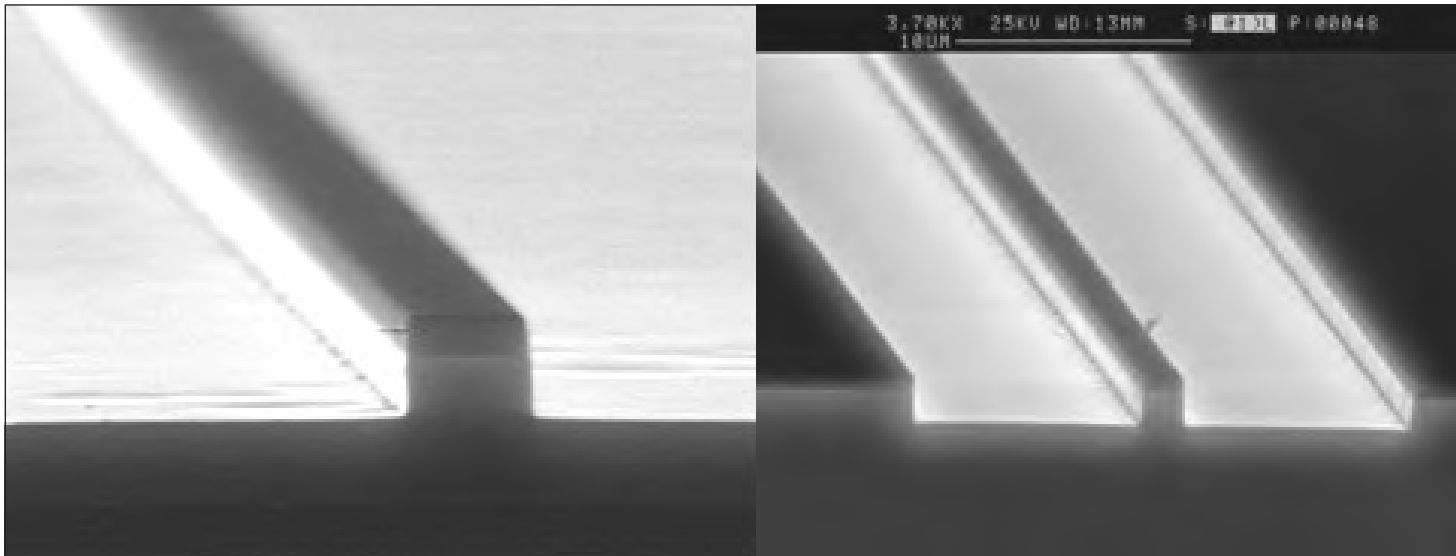


Figure 12. Controllable etch rate for shallow etching.

The results for CH_4/H_2 processes in both RIE and ICP modes are listed in Table 2.

$\text{CH}_4/\text{H}_2/\text{Cl}_2$, Cl_2/N_2 and HBr in ICP-mode processes can also be used for shallow etch. If the sample is pre-heated to above 150°C by the lower electrode, it has been shown that it is possible to reduce the etch rate

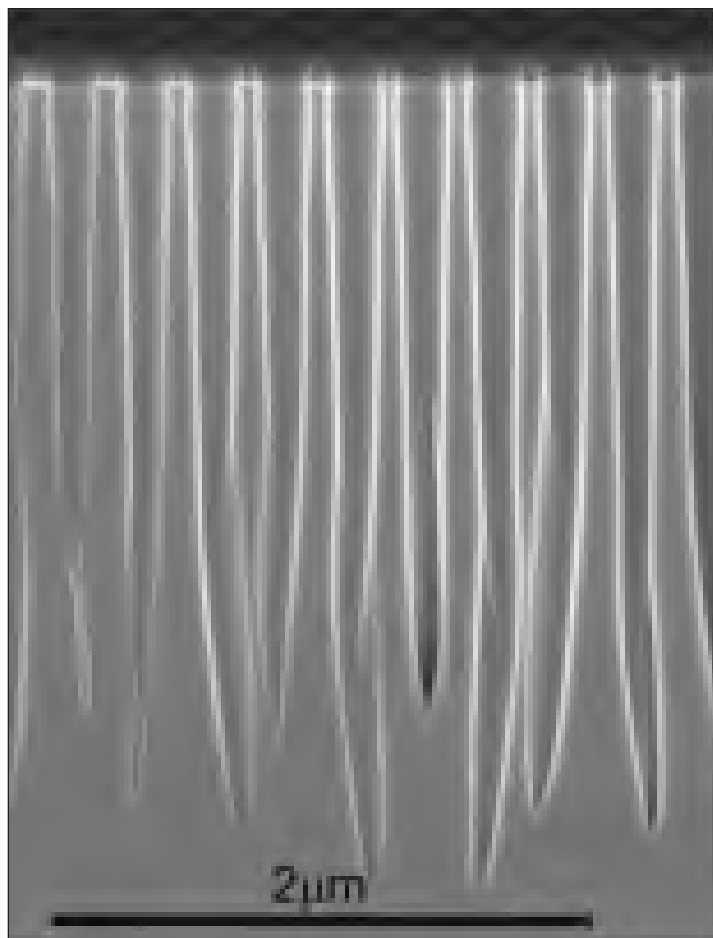


Figure 13. PhC etched in InP. The holes have a diameter of 180nm, and the etched depth is 2.9μm (with kind permission of P Strasser etc, Communication Photonics Group, ETH Zurich).

from $>1\mu\text{m}/\text{min}$ to $0.2\mu\text{m}/\text{min}$ by choosing low ICP power. A typical etched profile is shown in Figure 12.

2.3 InP photonic crystal (PhC) etching

The etching of an InP photonic crystal waveguide structure is very challenging, since it requires a high aspect ratio with feature sizes of less than $0.5\mu\text{m}$. The most common structure is two-dimensional arrays of holes.

All InP etch processes mentioned above can be employed to etch PhC. P Strasser from ZTH Zurich developed an etching process using the ICP180 tool. The conclusion from his work is that $\text{Cl}_2/\text{N}_2/\text{Ar}$ is the best chemistry for PhC etch. This is a polymer-free process, and can also provide a square foot. The wafer temperature is set at above 200°C . Cl_2 is the etch gas, Ar is used as a dilute gas, and N_2 gives passivation at the sidewall. An aspect ratio of $>15:1$ was achieved. Figure 12 shows an etched depth of $2.9\mu\text{m}$, and an etch rate of $1.75\mu\text{m}/\text{min}$ achieved for 190nm diameter holes, which gives an aspect ratio of $\sim 16:1$. The small sample pieces have to be glued on to the carrier plate and backside helium cooling is required.

3. Summary

InP-based material etching is a vital technology for the fabrication of optoelectronic and electronic devices. OIPT's PlasmaPro 100 ICP etcher (OIPT CS1 hardware) provides a wide range of III-V material etching solutions. Highly vertical (or controlled slope) etched profiles, smooth sidewalls, with good selectivity to oxide, nitride or a PR mask, as well as a controllable etch rate, can be achieved. ■

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Bifunctional quantum cascade laser/detector

Vienna University of Technology has used a narrow InGaAs well to align the emission and detection wavelengths of a quantum cascade structure.

Vienna University of Technology has developed a quantum cascade device that can act as both laser and detector over the same wavelength range [Benedikt Schwarz et al, Appl. Phys. Lett., vol101, p191109, 2012].

Quantum cascade (QC) structures consist of a large number of semiconductor layers that present a series of steps as electrons proceed through the device. Transitions between the energy levels of the steps can be arranged to emit coherent photons, if the laser condition of population inversion can be produced through a lower level that is very rapidly emptied.

The first quantum cascade laser (QCL) was reported in 1994. More recently, QC structures have been produced that reverse the process by detecting electromagnetic radiation.

QCLs have potential application for spectroscopy of biological and chemical sensing in gas- and liquid-phases. By combining with detector capabilities, it is hoped to develop more compact monolithic systems for mobile chemical fingerprinting. One further attraction of QC detectors (QCDs) is that they are operated at zero-bias, avoiding problems due to dark current. QCDs can also perform better than quantum well infrared photodetectors (QWIPs) at higher temperatures.

In principle, it would seem simple to combine the two functions of light emission and detection. There is a catch, however. The laser transition is usually between two excited levels, with the lower level having a fast non-electromagnetic transition to the ground state to give population inversion. By contrast, detection is achieved through excitation from the ground state.

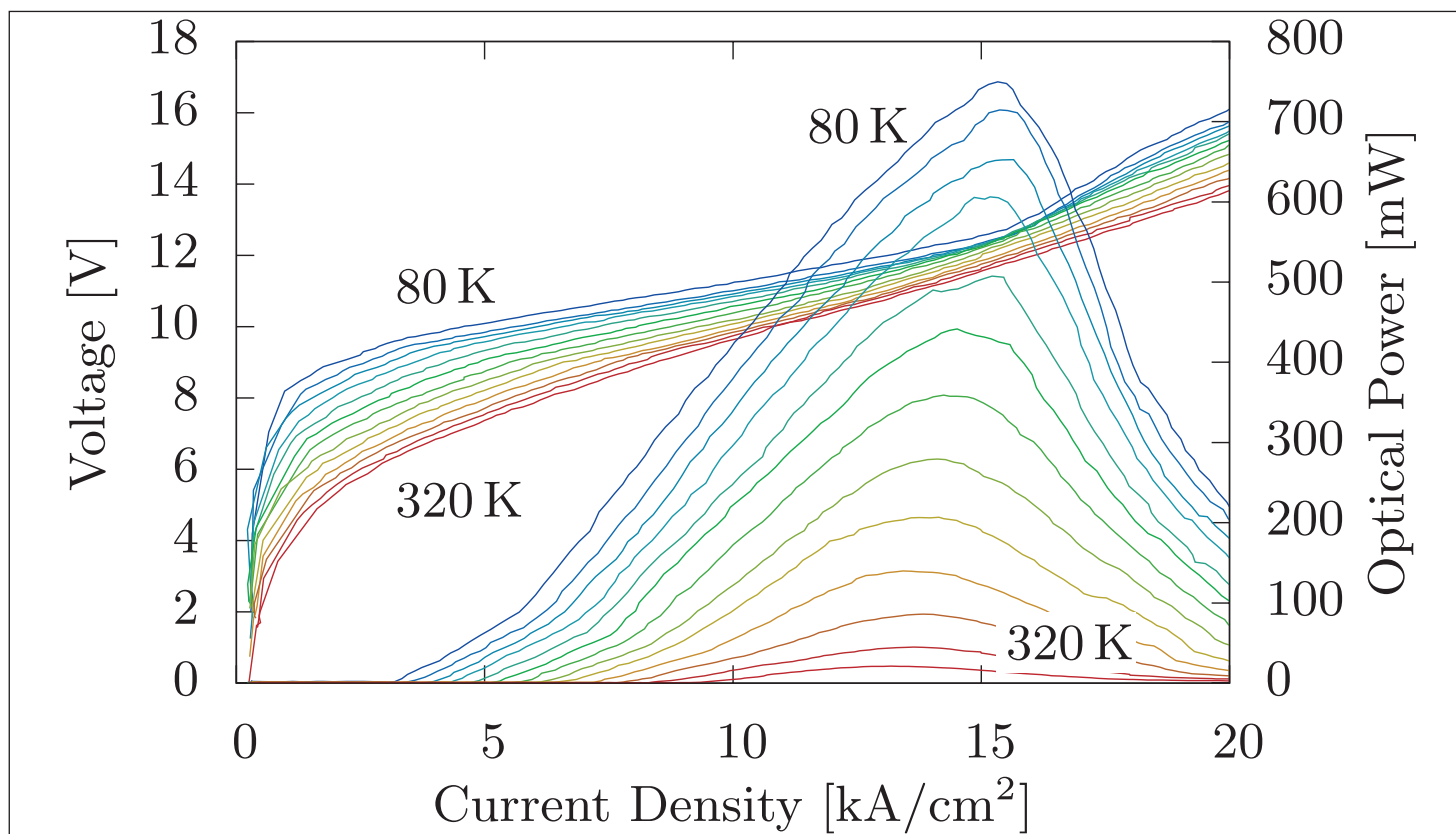


Figure 1. Optical output power and current–voltage characteristic of the bifunctional device. Curves were measured from a 10µm x 2mm ridge laser with 100ns pulses at 5kHz. Absolute output power was measured with a calibrated DTGS pyroelectric detector.

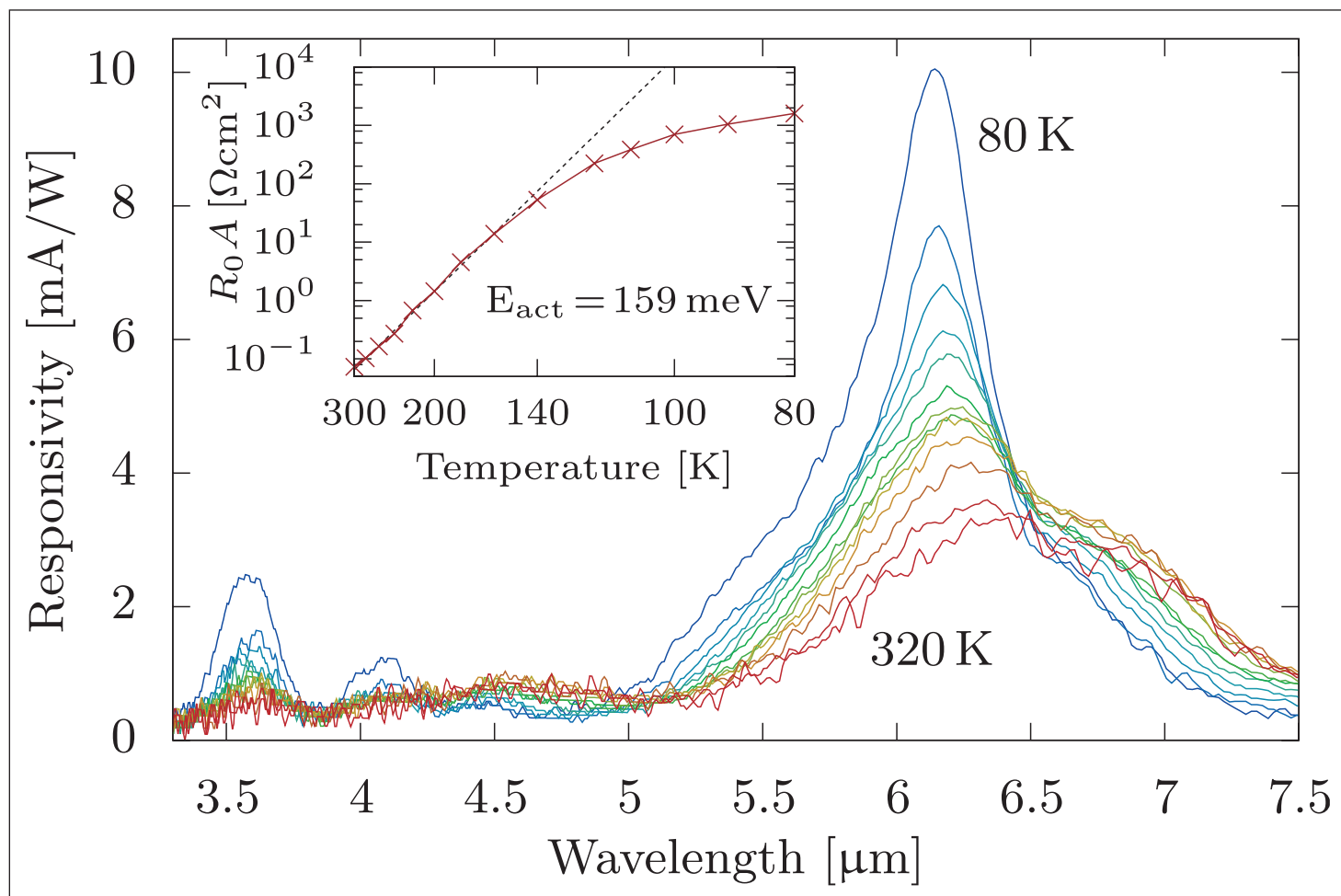


Figure 2. Spectral responsivity of the detector at different temperatures. Inset: resistance-area product as a function of inverse temperature. Spectra were measured from a $10\mu\text{m} \times 0.6\text{mm}$ ridge with a FTIR spectrometer, normalized by atmospheric absorption spectrum. Absolute values were measured with a cw laser adjusted to 10mW. Considering the measured spot profile and the $5\mu\text{m} \times 10\mu\text{m}$ facet, as well as the transmission of the ZnSe cryo-window, the researchers corrected the laser power for the responsivity calculation to 2.8mW.

The laser transition therefore generally has a smaller energy difference than the detector. This smaller energy red-shifts the laser emission wavelength range compared with the detector capability of a given QC structure.

To overcome these problems, the Vienna University of Technology team carried out extensive simulations before producing their device experimentally. The intrinsic wavelength shift between laser and detector operation was compensated for by inserting a narrow well between the injector and active-well sections of the cascade. By tuning the narrow well, the researchers were able to red-shift the wavelength band for detection, overcoming the intrinsic blue-shift.

Molecular beam epitaxy (MBE) was used to create the many-layered slightly strain-compensated indium gallium arsenide (InGaAs) well in indium aluminium arsenide (InAlAs) structure on n-type indium phosphide (n-InP) substrate. The 35-period active region was sandwiched between InGaAs cladding layers. A top cladding of InAlAs was also used. Laser devices were produced with $10\mu\text{m}$ -wide ridges. Two cavity lengths

were studied: 2mm and 0.6mm.

The laser wavelength and detector sensitivity range overlapped in the range $6.4\text{--}6.8\mu\text{m}$. The researchers believe that, operated in a distributed feedback cavity, the device structure could offer bifunctional operation in the range $6.2\text{--}7.1\mu\text{m}$.

Laser operation for the device with a 2mm cavity had a threshold current at room temperature of $8\text{kA}/\text{cm}^2$. The pulsed peak output power was 45mW. The researchers comment: "The improvement of the device performance, especially the reduction of the threshold current, will be a major issue of our future work on bifunctional quantum cascade devices."

Detector operation (0.6mm cavity) had a peak responsivity of $10\text{mA}/\text{W}$ at 80K and $3.6\text{mA}/\text{W}$ at 300K. The detector performance is comparable with that of pure QCDs. The detector is Johnson noise limited. The specific detectivity is 2.8×10^9 Jones at 80K and 6.9×10^6 Jones at 300K. ■

<http://link.aip.org/link/doi/10.1063/1.4767128>

Author: Mike Cooke

Diffuse reflection through zinc oxide nanorods boosts LED light extraction

Researchers in Taiwan have boosted light output by 57% over conventional nitride LEDs using ZnO nanorods and an aluminium reflector.

Taiwan's National Cheng Kung University has used zinc oxide nanorods and an aluminium reflector to improve light extraction from nitride semiconductor flip-chip light-emitting diodes (FCLEDs) through diffuse reflection [Ching-Ting Lee and Chia-Yin Chuang, Appl. Phys. Express, vol5, p112104, 2012].

Light extraction is a problem in nitride semiconductor LEDs because the difference in refractive index (n) between gallium nitride (GaN, $n \sim 2.4$) and air ($n \sim 1$) is large, reducing the escape cone to a critical angle of around 24° . This means that a large amount of the light reaching GaN/air interfaces is reflected back into the device.

If the angle of reflection at one of the surfaces of the device can be changed to fall within the escape cone then the light may eventually emerge from the LED rather than reabsorbed into the material of the device. A number of techniques have been developed to do this such as surface texturing.

Diffuse reflection is one way of changing the reflection angle. In mirror-like 'specular' reflection, the light rays are reflected at an

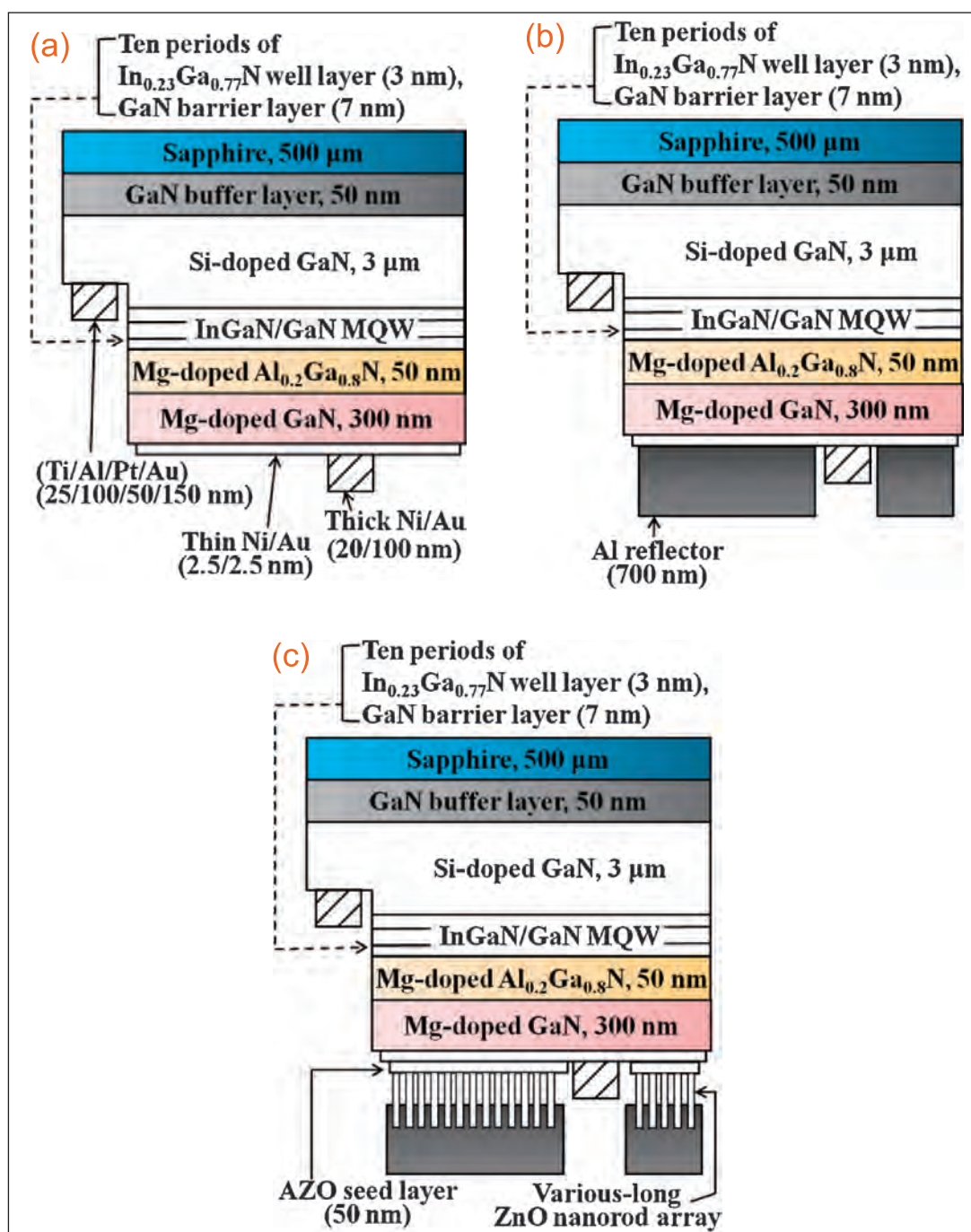


Figure 1. Schematic configuration of (a) conventional FCLEDs, (b) FCLEDs with flat reflector, and (c) FCLEDs with ZnO nanorod diffuse reflector.

angle equal to that at incidence. Diffuse reflection gives a spread of reflection angles.

The nitride semiconductor epitaxial material for the LEDs was grown on c-plane sapphire using metal-organic chemical vapor deposition (Figure 1). In the final LED, the grown material is flipped so that the contacts made with the nitride semiconductor don't get in the way of the light that is emitted through the sapphire substrate.

The InGaN/GaN multi-quantum well (MQW) active region consisted of 10 periods with 3nm-thick $\text{In}_{0.23}\text{Ga}_{0.77}\text{N}$ wells and 7nm-thick barriers. The material was annealed at 750°C for 30 minutes in nitrogen to activate the magnesium doping of the p-type layers.

A nickel mask was patterned to create 300µm x 300µm mesas through reactive ion etching down to the n-type layers for isolation of the LED devices. The n-contact metals were titanium/aluminium/platinum gold annealed at 850°C for 2 minutes in nitrogen to give an ohmic contact.

The p-contact consisted of thin nickel/gold (2.5nm/2.5nm) layers designed to spread the current across the more resistive p-contact GaN layer. Thicker layers of nickel/gold (20nm/100nm) were used for the p-electrodes. The nickel/gold layers were annealed at 500°C for 10 minutes to give an ohmic contact.

Without further processing, these devices (Figure 1a) constituted conventional flip-chip LEDs (FCLEDs). A simple way to increase light output is to deposit a 700nm aluminium reflector on the annealed nickel/gold p-contact layers (Figure 1b).

The third type of LED with an array of ZnO nanorods was produced by depositing a 50nm Al-doped ZnO layer on the nickel/gold p-contact layer as seed and then using the hydrothermal method to grow ZnO nanorods. The nanorod layer was capped with a 700nm Al layer to create a 'Lambertian' diffuse reflector (Figure 1c).

Different lengths of nanorod gave different amounts of diffuse reflection, with 500nm nanorods showing the strongest diffusion intensity in tests under helium-neon laser illumination at a 15° angle of incidence. If the nanorods become too long, the reflector's performance becomes degraded by light absorption. Reflectors with too short nanorods do not have enough roughness at the Al-nanorod interface to diffuse the reflection.

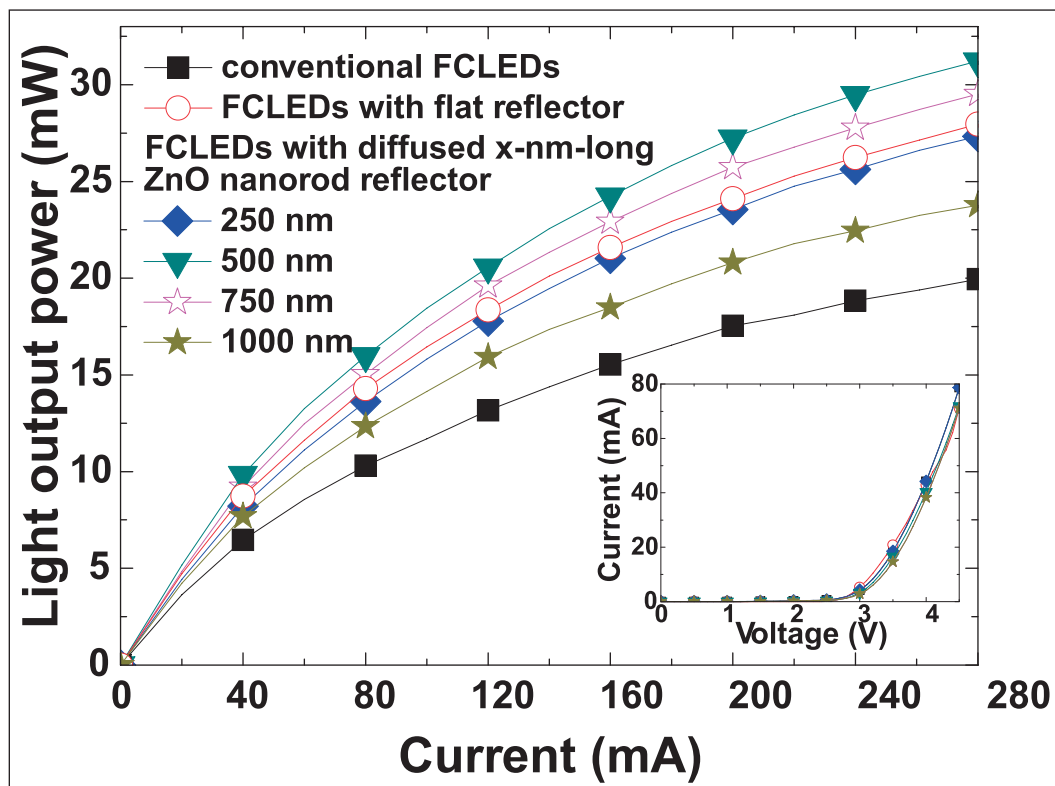


Figure 2. Light output power of conventional FCLEDs, FCLEDs with flat reflector, and FCLEDs with diffused nanorod reflectors. Inset: current–voltage characteristics.

Table 1. Light output power at 280mA for FCLEDs with various ZnO nanorod diffuse reflectors.

Nanorod length	Output power
None	19.94mW
None with flat reflector	27.95mW
250nm	27.38mW
500nm	31.22mW
750nm	29.91mW
1000nm	24.02mW

The optimal nanorod length of 500nm was confirmed in electroluminescence measurements at injection currents up to 280mA (Table 1 and Figure 2). The forward voltage at 20mA was roughly 3.51V for all devices. The light output for the optimal 500nm nanorod device was enhanced 56.6% over the conventional device at 280mA, and 11.7% over the device with flat reflector under the same injection current.

Another effect of using nanorod diffuse reflectors was to give a much smoother angular distribution, particularly in the region from 60° to 120°. This phenomenon was attributed to emitted photons being scattered more uniformly to a wider angle by the combination of roughened Al metal reflector and ZnO nanorod array. Overall, the improved performance was attributed to the use of highly reflective roughened Al metal and the lower refractive index of the ZnO nanorod array. ■

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Author: Mike Cooke

First 268nm DUV LEDs on AlN substrate

Continuous-wave output power of 28mW and external quantum efficiency of 2.4% have been achieved at a drive current of 250mA.

Researchers from Japan and the USA have reported the first fabrication on hydride vapor phase epitaxy (HVPE) aluminium nitride (AlN) substrates of aluminium gallium nitride (AlGaN) light-emitting diodes (LEDs) that emit at the deep-ultraviolet (DUV) wavelength of 268nm [Toru Kinoshita et al, Appl. Phys. Express, vol5, p122101, 2012].

The Japanese organizations involved were Tokuyama Corp, Kobe University, Tokyo University of Agriculture and Technology, and the National Institute of Information and Communications Technology. They were joined by US company HexaTech Inc and North Carolina State University.

There is much interest in shrinking the wavelength of AlGaN LED emissions to the DUV range around 265nm for air and water purification. This range is an absorption maximum for DNA, and hence 265nm DUV can be used to disrupt biological agents such as bacteria. UV-based purification presently depends on costly, bulky mercury lamp systems. The breakage of such lamps can also result in toxic mercury pollution.

Most work on AlGaN LEDs for this wavelength range is carried out on sapphire substrates. However, large lattice mismatches lead to dislocations in the active material region that emits the light, reducing energy efficiency to a couple of percent.

The Japan/US team hopes that developing AlGaN LEDs on AlN will reduce the mismatch and lead to more efficient devices.

HVPE was used to grown thick 250_μm AlN layers on c-plane physical vapor transport (PVT) AlN substrates. Chemical mechanical polishing (CMP) was used to prepare the HVPE AlN surface for the subsequent epitaxy of the LED structure. After CMP, the root-mean-square surface roughness was less than 0.2nm.

The device layers were grown using metal-organic chemical vapor deposition (MOCVD) in an Aixtron AIX200/4RF-S reactor (Figure 1). The active region consisted of a three-period multi-quantum well (MQW). The p-type layers were an AlN electron-block layer, an AlGaN cladding layer, and a GaN contact layer. Although GaN absorbs DUV, the researchers felt that it was needed to provide a suitable ohmic contact with the nickel/gold p-electrode. Unfortunately, p-type doping becomes even more difficult as the aluminium

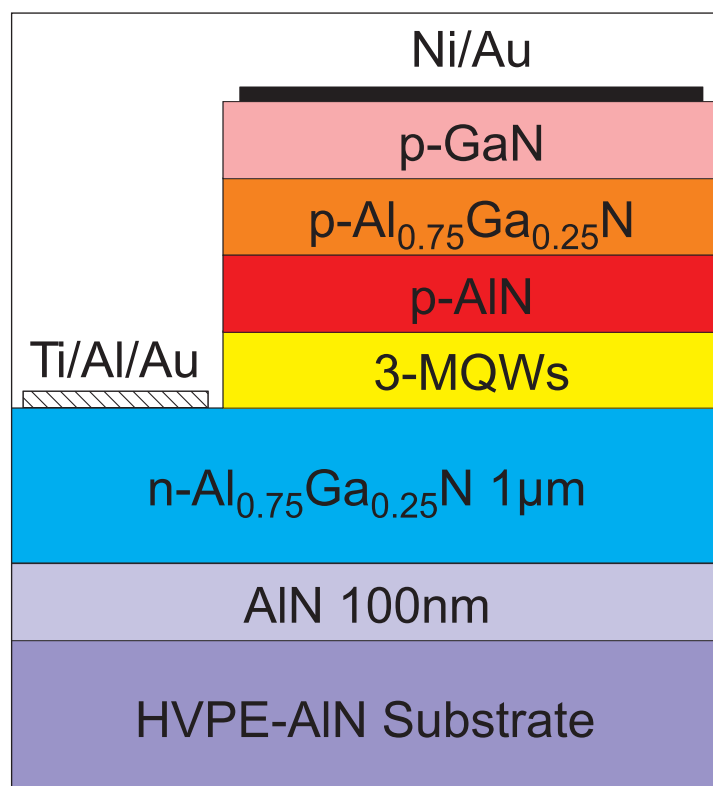


Figure 1. Schematic structure of a 268nm DUV-LED.

content of AlGaN is increased.

X-ray analysis showed that the layers of the device were strained pseudomorphically to the underlying AlN, except for the final p-GaN, which was almost completely relaxed due to the large lattice mismatch.

The 400μm x 600μm LED devices were produced using photolithography, dry etching, and metal evaporation. The PVT-AlN was removed using mechanical polishing to reduce the amount of DUV absorption. Some of the HVPE-AlN was also removed, and the researchers estimate that the thickness of this layer after polishing was 170μm.

Fortunately, the HVPE-AlN absorbed far less of the 265nm-wavelength radiation than does the PVT-AlN substrate. Below 300nm wavelengths, the transmittance of the PVT-AlN substrate was effectively zero. By contrast, the HVPE-AlN allowed as much as 62% of the 265nm radiation through. "This value is close to the ideal value when surface reflection is taken into account," the researchers comment. The intrinsic

absorption of HVPE-AlN was measured at 10/cm for 265nm UV.

Without removal of the PVT-AlN, LEDs produced little external radiation and none detectable below 300nm. Weak peaks at 320nm and 450nm were attributed to photoluminescence in the PVT-AlN excited by the DUV from the MQW.

Reduction in light absorbance is important since nitride semiconductor UV LEDs are generally operated in a flipped orientation, with the light being extracted through the growth substrate. This is because p-GaN contact layers heavily absorb DUV that has higher energy than the GaN bandgap.

The individual LED chips were flipped onto sintered AlN submounts and attached with gold-tin solder bumps. This assembly was then glued into a 1mm x 0.5mm AlN carrier with silver paste.

Electroluminescence spectra showed a main peak at 268nm and a weak parasitic peak around 300nm. "This peak is likely to be due to the recombination from the conduction band to the deep acceptor level in the p-Al_{0.75}Ga_{0.25}N cladding layer," the researchers comment.

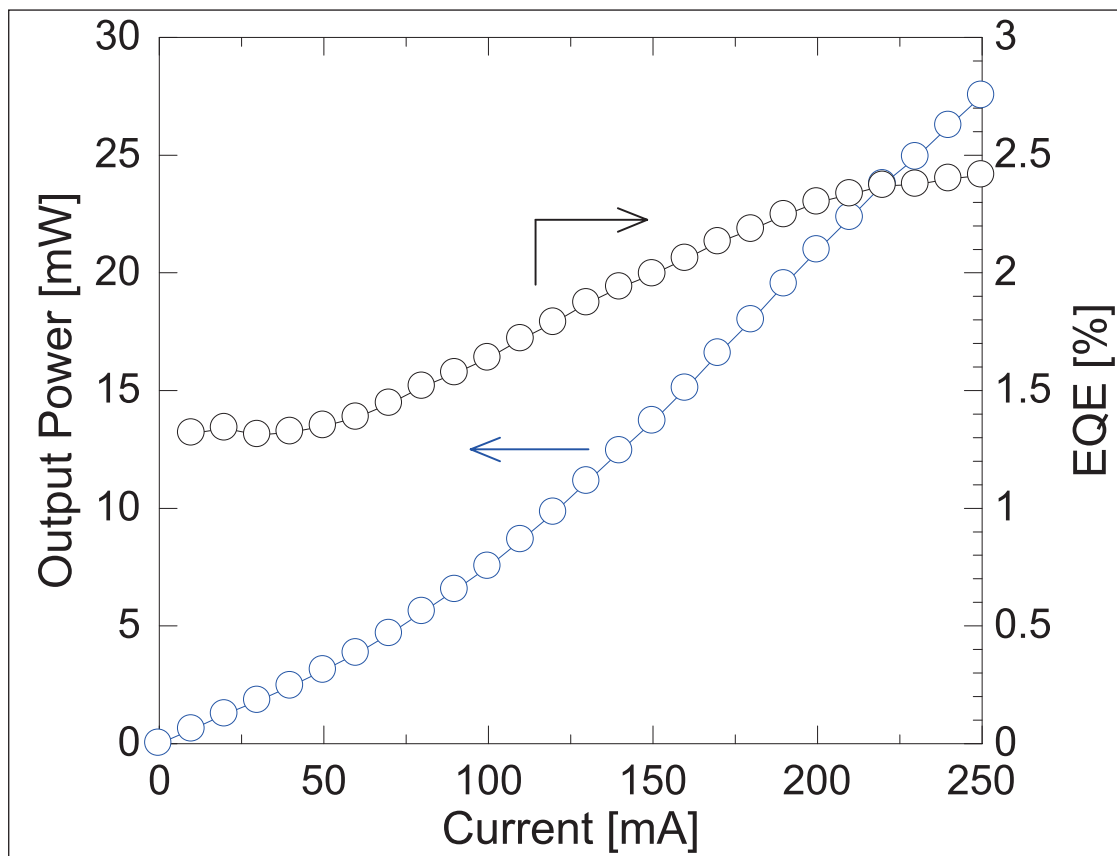


Figure 2. Output power and EQE of flip-chip-mounted DUV-LED as function of injection current.

The continuous-wave output power was 28mW at 250mA, with external quantum efficiency (EQE) of 2.4% (Figure 2). A super-linear increase in output power and increase in EQE with injection current is attributed to thermal activation of the p-type layers from self-heating effects. ■

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Gold-doped graphene for transparent and current-spreading electrodes in UV LEDs

Transparent and current-spreading gold-doped graphene electrodes show a 20% enhancement over ITO with comparable forward voltage.

Researchers in Korea have developed gold-doped graphene as a transparent and current-spreading electrode (TCSE) for ultraviolet (UV) light-emitting diodes (LEDs) [Tae Hoon Seo et al, Appl. Phys. Express, vol5, p115101, 2012].

Some of the research group from Chonbuk National University and Sungkyungyun University last year reported with others on the use of monolayer graphene for transparent conduction in nitride semiconductor UV LEDs [www.semiconductor-today.com/news_items/2011/DEC/SEO_311211.html].

One problem with using graphene as a TCSE is high sheet resistance. Recently, another group in Korea has used gold nanoparticles to improve graphene performance as TCSE in nitride semiconductor LEDs [www.semiconductor-today.com/news_items/2012/AUG/GIST_020812.html].

Suggested applications for near UV (300–400nm) include germicidal instrumentation, biological agent identification, chemical sensing, fluorescence excitation, and optical data storage. Further, UV can be used as a pumping source for creating white light through phosphorescence.

An alternative technology for TCSEs is indium tin oxide (ITO), which provides low sheet resistances. However, as the wavelength enters the UV region, ITO's transparency to light is severely curtailed.

The aluminium indium gallium nitride (AlInGa_N) semiconductor material for the 380nm UV LED was grown using metal-organic chemical vapor deposition (MOCVD) on sapphire (Figure 1). Mesa regions were formed in the material by inductively coupled plasma (ICP) etch down to the n-type layers.

The graphene was produced through chemical vapor deposition (CVD) on 70µm copper foil and then transferred to the UV LED. Gold trichloride (AuCl₃) in nitromethane was spin coated on the graphene layer on the UV LED. The optimum gold doping was obtained with a 10mM AuCl₃ concentration. The graphene TCSE structure that was used was a bilayer with an inter-layer distance of 0.38nm.

Annealing of the assembly was carried out for 30 minutes at 500°C to prevent oxidation of the LED and to strengthen the adhesion between graphene and p-GaN contact.

The metal electrodes for both the p- and n-contacts consisted of chromium and gold layers. A conventional LED with ITO transparent conducting layer was also produced.

The gold doping was found to have a slight effect on transmittance. At a wavelength of 380nm, the transmittance of undoped 'pristine' graphene was 92% and the transmittance of gold-doped graphene was 88.5%. A comparison 200nm ITO layer had transmittance of

Contact	p-GaN	1040°C	100nm
Electron blocking	p-AlGa _N (Al 25%)	1040°C	25nm
Multi-quantum well	5xInGa _N /AlGa _N (In 4%, Al 8%)	800°C	2nm/12nm
Contact	n-GaN	1040°C	2µm
Buffer	GaN	1040°C	1.5µm
Nucleation/buffer	GaN	550°C	30nm
Substrate	Sapphire		

Figure 1. .Epitaxial material structure of UV LED.

74%. The wavelength dependence of the graphene films was small, but the ITO only showed reasonable transmittance in the visible-infrared range of 400nm to 800nm.

The researchers comment: "The loss in optical transmittance of the graphene film after Au doping was about 3.5% owing to Au nanoparticles acting as a scattering center for the light."

The advantage of the gold doping was seen in the much lower sheet resistance of $90\Omega/\text{square}$, compared with $500\Omega/\text{square}$ for the undoped graphene layer. UV photoelectron spectroscopy (UPS) revealed another effect of gold doping — a shift in work function from 4.51eV for undoped graphene to 4.90eV for the doped layer. ITO has been measured with similar techniques as having a work function of $\sim 4.5\text{eV}$.

The gold-doped graphene LED showed improved electrical performance and light output (Figures 2 and 3). The forward voltage at 20mA was 3.98V, compared with 5.85V for an LED with undoped graphene TCSE. The forward voltage was only slightly more than the 3.92V of the 200nm ITO TCSE. The high forward voltage of the undoped graphene is a reflection of the material's higher sheet resistance, along with the larger work-function difference with that of p-GaN (5.5–5.9eV).

The emission from the gold-doped graphene LED was enhanced by about 20% over that of the ITO LED. Here, the improvement is related to the improved transmittance of graphene at the target wavelength, along with low work-function difference, while maintaining effective current spreading.

The researchers comment: "Further efficiency enhancement can be expected in GaN-based UV LEDs using graphene as their electrical properties are improved further."

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Author: Mike Cooke

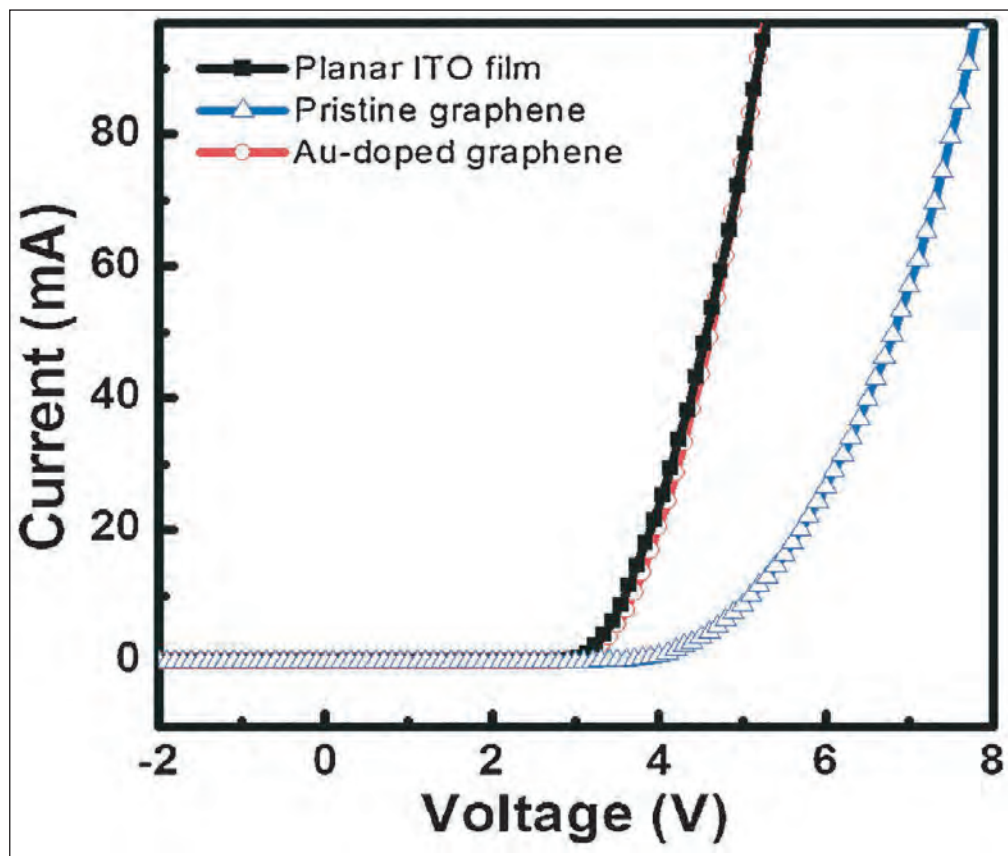


Figure 2. Current–voltage curves for InGaN/AlGaIn UV LED with pristine graphene film, Au-doped graphene film, and conventional planar ITO layer.

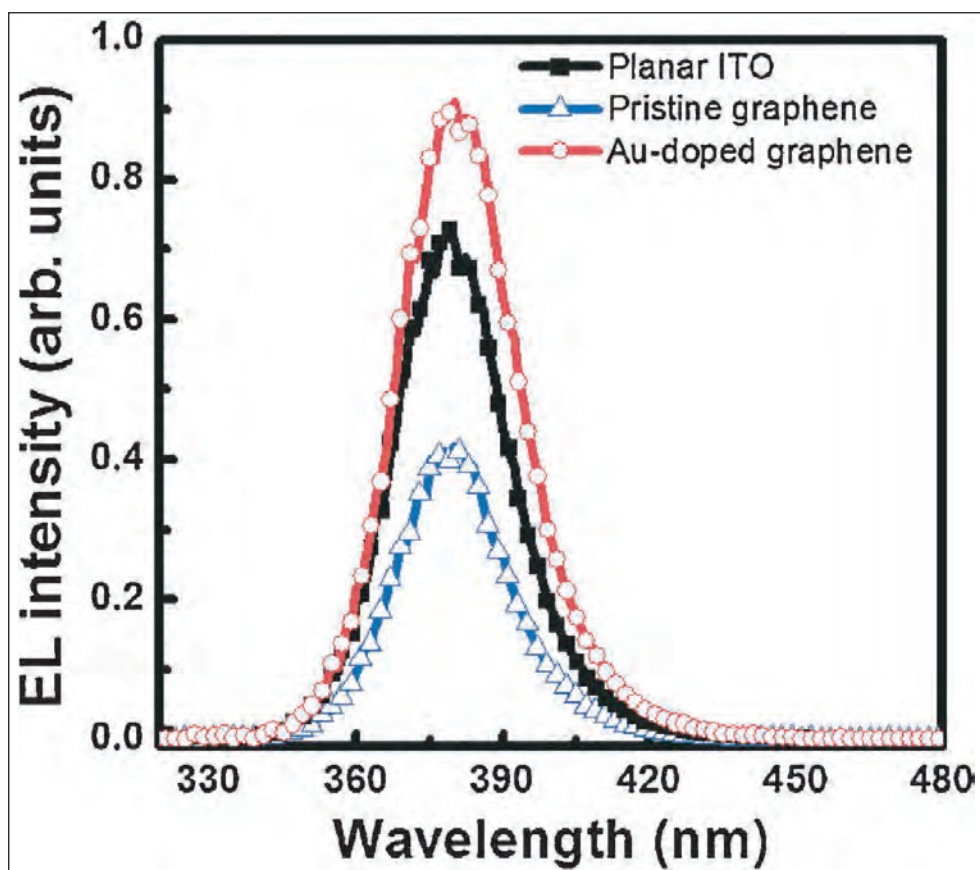


Figure 3. Electroluminescence (EL) spectra at an applied current of 100mA of InGaN/AlGaIn UV LED with pristine graphene film, Au-doped graphene film, and conventional planar ITO layer.

Silicon carbide steps to wider bandgaps in graphene

X-ray measurements have revealed an energy gap of more than 0.5eV in graphene nanoribbons via growth along steps in the SiC substrate.

Researchers based in the USA and France have created graphene nanoribbon structures with regions that have relatively large energy bandgaps of about 0.5eV [J. Hicks et al, Nature Physics, published online 18 November 2012].

Flat graphene tends to have a zero/minimal gap, with the energy bands meeting in a 'Dirac cone' at six 'Dirac points' in wavevector (k) space.

Materials with zero bandgap have (semi-)metallic behavior for electron flow. This is attractive for interconnects, but not if one wants active switching or amplification. For active devices one needs materials with controllable bandgaps. Imperfections in graphene produced by lithography techniques can widen the bandgap, but not in a controllable manner.

The behavior of electrons near the Dirac points can be approximated with a two-dimensional Dirac equation. The Dirac equation is the relativistic generalization of the Schrodinger equation that describes the spin- $\frac{1}{2}$ behavior of electrons, neutrinos and quarks. For these

particles the energy-wavevector relation is cone-like if they have negligible rest mass (m_0 , the mass of the stationary particle) – i.e. the energy is very much greater than m_0c^2 .

The work of creating and measuring the 0.5eV bandgap of graphene nanoribbons was carried out at the USA's Georgia Institute of Technology, along with scientists from France's CNRS, Cassiopée beamline (SOLEIL), Institut Jean Lamour in Nancy and Institut Néel in Grenoble.

Georgia Institute of Technology has previously worked with Institut Néel on using bottom-up techniques to grow graphene nanoribbons on silicon carbide (SiC) with bandgaps. In 2010, they reported graphene nanoribbons with small bandgaps by growing them along steps in the SiC surface. The bending of the graphene introduces strain and hence a bandgap. The strain can be controlled by varying the step height. Also, confinement effects are believed to play a role in developing the bandgap in nanoribbons.

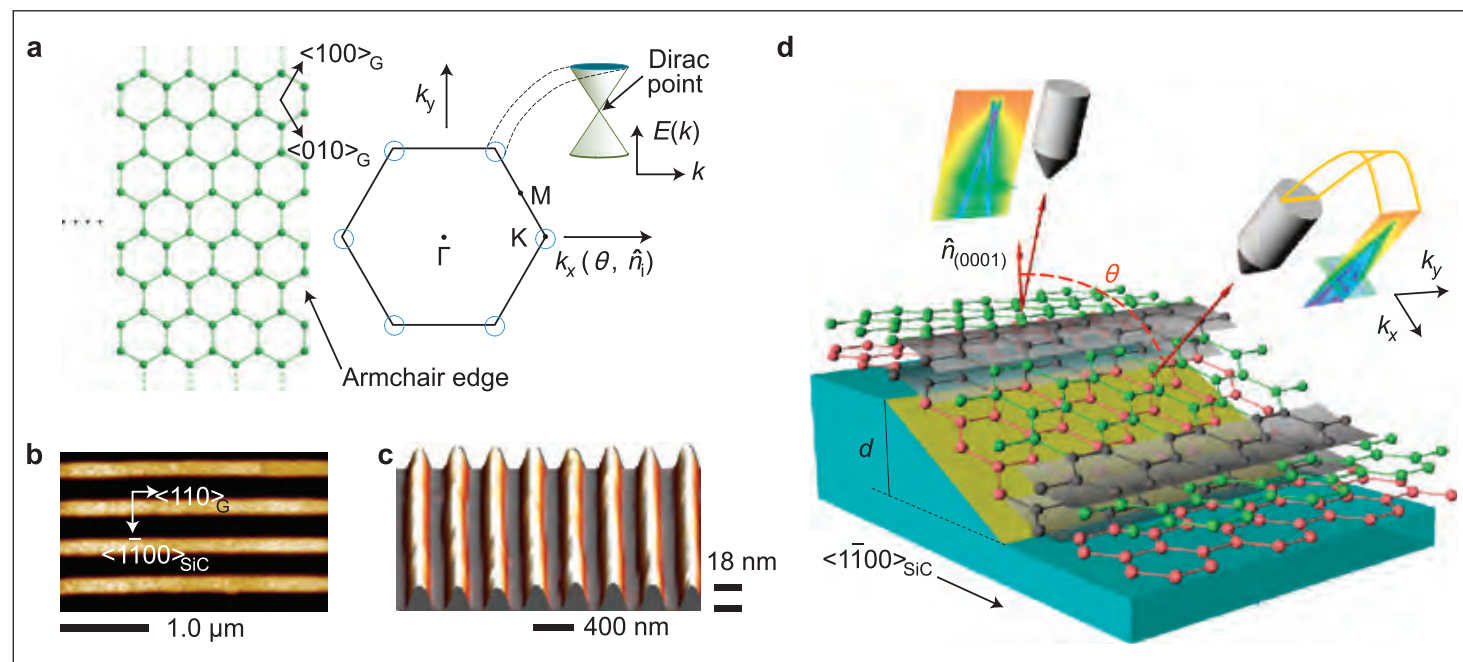


Figure 1. Experimental geometry of graphene on SiC trenches: a, graphene Brillouin zone orientation relative to armchair edge ribbons; b, AFM top view of sidewall ribbons showing long-range order; c, perspective AFM view of 18nm-deep graphitized trenches; d, schematic side-view of sidewall ribbons containing two graphene sheets (lower sheet in red is referred to as buffer). Grey regions are curved semiconducting parts of the graphene structure. Schematic shows two detector orientations used to reach both the K-point (Dirac point) of flat surface and facet.

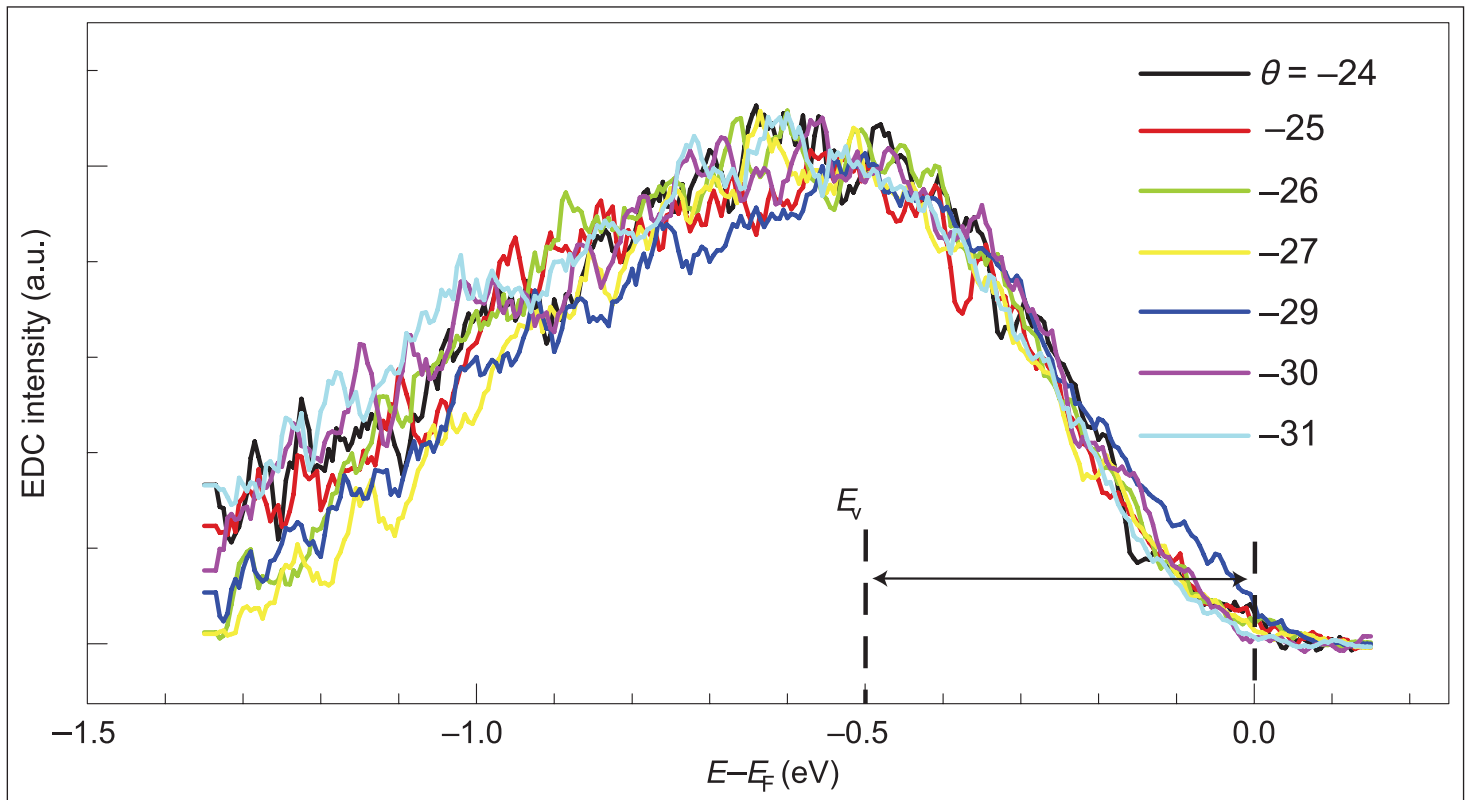


Figure 2. Normalized energy distribution curves (EDCs) of cones in the transition region for different angles. All cones in the transition region have the same profile, demonstrating the 1D nature of the region.

The new structures build on this work and were produced on n-type 4H-SiC substrates. Vertical trenches were produced in the (0001) surface by reactive ion etch (RIE) and then graphitized to create graphene bilayers. The 1mm-long trenches were between 7.5nm and 18nm deep and were arranged in an array with a pitch of 400nm over a 1mm x 3mm area. The graphitization was carried out in a carbon radio-frequency furnace at a temperature of 1560°C. The initially vertical walls of the SiC surface become facets during the graphene growth process. The ribbons were up to 36nm wide.

The flat regions were n-type (negative charge electron conductivity) and the bent regions were p-type (positive charge hole conductivity).

"We can make thousands of these trenches, and we can make them anywhere we want on the wafer," said Georgia Institute of Technology professor Edward Conrad. "This is more than just semiconducting graphene. The material at the bends is semiconducting, and it's attached to graphene continuously on both sides. It's basically a Schottky barrier junction."

The main technique used to explore the band structure of the resulting material was angle-resolved photo-emission spectroscopy (ARPES), where x-rays are used to eject electrons whose angle and energy are measured to give information about their original state in the material.

The ARPES measurements were carried out at the Cassiopée beamline at the SOLEIL synchrotron facility in France. The samples were transported in air to the SOLEIL site. The samples were annealed at 800°C in ultra-high vacuum before the ARPES measurements were made at 100K.

The bandgap for 1.4nm bent sections of graphene nanoribbon was found to be more than 0.5eV. This determination is based on the top of the valence band being measured at -0.5eV relative to the Fermi level (Figure 2). Since the bottom of the conduction band is not observed, it must be above the Fermi level. The flat sections had traditional metallic properties with zero bandgap. The flat regions were n-type (negative charge electron conductivity) and the bent regions were p-type (positive charge hole conductivity).

"We can make thousands of these trenches, and we can make them anywhere we want on the wafer," said Georgia Institute of Technology professor Edward Conrad. "This is more than just semiconducting graphene. The material at the bends is semiconducting, and it's attached to graphene continuously on both sides. It's basically a Schottky barrier junction." ■

www.nature.com/uidfinder/10.1038/nphys2487

Author: Mike Cooke

First InGaAs n-MOSFETs on germanium-on-insulator

Singapore researchers have achieved InGaAs-channel n-type MOSFETs on GeOI substrates with performance comparable to those on InP.

Singapore researchers have developed high-mobility III-V indium gallium arsenide (InGaAs) channel n-type metal-oxide-semiconductor field-effect transistors (n-MOSFET) on germanium-on-insulator (GeOI) substrates [Ivana et al, Appl. Phys. Express, vol5, p116502 2012].

The group, based at National University of Singapore (NUS) and Nanyang Technological University (NTU), comments: "To our best knowledge, this is the first demonstration of InGaAs surface channel n-MOSFET made on InGaAs-on-GeOI substrate."

So far, high-performance InGaAs devices have been grown on indium phosphide (InP) substrates. The aim for such devices is high performance at low power consumption at low cost. For mass production, InGaAs transistors need to be transferred to large-area silicon substrates — either by layer transfer from devices grown on InP (complex, expensive), or by direct growth on the substrate.

Previous InGaAs devices grown on silicon have been low performance due to low material quality resulting from poor lattice matching between silicon and III-V semiconductors. The lattice mismatch between InGaAs and Ge is smaller, and GeOI wafers have recently become commercially available. GeOI generally consists of a Ge layer on an insulating layer on silicon.

- MBE Growth:**
- 650°C Anneal of GeOI
 - GaAs migration-enhanced epitaxy
 - Undoped GaAs buffer growth
 - AlInAs graded buffer growth (from 0 to 52% In composition)
 - $\text{In}_{0.7}\text{Ga}_{0.3}\text{As}/\text{In}_{0.53}\text{Ga}_{0.47}\text{As}$ growth
- Transistor Fabrication:**
- Pre-gate clean
 - ALD Al_2O_3 deposition
 - Post-deposition annealing
 - WN deposition and gate patterning
 - Al_2O_3 removal in S/D regions
 - Ni deposition
 - Ni-InGaAs formation by RTA
 - Selective etching of unreacted Ni

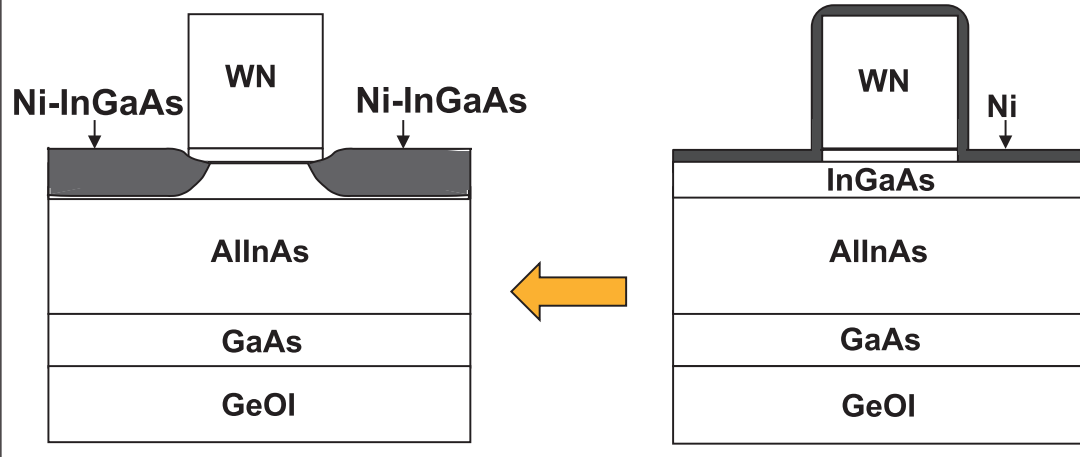


Figure 1. Process flow used, including growth of InGaAs on GeOI and fabrication of n-MOSFET. Schematics on right illustrate the self-aligned metallic S/D formation scheme that was employed.

A further attraction of the GeOI approach is that Ge channels are a leading contender for the high-mobility p-MOSFETs that need to be combined with high-mobility n-MOSFETs to create complementary metal-oxide-semiconductor (CMOS) transistor circuitry.

Molecular beam epitaxy (MBE) was performed on GeOI with the (001) Ge surface offcut by 10° in the <111> direction. Offcut surfaces are used to overcome

Monolithic InAs on silicon with high electron mobility

A French–German team has optimized the growth of a gallium antimonide buffer to avoid anti-phase domains in high-mobility indium arsenide channels on silicon substrates.

Researchers based in France and Germany have developed techniques for growing indium arsenide (InAs) channel structures on silicon [L. Desplanque et al, Appl. Phys. Lett., vol101, p142111, 2012]. Room-temperature mobility for the epitaxial material was an extremely high 27,800cm²/V-s.

The researchers were associated with Institute of Electronics, Microelectronics and Nanotechnology (IEMN) of France's CNRS and University of Lille, German company NAsPIII/V GmbH, Philipps-University Marburg, and Centre de Recherche sur les Ions, les Matériaux et la Photonique (CIMAP).

InAs channels are among the options for future high-electron-mobility devices for mass production. For such low-cost production, devices using such

channels need to be incorporated into large-diameter silicon wafer processes.

In combination with aluminium antimonide (AlSb), which has a large conduction-band offset and small lattice mismatch with InAs, extremely high electron mobility has been achieved on indium phosphide (InP) and gallium arsenide (GaAs) substrates. However, up to now high-quality crystal material has been difficult to grow monolithically on silicon due to the lattice mismatch of 12% between the InAs and Si. Such a discrepancy tends to lead to anti-phase domains (APDs) and other structural problems that degrade electron transport performance.

The researchers began their work by optimizing the growth of AlSb/InAs layers on (001) gallium phosphide

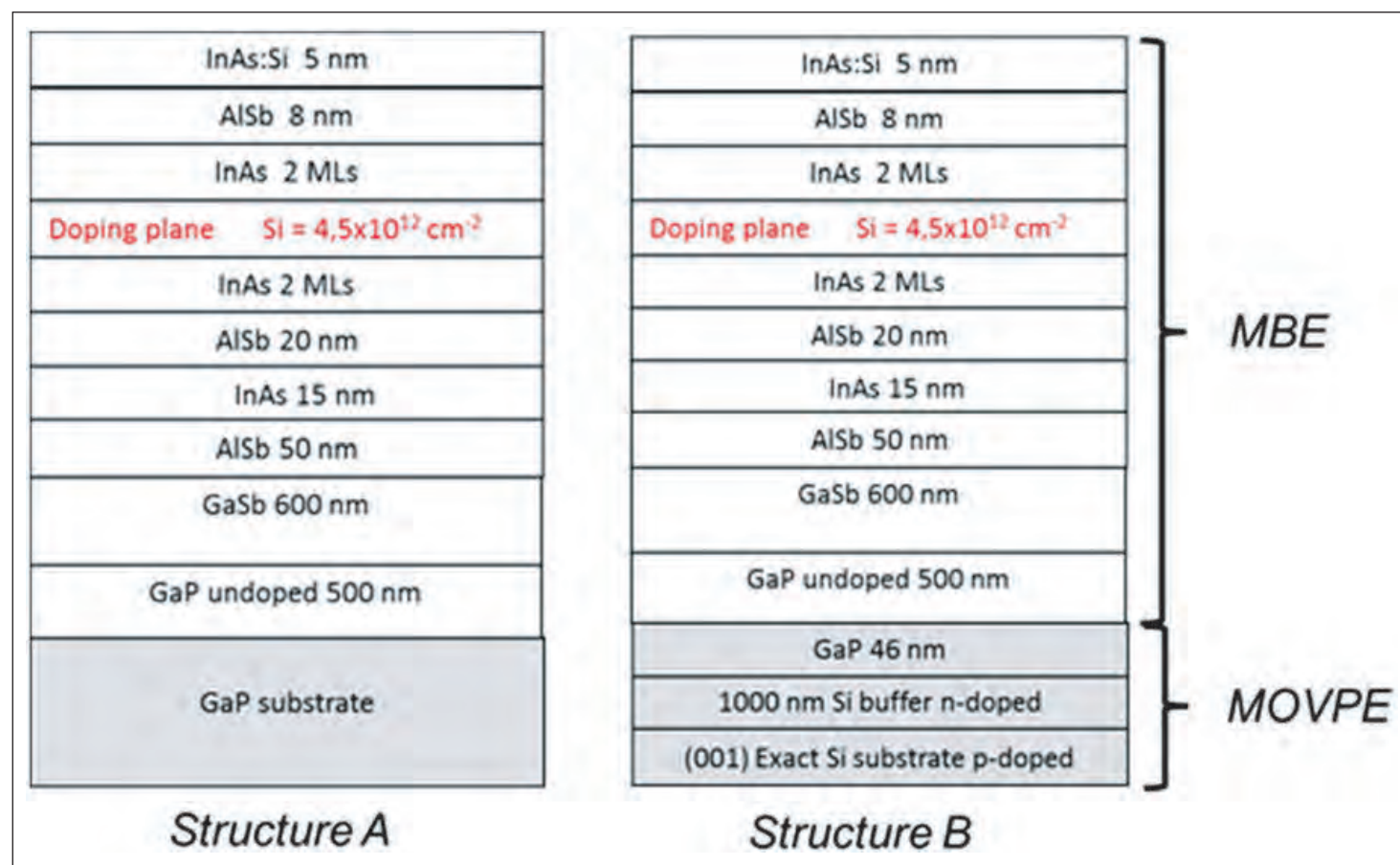


Figure 1. Schematics of AlSb/InAs heterostructures grown by MBE on GaP substrate (structure A) and grown by MOVPE and MBE on exactly oriented silicon substrate (structure B).

(GaP) substrates (Figure 1, structure A) using a Riber 32P molecular beam epitaxy (MBE) reactor. The purpose of this optimization was particularly to avoid APDs. Using these results, the researchers then performed MBE on 4cm x 4cm GaP/Si templates (Figure 1, structure B).

The templates were produced by metal-organic chemical vapor phase epitaxy (MOVPE) on 300mm (001) $\pm 0.5^\circ$ p-doped Si wafers. The MOVPE reactor was an Aixtron Close Coupled Showerhead CRIUS system. The GaP growth surface was strained pseudomorphically to the structure of the silicon substrate without any misfit or threading dislocations.

The resulting heterostructures were analyzed with atomic force microscopy (AFM), transmission electron micrography (TEM) and x-ray diffraction (XRD). Hall measurements were carried out on mesa bridge and van der Pauw structures with alloyed indium contacts, carefully annealed at 180°C for 2 minutes in the case of structure B to ensure ohmic contact while avoiding short-circuiting the InAs channel through the n-type doping plane.

The researchers used AFM surface morphology studies to explore the tradeoff between relaxation and rapid island coalescence of the gallium antimonide (GaSb) buffer layer by reducing both the temperature and the Sb flux during growth of the nucleation layer. After nucleation, the growth temperature and flux can be raised to improve the GaP template surface. The use of GaSb buffer gives tensile-strained InAs layers.

The optimum condition for nucleation was found to be 450°C with Sb flux of 0.9 ML/s (monolayers per second), giving heterostructures on GaP substrates with smooth surfaces of 0.8 nm root-mean-square (RMS) roughness. These conditions also resulted in the best Hall properties (Figure 2) with the sheet carrier density at $1.5 \times 10^{12}/\text{cm}^2$, giving room-temperature (300K) van der Pauw electron mobility at $27,800 \text{ cm}^2/\text{V-s}$, and 77K mobility at $120,000 \text{ cm}^2/\text{V-s}$.

Having found the optimal growth conditions on GaP substrate, the recipe was transferred to GaP/Si templates. Again, AFM gave RMS roughness of 0.8 nm. The van der Pauw Hall effect measurements on structure B with sheet carrier density $1.5 \times 10^{12}/\text{cm}^2$ gave room-temperature mobility at $27,800 \text{ cm}^2/\text{V-s}$ and 77K mobility of $111,000 \text{ cm}^2/\text{V-s}$. There is almost no anisotropy in the mobility, indicating the usefulness of the InAs structure for the realiza-

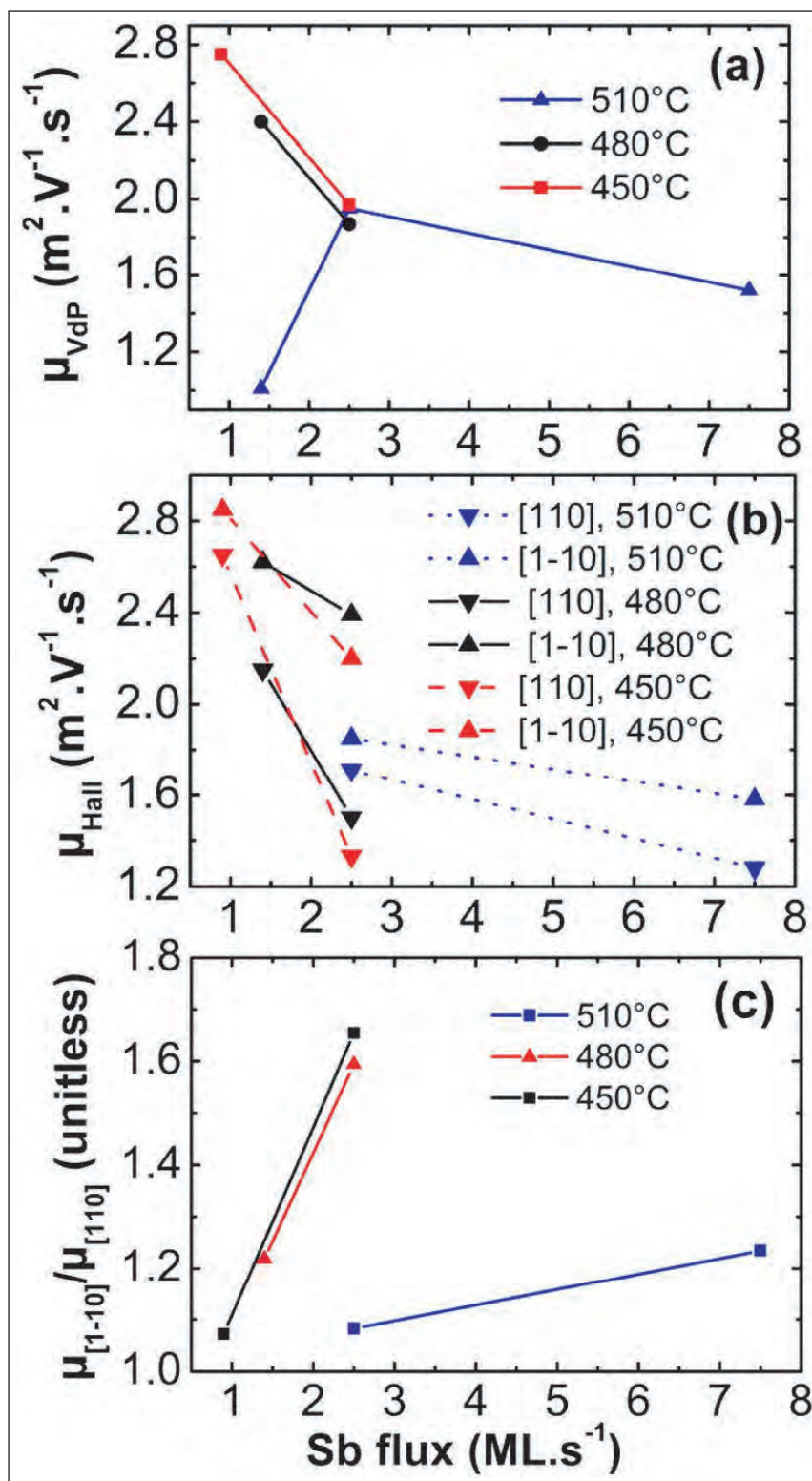


Figure 2. Transport measurements on heterostructures grown on GaP substrates with different temperatures and Sb fluxes during the first 50nm of GaSb buffer layer:

(a) room-temperature van der Pauw electron mobility (μ_{VdP}), (b) Hall Bridge measurements (μ_{Hall}) in different crystal directions, and (c) anisotropy of electron mobility deduced from (b).

tion of high-speed and low-power-consumption electronic devices, according to the researchers. ■

<http://link.aip.org/link/doi/10.1063/1.4758292>

Author: Mike Cooke

Renewed enthusiasm for high-mobility channel development

Mike Cooke reports on presentations on high-mobility III-V and Ge-channel devices at December's International Electron Devices Meeting in San Francisco.

The past year has seen a renewed effort in developing high-mobility channels for high-performance and low-power electronics, at least according to the presentations at the 2012 International Electron Devices Meeting (IEDM) in December. While in previous years the III-V contributions were fairly evenly balanced between narrow-bandgap materials for high mobility and wide-bandgap materials for high power density, the 2012 IEDM seemed dominated by high-mobility reports for logic and radio-frequency devices. In addition to III-V materials, there were important developments in germanium-based devices for p-type (and in some cases n-type) channels.

This is not to say that there were not some important wide-bandgap contributions. For example, HRL Laboratories LLC of Malibu, CA, USA claimed a record cut-off frequency of 500GHz for a nitride semiconductor high-electron-mobility transistor (HEMT) [K. Shinohara et al, session 27.2]. This achievement was based on a process for creating deeply scaled self-aligned-gate gallium nitride (GaN) HEMTs with heavily doped n^+ -GaN source/drain (S/D) regions in direct contact with the two-dimensional electron gas (2DEG) channel near the gate. Devices with a gate

length of 20nm had an on-resistance of $0.23\Omega\cdot\text{mm}$, maximum drain current of more than 4A/mm , and transconductance of more than 1S/mm over the drain current range of $0.5\text{--}3.5\text{A/mm}$.

Here, however, we will focus on some of the progress presented for producing high-mobility devices on silicon using III-V- and germanium-based semiconductors.

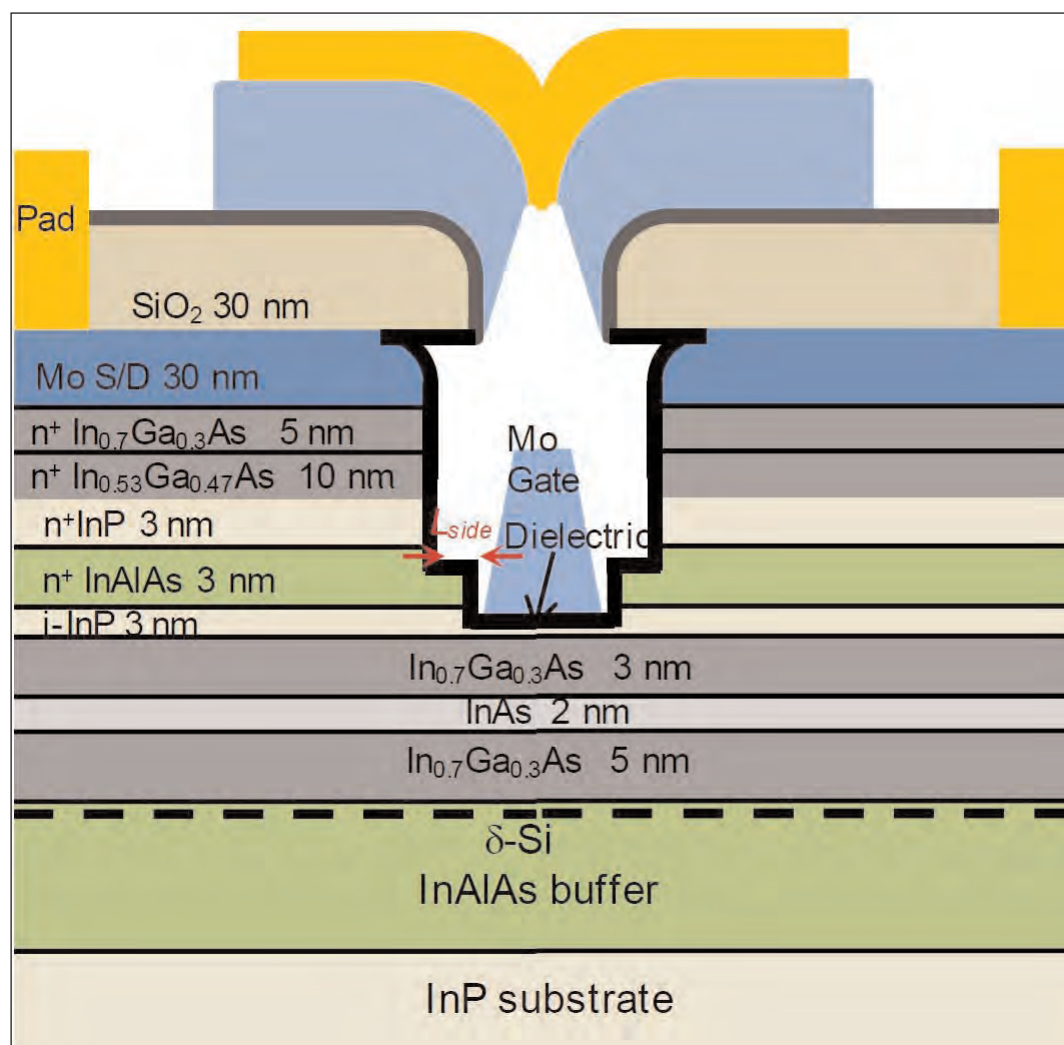


Figure 1. Cross-sectional schematic of MIT's InAs QWMOSFET with ultra-scaled HfO_2/InP composite barrier.

Smallest working III-V transistors

Researchers at Massachusetts Institute of Technology (MIT) claimed the shortest gate for working transistors yet built using III-V channels [J. Lin et al, IEDM, session 32.1]. The metal-oxide-semiconductor field-effect transistors (MOSFETs) were also the first to use self-aligned contacts to reduce the distance between the gate and source-drain regions to 20–30nm. The researchers were keen to reformulate the production processes to more closely resemble those of silicon semiconductor manufacturing. Self-alignment is one such technique.

Matthias Passlack, of Taiwanese semiconductor manufacturer TSMC, commented on the work, led by MIT professor Jesús del Alamo: “He and his team have experimentally proven that indium arsenide channels outperform silicon at small-device dimensions. This pioneering work has stimulated and facilitated the development of CMOS-compatible, III-V-based-technology research and development worldwide.”

The MIT research was funded by US Defense Advanced Research Projects Agency (DARPA), Intel and the Semiconductor Research Corporation's Center for Materials, Structures and Devices (FCRP-MSD).

The semiconductor material for the MIT device was produced at Intelliepi using molecular beam epitaxy (MBE) on indium phosphide (InP) substrates (Figure 1). The channel consisted of a quantum well (QW) of indium arsenide (InAs) in indium gallium arsenide (InGaAs) barriers. The upper n^+ -InP/ n^+ -InAlAs/i-InP layers are a ‘ledge’ designed to lower access resistance between the n^+ -InGaAs source-drain contact regions and the QW channel.

Sputtered, low-resistance $5\Omega/\text{square}$ molybdenum (Mo) was used for metal contacts. This was covered with silicon dioxide (SiO_2) in a chemical vapor deposition (CVD) process.

The devices were then patterned with electron-beam lithography and mesa isolation and gate formation achieved with reactive-ion etch (RIE) through the SiO_2 and Mo (Figure 2). The RIE damage was repaired using 350°C annealing, the highest temperature used in the entire transistor fabrication process. The gate length was defined by the amount of gate opening, and the researchers believe that this can be scaled to less than 20nm.

Further wet and dry etch steps were used to recess the gate region, leaving about 1nm of the 3nm InP layer above the top InGaAs barrier of the QW. The control of this last etch was achieved through a self-limiting ‘digital’ technique involving plasma oxidation and dilute sulfuric acid (H_2SO_4).

The gate dielectric consisted of 2nm of hafnium dioxide (HfO_2), applied using atomic layer deposition (ALD). The dielectric was deposited conformally and therefore also provided passivation of the access region between

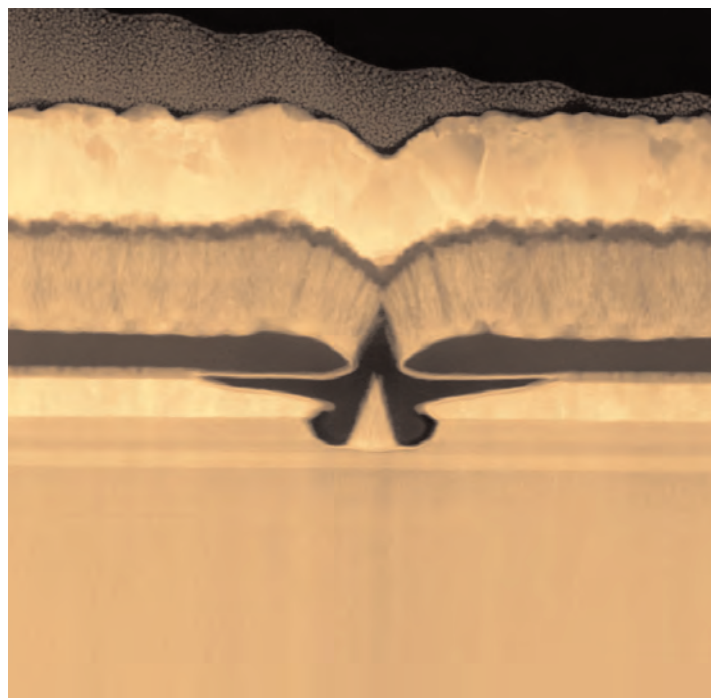


Figure 2. Cross-sectional transmission electron micrograph (TEM) of fabricated MIT transistor. Central inverted V is the gate. Two molybdenum contacts on either side are the transistor's source and drain. The channel is the InGaAs light color layer under the source, drain and gate. Image courtesy of the MIT researchers.

the edges of the gate and the n^+ -InGaAs cap. The dielectric had an equivalent oxide thickness (EOT) of 0.4–0.5nm. The total EOT, including the InP barrier, was $\sim 0.8\text{nm}$. The Mo gate metal was evaporated on and patterned through etching.

The researchers found a source–drain resistance of $445\Omega\text{-}\mu\text{m}$, which they describe as ‘relatively high’,

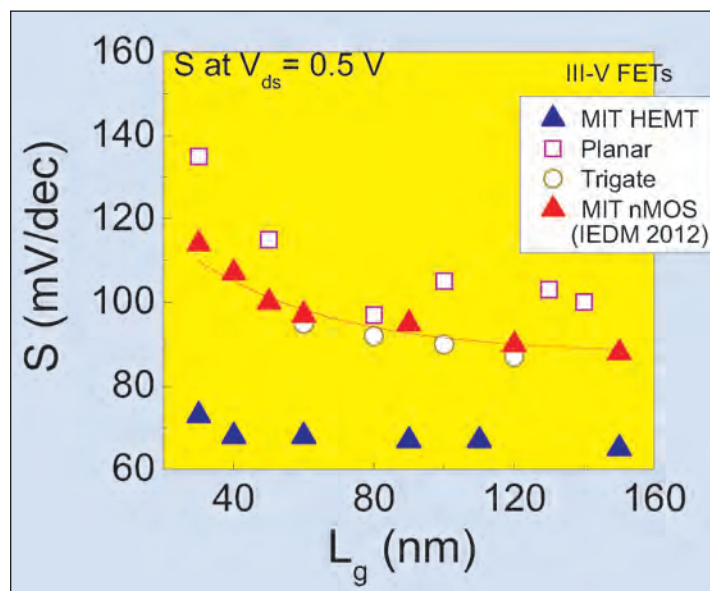


Figure 3. Subthreshold swing (S) vs gate-length at 0.5V for III-V MOSFETs and HEMTs (essentially transistors without gate insulation).

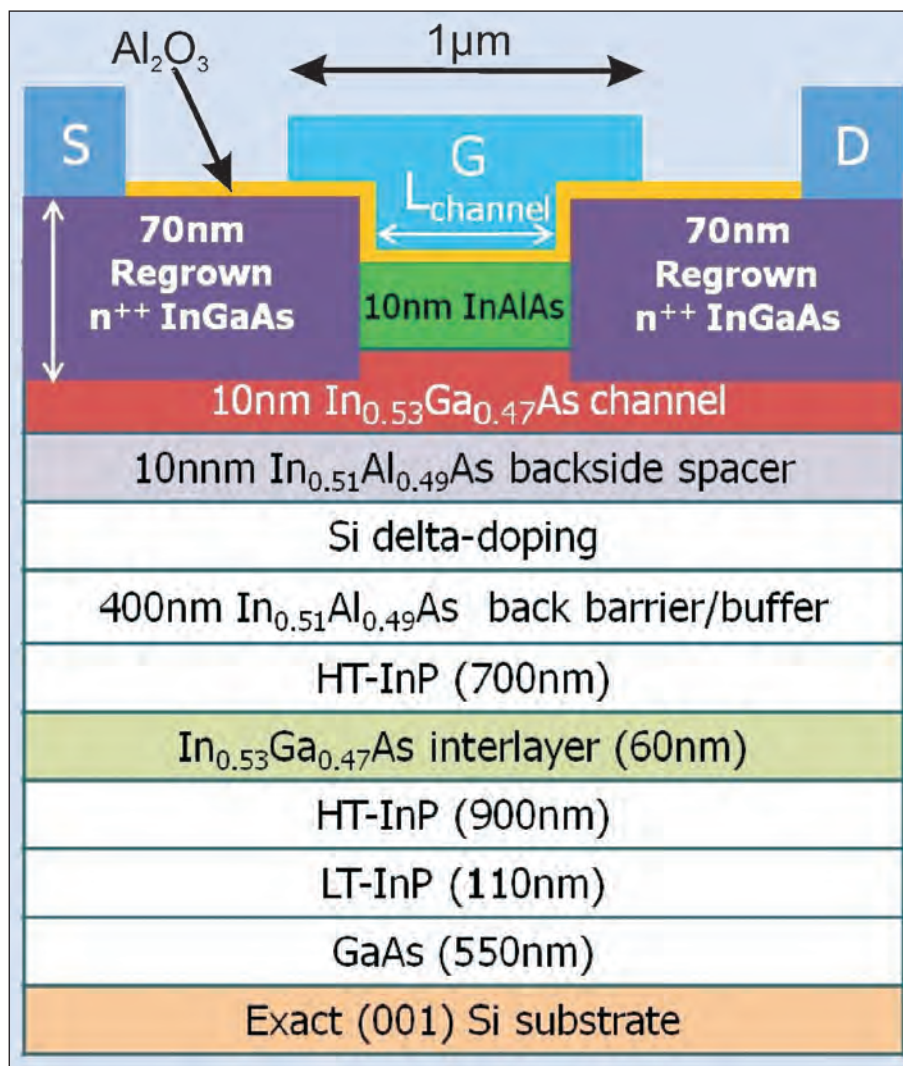


Figure 4. Schematic of HKUST device with nominal layer thicknesses (LT-low temperature, HT-high temperature, figure not drawn to scale).

blaming this on the small uncapped regions of the source–drain stacks (L_{side} in Figure 1). “This can be solved through an improved n^+ -InP S/D ledge design,” they say.

For a 30nm-gate device, the researchers quote a subthreshold swing of 103mV/dec at 50mV drain bias and 114mV/dec at 0.5V drain bias. The drain-induced barrier lowering was “relatively high” at 236mV/V, related to the heterostructure buffer and not the fabrication process. Despite the HfO_2 insulation being very thin at 2nm, gate leakage was less than 1nA/ μm .

With 0.5V drain bias, the peak transconductance was 1420 $\mu\text{S}/\mu\text{m}$ (1530 $\mu\text{S}/\mu\text{m}$ for 60nm-gate). A ‘fully operational’ 22nm-gate device had a peak transconductance of 1050 $\mu\text{S}/\mu\text{m}$ with 0.5V drain.

Comparing their device with others (Figure 3), the researchers comment: “Our ultra-scaled barrier MOSFETs exhibit a subthreshold swing that is superior to any other planar III-V MOSFET, and that matches the best Tri-gate III-V devices.” Also, for sub-60nm-gate transistors, the transconductance performance is “superior to any other planar or Tri-gate III-V MOSFET.”

The researchers also produced a variant device with a 15nm InGaAs channel and a composite gate dielectric consisting of 0.4nm aluminium oxide and 2nm HfO_2 . A long-gate (300 μm) device achieved a subthreshold swing of 69mV/dec, near to the ideal room-temperature value for planar structures of 60mV/dec. This very low value is among the best ever reported for III-V MOSFETs.

A 20 μm -gate device had a mobility of 4650 $\text{cm}^2/\text{V}\cdot\text{s}$ at a sheet carrier density (N_s) of $4 \times 10^{12}/\text{cm}^2$. “This is the one of the highest mobility values at this N_s published in InGaAs MOSFETs to date,” the researchers write.

The team plans to next work on improving the electrical performance by reducing the parasitic resistance in these devices. This will enable further shrinking, with the ultimate aim being sub-10nm gate lengths.

Another group at MIT and University of British Columbia Vancouver [W. Chern et al, session 16.5] demonstrated “for the first time asymmetrically strained Ge, high-k/metal gate nanowire (NW) trigate p-MOSFETs with record hole mobility of 1490 $\text{cm}^2/\text{V}\cdot\text{s}$.” The researchers add: “This mobility is 2x above on-chip biaxially strained Ge FETs and ~15x above Si universal mobility.”

Hong Kong University of Science and Technology has also been developing

very short gate-length III-V InGaAs devices (Figure 4) grown directly on silicon using metal-organic chemical vapour deposition (MOCVD) [X. Zhou et al, session 32.5]. The source–drain regions were selectively re-grown with n^+ -InGaAs material to reduce access resistance. The contact metals were nickel/germanium/gold/germanium/nickel/gold. The gate stack consisted of an InAlAs barrier, 6nm of aluminium oxide (Al_2O_3) dielectric and a titanium/platinum/gold gate.

A post-metallization anneal (PMA) was performed in an ALD system (300°C for 5 minutes in nitrogen) to shift the threshold voltage in a positive direction from –1.4V to +0.08V for enhancement-mode/normally-off operation. Another effect of the PMA was enhanced electrostatic control, resulting in the peak transconductance increasing from 1074mS/mm (before PMA) to 1700mS/mm (after). Also, the subthreshold swing with 50mV drain bias was reduced from 172mV/dec to 142mV/dec (after PMA). The on/off ratio (0.5V above/below threshold) was 1.7×10^4 . A maximum drain current was 1327mA/mm at 1.6V gate with 0.5V drain bias.

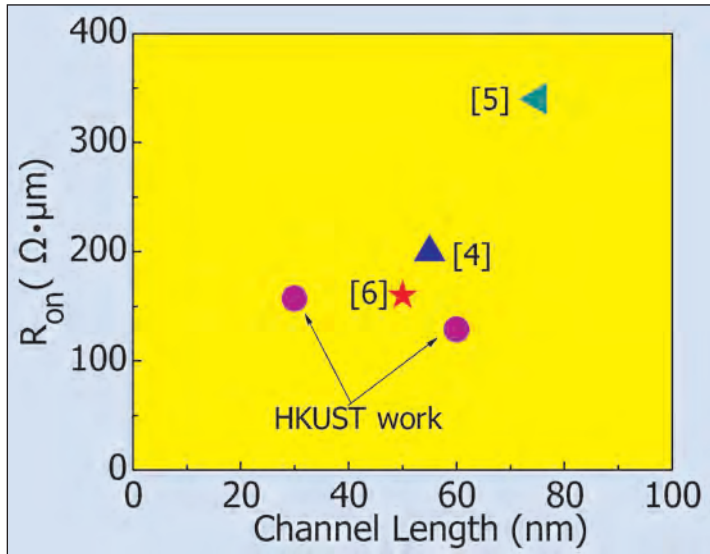


Figure 5. Comparison of HKUST R_{on} with state-of-the-art InGaAs MOSFETs.

Compared with other groups (Figure 5), the HKUST device had the lowest on-resistance, at $157\Omega \cdot \mu m$. The researchers comment: “We attribute the impressive R_{on} to the high-quality S/D re-growth with high doping level.” The same group has recently reported even lower on-resistance in a similar 30nm-gate device with a record $133\Omega \cdot \mu m$ [Xiuju Zhou et al, IEEE Electron Device Letters, vol33, p1384, 2012].

A longer 60nm channel achieved a lower subthreshold swing of 101mV/dec with 50mV drain bias.

The researchers suggest that one effect of the PMA is to repair damage from the electron-beam evaporation process. For example, the titanium gate layer becomes smoother and more dense after PMA. Energy-dispersive x-ray spectroscopic analysis also showed the presence of oxygen in the metal layers before PMA but not after.

Setting up for 4D electronics

Purdue and Harvard universities presented stacked InGaAs nanowire (NW) transistors with increased drive current and maximum transconductance [J.J. Gu, X.W. Wang et al, IEDM 2012, session 23.7]. Since the nanowire transistors already have ‘three dimensional’ (3D) wrap-around gates, the extension into stacking has been labeled ‘4D electronics’ (Figure 6).

The researchers have built on their previous work with transistors produced using indium gallium arsenide (InGaAs) NW channels with the ‘gate all-around’ (GAA). The Christmas tree-effect is due to the diameter of the nanowires in the upper layers being smaller than in layers below.

The epitaxial layers of III-V material were grown on semi-insulating (SI) InP substrates using molecular beam epitaxy (Figure 7.1). The source/drain regions were defined using a silicon implant at two energies, designed to drive the donor atoms to give a spread of depths uniformly contacting all three nanowire channels

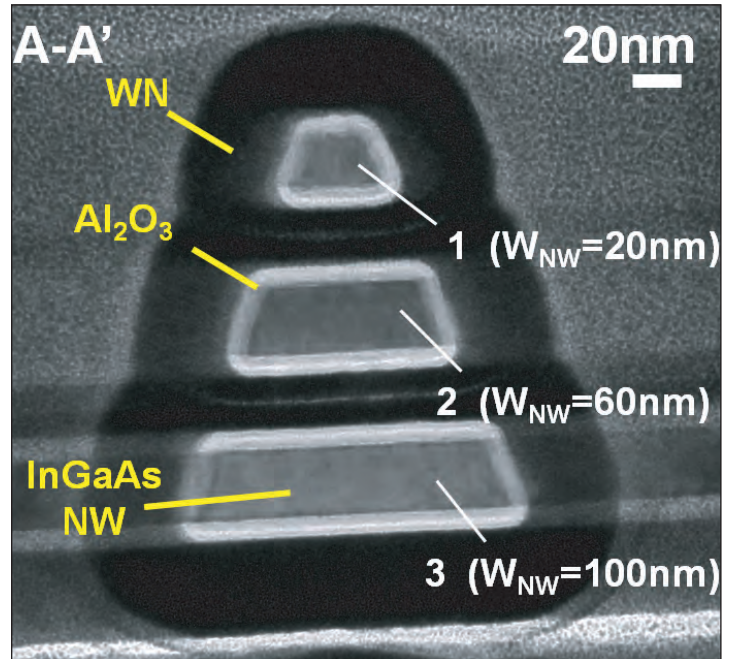


Figure 6. TEM of Purdue/Harvard 4D transistor cross-section.

(see Figure 7.2).

The nanowires were formed by first reactive ion etching of fins in the epitaxial material, using aluminium oxide (Al_2O_3) as a mask (Figures 7.3–5). The Al_2O_3 was applied using ALD. The hard mask material was chosen since it does not re-deposit during the etch process, unlike electron-beam lithography resist. Also, a new etch chemistry of chlorine/oxygen, rather than the usual boron trichloride, aimed to increase the etch rate and improve quality in terms of smoother sidewalls.

The lateral etch needed to separate the InGaAs nanowires was achieved through a hydrochloric acid solution based process that removed the intervening InP material (Figure 7.6).

The all-around gate ‘stack’ was achieved through ALD coating of 10nm Al_2O_3 and conformal ALD of tungsten nitride (WN) to give the gate electrode (Figure 7.7). The source/drain electrodes were then applied (Figure 7.8).

The researchers compared the ‘4D’ structure (3x4 NW) with ‘3D’ single-layer 1x4 NW GAA transistors. The ‘1x4’ consists of four lateral nanowires on the same level grouped together as transistors and ‘3x4’ consists of 12 NWs in all, with 4 NWs each in 3 layers. The researchers also compared the transistors with the group’s previous 3D devices reported at IEDM in 2011.

The new 3D devices benefited from smaller equivalent oxide thickness (EOT, 2.2nm versus 4.5nm for an older device given by 5nm and 10nm of Al_2O_3 , respectively) of the gate insulating Al_2O_3 dielectric, leading to improvement in performance with respect to short-channel effects such as much reduced drain-induced barrier lowering ($\sim 50mV/V$), subthreshold swing ($\sim 94mV/decade$), and threshold voltage stability over different channel lengths ($\sim -0.25V$). ➤

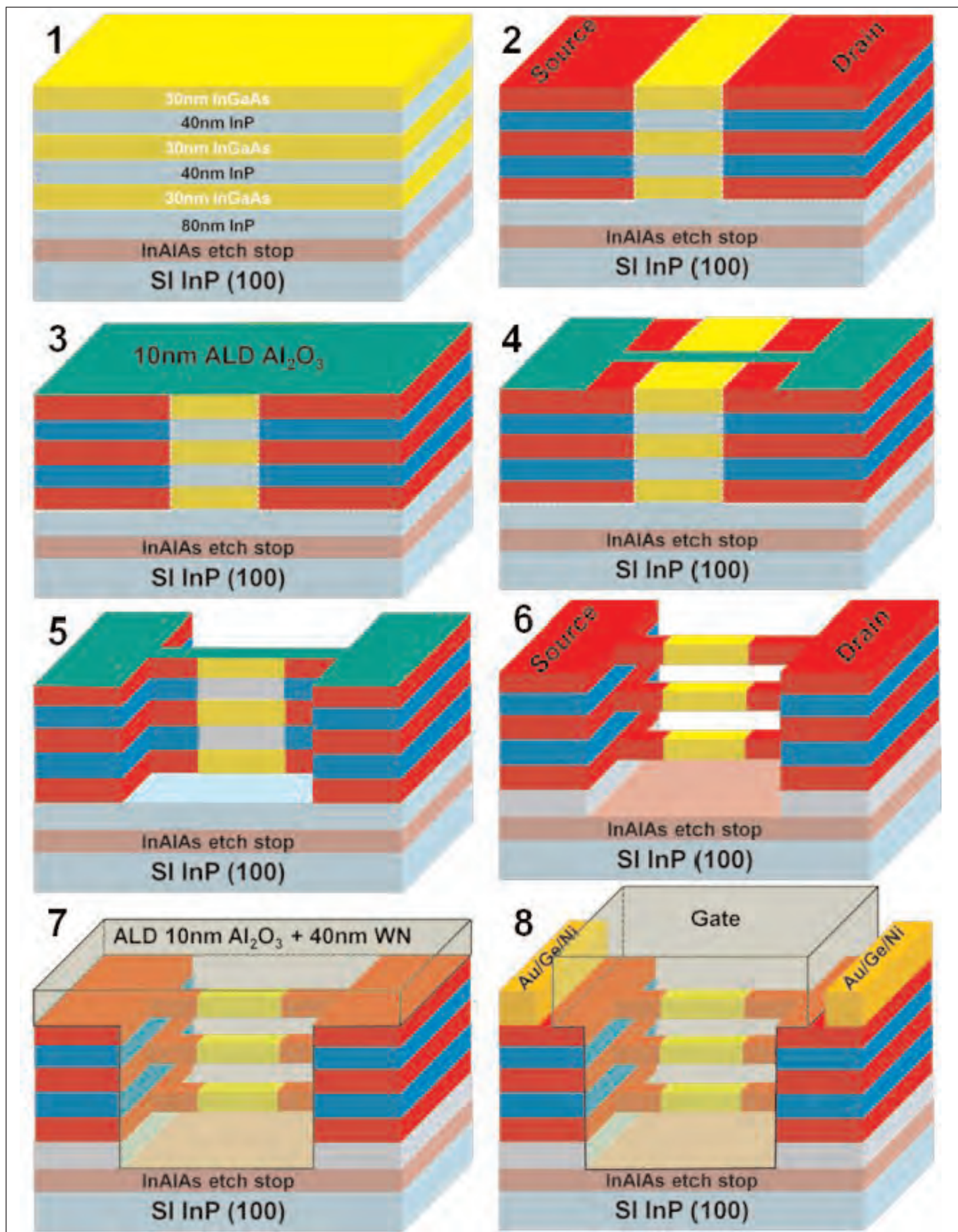


Figure 7. Schematic diagram of key process steps in the fabrication of III-V 4D transistors with three layers of InGaAs NWs stacked vertically.

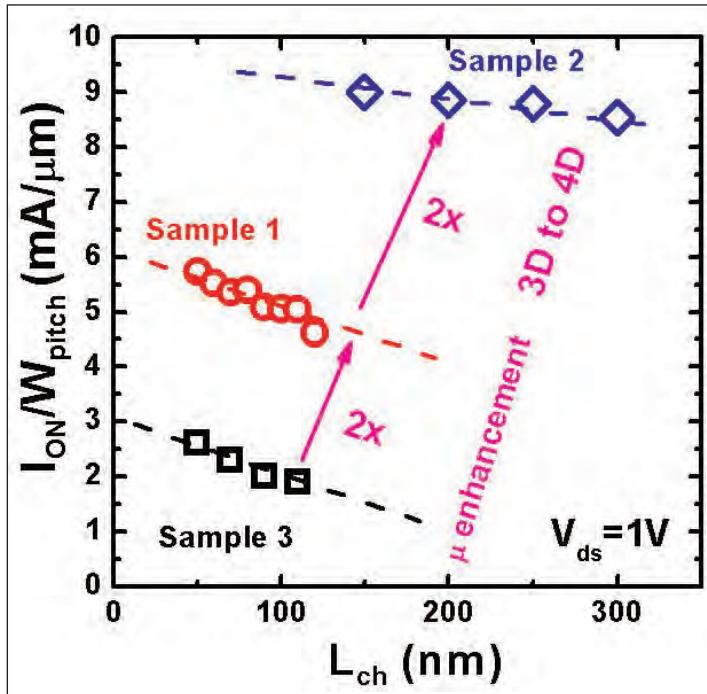


Figure 8. Benchmarking on-current (I_{ON}) normalized with respect to the maximum pitch of the nanowires in a stack (W_{pitch}) for new 3D, 4D, and old 3D transistors (samples 1-3, respectively), indicating the benefit of EOT scaling, mobility enhancement and vertical NW stacking from 3D to 4D integration.

- For the 4D structures (with larger EOT $\sim 4.5\text{nm}$), the main benefits were increased on-current (Figure 8) and maximum transconductance (Figure 9).

Although there are possibilities for thinner EOTs for both the 3D and 4D devices, there is a potential penalty in terms of increased gate leakage current. This was seen with the new 3D device.

Purdue and Harvard have also reduced the channel length of their 3D GAA nanowire devices to 20nm [J.J. Gu et al, session 27.6]. The on-current was $850\mu\text{A}/\mu\text{m}$ at 0.8V drain voltage. The peak transconductance was $1.65\text{mS}/\mu\text{m}$ at 0.5V drain. The lowest subthreshold swing was 63mV/dec and the DIBL was only 7mV/V.

Tackling gate oxide road block to Ge/III-V logic ICs

An international research team reported research into the role of gate oxide border traps in devices being developed for future electronics [D. Lin et al, IEDM 2012, session 28.3]. The work was carried out at the IMEC development center in Belgium, along with Globalfoundries and Stanford University in the USA. IMEC also worked with key partners in its core CMOS technology program: Intel, Micron, Panasonic, Samsung, TSMC, Elpida, SK Hynix, Fujitsu, Toshiba/Sandisk, and Sony.

IMEC has been developing germanium (Ge) p-channel devices on 75% localized strain-relaxed buffers of silicon germanium (SiGe). This boosted mobility by

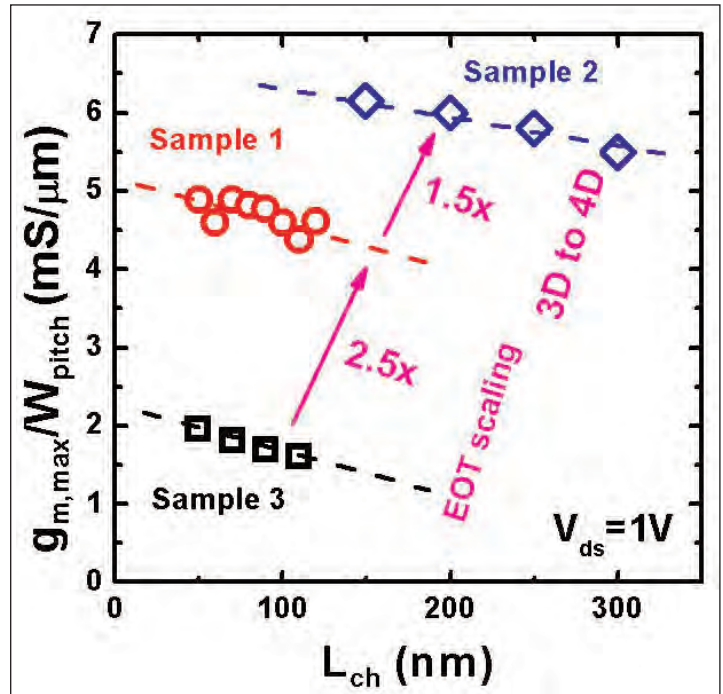


Figure 9. Benchmarking maximum transconductance (g_m) per W_{pitch} for same devices as Figure 8.

59% compared with strained silicon buffers (Figure 10). The team studied Ge Fin field-effect transistors (FETs) that were created using a silicon replacement process which the researchers see as having potential for the 10nm and 7nm transistor nodes.

Much work on high-mobility transistors has recently focused on traps at the interface between the gate oxide insulation and the channel. These traps introduce adverse delay effects on device performance. The

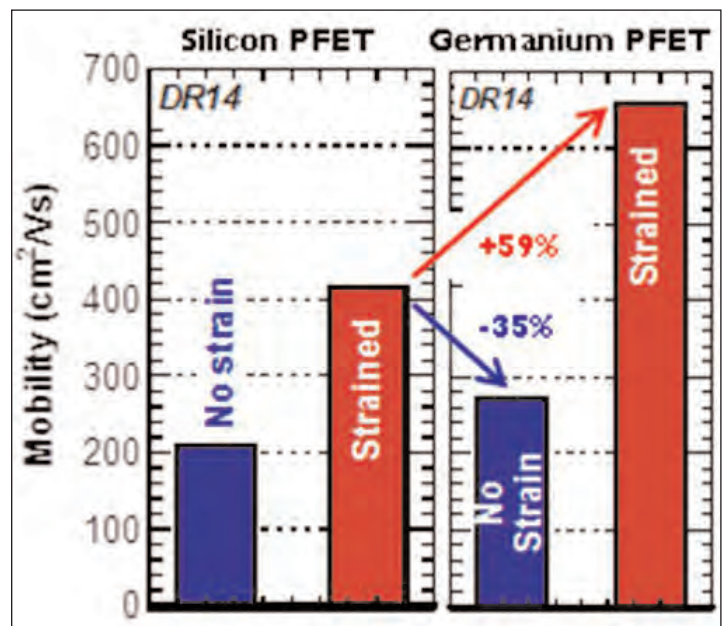


Figure 10. Comparison of mobility in unstrained and strained Si and Ge p-FinFETs, according to IMEC-led research. Unstrained Ge shows degraded mobility with respect to strained Si. Strained Ge can improve pFET mobility by 59%.

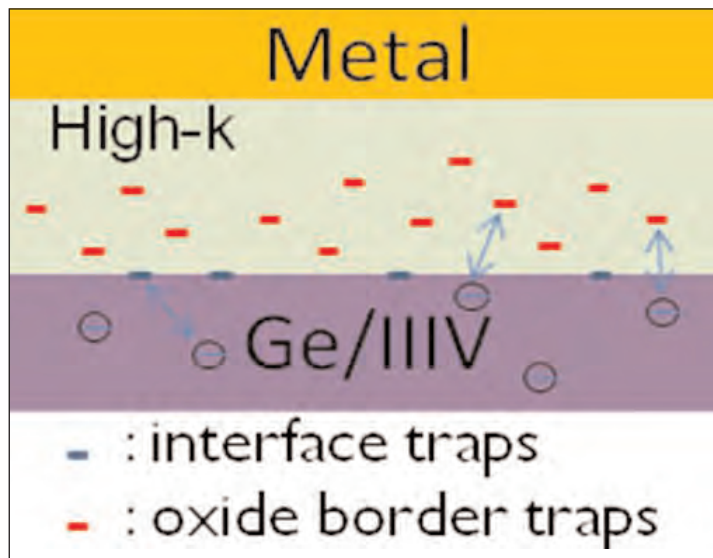


Figure 11. Without a highly insulating interfacial blocking layer (e.g. SiO_2), carriers in the channel can directly interact with border traps in high-k dielectric.

researchers say that, as a result of this work, this particular problem now appears to be contained.

The new work by IMEC et al explored the adverse impact of oxide border traps inside the oxide insulator of the metal-oxide-semiconductor (MOS) gate stack (Figure 11). Shallow, fast oxide traps have been linked to frequency-dependent transconductance effects in non-silicon MOSFETs. Such a frequency dependence can pose significant problems for circuit design using the new transistors.

The researchers also mapped out slower traps using trap spectroscopy by charge injection and sensing (TSCIS). These traps cause threshold voltages (V_T) to drift, creating problems with predicting how a circuit will perform over time. Further, the overdrive voltages ($V_{ON}-V_T$) for III-V (255mV) and Ge-based (212mV) transistors are expected to be about a factor of three smaller than for existing silicon-based devices, making threshold drift a much more significant problem. The lower overdrive without drift is targeted by the International Technology Roadmap for Semiconductors (ITRS) because it allows lower-voltage/power operation.

The researchers write: "This study raises the urgent issues of border traps and the need for engineering workarounds. Fundamental understandings on the nature and formation of these traps are required for long-term solutions."

Another area that the team is exploring is germanium-tin (GeSn) alloy channels, where it is hoped to develop high-mobility n- and p-channel devices in one material system. The researchers have managed to grow high-quality GeSn on Ge on Si using CVD [S. Gupta et al, session 16.2]. NMOSFETs incorporating channels with Sn content up to 8.5% were demonstrated "for the first time". Previously, GeSn PMOSFETs have been developed that outperform Ge-based devices.

Tunneling

A number of groups reported improvements of tunnel FETs (TFETs) that promise better control of sub-threshold behavior, but tend to suffer from reduced maximum drain current. Zurich-based researchers at IBM and ETH [H. Riel et al, session 16.6] reported InAs-Si vertical heterojunction nanowire tunnel diodes with record high currents of $6\text{MA}/\text{cm}^2$ at 0.5V in reverse bias and TFETs with $2.4\mu\text{A}/\mu\text{m}$ on-current, on/off current ratio of 10^6 and a subthreshold slope of 150mV/dec over three decades.

University of Notre Dame and IntelliEpi also reported record current densities for InGaAs/GaSb TFETs of $180\mu\text{A}/\mu\text{m}$ at 0.5V drain bias [G. Zhou et al, session 32.6]. The structure was again vertical and incorporated a novel gate-recess process, enabling low drain ohmic contact and access resistances. The InAs/GaSb tunnel junction features a broken band alignment. The on/off current ratio was 6×10^3 . The minimum subthreshold swing (SS) was 200mV/dec at 300K and 50mV/dec at 77K. C-V measurements indicated the subthreshold performance was degraded by a high interfacial trap density.

Gate stack developments

Finally, three groups reported gate stack developments. National Taiwan University, Taiwan's National Nano Device Laboratories, and University of California Berkeley reported low gate leakage of $\sim 2\times 10^{-3}\text{A}/\text{cm}^2$ for zirconium oxide (ZrO_2) gate insulator on Ge channel with an equivalent oxide thickness (EOT) of 0.39nm [C.-M. Lin et al, session 23.2]. The gate stack was applied to Ge pFET devices without an interfacial layer. The structure gave 104x less leakage than other reported dielectrics in the same EOT region. The subthreshold swing was $\sim 85\text{mV}/\text{dec}$ and the on/off ratio was $\sim 6\times 10^5$ at -1V drain bias. A Ge nFET was also produced with SS of $90\text{mV}/\text{dec}$ and on/off of $\sim 1\times 10^5$ at $+1\text{V}$ drain bias.

Taiwan Semiconductor Manufacturing Corp (TSMC) reported the first demonstration of scaled Ge p-channel FinFET devices fabricated on a Si bulk FinFET baseline using the Aspect-Ratio-Trapping (ART) technique [M.J.H. van Dal et al, session 23.5]. The subthreshold swing (SS) for long-channel devices was 76mV/dec at 0.5V drain bias. The peak transconductance (g_m) was $1.2\text{mS}/\mu\text{m}$ at 1V and $1.05\text{mS}/\mu\text{m}$ at 0.5V. The researchers comment: "The Ge FinFET presented in this work exhibits highest g_m/SS at $V_{dd} = 1\text{V}$ reported for non-planar unstrained Ge pFETs to date."

Teddyne Scientific, UNIST and IntelliEpi have developed a three-step recess process for planar InGaAs MOSFETs that achieves, the researchers reckon, the highest value for transconductance of $2\text{mS}/\mu\text{m}$ with a 0.5V drain for any III-V MOSFETs [D.-H. Kim et al, session 32.2]. The gate stack contained an $\text{InP}/\text{Al}_2\text{O}_3/\text{HfO}_2$ composite insulator with an EOT of 0.8nm. An enhancement-mode device with a gate length of 35nm had a 0.17V threshold, DIBL of 135mV/V, and SS of 115mV/dec. ■



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www.plasmatherm.com



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95873 Bezons Cedex,
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Tel: +33 (0) 1 39 96 65 00
Fax: +33 (0) 1 39 47 45 62
www.riber.com

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Eden Prairie, MN 55344,
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Tel: +1 952 934 2100
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www.svta.com

Temescal, a part of Ferrotec

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Positas Rd,
Livermore,
CA 94551,
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Tel: +1 925 245 5817
Fax: +1 925 449-4096
www.temescal.net

(see section 10 for full contact details)

Temescal, the expert in metallization systems for the processing of compound semiconductor-based substrates, provides the finest evaporation systems available. Multi-layer coatings of materials such as Ti, Pt, Au, Pd, Ag, NiCr, Al, Cr, Cu, Mo, Nb, SiO₂, with high uniformity are guaranteed. Today the world's most sophisticated handsets, optical, wireless and telecom systems rely on millions of devices that are made using Temescal deposition systems and components.



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Fax: +1 516 714 1231

www.veeco.com



Veeco is a world-leading supplier of compound semiconductor equipment, and the only company offering both MOCVD and MBE solutions. With complementary AFM technology and the industry's most advanced Process Integration Center, Veeco tools help grow and measure nanoscale devices in worldwide LED/wireless, data storage, semiconductor and scientific research markets—offering important choices, delivering ideal solutions.

7 Wafer processing materials

Air Products and Chemicals Inc

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Tel: +1 610 481 4911

www.airproducts.com/compound

MicroChem Corp

1254 Chestnut St. Newton,
MA 02464,
USA

Tel: +1 617 965 5511

Fax: +1 617 965 5818

www.microchem.com

Power + Energy Inc

(see section 10 for full contact details)

Praxair Electronics

(see section 5 for full contact details)

8 Wafer processing equipment

EV Group

DI Erich Thallner Strasse 1,
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(see section 6 for full contact details)

Plasma-Therm LLC

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Power + Energy Inc

(see section 10 for full contact details)

SAMCO International Inc

532 Weddell Drive,
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Tel: +1 408 734 0459

Fax: +1 408 734 0961

www.samcointl.com

SPP Process Technology Systems Ltd

Imperial Park, Newport NP10 8UJ,
Wales, UK

Tel: +44 (0)1633 652400

Fax: +44 (0)1633 652405

www.spp-pts.com

Veeco Instruments Inc

(see section 6 for full contact details)

9 Materials & metals

Goodfellow Cambridge Ltd

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Fax: +44 (0)1954 786818

www.cambridge-fluid.com

CS CLEAN SYSTEMS AG

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Germany

Tel: +49 89 96 24 00 0

Fax: +49 89 96 24 00 122

www.cscleansystems.com

Power + Energy Inc

106 Railroad Drive,
Ivyland, PA 18974, USA

Tel: +1 215 942-4600

Fax: +1 215 942-9300

www.powerandenergy.com

SAES Pure Gas Inc

4175 Santa Fe Road,
San Luis Obispo, CA 93401,
USA

Tel: +1 805 541 9299

Fax: +1 805 541 9399

www.saesgetters.com

11 Process monitoring and control

k-Space Associates Inc

2182 Bishop Circle
East, Dexter,
MI 48130, USA

Tel: +1 734 426 7977

Fax: +1 734 426 7955

www.k-space.com



k-Space Associates Inc specializes in in-situ, real-time thin-film process monitoring tools for MBE, MOCVD, PVD, and thermal evaporation. Applications and materials include the research and production line monitoring of compound semiconductor-based electronic, optoelectronic, and photovoltaic devices.

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Fax: +1 408 875 4144
www.kla-tencor.com

LayTec AG

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Germany
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www.laytec.de



LayTec develops and manufactures optical in-situ and in-line metrology systems for thin-film processes with particular focus on compound semiconductor and photovoltaic applications. Its know-how is based on optical techniques: reflectometry, emissivity corrected pyrometry, curvature measurements and reflectance anisotropy spectroscopy.

Optical Reference Systems Ltd

OpTIC Technium,
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St Asaph, LL17 0JD,
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Fax: +44 (0)1745 535 186
www.ors-ltd.com

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Bregstrasse 90, D-78120
Furtwangen im Schwarzwald,
Germany
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Fax: +49 7723 9197 22
www.wepcontrol.com

12 Inspection equipment

Bruker AXS GmbH

Oestliche Rheinbrueckenstrasse 49,
Karlsruhe, 76187,
Germany
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Fax: +49 (0)721 595 4587
www.bruker-axs.de

13 Characterization equipment

J.A. Woollam Co. Inc.

645 M Street Suite 102,
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Fax: +1 402 477 8214
www.jawoollam.com

Lake Shore Cryotronics Inc

575 McCorkle Boulevard,
Westerville, OH 43082,
USA
Tel: +1 614 891 2244
Fax: +1 614 818 1600
www.lakeshore.com

14 Chip test equipment

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USA
Tel: +1 440.248.0400
Fax: +1 440.248.6168
www.keithley.com

SUSS MicroTec Test Systems

228 Suss Drive,
Waterbury Center, VT 05677,
USA
Tel: +1 800 685 7877
Fax: +1 802 244 7853
www.suss.com

15 Assembly/packaging materials

ePAK International Inc

4926 Spicewood Springs Road,
Austin, TX 78759, USA
Tel: +1 512 231 8083
Fax: +1 512 231 8183
www.epak.com

Gel-Pak

31398 Huntwood Avenue,
Hayward, CA 94544, USA
Tel: +1 510 576 2220
Fax: +1 510 576 2282
www.gelpak.com

Wafer World Inc

(see section 3 for full contact details)

Williams Advanced Materials

2978 Main Street,
Buffalo, NY 14214, USA
Tel: +1 716 837 1000
Fax: +1 716 833 2926
www.williams-adv.com

16 Assembly/packaging equipment

Ismeca Europe Semiconductor SA

Helvetie 283, La Chaux-de-Fonds,
2301, Switzerland
Tel: +41 329257111
Fax: +41 329257115
www.ismeca.com

Kulicke & Soffa Industries

1005 Virginia Drive,
Fort Washington, PA 19034, USA
Tel: +1 215 784 6000
Fax: +1 215 784 6001
www.kns.com

Palomar Technologies Inc

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Carlsbad, CA 92010, USA
Tel: +1 760 931 3600
Fax: +1 760 931 5191
www.PalomarTechnologies.com

TECDIA Inc

2700 Augustine Drive, Suite 110,
Santa Clara, CA 95054, USA
Tel: +1 408 748 0100
Fax: +1 408 748 0111
www.tecdia.com

17 Assembly/packaging foundry

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10987 Via Frontera,
San Diego, CA 92127, USA
Tel: +1 858 674 4676
Fax: +1 8586 74 4681
www.quikicpak.com

18 Chip foundry

Compound Semiconductor Technologies Ltd

Block 7, Kelvin Campus,
West of Scotland, Glasgow,
Scotland G20 0TH,
UK

Tel: +44 141 579 3000

Fax: +44 141 579 3040

www.compoundsemi.co.uk

United Monolithic Semiconductors

Route departementale 128,
BP46, Orsay, 91401,
France

Tel: +33 1 69 33 04 72

Fax: +33 169 33 02 92

www.ums-gaas.com

19 Facility equipment

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Albany, OR 97322-7014,
USA

Tel: +1 541 917 3626

Fax: +1 541 917 3623

www.marlerenterprises.net

20 Facility consumables

W.L. Gore & Associates

401 Airport Rd,
Elkton, MD 21921-4236,
USA

Tel: +1 410 392 4440

Fax: +1 410 506 8749

www.gore.com

21 Computer hardware & software

Ansoft Corp

4 Station Square, Suite 200,
Pittsburgh, PA 15219,
USA

Tel: +1 412 261 3200

Fax: +1 412 471 9427

www.ansoft.com

Crosslight Software Inc

121-3989 Henning Dr.,
Burnaby, BC, V5C 6P8,
Canada

Tel: +1 604 320 1704

Fax: +1 604 320 1734

www.crosslight.com

Semiconductor Technology Research Inc

10404 Patterson Ave., Suite 108,
Richmond, VA 23238,
USA

Tel: +1 804 740 8314

Fax: +1 804 740 3814

www.semitech.us

22 Used equipment

Class One Equipment Inc

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Decatur, GA 30035,
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Tel: +1 770 808 8708

Fax: +1 770 808 8308

www.ClassOneEquipment.com

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Fishbone Consulting SARL

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78460 Choisel,
France

Tel: + 33 (0)1 30 47 29 03

E-mail: jean-luc.ledys@neuf.fr

25 Resources

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3081 Zanker Road,
San Jose, CA 95134, USA

Tel: +1 408 943 6900

Fax: +1 408 428 9600

www.semi.org

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28 January – 1 February 2013

5th International Symposium on Advanced Plasma Science and its Applications for Nitrides and Nanomaterials (ISPlasma 2013)

Nagoya, Japan

E-mail: isplasma@astf.or.jp

www.isplasma.jp

30 January 2013 – 1 February 2013

LED Korea 2013 — SEMICON Korea 2013

COEX Seoul, South Korea

E-mail: semiconkorea@semi.org

www.led-korea.org/en

www.semiconkorea.org/en

31 January – 2 February 2013

Second International Symposium on Semiconductor Materials and Devices (ISSMD-2)

Department of Physics and Electronics, University of Jammu, India

E-mail: convener@issmd.com

www.issmd.com

1 February 2013

Tuscany-Europe 2020: NEW FRONTIERS OF SILICON PHOTONICS (thematic workshop)

Brussels, Belgium

E-mail: livio.stefanelli@regione.toscana.it

<http://siliconphotonics.tecip.sssup.it>

12–14 February 2013

Strategies in Light 2013 Conference & Expo

Santa Clara Convention Center, CA, USA

E-mail: Tcarli@pennwell.com

www.strategiesinlight.com

24–28 February 2013

SPIE Advanced Lithography 2013

San Jose Convention Center and Marriott, CA, USA

E-mail: customerservice@spie.org

<http://spie.org/advanced-lithography.xml>

1–4 March 2013

LED CHINA 2013

Guangzhou Pazhou Complex, China

E-mail: led-trust@ubm.com

www.LEDChina-gz.com

17–23 March 2013

Optical Fiber Communications (OFC 2013)

Anaheim, CA, USA

E-mail: info@ofcconference.org

www.ofcnfoec.org

17–21 March 2013

Applied Power Electronics Conference and Exposition (APEC 2013)

Long Beach Convention Center, CA, USA

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www.apec-conf.org

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17–18 March 2013

China Semiconductor Technology International Conference (CSTIC 2013)

Kerry Hotel Pudong, Shanghai, China

E-mail: kwu@semi.org

<http://semiconchina.semi.org/cstic>

19–21 March 2013

SEMICON China 2013

Shanghai New International Expo Centre (SNIEC), China

E-mail: semichina@semi.org

www.semiconchina.org

19–21 March 2013

LASER World of PHOTONICS CHINA

Shanghai New International Expo Centre (SNIEC), China

E-mail: laser@mimi-shanghai.com

www.world-of-photonics.net/en/laser-china/start

21–22 March 2013

**CPV International 2013
(4th Annual Concentrated Photovoltaics Conference & Expo)**

Madrid, Spain

E-mail: lthomas@pv-insider.com

www.pv-insider.com/cpv-international

15–17 April 2013

9th International Conference on Concentrator Photovoltaic Systems (CPV-9)

Phoenix Seagaia Resort, Miyazaki, Japan

E-mail: info@cpv-9.org

www.cpv-9.org

29 April – 3 May 2013

SPIE Defense, Security, and Sensing 2013

Baltimore Convention Center, Maryland, USA

E-mail: customerservice@spie.org

<http://spie.org/defense-security-sensing.xml>

5–8 May 2013

IEEE Optical Interconnects Conference (OI Conference 2013)

Eldorado Hotel & Spa, Santa Fe, NM, USA

E-mail: m.figueroa@ieee.org

www.oi-ieee.org

12–16 May 2013

World of Photonics Congress, incorporating European Conference on Lasers and Electro-Optics and International Quantum Electronics Conference (CLEO/Europe-IQEC 2013)

International Congress Centre Munich (ICM), Germany

E-mail: info@photonics-congress.com

www.world-of-photonics.net/en/photonics-congress/start

13–16 May 2013

21st LASER World of Photonics

Messe München, Munich, Germany

E-mail: info@world-of-photonics.net

www.world-of-photonics.net

12–17 May 2013

223rd Electrochemical Society (ECS) Meeting

Toronto, Ontario, Canada

E-mail: meetings@electrochem.org

www.electrochem.org/meetings/biannual/fut_mtgs.htm

13 May 2013

JEDEC's 28th Annual ROCS (Reliability of Compound Semiconductors) Workshop

Hilton New Orleans Riverside, New Orleans, LA, USA

E-mail: ptanner@jedec.org

www.jedec.org/home/gaas

13–16 May 2013

2013 CS MANTECH: International Conference on Compound Semiconductor Manufacturing Technology

Hilton New Orleans Riverside, New Orleans, LA, USA

E-mail: csmantech@csmantech.org

www.csmantech.org

2–5 June 2013

15th European Workshop on Metalorganic Vapour Phase Epitaxy (EWMOVPE 2013)

Technology Centre in Aachen, Germany

E-mail: ewmovpe2013@jara.org

www.jara.org/index.php?id=606

5–6 June 2013

SEMICON Russia 2013

Moscow, Russia

E-mail: eweller@semi.org

www.semiconrussia.org/en

17–20 June 2013

LASER World of PHOTONICS 2013

Munich, Germany

E-mail: info@world-of-photonics.net

www.world-of-photonics.net/en

24–25 June 2013

euroLED 2013

The ICC, Birmingham, UK

E-mail: info@euroled

www.euroLED.org.uk

9–11 July 2013

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