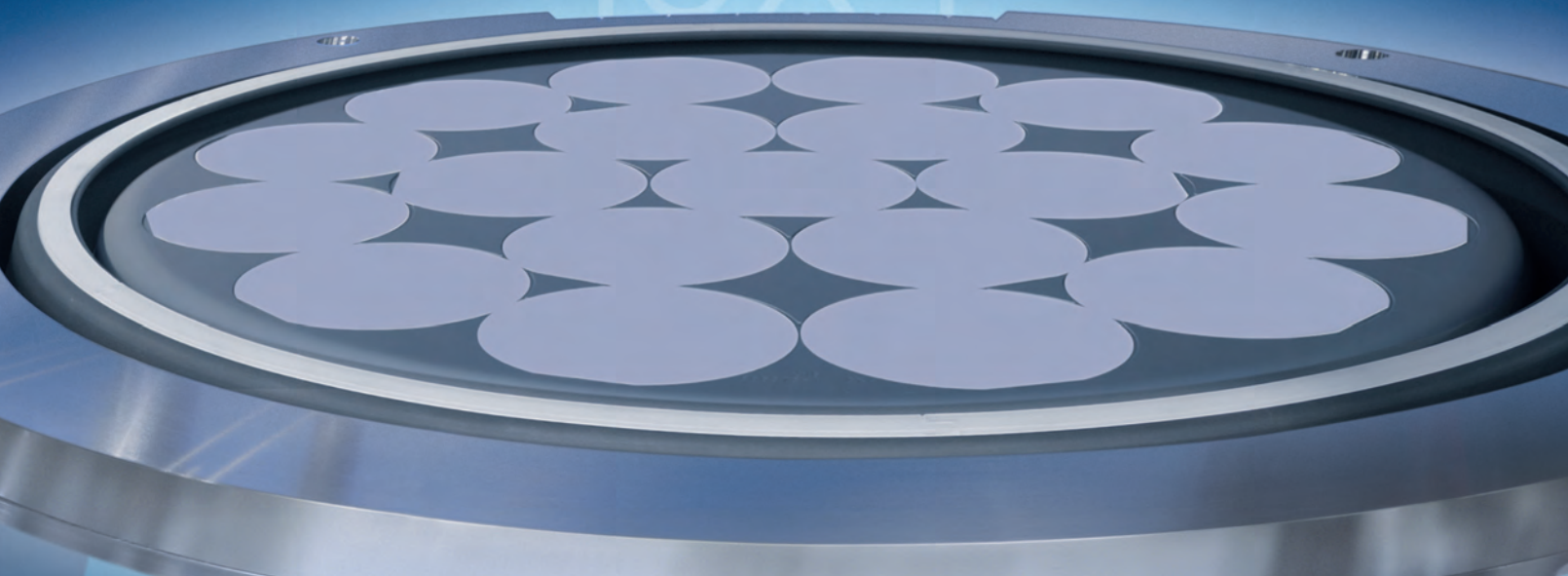


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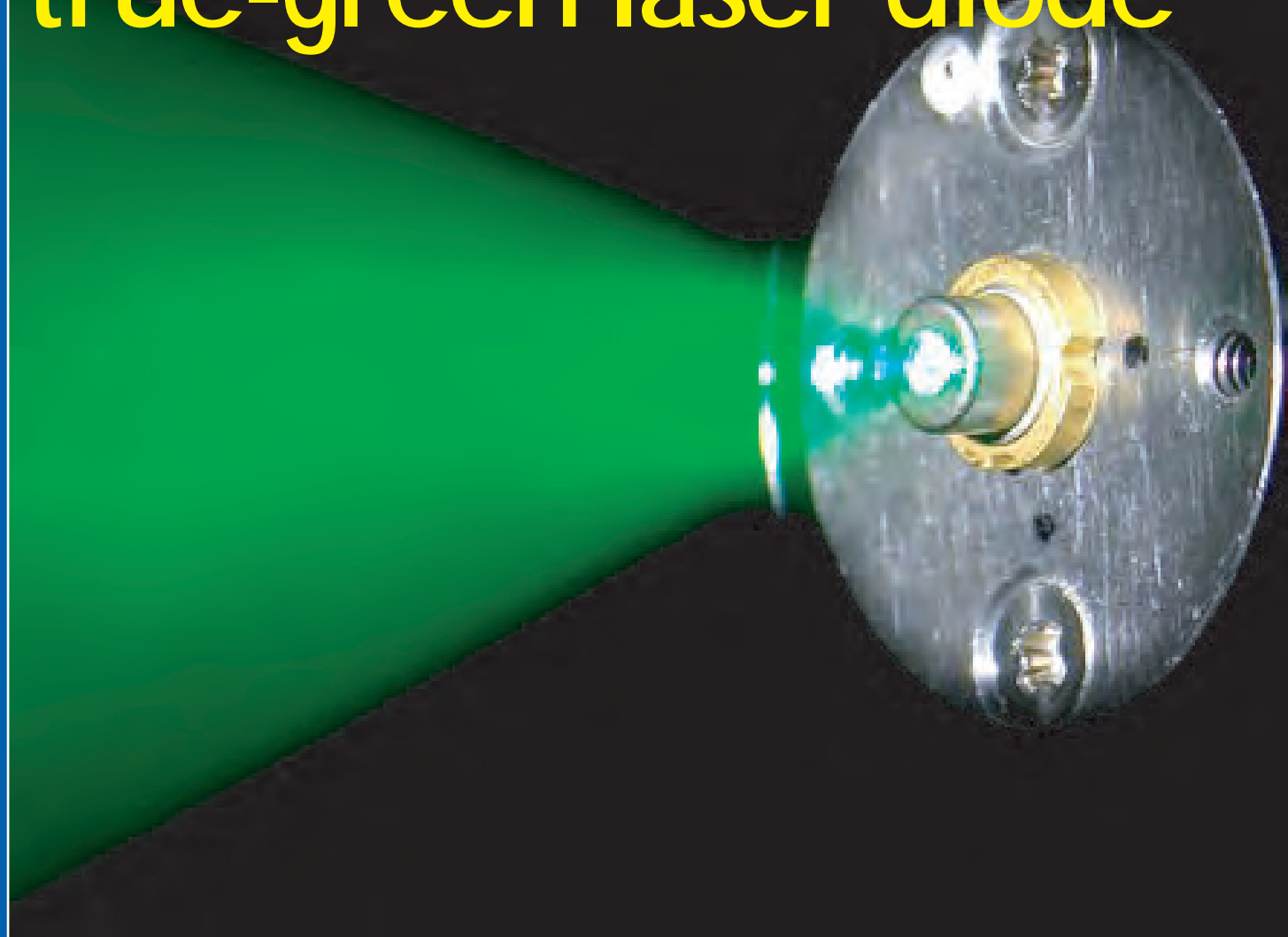
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Vol. 7 • Issue 4 • May/June 2012

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Multispectral detection First 100mW 530nm true-green laser diode



RFMD divests MBE to IQE • China LED assembly plant for Osram
EpiGaN opens production site • Emcore launches CPV system

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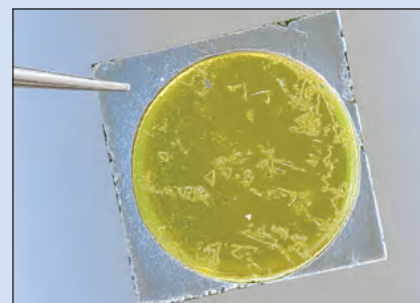
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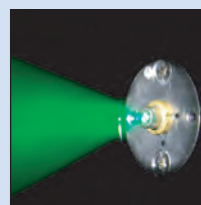
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p40 Veeco has launched three new TurboDisc MOCVD systems for producing HB-LEDs. MaxBright MHP is a high-performance version of the new modular 'M' model.



p65 Osram Opto Semiconductors' new Ostar Projection Cube green LED has luminous efficiency of 110lm/W for embedded projection applications.



Cover: Japan's Sumitomo Electric Industries and Sony have developed what they claim is the first semiconductor laser diode with output power exceeding 100mW in the true-green region of the spectrum at a wavelength of 530nm, roughly doubling the output of other GaN-based green lasers at 520nm. **p66**

Trends and developments

In this issue we include a feature article focusing on not LEDs or lasers but on the less frequently covered topic of photo-detectors. Specifically, we look at the topic of integrating multispectral capabilities into III-V detectors to allow operation in multiple infrared wavelength bands (enabling sensing equipment to be lighter and more compact). This can be accomplished by integrating layers of various compositions using buffer layers with graded or metamorphic compositions, or by using structures that enable quantum cascade operation through inter-subband energy transitions (page 106).

Another photo-absorbing device that uses a novel material composition is the solar cell detailed on pages 86–87, which uses a quinary InGaAsSbN (indium gallium arsenide antimonide nitride) layer grown lattice matched on GaAs to allow capture of wavelengths around the 1eV spectral region.

Although grown by metal-organic chemical vapor deposition (MOCVD), such bandgap engineering is often performed using molecular beam epitaxy (MBE) growth. A particular development reported on page 10 of this issue is the divesting by US-based RFIC maker RF Micro Devices of its MBE manufacturing unit to epiwafer foundry IQE. RFMD expects the transfer to outsourcing MBE will lower its manufacturing costs. IQE gains a long-term supply agreement. However, it also gains MBE manufacturing capacity that it aims to use for the growth of concentrator photovoltaic (CPV) solar cell epiwafers, which it is targeting since its technology transfer and wafer supply agreement in February with MBE-based PV cell maker Solar Junction.

CPV has had a faltering market take-off, and some cell and system makers have suffered in the shake-out. For example, OPEL has cut staffing as it refocuses from CPV to its optoelectronic circuit integration technology (see page 78). However, Soitec has been making strides in solar project development (page 81), while Emcore has just launched its commercial rooftop CPV system (page 75). In addition, Japan's Sharp has equalled Solar Junction's conversion efficiency record of 43.5% (page 80). Such technical developments can only help to enhance the economic competitiveness of CPV.

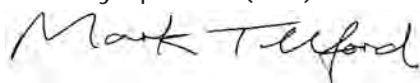
Regarding the LED market, on page 8 we report a further reduction by market analyst firm IMS Research in its forecast of the number of MOCVD systems to be shipped in 2012, from the prior estimate of 342 systems to 281 (follows a prior cut in its forecast from 583 to under 400).

Nevertheless, on page 9 we report how NPD DisplaySearch is reckoning on supply and demand of LEDs coming back into balance again this year, boosted in 2013 by growing popularity of new, low-cost direct LED backlights, and then in 2014 by lighting becoming the dominant source of demand for LEDs. Such market trends (and timing) correlate with Veeco launching a new suite of its TurboDisc MOCVD systems for nitride-based LED making, with three new models variously targeting high performance or manufacturing efficiency/flexibility.

● Next issue, we report on developments in nitride microelectronic devices from June's IEEE International Microwave Symposium (IMS) in Montreal.

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- conference reports;
- event calendar and event previews;
- suppliers' directory.

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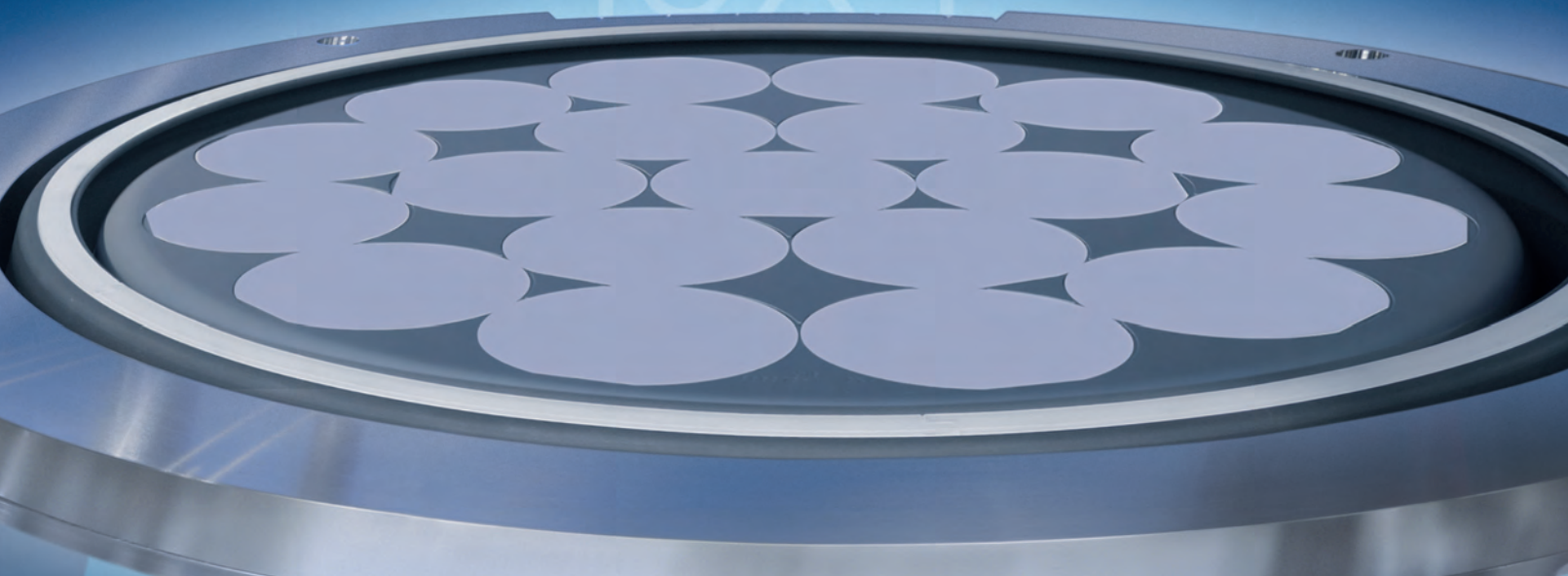
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Handset RF device market to grow from \$3.8bn to \$5bn in 2016

Value driven by \$9–11 cost for 4G devices, twice that for 3G devices and six times that for 2G devices

As handset RF front ends (containing gallium arsenide) are becoming increasingly sophisticated in the 4G era, they cost \$9–11 for 4G devices, which is twice that for 3G and six times that for 2G, according to the 'Global and China GaAs-based Device Industry Report, 2011–2012' from Research and Markets.

With handset RF systems consisting mainly of transceivers, power amplifiers (PAs), filters and antenna switches, the handset RF market is hence expected to grow from about \$3.8bn currently to \$5bn in 2016.

Taking the 4G iPad for example, it uses as many as 19 RF front-end components, including seven PAs, one transceiver and two antenna switch modules (ASMs). Of these, three PAs are provided by Avago Technologies (corresponding to three LTE frequency bands); two PAs are supplied by Skyworks Solutions (corresponding to two 3G frequency bands); one PA comes from by TriQuint Semiconductor (containing three separate PA dies and corresponding to four 2G frequency bands); and the remaining PA is in the ASM and is supplied by Japan-based Murata (which also supplies the two ASMs).

Additionally, the 4G iPad is integrated with 802.11/Bluetooth/FM supported by Broadcom's BCM4330 single-chip device, and its system-in-package (SiP) IC contains a GaAs pHEMT PA provided by Skyworks.

Murata is the world's largest manufacturer of multi-layer ceramic capacitors (MLCCs), the largest producer of communication modules (including Bluetooth and WLAN), the second largest SAW (surface

acoustic wave) filter manufacturer, and the largest antenna switch producer. On 1 March, it entered the PA market by completing its acquisition of the PA Division of Renesas. The firm now claims to possess the most complete product line in the handset RF market.

Kopin, VPEC and IQE are the top three GaAs epilayer manufacturers, collectively accounting for over 60% market share, reckons the report. Kopin and VPEC use MOCVD (metal-organic chemical vapor deposition) while IQE uses both MOCVD and MBE (molecular beam epitaxy).

Taiwan's WIN Semiconductor is the largest GaAs foundry (with Avago as its main customer). Fellow Taiwanese GaAs foundry AWSC's major client is Skyworks, which has its own GaAs fab capability but outsources some production to provide extra capacity when needed. Anadigics is the smallest GaAs IDM (integrated device manufacturer), and its revenue fell by 29% in 2011.

Once the world's largest PA maker, RFMD relies heavily on large customers. In fiscal 2008, Nokia comprised 59% of its revenue and Motorola 14%. However, in the 3G/smartphone era, Nokia's business has fallen sharply, so RFMD has exhibited a slow transition and has seen declining performance, with revenue slipping about 17% in 2011

Once the world's largest PA manufacturer, RF Micro Devices relies heavily on large customers, notes the report. In fiscal 2008, Nokia comprised 59% of its revenue and Motorola 14%. However, in the 3G/smart-phone era, Nokia's business has fallen sharply, so RFMD has exhibited a slow transition and has seen declining performance, with revenue slipping about 17% in 2011.

Supported by its main customers (the world's top 10 mobile phone vendors), Skyworks has the most favorable customer distribution, reckons the report. Avago is a rising star and provides services for 3G and 4G devices. Its acquisition of Infineon's BAW Division in 2008 makes Avago's market share in BAW (bulk acoustic wave) filter area is as high as 65%, and BAW filters enjoy the highest price among handset RF front-end components, notes the report. Avago and Skyworks may rival each other in the coming years.

Sumitomo Electric Device Innovations Inc (SEDI) is a subsidiary of Japan's Sumitomo Electric Industries Ltd that acts as a manufacturer possessing the complete industry chain, ranging from upstream substrates to downstream ICs. SEDI's products target base-station PAs.

China-based manufacturer RDA Microelectronics is booming (with revenue growing 51.3% in 2011) by virtue of unbranded phone manufacturing. The firm ranks number. 1 in the market for unbranded cell-phone PAs, Bluetooth, FM tuners and DVB-S tuners (with more than 50% market share for FM tuners and DVB-S tuners).

www.researchandmarkets.com

SiC drives material innovation for high-power electronics

Power electronics switching from silicon to SiC due to its superior properties

Due to its superior thermal and electrical properties, the wide-bandgap material silicon carbide (SiC) has emerged as a key enabling material that has the potential to displace silicon-based insulated-gate bipolar transistors (IGBTs), metal oxide semiconductor field-effect transistors (MOSFETs), diodes and rectifiers (specifically in high-power electronics for applications in photovoltaic panels, hybrid/electric cars, high-power industrial drives, motor drives, smart grids and power utilities), according to Frost & Sullivan's report 'Silicon Carbide Electronics —Technology Market Penetration and Roadmapping'.

The report finds that SiC-based power electronics are well positioned to meet some of the key performance criteria, such as decreased overall system costs and enhanced system efficiency for emerging applications such as hybrid vehicles and inverters for solar energy.

"Silicon carbide electronics exhibit superior thermal resistance, low conductivity losses and higher material strength than silicon," says Avinash Bhaskar, industry analyst with Frost & Sullivan's Technical Insights research group. "Thus, silicon carbide-based power electronics such as diodes and transistors can potentially reduce the size and also switch losses in power systems by 50%," he adds.

Encouraged by their superior material properties, major automotive manufacturers involved in developing hybrid and electric vehicles are currently testing SiC-based MOSFETs and other transistors as a viable alternative to silicon-based transistors, particularly for under-the-hood applications where the operating conditions are challenging.

"Defense agencies are also driving the research on using silicon carbide for developing power electronic devices," says Technical Insights industry manager Kasthuri Jagadeesan. "A commercial volume market in the renewable sector, industrial sector and automotive sector could present a big market opportunity for silicon carbide power electronics."

The future of SiC will lie in developing reliable transistors such as MOSFETs and bipolar junction transistors. While SiC-based diodes have made their way into a number of applications, end-users are truly interested in a reliable SiC-based MOSFET that can challenge the dominance of silicon-based IGBTs.

Hybrid electric cars will greatly benefit from having SiC MOSFETs under the hood, as SiC has a better thermal resistance than silicon-based IGBTs, notes the report. This will reduce the overall system cost in electric cars, as adopting SiC devices will lead to eliminating the use of heat sinks and other cooling devices.

"However, silicon carbide material defects, higher cost of manufacturing wafers and packaging issues could hamper the growth of silicon carbide power electronics," cautions Bhaskar. "The research efforts in developing reliable silicon carbide-based transistors in the higher-power realm have been sluggish, slowing down the time to market."

Strong collaborations and alliances along with increased investments will accelerate developments in the SiC power electronics technology space, reckons the market research firm. Several companies have started sampling SiC MOSFETs and DMOSFETs, which will aid the rapid deployment of SiC power electronics in the commercial market, it concludes.

www.technicalinsights.frost.com

LEDs in signage/ professional displays to grow from \$1.63bn to \$3.3bn in 2017

Consumption of packaged LEDs used in signage and professional displays rose from \$1.5bn in 2010 to over \$1.63bn in 2011 and will grow to \$3.3bn in 2017, according to ElectroniCast Consultants. The consumption value will rise, but with quantity growth largely offset by declining average prices (ASPs).

The 2011–2017 report is presented for standard versus high-brightness (HB) LEDs used in signage and professional displays. Of component-level bulbs, ElectroniCast defines HB-LEDs as having a lumen-per-Watt rating of 30lm/W and above, and standard LEDs as having a rating of less than 30lm/W.

In terms of volume (the quantity/number of LEDs), the market share leader is the standard LED, with a share of more than 95%. However, since there is a huge difference in ASP between HB-LEDs and standard LEDs, HB-LEDs hold the lead in terms of consumption value, with a share of nearly 67% in 2012.

The high-brightness category also includes ultra-high-brightness (UHB) light-emitting diodes (with a rating of over 70lm/W). The ASP for both conventional (standard) and HB LEDs will decrease annually. However, UHB-LED prices have a substantial premium over HB-LEDs. There is currently relatively little use of UHB-LEDs in this application but, as their use increases, the overall effect results in just a slight annual decrease in ASPs in the HB-LED category during 2011–2017.

The American region (South, Central and North America) and the Asia Pacific region (APAC) are even in market share this year. However, APAC is forecast to expand at a faster pace. The Europe, Middle East and African region (EMEA) holds over 20% share of global consumption value, but is forecast for relatively flat growth for the next few years.

www.electronicast.com

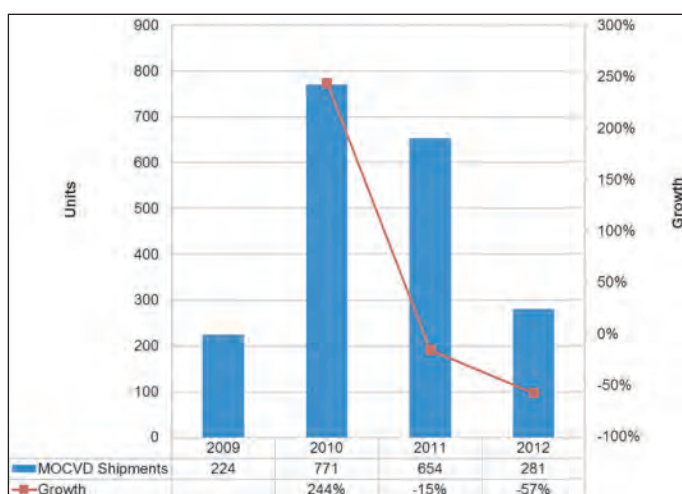
IMS Research cuts 2012 MOCVD shipment forecast from 342 systems to 281

Purchase plans cut in recent months, particularly in China, during lull between backlighting and lighting cycles

Market analyst firm IMS Research has cut its forecast for 2012 gallium nitride (GaN) metal-organic chemical vapor deposition (MOCVD) shipments from 342 systems to 281, according to the second-quarter 2012 MOCVD update of its 'GaN LED Quarterly Supply and Demand' report. This follows previous cuts in its forecast from 583 systems to under 400.

"The decline in 2012 is due to sufficient tools being in place for backlighting, lighting not yet fully taking off, and expiring subsidies in China," says analyst Jamie Fox. "The revision to our forecast is due to an analysis of the latest supplier earnings calls and our latest surveys of manufacturers, which showed that some companies' purchase plans have been cut back more than expected in recent months, particularly in China," he adds. "We have heard about capacity utilization moving up in Taiwan this quarter, but we don't see this as a worldwide trend at the moment."

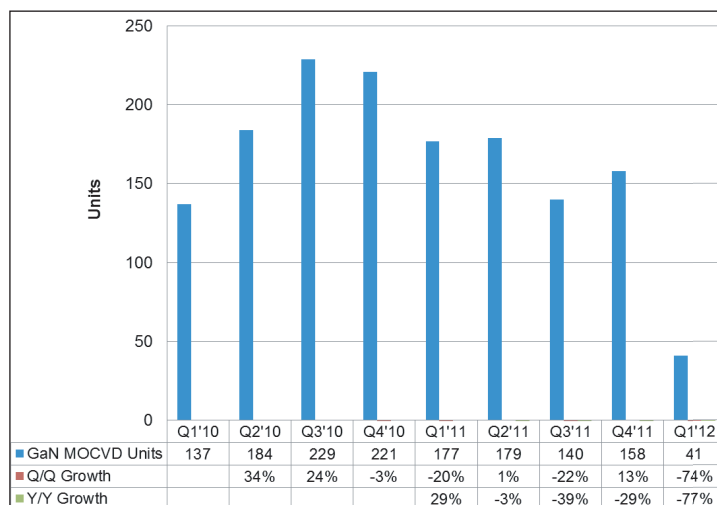
Figure 1 shows that 2012 will be much lower than 2010 and 2011 (down 57% on 2011), but will still be higher than 2009's 224 systems. This year will be a



MOCVD system shipments from 2009-2012.

quiet as, in terms of equipment installation, it will be the low point between the backlighting and lighting cycles. After a huge rush to buy in China in 2011 (peaking at 92% of shipments in the fourth quarter), sales there are dropping markedly in 2012.

The entire worldwide market in first-quarter 2012 was about the same size as the one largest order in China in fourth-quarter 2011, notes IMS Research. However, the firm believes that the market has bottomed out in first-half 2012.



GaN MOCVD system shipments by quarter, from Q1/2010 to Q1/2012, showing variations both quarter-on-quarter and year-on-year.

Modest growth should return in second-half 2012.

While the industry is currently in an overcapacity situation that will continue in the short term, longer-term projections show that many more reactors will be needed over the coming years to meet the demand in lighting. At the end of June, IMS will release its latest demand and supply projections, but at present big changes to the long-term outlook are not anticipated.

In fourth-quarter 2011, Aixtron reported a strong quarter, regaining the lead in the MOCVD market. However, as expected, this has not lasted, and Veeco was well ahead again in first-quarter 2012, with an estimated 59% market share (with its K465i GaN LED MOCVD system being the most popular). In addition, according to surveys of end customers, Veeco will also have a clear lead over Aixtron in MOCVD systems for GaN LEDs for full-year 2012. Overall, typical MOCVD system prices remained about \$2m in first-quarter 2012.

The report also highlights that China was top region for shipments in first-quarter 2012, followed by Taiwan. In particular, while Taiwan-based LED chip maker Epistar is the leader in cumulative tools installed, China's Elec-Tech is ranked top among projected 2012 customers.

IMS will be holding the LED Lighting Evolution Conference: From Sapphire to Lumens examining LED and MOCVD supply/demand on June 6th in Boston at the Hynes Convention Center featuring influential industry executives and leading financial and industry analysts. Companies presenting include Acuity Brands, Barclays, Canacord Genuity, Cree, Displaybank, GTAT, IMS Research, KLA Tencor, Nichia, QD Vision, Veeco and many more.

www.ledmarketresearch.com

Supply and demand for LEDs moving towards equilibrium in 2012

Demand from LCD backlights will continue to dominate LED demand until 2013, when it will reach its peak, according to the NPD DisplaySearch's 'Quarterly LED Supply/Demand Market Forecast Report'.

After taking off in 2010, in 2011 the growth in LED demand from LCD TV backlights reversed course, due to slower growth in LED-backlit LCD TV sales and (due to efficiency increases) slower growth in chips used per backlight. However, demand for LEDs in LCD backlights did grow slightly, as use in tablet PCs and strong penetration growth in LCD monitors made up for the drop in demand from TV. Growth was also modest in lighting, as the market penetration of LEDs only grew from 1.4% in 2010 to 1.9% in 2011.

Meanwhile, many new LED suppliers have entered the industry, and have been rapidly ramping up production. Measured in standard units of 500µm x 500µm chip size, supply grew by 41% in 2011, versus just 10% growth in demand, leading to significant over-supply in 2011.

"LEDs have been in surplus since the end of 2010, setting the stage for a decrease in LED prices and margins," says NPD DisplaySearch analyst Steven Sher. "As a result of this surplus situation, there has been

almost no investment in LED applications, nor any significant capacity increases in 2012. This is resulting in a halving of the supply/demand glut from 2011 to 2012," he adds.

Due to the growing popularity of new, low-cost direct LED backlight designs for LCD TVs, the demand for LEDs in backlights will continue to increase through 2013, forecasts the report. While the number of LED packages per LCD backlight unit will peak in 2012, continued growth in penetration of LED backlights will lead to a slight increase in LED demand in 2013. By 2014, lighting will become the dominant source of demand for LEDs as price reductions and efficacy improvements drive increased adoption.

The penetration of LEDs in lighting will reach 16.8% in 2015, reckons the report. Also, spotlights and LED street lights should gain higher penetration in lighting due to government incentives, such as the 12th Five-Year Plan in China and the LED subsidy policy in Taiwan, as well as continued growth in commercial applications. LED bulbs and fluorescent tubes are growing in Japan due to government incentives and energy-saving consciousness, especially after the March 2011 earthquake.

www.displaysearch.com

Lighting market to shrink as LEDs displace conventional technology

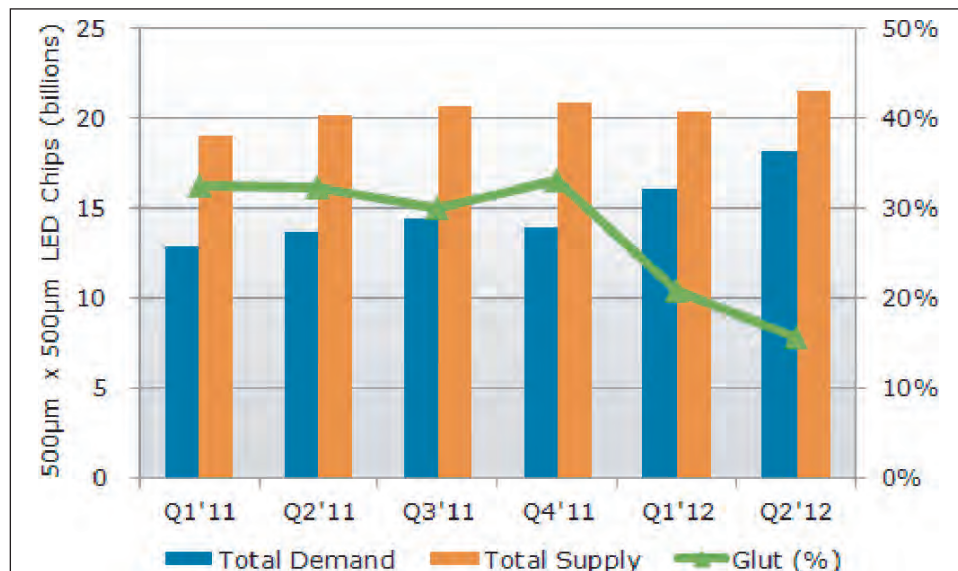
LEDs will displace more than 52% of the global market for lamps in commercial buildings by 2021, according to a recent report 'Energy Efficient Lighting for Commercial Markets' from cleantech market intelligence firm Pike Research. The firm anticipates that the combination of declining prices for LED lighting and the accompanying extended lamp lifetimes will have the effect of shrinking the overall value of the market.

While revenues from LED lamps in the commercial sector will rise by 8.5% through 2021 to \$2.7bn, Pike forecasts, the overall market for commercial lighting will peak at \$54bn in 2012 before contracting through the remainder of the decade, reaching about \$30bn in 2021.

"It would be hard to imagine in today's world that technology will not beat out tradition," says senior analyst Eric Bloom. "The commercial lighting industry will undergo a transformation over the next 10 years that will result in a significant drop in direct revenue from unit sales," he adds. "Lamp and luminaire manufacturers and others in the value chain will have to rely on lighting controls and services to offset the revenue and profit lost in this process."

Internationally, the trend toward efficiency is highly correlated with economic and infrastructure conditions, the firm notes. While Europe and Asia are conservation-minded and open to government programs to limit consumption, the USA is highly fragmented due to state-driven codes and regional electric rate variations, and is comparatively new to the concept of conservation, it adds. Much, but not all of Africa, the Middle East, Latin America, and parts of Asia are working toward developing adequate infrastructure and are lagging behind in commercial lighting efficiency due to other higher priorities, concludes Pike.

www.pikeresearch.com



LED supply/demand for backlight and lighting applications.

IQE acquires RFMD's MBE manufacturing unit and secures seven-year wafer supply agreement

Outsourcing to improve RFMD's operating performance; IQE to use unallocated capacity for CPV epi

Epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK has acquired the entire in-house molecular beam epitaxy (MBE) epiwafer manufacturing unit of RF Micro Devices Inc of Greensboro, NC, USA (which supplies wafer starting material to RFMD's chip-making facilities, which it will continue to own and operate in Greensboro and Newton Aycliffe, UK). As part of the deal, IQE acquires a fully furnished epi manufacturing plant, including 16 operational MBE tools.

RFMD's gallium arsenide (GaAs) products incorporate transistor layers grown on either an MBE or a metal-organic chemical vapor deposition (MOCVD) process. The firm outsources all MOCVD-based starting material and, with the completion of the transfer, it will outsource MBE-based starting material.

"This landmark agreement with RFMD, one of the true global leaders in the wireless semiconductor industry, provides us with a significant step up in our manufacturing capacity, bringing substantial financial and scale benefits," says IQE's president and CEO Dr Drew Nelson. "This is a clear win-win for both organizations," he adds.

The assets transferred to IQE include a fully fitted cleanroom of over 90,000ft², 16 MBE manufacturing systems and equipment, all housed in a 135,000ft² stand-alone

building in Greensboro. The value of the transferred assets is about \$27m. Local management and staff for the unit (consisting of 70 people) also transfer directly to IQE.

In exchange for the transfer of the assets, there is no upfront cash outlay (resulting in no IQE shareholder dilution). Instead, the parties have agreed to a seven-year wafer supply agreement, with a minimum purchase commitment of \$55m over the first two years, whereby IQE will exclusively supply all of RFMD's MBE wafer requirements and a majority of its MOCVD wafer requirements under a discounted pricing arrangement.

"The deal secures IQE world-class epi-wafer production assets and staff, together with a long-term wafer supply agreement, further strengthening our leadership position in the supply of wafers to the global wireless industry," Nelson says. The firm says that the transaction will result in major enhancements across all its key group activities, particularly in its products for the wireless sector through increased purchasing power and greater manufacturing efficiencies.

IQE intends to use unallocated capacity from the transferred MBE facility to rapidly accelerate its wafer supply to meet the dramatically growing demand for concentrator photovoltaic (CPV) solar products in relation to its technology

transfer and exclusive wafer supply agreement with Solar Junction, announced in February. This is expected to allow CPV wafer production with annual revenue capacity of up to \$35m, without the need for significant up-front capital expenditures.

IQE says that the transaction will be immediately revenue and earnings enhancing, while free cash flow generation will reflect the discounted wafer pricing agreed between the parties. The transaction should be significantly earnings accretive in future years.

Similarly, RFMD expects that the transfer agreement and outsourced wafer supply model will improve its operating performance by lowering its manufacturing costs, starting in the September quarter. RFMD currently estimates that, in the June quarter, the transaction will result in a non-cash GAAP charge of \$0.02–0.03 related to equipment and inventory write-offs, and will be approximately neutral to non-GAAP operating results.

"We expect this transaction will provide RFMD with lower MBE and MOCVD pricing, higher return on invested capital (ROIC), and more predictable operating results," says RFMD's president & CEO Bob Bruggeworth. "This is a mutually beneficial transaction for both RFMD and IQE," he believes.

www.iqep.com

RFMD launches 2.5–2.7GHz front-end module for LTE/WiMAX

RFMD has launched the RFFM7600 front-end module (FEM), which contains an integrated three-stage power amplifier (PA) with Tx harmonic filtering and Tx/Rx switching. The RFFM7600 is provided in a 6mm x 6mm laminate package, incorporating surface-mounted

devices for filtering and matching.

Features include a 5V single supply voltage; gain of 35dB (typical); output power (P_{OUT}) of 24dBm; adjacent channel power ratio (ACPR) of –48dBc (LTE downlink); and error vector magnitude (EVM) of 27dBm < 2.5% (WiMAX).

Applications include 2.5–2.7GHz WiMAX; LTE TDD; customer premises equipment (CPE); data cards and terminals; and spread-spectrum and MMDS systems.

Pricing begins at \$4.96 each in 100-unit quantities.

www.rfmd.com

RFMD launches 400–2700MHz GaAs HBT linear power amplifier for wireless infrastructure

RF Micro Devices Inc of Greensboro, NC, USA has launched the RFPA1012 linear power amplifier, designed specifically for wireless infrastructure applications.

Using a GaAs HBT fabrication process, the single-stage amplifier operates on low DC power (5V, 90mA), and has high linearity (OIP3 = 44dBm at 900MHz). It also achieves a high IP3/DC power ratio that operates over a broad frequency range of 400–2700MHz.

The linear PA also offers a low noise figure (NF = 3.5dB at 900MHz), suiting second- and third-stage low-noise amplifiers (LNAs). Other applications include GaAs pre-drivers for base-station amplifiers, and Class AB operation for DCS, PCS, UMTS and WiFi transceiver applications.

The RFPA1012 is currently available in production quantities. Pricing begins at \$2.76 each in 100-unit quantities.

RFMD has also launched the RFVA0016, an integrated, analog-controlled, variable-gain amplifier (VGA) for broadband applications

with external matching, allowing operation in all bands from 400MHz to 2700MHz with a single module.

Operating from a +5V supply, the device features what is claimed to be exceptional linearity (OIP3 of greater than 40dBm), and provides a gain control range of more than 30dB. Gain is 25dB. A mode logic pin enables the VGA to be selected for either a 0V to +3V or a +3V to 0V analog-controlled attenuation slope. The adjacent channel power ratio (ACPR) is better than –60dBc at +10dBm P_{OUT} (for dual-carrier WCDMA).

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

Applications include: cellular, 3G infrastructure; WiBro, WiMax, and LTE; microwave radio; and high-linearity power control.

The RFVA0016 is available in production quantities. Pricing begins at \$8.72 each in 100-unit quantities.

RF Micro Devices launches GaAs pHEMT SP3T symmetric switch

RF Micro Devices Inc of Greensboro, NC, USA has launched the RFSW6131, a GaAs pHEMT single-pole three-throw (SP3T) switch designed for use in cellular, 3G, LTE, and other high-performance communications systems. The device has a symmetric topology and offers what is claimed to be excellent linearity and power handling capability. It is also 3V and 5V positive logic compatible.

Features include: LF to 6000MHz operation; low loss of 0.5dB and high isolation of 27dB at 2GHz;

a high IP3 of 56dBm; $PO.1dB$ of 31dBm (at 5V and 2.2GHz); and a 1.5mm x 1.5mm DFN (dual-flat no-leads) package.

As well as cellular, 3G and LTE infrastructure and other high-performance communications systems, applications include WiBro, WiMAX and LTE; wireless backhaul; and GMSK, QPSK, DQPSK and QAM modulation.

The RFSW6131 is currently available in production quantities. Pricing begins at \$0.60 each in 1000-unit quantities.

www.rfmd.com

IN BRIEF

RF Micro Devices launches AMI/AMR smart energy T/R front-end modules

RF Micro Devices Inc of Greensboro, NC, USA has launched the RF65x9 series of transmit/receive modules, which integrate a complete solution in a single front-end module (FEM) for not only AMI/AMR (advanced metering infrastructure/automated meter reading) applications but also smart grid applications.

The front-end modules integrate a power amplifier (PA), transmit (Tx) filtering, input and output switches, a transmit or receive (Rx) attenuation path, and a low-noise amplifier (LNA) with bypass mode.

Single-ended input and output are included for optimized ease of use and implementation. The pin-out of the FEM enables users to implement additional filtering external to the module, if needed.

For the RF6509, RF6519 and RF6569 devices respectively, Tx output power is 29.5dBm, 26dBm and 30dBm, and Tx gain is 31dB, 30dB and 15dB.

For the RF6509 and RF6519 devices respectively, Rx gain is 18dB and 17dB, and the Rx noise figure is 2.5dB and 1.5dB.

Applications include 868MHz/900MHz ISM-band applications; single-chip RF front ends; modules; portable battery-powered equipment; and wireless automatic metering applications.

The products are now available in production quantities. Pricing (in 750-unit quantities) begins at:

\$3.41 for the RF6509;
\$2.14 for the RF6519; and
\$1.75 for the RF6569.

www.rfmd.com

Avago and TriQuint settle BAW filter patent dispute

Avago Technologies Ltd of San Jose, CA, USA and Singapore (a designer, developer and supplier of III-V-based analog interface components for communications, industrial and consumer applications) and RF front-end component maker TriQuint Semiconductor Inc of Hillsboro, OR, USA have agreed to settle all claims between the two firms concerning intellectual property for bulk acoustic wave (BAW) filters.

In July 2009, TriQuint filed a complaint in the US District Court for the District of Arizona against Avago Technologies Ltd, Avago Technologies US, and Avago Technologies Wireless IP seeking a judgment that four of Avago's US patents (nos. 6,878,224, 6,472,954, 6,262,637 and 6,384,697) were not infringed upon by any TriQuint products and were invalid. The complaint further alleged that certain Avago products infringed TriQuint's US Patent Nos. 6,114,635, 5,231,327 and 5,894,647.

That September, Avago filed counterclaims alleging that TriQuint's

products infringed ten of its US patents (nos. 6,262,637, 6,377,137, 6,841,922, 6,864,619, 6,909,340, 6,933,807, 7,268,436, 7,365,619, 6,051,907 and 6,812,619) and seeking damages and injunctive relief. In the October, TriQuint filed an anti-trust counterclaim (under Section 7 of the Clayton Act and Section 2 of the Sherman Act) alleging anti-competitive conduct through its acquisition of the BAW business of Infineon Technologies Inc and a series of acquisitions of BAW-related patents from Infineon and other companies, and through other anti-competitive conduct in the market.

In November 2009, Avago filed a motion to dismiss the anti-trust counterclaims and asked that the court bifurcate and/or stay those claims. On 5 March 2010, Avago filed counterclaims asserting violation of the California Uniform Trade Secret Act related to Infineon information included in Avago's acquisition of Infineon's BAW division. On 16 March 2010, the court issued an order denying Avago's motion to

dismiss TriQuint's anti-trust counterclaims. On 5 April 2010, TriQuint filed an answer denying Avago's allegations regarding violation of the California Uniform Trade Secret Act.

The two firms had been due to go to trial this July, but have now entered into patent cross licenses and have agreed to dismiss all related litigation. The specific terms of the settlement and the resulting licensing agreement are confidential.

"We are pleased to have reached an amicable resolution with TriQuint," comments Avago's president & CEO Hock Tan. "We are happy to have successfully put this litigation behind us," adds TriQuint's CEO Ralph Quinsey.

TriQuint spent \$19.2m on litigation expense last year, and another \$3.9m in first-quarter 2012, due mainly to the Avago dispute. The firm had expected litigation expense to rise to about \$11m in second-quarter 2012 as it prepared for trial.

www.triquint.com

www.avagotech.com

TriQuint recognizes top sales representatives and distributors

TriQuint Semiconductor has announced the winners of its 2011 Sales Award Program, which recognizes the overall contribution of sales representatives and distributors to growth (including technical support, increasing design wins, revenue and a high level of responsiveness to customers).

Award winners were chosen on the basis of nomination by members of TriQuint's executive sales team and announced at the firm's 2012 Global Sales Conference (an annual training and networking



Winners of the Distributor of the Year award from Marubun Corp.

event for representatives and distributors).

The categories, winners and nominees are as follows:

● Representative Sales Person of the Year:

Winner: Bernd Prediger of Redtree Solutions Ltd.

Nominees: Dave Richter of Neutronics; Roy Wirick of Spectrant.

● Representative Company of the Year:

Winner: Redtree Solutions Ltd.

Nominees: Neutronics; Spectrant.

● Distributor of the Year:

Winner: Marubun Corp.

Nominees: RFMW Ltd; Versatech.

www.triquint.com

TriQuint launches CATV/FTTH RF amplifiers to reduce consumption of materials and power

In conjunction with exhibiting at the ANGA Cable Show trade fair for cable, broadband and satellite in Cologne, Germany (12–14 June), RF front-end component maker and foundry services provider TriQuint Semiconductor Inc of Hillsboro, OR, USA has announced the availability of two new TriAccess amplifiers, designed to replace multiple products in CATV systems.

TriQuint says that the new devices are economical and fabricated with gallium arsenide technology, offering greater functional integration (in a 6mm x 6mm leadless SMT package) and higher efficiency.

The new 45–1003MHz TAT6281 variable gain receiver for single family units (SFUs) employs proven PIN diode variable gain attenuation

to provide a consistent, low-distortion method of adjusting gain, says TriQuint. Gain is 18dB typical and 37dB maximum. The integrated module delivers reliable, low-noise RF performance while simplifying FTTH amplifier designs and reducing bills of materials (BOMs), the firm adds. The TAT6281 builds on the TAT6254 product line, millions of which have been deployed in CATV/FTTH networks worldwide. Samples will be available on 27 July.

The new 45–1003MHz TAT2814A variable gain amplifier satisfies the DOCSIS 3.0 specification with more than 4dB (typical) margin. Typical maximum gain is 30dB. By integrating two stages of amplification and a 20dB PIN diode variable gain attenuator, it can

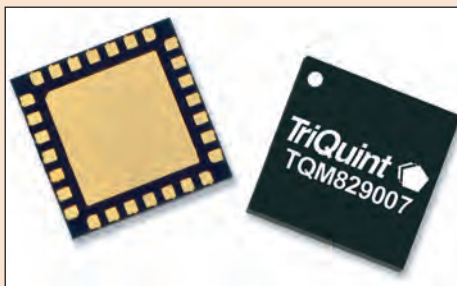
simplify CATV RF design by reducing the number of discrete RF components, whereas other solutions require up to five times the PCB space to deliver DOCSIS 3.0 performance while consuming up to twice the electrical power, claims the firm. With low-reflection differential input/output stages, nominal power consumption is less than 5W between the 5V input amplifier supply and 8V output amplifier supply. The device suits DOCSIS 3.0 output-stage amplifier designs including Edge QAM and CMTS (cable modem termination system) applications. It is also suited to Ethernet over Coax (EOC) supporting DOCSIS 3.0 PA levels. Samples are available now.

www.angacable.com

TriQuint launches integrated DVGAs to reduce base-station BOMs

TriQuint Semiconductor has launched two compact, digitally controlled variable gain amplifiers (DVGAs) that the firm says integrate key functionality and can reduce bill of material (BOM) part counts. The high-performance devices provide receiver or transmitter gain control in base-station transceivers, repeaters, point-to-point microwave radios, and satellite communications terminals. They also suit applications that require automatic gain control to increase system dynamic range.

The TQM829007 operates at 600–1000MHz, and the TQM879008 operates at 1.5–2.7GHz. Both are highly integrated modules that simplify circuit design by combining all required components within leadless 28-pin, 6mm x 6mm, industry-standard SMT packages. The modules include gain blocks, a highly linear amplifier, matching components, bias chokes and blocking capacitors, as well as a digitally controlled, 6-bit digital-step attenuator (DSA) that varies



amplifier gain in 0.5dB steps (across a 31.5dB range) via a serial programming interface (SPI). The TQM829007 has gain of 31.5dB, RF output of +24.3dBm P1dB (+39.5dBm OIP3), a noise figure of 2.1dB, and it draws a current of 174mA, while the TQM879008 has gain of 41.5dB, RF output of +27.3dBm P1dB (+48.5dBm OIP3), a noise figure of 3.9dB, and it draws a current of 285mA, both using a 5V supply. The new DVGAs operate over a temperature range of –40°C to +85°C and have a minimum MTTF (mean time to failure) of 1000 years at a mounting temperature of +85°C.

TriQuint says that existing transceivers require the highest possi-

ble levels of functional integration with high performance to cost-effectively simplify RF design and manufacturing. The TQM829007 and TQM879008 are designed to achieve this goal, eliminating the need for commonly used external components found in discrete designs to provide a complete gain-control solution optimized for best performance. The DVGAs are also pin-compatible with TriQuint's TQM879006 DVGA, which covers frequencies of 1.4–2.7GHz and provides 31dB of gain control, +25.4dBm RF output and a 1.5dB noise figure.

The 600–1000MHz TQM829007 complements other TriQuint devices with similar performance at key cellular frequencies, including the TQM879006 (1.4–2.7GHz) and TQM879008 (1.5–2.7GHz.).

The new TQM829007 and TQM879008 are in production. Fully assembled evaluation fixtures (including a USB control board and related software) are available.

Anadigics expands family of small-cell wireless infrastructure PAs for Band 5 WCDMA and LTE

Anadigics Inc of Warren, NJ, USA has launched the AWB7125 and AWB7225 small-cell power amplifiers (PAs), optimized for Band 5 WCDMA and LTE applications including pico-cells, enterprise-class femtocells, and high-performance customer premises equipment (CPE).

"The rapid growth in mobile data usage is driving carriers to seek cost-effective methods to increase network capacity, especially in dense geographic locations," says Glenn Eswein, director of product marketing for broadband RF products. "Small-cell devices, such as picocells and femtocells, provide carriers with an economical, high-performance solution that can be deployed quickly," he adds. Anadigics' small-cell power amplifiers have been developed specifically for these applications, and enable wireless infrastructure solutions that are more thermally efficient, consume less power, enable higher throughput, and provide greater coverage and range, it is claimed.



Anadigics' AWB7125 & AWB7225 PAs.

Performance is optimized for linear output power of $\frac{1}{4}$ W, +24.5dBm (AWB7125) and $\frac{1}{2}$ W, +27dBm (AWB7225). RF matching is optimized for output power, efficiency and linearity in a 50 ohm system, and housed in a compact 7mm x 7mm x 1.3mm surface-mount package. Both power amplifiers are compliant with WCDMA, HSPA, and LTE small-

cell base-stations operating in the 860–894MHz frequency band.

Anadigics' complete family of small-cell wireless infrastructure power amplifiers is manufactured using the firm's exclusive InGaP-Plus technology to achieve what is claimed to be best-in-class power-added efficiency (PAE) of 15% (AWB7125) and 13% (AWB7225) at rated output power, exceptional linearity of –47dBc ACPR @ ± 10 MHz offset (10MHz LTE channel bandwidth), and excellent thermal performance (with low transistor junction temperature).

Pre-production samples of the AWB7125 are available now. Engineering samples of the AWB7225 are available for qualified programs.

Anadigics exhibited at the 2012 IEEE MTT-S International Microwave Symposium (IMS) in Montréal, Canada (19–21 June). Also, on 20 June in the Richardson RFPD booth, Eswein gave a presentation focusing on small-cell wireless infrastructure power amplifiers.

Anadigics appoints vice president, infrastructure products and promotes Bayruns to chief technology officer

Tim Laverick has joined Anadigics as VP, infrastructure products, and Robert Bayruns has been promoted to VP & chief technology officer. Laverick is a business and engineering leader with over 20 years of experience in the RF and microwave semiconductor industry, and Bayruns has over 30 years of leadership and engineering experience.

"Tim brings to Anadigics proven leadership in running high-margin technical businesses," says president & CEO Ron Michels. "He has an impressive track record of developing new products, strengthening strategic relationships, and driving growth... Tim will lead our infrastructure businesses in both CATV and wireless," he adds.

"Over the last three quarters, Anadigics has made tremendous strides in refocusing its efforts on new product development and strategic relationships," comments Laverick.

Laverick has a general management background, including sales, marketing, and manufacturing. Starting as a circuit designer, he held engineering and management roles, eventually serving as general manager of the fiber-optic product segment at Anadigics, as well as VP of design technology. He holds three US patents.

"Bayruns is a technology expert with an impressive leadership track record, and he will lead the continued advancement of Anadigics' differentiated technology," says Michels.

"Having recently led the advanced development team at Anadigics, I have worked closely with the design teams responsible for developing our next generation of RF solutions," says Bayruns.

Bayruns was previously VP of engineering & product development at Jacket Micro Devices. He has been VP of engineering & product development at Mobilian, TROPIAN and WJ Communications. Bayruns played a key role during Anadigics' start-up in 1985, where he led the development of the industry's first GaAs MMIC power amplifier (PA) to go into volume production in a cell phone. He has extensive experience in silicon and GaAs ICs, systems, and device technologies, and holds 20 US patents.

Anadigics' HELP4 power amplifiers powering Huawei Honor, NEC MEDIAS and ZTE Android smartphones

Anadigics is shipping production volumes of its AWT6621, AWT6624, AWT6625A, and AWT6628A fourth-generation High-Efficiency-at-Low-Power (HELP4) power amplifiers (PAs) to Chinese handset maker ZTE for the V889D, V788D, N788, N910 and PF200 smartphones. The V788D, N788, N910 and PF200 feature a 3.5" screen, 5 megapixel camera and Android 2.3 Gingerbread operating system. The V889D has a 4" screen and Android 4.0 Ice Cream Sandwich operating system.

The V889D is powered by the AWT6621 and AWT6628A PAs and the V788D by the AWT6621. The N788 features the AWT6625A and the N910 features the AWT6624. The PF200 features the AWT6624.

"We look forward to working with ZTE as it continues to develop innovative smartphones for the global wireless market," says Michael Canonico, senior VP of worldwide sales. "The strength of our product portfolio, coupled with our Asia-centric strategy, demonstrates Anadigics' commitment to both product and service excellence," he adds. "Our world-class applications centers in China further support Anadigics' growth initiative."

HELP4 4G PAs use Anadigics' exclusive InGaP-Plus technology to achieve optimal efficiency across low-range and mid-range output power levels (with three mode states) and provide low quiescent currents of less than 4mA. Anadigics



Anadigics' AWT6621 HELP4 PA.

ics also claims best-in-class linearity at maximum output power. In particular, the AWT6621, AWT6624, AWT6625A and AWT6628A power amplifiers deliver what is claimed to be industry-leading efficiency in WCDMA, HSPA and HSPA+ systems, helping to extend battery life in handsets, smart phones, tablets, netbooks, and notebooks.

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

Anadigics is also shipping production volumes of its AWT6621 PAs to

China's Huawei Technologies Co Ltd for the Huawei Honor smartphone.

The Honor has a 4" high-definition (HD) screen, 8 megapixel camera, 1.4GHz processor, and Android 2.3 Gingerbread operating system.

"We look forward to continuing our successful relationship with Huawei, a supplier of handsets and telecom network equipment to some of the world's largest wireless networks," says Michael Canonico, senior VP of worldwide sales.

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

Anadigics is also shipping production volumes of its AWT6621 PAs to NEC CASIO Mobile Communications for the new MEDIAS IS11N smartphone, which features a 3.6" display, 8 megapixel camera, and Android 2.3 Gingerbread operating system.

"Our proven high-volume manufacturing capabilities coupled with support centers located around the world allow us to deliver superior service to multiple leading wireless device manufacturers," claims says senior VP of worldwide sales Michael Canonico. "We are proud to expand our successful relationship with NEC CASIO Mobile Communications and look forward to working together to develop the next-generation of mobile devices."

www.anadigics.com

M/A-COM Tech launches 120W SPDT switch for LTE base-stations and military communications

M/A-COM Technology Solutions has launched a 120W PIN diode SPDT switch for network applications and military communications.

The T/R switch offers high isolation of 50dB at 2.7GHz, low insertion loss of 0.2dB, and high Tx RF input power handling of 120W at 85°C. Supplied in a surface-mount 4mm 16-lead PQFN package, the MASW-000936

is a SPDT high-power, high-linearity PIN diode T/R switch suiting applications requiring small footprint and operating at 0.05–6.0GHz, including LTE and WiMAX base-stations, radar, land mobile, and two-way radios.

"The MASW-000936 was designed with high-power LTE base-stations in mind, where it can handle average transmit power levels over 100W,"

says Amer Droubi, product manager, Cellular Infrastructure. "The switch offers high isolation needed for protecting the sensitive elements of the receiver," he adds. "This switch simplifies the system design, shrinks the PCB board area and reduces the bill of material cost by replacing multiple discrete pin diodes."

www.macomtech.com

IN BRIEF

Skyworks starts volume production of RF solutions for Broadcom's 5G WiFi platforms

Skyworks Solutions has started volume production of several RF solutions supporting Broadcom 5G WiFi (IEEE 802.11ac) chips, including minicards for access points, routers and customer premise equipment (CPE).

The firm says that the explosion of video consumption and the growing number of wireless devices being used by consumers are putting great stress on existing 802.11 a/b/g/n networks and resulting in video buffering, skipping and battery drain. Broadcom's new 5G WiFi chips deliver Ethernet-quality speeds three times faster and six times more power efficiently than previous generations of Wi-Fi devices, enabling faster download of Web content from anywhere in the homes as well as the connection of multiple devices to the user's network simultaneously — all while consuming less device power.

"Consumers want access to high-definition quality video at fast speeds on multiple devices anywhere in the house — on the TV, or transferred to tablets and smartphones," says Broadcom's VP of marketing Rahul Patel. "Broadcom is working closely with Skyworks and other ecosystem partners and customers to address this demand and create 5G WiFi products," he adds.

According to Gartner analyst Mark Hung, Wi-Fi enabled devices will grow from less than 1 billion units in 2010 to over 3 billion in 2015, fueled by 802.11ac. Many believe the 5th-generation Wi-Fi standard will become one of the most influential mobile and wireless technologies in the years to come.

Custom MMIC launches LNA offering noise figure of 1.5dB at 6–18GHz

Monolithic microwave integrated circuit developer Custom MMIC of Westford, MA, USA is offering two new devices from its growing MMIC design library. The CMD157 (die) and CMD157P3 (packaged) are gallium arsenide (GaAs) MMIC low-noise amplifiers (LNAs) for applications at 6–18GHz. The broadband devices each have a low noise figure of 1.5dB, deliver greater than 25dB of flat gain, and have a corresponding output 1dB compression point (P1dB) of +10dBm.

Both the CMD157 and CMD157P3 are 50 Ohm matched designs, eliminating the need for external DC blocks and RF port matching. The CMD157 is suitable for chip-

and-wire applications, whereas the CMD157P3 is housed in a leadless RoHS-compliant 3mm x 3mm plastic surface-mount package. The amplifiers are biased with a single positive voltage of +3.0V @ 52mA. RF power can be applied at any time.

Custom MMIC says that the LNAs are much smaller, lower-cost alternatives to hybrid amplifiers in this frequency range. Suited to broadband electronic warfare (EW) and communication systems, where small size and low power consumption are needed, they can also be used in low-noise down-converters, microwave radio receiver systems, and radar receivers.

www.custommmic.com

Boston Globe lists Skyworks in Globe 100 for fourth consecutive year, ranking 8th again

Skyworks Solutions Inc of Woburn, MA, USA (which manufactures high-reliability analog and mixed-signal semiconductors) has been named to the Boston Globe's list of top-performing public companies in Massachusetts for the fourth consecutive year. After falling from 15th for 2008 to 42nd for 2009, Skyworks has been ranked 8th for the second year in succession.

Now in its 24th year, the Globe 100 ranks Massachusetts-based public companies on four criteria (return on average equity, one-year percentage change in both revenue and profit margin, and 2011 revenue) based on financial data from the four quarters to end-December 2011. To be eligible, a firm must be traded publicly for the entire 2011 calendar year on the New York Stock Exchange, the Nasdaq or the American Stock Exchange and report revenue and profit for both 2010 and 2011. For the first time in three years, the Globe 100 list features 100 companies. In 2010 and 2011, less than 100 companies

qualified, given the impact of the recession.

"The positive momentum we are seeing in the economic recovery is illustrated by the Globe 100 returning to full strength," says Boston Globe business editor Shirley Leung. "It's a powerful testament to the resiliency of Massachusetts' businesses," she adds.

"Skyworks is delighted to once again be recognized as one of Massachusetts's most highly regarded and well performing companies," says president & CEO David J. Aldrich. "In 2011, Skyworks made significant progress towards solidifying our leadership position in analog semiconductor solutions across a diverse set of applications," he adds. "We are capitalizing on consumers' demand for mobile connectivity and are well positioned to benefit from the explosive growth in wirelessly-enabled platforms and services."

www.bostonglobe.com/business/specials/globe-100
www.skyworksinc.com

Skyworks adds low-power LNAs with sub 1.0dB noise figure for cellular infrastructure and ISM-band applications

At the 2012 IEEE MTT-S International Microwave Symposium (IMS) in Montreal, Canada (19–21 June), Skyworks Solutions Inc of Woburn, MA, USA (which manufactures high-reliability analog and mixed-signal semiconductors) has unveiled two new series of high-performance and low-power low-noise amplifiers (LNAs) for multiple industrial, scientific & medical (ISM) bands and next-generation cellular infrastructure applications.

The firm says that its newest LNAs enable enhanced wireless receiver sensitivity, wider dynamic range and a high level of design flexibility. With the addition of these devices, Skyworks now powers solutions with continuous coverage from 30MHz to 3000MHz. Various customers are already leveraging them for power line monitoring and security systems, government radio networks, in-building wireless devices and cell signal boosters.

"Skyworks' suite of solutions highlights our continued focus on broad market, low-noise amplifier products for performance-driven customer applications," says Liam K. Griffin, executive VP & general manager of high-performance analog. "Our products leverage Skyworks' strength in GaAs pHEMT design technology as well as our high-volume, low-cost multi-chip module (MCM) assembly capabilities - two key differentiators within our analog portfolio," he adds.

The SKY67012-396LF (300–600MHz), SKY67013-396LF (600–1500MHz) and SKY67014-396LF (1500–3000MHz) and SKY67015-396LF (30–400MHz) discrete low-power LNAs suit use in battery powered receivers in applications including wireless metering and security, public safety radio, wireless microphones and Bluetooth headsets. The supply voltage

is adjustable over a wide 1.8-5V range and current draw is as low as 5mA. The LNAs are manufactured in a 2mm x 2mm RoHS-compliant, surface-mount technology (SMT) package.

The SKY67215-11 (400–700MHz), SKY67216-11 (500–1200MHz), SKY67221-11 (1600–2100MHz) and SKY67226-11 (2100–3000MHz) are designed for next-generation wireless infrastructure applications including femto- and pico-cell access points, micro base stations, tower-mounted amplifiers, remote radio units and in-building repeaters/cell signal boosters. These fully integrated LNAs are fully matched to 50Ω and require only a single, external component. The internal biasing and matching network eliminates the need for costly external components, customer tuning and greatly reduces required board space. The LNAs also greatly reduce customer design-in time and overall circuit complexity, the firm claims.

The LNAs are manufactured in a compact, 4mm x 4mm MCM-based RoHS-compliant SMT package.

Both new enhancement-mode GaAs pHEMT-based LNA families offer what is claimed to be excellent return loss, very low noise figure (<1.0dB), high linearity, unconditional stability and high gain. These features enable highly efficient and cost-effective signal amplification for enhanced receiver sensitivity and long battery life, the firm adds. In addition, all eight devices offer the ability to externally adjust the supply current to optimize the amplifier linearity and power handling performance for the chosen application. For enhanced design flexibility, each LNA family uses a common footprint and circuit layout.

www.skyworksinc.com

IN BRIEF

Skyworks launches 50W and 100W SPDT switch control devices for diverse markets

At the 2012 IEEE MTT-S International Microwave Symposium (IMS) in Montreal, Canada (19–21 June), Skyworks Solutions Inc of Woburn, MA, USA launched a line of high-power RF switches (up to 100W) supporting diverse market applications including TD-LTE infrastructure base stations, repeaters and low-frequency military/microwave UHF and UVF radios. The firm claims that the highly integrated single-pole double-throw (SPDT) solutions offer high-performance, cost-competitive devices in a compact design.

"By replacing expensive mechanical switches and complicated relays, our newest devices simplify architectures for applications with challenging power levels," says VP of analog components David Stasey, citing design wins at several tier-one customers across multiple and diverse markets.

The SKY12207-478LF (0.9–4.0GHz), SKY12208-306LF (0.02–2.7GHz) and SKY12210-478LF (0.9–4.0GHz) are high-power SPDT silicon-based PIN diode switches. The 4mm x 4mm, 16-pin quad flat no lead (QFN) packaged devices feature low insertion loss (0.4dB), high isolation (44 dB) and what is claimed to be excellent power handling (50W and 100W) and superb linearity with low direct current (DC) power consumption. They all operate with a 5V or 28V positive DC voltage supply across a broad frequency range (20MHz–4.0GHz). Skyworks has also developed a complementary driver application circuit to align with the switches.

www.skyworksinc.com

Phasor launching phased array transceiver using TowerJazz's SiGe BiCMOS for satcoms on the move

Specialty foundry TowerJazz (which has fabrication plants at Tower Semiconductor Ltd in Migdal Haemek, Israel, and at its subsidiaries Jazz Semiconductor Inc in Newport Beach, CA, USA and TowerJazz Japan Ltd) and Phasor Solutions Ltd of Lebdury, UK (which was founded by Anglo Scientific Ltd and Richard Mayo in 2005 to develop flat and conformal high-gain antennas to fit on the roof of moving vehicles) have announced a new phased array technology for communications on the move using silicon germanium (SiGe) process platforms from TowerJazz.

Phasor is targeting the multi-billion-dollar satellite communications and radar market with a unique design that provides order-of-magnitude improvement over competing solutions, it is claimed. Phasor recently demonstrated a proprietary technology that allows moving vehicles (aircraft, ships or trucks) to communicate with stationary satellites, or antennas that track moving satellites, with no moving parts. Technically, the system is able to self-align to a desired signal source and track it in real time, which has never been done before, the firm adds.

Phasor is using TowerJazz's 155GHz SiGe BiCMOS process (SBC18HX) to manufacture its transceiver chipset for mobile broadband service on moving platforms such as trains, manned and unmanned airplanes, and military vehicles. TowerJazz says that Phasor chose its SiGe BiCMOS process over traditional gallium arsenide (GaAs) solutions used in phased array radar due to its ability to operate in the required 12–15GHz band and for its integration capabilities, allowing for multiple analog and digital functions to be integrated into a single chip. As a result, TowerJazz's process yields a reduction in component count, cost and complexities associated with multi-

ple discrete devices.

Over the past 50 years, conventional phased arrays have followed a similar system design, whereas Phasor offers the opportunity to rethink the system design, providing massive efficiencies in cost, it is claimed. Phasor chips include all the radio-frequency functions (amplifiers, oscillators) and phase-shifting circuits, as well as the logic and data modulation/demodulation required. This approach to phased array technology aims to reduce costs more than ten-fold and provide added value such as a flat design (less than 1 inch high), conformal to any surface, modular approach, and high reliability, as there are no moving parts. One of Phasor's initial targets is wireless internet access on trains, which is an estimated available market of more than 500 million users worldwide. However, airborne satcoms and other Comms-On-The-Move (COTM) applications are likely to be larger markets.

The SBC18HX process offered by TowerJazz includes 0.18µm SiGe bipolar and passive elements combined with high-density 0.18µm CMOS, well suited for high-speed networking and millimeter-wave applications. This process achieves a current-gain cut-off frequency (f_T)

of 155GHz and a maximum oscillation frequency (f_{max}) of 200GHz (an optimal choice for a variety of high-frequency applications, it is reckoned). Six layers of metal are standard, with deep trench and metal resistor options.

"It took the industry over 40 years to develop phased arrays which are typically expensive to buy and to operate. But now, with the invaluable support of our partners, and in particular TowerJazz, we have been able to deliver semiconductors which provide an order-of-magnitude reduction in costs compared to current solutions," says Phasor Solutions' managing director David Garrood. "Phasor has been able to achieve this milestone with the support of the TowerJazz team and relying on the stability and performance of its SBC18HX process," he adds.

"Our advanced SiGe BiCMOS technology provides higher integration at lower cost than GaAs solutions, allowing cost-effective satellite communications on the move to be realized," claims Dr Marco Racanelli, senior VP & general manager for the RF & High Performance Analog and Aerospace & Defense Business Groups at TowerJazz. "Together, we have begun volume manufacturing to enable a high-gain antenna, which consists of 20,000 chips," he adds.

"In addition, we continue to invest in advanced SiGe, and recently announced our latest process, SBC18H3, which supports devices with speeds of 270GHz and offers a path for further performance, power, and noise improvement in next-generation products," Racanelli notes.

Phasor Solutions is launching the new phased array product at the Farnborough International Airshow 2012 in the UK (9–13 July).

www.towerjazz.com
www.phasorsolutions.com
www.farnborough.com

ITC to investigate RFMD, Motorola Mobility and HTC based on Peregrine's patent infringement complaint

Peregrine Semiconductor Corp of San Diego, CA, USA, a fabless provider of radio-frequency (RF) integrated circuits (ICs) based on silicon-on-sapphire (SOS), says that the US International Trade Commission (ITC) has launched an investigation into whether products made by RF Micro Devices Inc (RFMD) of Greensboro, NC, USA infringe its patents relating to RF ICs and switch technology. The action and investigation further include Motorola Mobility Inc of Libertyville, IL as well as HTC America Inc of Bellevue, WA and Taiwan-based HTC Corp, whose products incorporate the alleged infringing RF ICs.

The investigation is based on complaints filed by Peregrine with the ITC on 14 February and 11 May alleging that certain RFMD devices infringe patents related to silicon-on-insulator (SOI) technology for RF ICs (hence violating section 337 of the Tariff Act of 1930). The investigation involves five Peregrine patents and 38 separate patent claims. Peregrine is seeking, among other remedies, an exclusion order preventing the importation and sale of infringing products in the USA.

The ITC says that, within 45 days after instituting the investigation, it will set a target date for completion. ITC remedial orders in section 337 cases are effective when issued and become final 60 days after issuance (unless disapproved for policy reasons by the US Trade Representative within that 60-day period).


"The employees of Peregrine have spent 20 years of intensive research and development activity to bring our proprietary UltraCMOS process and design innovations to the RF marketplace," says president & CEO Jim Cable. "We are steadfast in our position to protect that investment on behalf of all the stakeholders of Peregrine," he adds.

Peregrine has been awarded numerous US and foreign patents based on its work in developing and manufacturing high-performance products for the RF front-end, which can be produced using standard CMOS-based semiconductor manufacturing processes. It adds that the patented innovations allow RF solutions to be produced with a combination of high levels of monolithic integration and performance, small size and low power consumption.

Peregrine has spent 20 years of intensive R&D activity to bring our proprietary UltraCMOS process and design innovations to the RF marketplace

facturing high-performance products for the RF front-end, which can be produced using standard CMOS-based semiconductor manufacturing processes. It adds that the patented innovations allow RF solutions to be produced with a combination of high levels of monolithic integration and performance, small size and low power consumption.

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RFaxis launches CMOS dual-mode Wi-Fi/Bluetooth RFeIC

RFaxis Inc of Irvine, CA, USA is sampling its pure-CMOS, RFX8420 RF front-end integrated circuits (RFeICs). The chip was designed to meet the high performance and ultra-compact size requirements for dual-mode Wi-Fi/Bluetooth operation in mobile devices such as smartphones, featurephones and tablets. RFaxis showcased the RFX8420, along with its commercial-ready 5GHz RFeIC RFX5000, at Computex 2012 in Taipei, Taiwan (5–9 June).

The RFX8420 is a fully integrated, single-chip/single-die RFeIC that incorporates all RF functionality for dual-mode WLAN 802.11b/g/n and Bluetooth operation in the 2.4GHz band. It has a high-efficiency high-linearity PA providing 18dBm output power with 3% EVM at antenna port, a directional coupler and out-

put power detector, impedance matching networks, harmonic filters, and a SP3T switch for antenna sharing between Wi-Fi and Bluetooth, integrated onto a single CMOS device. Housed in an ultra-compact, low-profile 2.5mm x 2.5mm x 0.4mm 16-pin QFN package, the RFX8420 has the smallest-class solution size in the industry and is pin-to-pin compatible with incumbent front-end solutions from several vendors that use GaAs solutions.

"We developed the RFX8420 based on specific input from multiple handset/smartphone vendors to meet their most demanding requirements in terms of size, performance and functionality," says chairman & CEO Mike Neshat. "The RFX8420 is specifically designed to

support direct battery operation for mobile phone applications," he adds. "Pure-CMOS RF front-end solutions are significantly more cost-effective than alternative solutions currently available in GaAs," he claims.

With the RFX8420 all RF decoupling components and DC blocking capacitors are integrated completely on-chip, differentiating it from existing solutions that require multiple inductors and capacitors externally, which add additional cost and board space. These unique features enable RFaxis' customers to add Wi-Fi/Bluetooth functions to their products with the smallest external bill of materials (BOM) and effective PCB footprint, says the firm.

www.rfaxis.com

White paper on CMOS RF front-ends for Wi-Fi-enabled handsets

RFaxis has published the white paper 'CMOS Wi-Fi RF Front-Ends for Mobile Handset Applications — Part-I', the first in a three-part series that discusses RF-related technical challenges for dual-mode Wi-Fi/cellular handset designs, as well as some of the technical solutions that RFaxis has developed to mitigate these critical issues.

According to the Linley Group, smartphones are one of the most rapidly growing market segments in wireless, with 600 million units projected to ship in 2014. The mobile devices are capable of simultaneous 3G/LTE operation and Wi-Fi connectivity, so users can connect to a cellular network for voice calls while searching the Internet or downloading data files via Wi-Fi networks. Concurrent operation of different radios inside a tightly packed handset poses unprecedented challenges to RF designs that must meet uncompromised performance at an ever-decreasing bill of materials cost.

The paper provides comprehensive test data and comparison of noise

contributions from different Wi-Fi power amplifiers (PAs) and front-end modules (FEMs) in the UMTS/WCDMA receiver band (Band-1, 2.11–2.17GHz) from multiple tier-one vendors. The PAs/FEMs have been developed by the RF/wireless industry over many years on different materials/process technologies including GaAs HBT and pHEMT, BiCMOS SiGe HBT and, most recently, bulk RF CMOS. Key findings from the study include:

- Total noise power in the WCDMA receive band increases with WLAN transmit power level for all technologies except for bulk CMOS, which shows either negligible change or even slightly reduced noise power at high WLAN output signal levels.
- The need for high levels of rejection (30–35dB) for GaAs or SiGe HBT-based solutions translates to more costly co-existence filters, and extra degradation in Wi-Fi receiver sensitivity and increased current consumption by the transmit chain.
- CMOS-based Wi-Fi RF front-end ICs (RFeICs) from RFaxis require

1.0–1.5dB less linear power at PA output, which slashes current consumption, it is claimed, and helps to improve receiver sensitivity of the Wi-Fi system by the same amount.

"As more mobile devices require concurrent operation of 3G/4G cellular and Wi-Fi, there is an increased demand to improve the performance and cost structure of co-existence filters with paradoxical criteria such as low in-band insertion loss, high out-band rejection, minimal component size and lowest price," says chief technology officer Dr Oleksandr Gorbachov. "We have found an alternative solution to this problem by taking advantage of the unique device/process characteristics of RF CMOS; along with proprietary design methodology, we are able to significantly reduce the Wi-Fi PA noise leakage to the WCDMA receive band, thus allowing RF system designers to use co-existence filters with highly relaxed specifications. This not only helps them reduce BOM cost, but also results in improved Wi-Fi performance," he adds.

Teledyne acquiring LeCroy for \$291m

Oscilloscope maker to provide commercial outlet for Teledyne's indium phosphide technology

Teledyne Technologies Inc of Thousand Oaks, CA, USA has entered into a definitive agreement for the merger of LeCroy Corp of Chestnut Ridge, NY, USA with a subsidiary of Teledyne.

Founded in 1964, LeCroy is a supplier of oscilloscopes, protocol analyzers and signal integrity test solutions, with about 500 staff. For its fiscal year ended 2 July 2011, sales were \$178.1m. Teledyne designs and manufactures instrumentation, digital imaging products and software, aerospace & defense electronics, and engineered systems. operations are primarily located in the USA, Canada, the UK and Mexico, primarily in the USA, the UK and Mexico.

Teledyne will acquire all of the outstanding common shares of LeCroy for \$14.30 per share payable in cash. The aggregate

value for the transaction is about \$291m, taking into account LeCroy's stock options, stock appreciation rights and net debt as of 31 March. The transaction was unanimously approved by the boards of directors of both firms. In addition, LeCroy's directors and executive officers, including founder Walter LeCroy, have agreed to vote their shares in favor of the transaction.

"LeCroy will broaden our portfolio of analytical instrumentation businesses by adding a leader in electronic test & measurement solutions," says Teledyne's chairman, president & CEO Dr Robert Mehrabian. He also highlights LeCroy's strength in the market for high-performance oscilloscopes, as well as the potential for LeCroy to provide a commercial outlet for Teledyne's unique indium phosphide (InP) process technology

and ultra-high-frequency mixed signal design capabilities developed at its R&D laboratories (Teledyne Scientific Company).

"This transaction provides a substantial premium for our shareholders," notes LeCroy's president, CEO & director Thomas Reslewic. "Teledyne can help us accelerate our high-end oscilloscope programs to deliver real-time bandwidth well beyond 100GHz by utilizing Teledyne's leading InP technology," he adds. "Furthermore, through a combination of Teledyne's microwave and mixed-signal design capabilities with LeCroy's signal processing expertise, as well as our respective market channels, we envision growing our markets and adding new products such as signal generators and multi-function instruments."

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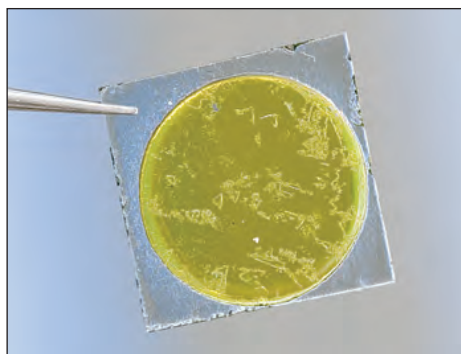
Cubic SiC grown with quality similar to hexagonal SiC

Growth on hexagonal SiC boosts carrier lifetime almost 100-fold

Cubic silicon carbide (3C-SiC) is considered to be very suitable for making highly efficient solar cells but the material quality has been poor compared with the established hexagonal polytypes of SiC. Now researchers in the Department of Physics, Chemistry and Biology at Sweden's Linköping University have developed a method for growing cubic SiC with quality similar to commercial hexagonal SiC (J. W. Sun et al, Appl. Phys. Lett. 100, 252101 (2012); doi: <http://dx.doi.org/10.1063/1.4729583>).

Cubic silicon carbide is a perfect material for impurity (intermediate-bandgap) solar cells, say the researchers. For boron-doped cubic SiC, the dopant band of boron in the energy bandgap of 3C-SiC leads to efficient use of sunlight, so that an efficiency up to 48–60% could be achieved (depending on the theoretical model).

But the hexagonal silicon carbide polytypes have been commercialized for many years, while cubic silicon carbide has faced challenges. It is metastable, i.e. it does not really want to form. To make it form, the growth temperature has to be decreased, but at the same time the growth rate is reduced.



Cubic SiC grown on hexagonal SiC.

The common approach is to use silicon as the substrate, but the lattice and thermal mismatch causes defects and stress.

The researchers at Linköping University have hence applied a bulk growth approach such as that used in the production of hexagonal silicon carbide. The trick is to lower the growth temperature while adjusting other parameters to maintain a high growth rate. The research group uses hexagonal SiC as the substrate, but the material is transformed to the cubic structure during the initial stage of growth. The advantage of using a hexagonal substrate is the perfect lattice matching.

The growth rate is 1mm/hr, and structural measurements show

similar quality to that of commercial hexagonal material. The key parameter that demonstrates the quality is carrier lifetime. Previously, lifetime was about 0.1μs, but the new record value is 8.2μs in as-grown material (an increase of almost two orders of magnitude). In comparison, this is even slightly better than that of as-grown hexagonal SiC.

Today's silicon solar cells have an efficiency of about 20%. To increase the efficiency of solar cells, multi-junction (thin-film) solar cells with different bandgaps are among the most promising. The best efficiency for such solar cells demonstrated on the research scale is 43.5%. However, challenges in the fabrication of multi-junction solar cells lie in the growth of multi-stacked material and balancing the junction currents. In contrast, cubic silicon carbide in a single material that is doped during growth, and with a high growth rate of about 1mm/hr, could pave the way for more efficient solar cell concepts, believe the researchers.

http://apl.aip.org/resource/1/applab/v100/i25/p252101_s1
www.ifm.liu.se/materialphysics/semicond

SemiSouth granted its 30th US patent

SemiSouth Laboratories Inc of Starkville, MS, USA (which designs and manufactures silicon carbide devices for high-power, high-efficiency, harsh-environment power management and conversion applications) has been granted its 30th US patent by the US Patent and Trademark Office.

The firm claims that its SiC power semiconductor transistors and diodes are rapidly gaining market share in the solar, UPS (uninterruptible power supply), traction, wind, automotive and aerospace industries due to their superior per-

formance in high-efficiency, harsh-environment power applications.

US Patent number 8,169,022 'Vertical Junction Field Effect Transistors and Diodes Having Graded Doped Regions and Methods of Making' was co-invented by Dr Michael Mazzola, a co-founder of SemiSouth in 2000 when the firm spun off from Mississippi State University.

"The underlying technology in this patent allows SemiSouth to fine tune their already performance-leading vertical channel junction

field-effect transistors and diodes to get ever closer to the unipolar theoretical limit," says Mazzola.

"Customers can expect even better value from the products based on this patent," he adds. "Our technology is state-of-the-art in terms of performance per unit area," claims co-founder, president & chief technology officer Dr Jeffrey B. Casady.

In addition to 30 its US patents, SemiSouth possesses 24 patents internationally and has 204 applications pending worldwide.

www.semisouth.com

SemiSouth first to sample 650V 55mΩ SiC JFETs

Range extended from 1700V through 1200V down to 650V for solar, UPS and automotive markets

SemiSouth Laboratories Inc of Starkville, MS, USA (which designs and manufactures silicon carbide device for high-power, high-efficiency, harsh-environment power management and conversion applications) claims that, after first releasing commercial 1200V trench JFETs in 2008 (currently being used in volume production by manufacturers of UPS, high-reliability products, audio systems and solar inverters), it is now delivering the industry's first 650V SiC JFET power transistors.

The firm says that the fast switching speeds, large current-handling capability, combined with the superior thermal properties of SiC, makes the devices suitable candidates for power electronic applications. The devices employ vertical trench JFET (junction field-effect transistor) structures, which allow what is claimed to be industry-leading on-resistance per unit area (as much as five to ten times lower than competing technologies).



SemiSouth's TO-220-packaged 650V/55mΩ SJDA065R055 SiC JFETs.

"Customers in markets such as EV drive train, UPS, welding, solar, induction heating have long been asking for SiC switches which are very reliable, cost-effective, and capable of high efficiency at high power densities," says president/chief technology officer Dr Jeffrey B. Casady.

"Markets where we are already in volume production using our 1200V switch, such as solar and UPS, also require lower-voltage switching at 650V for efficiency and higher-

power-density solutions where grid voltage or bus voltages are lower," says senior VP of sales & marketing Dieter Liesabeths. "Also, the automotive industry is split on the EV drive train, with some customers requiring 1200V and higher, and others requiring only 650V. So, we can now serve these markets even better with power transistor solutions from 650V through 1700V."

Like many SemiSouth devices, the 650V/55mΩ SJDA065R055 SiC JFETs feature a positive temperature coefficient for ease of paralleling and extremely fast switching with no 'tail' current at 1500C. $R_{ds(on)}$ typical for these new voltage-controlled devices is 0.044Ω, which also exhibit a low gate charge and low intrinsic capacitance.

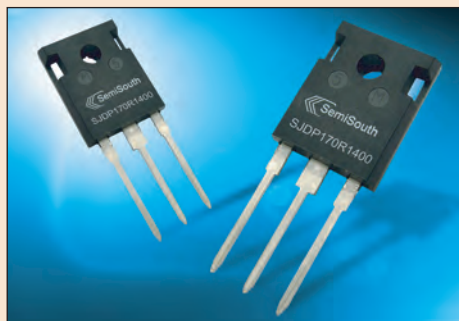
Typical applications for the TO-220-packaged JFETs include solar inverters, SMPS (switched-mode power supplies), PFC (power factor correction) circuits, induction heating, UPS (uninterruptible power supplies) and motor drives.

www.semisouth.com

SemiSouth launches 1700V/1400mΩ SiC JFETs that simplify fast start-up of 3-phase power supplies

SemiSouth has launched a 1700V/1400mΩ SiC JFET that simplifies start-up circuit design in three-phase auxiliary power supplies.

Traditional solutions either use an HV bleed resistor (resulting in a slow start-up at low line voltages and a high quiescent power loss) or are MOSFET-based (which necessitates overload protection and can suffer from high power losses in the MOSFET under fault condition, e.g. short circuit). "By using a depletion-mode JFET, designers can achieve a fast start-up using no extra components," says applications engineer Nigel Springett. "Our JFETs need no extra heat sink for this application," he adds.



SemiSouth's SJDT170R1400 SiC JFET.

The SJDT170R1400 will be supplied in a newly developed SMD D2PAK-7L package to simplify PCB layout and optimize switching performance due to lower inductance. This package will have a high creepage distance of 6.85mm (in order to

support 1700V applications) and has a size of 16mm x 10mm x 4.4mm.

"We are confident that the SJDT170R1400 will become the de-facto standard for all auxiliary 3-phase power supplies, as the benefits for the users are superior compared to traditional high-voltage MOSFET solutions and the cost becomes less for the total solution," says senior VP sales & marketing Dieter Liesabeths.

SemiSouth is initially sampling the normally-on 1700V/1400mΩ SJDP170R1400 in TO-247-3L packaging. The SJDT170R1400 in a surface-mount D2PAK-7L high-creepage package will sample in third-quarter 2012.

UK funds compound semiconductor R&D projects

Following opening of the competition last Autumn and closing for applications in December, the 'Technology Inspired Innovation' competition for collaborative R&D funding in the UK has now resulted in 43 projects being chosen for funding, of £250–500,000 each. Up to £15m comes from the Technology Strategy Board (TSB, the UK government's national innovation agency), while up to £2.75m comes from the economic development agency Scottish Enterprise.

In the sector 'Electronics, Photonics and Electrical Systems', projects chosen include the following:

- 'PEARGaN — Power Electronics Applications for Reliability in GaN' — Semiconductor manufacturers are growing gallium nitride (GaN) on silicon substrates to create discrete devices for high-voltage power electronics applications, with the potential to deliver superior performance in breakdown voltage, on-state resistance and higher switching speeds (reducing system losses and enabling higher efficiency at lower cost than current solutions). PEARGaN has assembled a consortium of partners from UK industry and academia in order to develop new system-level concepts and circuit architectures, evaluate advanced manufacturing process technologies, and create device demonstrators to fully understand the device behaviour and failure mechanisms (proving that the devices are robust and can deliver the required levels of life-time reliability that is demanded by the early adopters in a broad range of power management and control applications).

Led by NXP Semiconductors UK Ltd in Stockport, project partners include IQE (Europe) Ltd, Bristol University's Device Reliability Centre, Manchester University's Power Conversion Group and Liverpool University's Materials & Structures Centre (contact: andrew.rimington@nxp.com).

- 'Robust, High Temperature Driver Circuits for Power Transistors Using Low Cost SiC' aims to develop a new

integrated circuit technology developed specifically to build improved driver circuits for newly emerging silicon carbide (SiC)-based power transistors. SiC transistors enable more efficient power electronics, leading to improved energy efficiency in many application areas. However, adoption of these devices is being limited by the absence of suitable driver ICs able to operate at the elevated temperatures at which the power transistors run. The new technology integrates low-voltage transistors, built in a 3C-SiC epitaxial layer, grown on a silicon wafer. This technology promises to offer good performance and excellent high-temperature capability, and be much lower cost than all-SiC alternatives. Innovative steps include developing 3C-SiC on Si heteroepitaxy, developing the 3C-SiC IC process, and designing and developing a demonstrator driver IC.

Led by Raytheon UK in Glenrothes, Scotland, the other project partner is Anvil Semiconductor Ltd, which was spun off from the University of Warwick in July 2011 (contact: jennifer.cormack@raytheon.co.uk).

- 'PEPSC' (Primary Electrical Power Solid state power Controller) is a £1m technology program, 50% funded by UK government. Its goal is to replace electro-mechanical devices used in aerospace primary electrical power distribution systems with an SSPC (solid-state power controller) power module package using SiC technology. SSPCs have been used to provide switching capability for 28V_{DC}, 270V_{DC} and 115V_{AC} secondary electrical power switching systems on recent aircraft platforms; PEPSC intends to extend the use of SSPC technology into primary power systems capable of 270V_{DC} operation with an output current level of about 120A. PEPSC will enable the reduction of wire gauges (resulting in lighter wiring harnesses), while allowing power to be isolated rapidly in the event of a fault (improving system safety). PEPSC will also feature novel arc

fault detection capability, isolating power when an arc fault is detected.

Led by GE Aviation Systems Ltd in Cheltenham and Newmarket, its project partner is TT electronics plc, a subsidiary Semelab Ltd of Lutterworth, Leicestershire (contact: peter.handy@ge.com).

In the sector 'Nanotechnology', projects chosen for funding include:

- 'Novel Light Sources & Detectors for mid IR Gas Sensors Powered by Energy Harvesting', which proposes to develop novel low-cost mid-infrared light sources and detectors, based on light-emitting diodes (LEDs) and photodiodes (PDs) respectively, primarily for use in non-dispersive infrared (NDIR) gas sensors (replacing the conventional incandescent light bulbs and pyroelectric detectors used in current NDIR gas sensors). Energy per gas concentration measurement is reduced by a factor of typically 3000, enabling sensors to be powered from batteries and power harvesting. The main benefit is the economic deployment of wireless sensor networks and sensor portability. Specific objectives are: (a) to establish the necessary mid-IR device efficiencies; (b) to develop mid-IR LEDs and PDs operating at wavelengths matched to absorption wavebands for commercially relevant gases; and (c) to produce and test NDIR sensors powered from energy harvesting.

Led by Gas Sensing Solutions Ltd of Cumbernauld, North Lanarkshire, project partners include Compound Semiconductor Technologies Ltd, Gas Measuring Instruments Ltd, and the University of Glasgow (contact: des@gassensing.co.uk).

The offer of funding to the projects is conditional and remains subject to the successful completion of Technology Strategy Board, Scottish Enterprise and BBSRC (Biotechnology and Biological Sciences Research Council) compliance and financial review processes.

www.innovateuk.org

www.raytheon.co.uk

Mitsubishi Electric develops all-SiC inverter with power density of 50kVA per liter

Tokyo-based Mitsubishi Electric Corp has developed a prototype forced-air-cooled three-phase 400V output inverter with all-silicon carbide (SiC) power modules that has a power density of 50kVA per liter. The module, which is rated at 1200V/300A, incorporates a SiC MOSFET (metal oxide semiconductor field-effect transistor) and a SiC SBD (Schottky barrier diode). The inverter is expected to contribute to smaller and lighter power-electronics equipment in automotive and industrial applications, among others.

Mitsubishi Electric says that, to increase power density, the electric current density must be increased through lower electric resistance. So, it developed low-resistance wiring by using direct lead bonding to connect power semiconductor chips directly to the main terminals, eliminating the use of conventional high-resistance aluminum lead wires.



High-power-density full SiC inverter.

To achieve high current density, low-loss (low-resistance) power chips also had to be used, but this required the application of high-speed protection circuits to avoid a large destructive current during short circuits. Mitsubishi Electric applied a SiC MOSFET with a built-in current sensor function to its all-SiC power module and used a high-speed short-circuit-protection circuit, making it possible to use a low-

resistance SiC MOSFET even at a high current density. The firm hence achieved a power density of 50kVA per liter via an inverter operation with an output of 156kVA.

The firm says that, while silicon has traditionally been used for power semiconductor devices, in recent years SiC has come to be widely considered as a promising next-generation material. Compared to Si, SiC has a critical electric field for breakdown that is about 10 times higher and enables the reduction of power loss, helping to reduce carbon dioxide emission. Furthermore, the reduction of power loss enables a reduction in cooling equipment, contributing to the overall downsizing and lightening of electronic components for automotive and industrial applications.

Mitsubishi Electric says that it plans to further downsize the inverters for commercial viability.

www.mitsubishielectric.com

Raytheon wins UK funding for SiC-on-silicon driver ICs UK subsidiary to work with Warwick University spin-off Anvil

Raytheon Company of Waltham, MA, USA says that its technology facility in Glenrothes, Scotland, UK has been awarded grant funding by the Technology Strategy Board (TSB, the UK government's national innovation agency) that will be used to support the further development of low-cost silicon carbide (SiC) solutions.

The firm will receive funding towards the overall cost of its project to develop robust, high-temperature driver circuits for power transistors. New integrated circuit technology is being designed specifically to build improved driver circuits for newly emerging SiC-based power transistors. SiC transistors enable much more efficient power electronics, leading to improved energy efficiency in applications such as oil and gas exploration, energy gener-

ation and future electric vehicles, adds the firm. However, the adoption of such devices is being limited by the absence of suitable driver ICs, capable of operation at the elevated temperatures at which the power transistors run.

"As specialists in silicon carbide, Raytheon UK are keeping ahead by developing new processes and high-temperature devices," says Paul D'Arcy, semiconductor business manager for the Raytheon UK subsidiary. "This funding from the Technology Strategy Board gives us an opportunity to work with our partners in developing circuits on a low-cost SiC substrate," he adds.

The project will be carried out from October 2012 to September 2015, during which Raytheon UK will work with Anvil Semiconductors Ltd.

Anvil was spin off from the University of Warwick in July 2011 and specializes in the manufacture of low-cost SiC power semiconductor devices on 3C-SiC epitaxial layers grown on silicon wafers.

The new technology integrates low-voltage transistors, built in a 3C-SiC epitaxial layer, grown on a silicon wafer. Such technology has the potential to offer good performance, excellent high-temperature capability, and much lower cost than other SiC alternatives, reckons Raytheon. The innovative steps include the development of the 3C-SiC on silicon hetero-epitaxy, the development of the 3C-SiC IC process, and the design and development of a demonstrator driver IC.

www.raytheon.co.uk

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IN BRIEF

RFMD adds 280W GaN matched power transistor family for pulsed-radar

RF Micro Devices has launched the RFHA1025, a highly efficient 280W pulsed GaN RF matched power transistor that delivers superior performance versus competing silicon power technologies, it is claimed.

The RFHA1025 complements the recently released 380W RF3928B, the highest-output-power S-band device in RFMD's matched power transistor family. The firm says that it is expanding its portfolio of GaN-based power amplifier transistor products across bands, aiming to boost its position in the radar market.

RFMD says that its GaN matched power transistors extend range, reduce size and weight, and improve overall ruggedness in radar architectures. The RFHA1025 operates over a broad frequency range (0.96–1.2GHz) and delivers 280W pulsed power, high gain (>14dB) and high peak efficiency (>55%). Also, it incorporates internal matching to simplify and shrink designers' circuits. Packaged in a hermetic, flanged ceramic package, the RFHA1025 leverages RFMD's advanced heat-sink and power dissipation technologies, delivering what is claimed to be excellent thermal stability and conductivity. The firm's RF393x unmatched power transistors (UPT) can be used as drivers to the RFHA1025.

"We look forward to introducing additional GaN devices in the near term that feature superior power density, high power efficiency, and rugged dependability," says Jeff Shealy, general manager of RFMD's Power Broadband business unit.

www.rfmd.com

David Reusch joins EPC as director Applications Engineering

Efficient Power Conversion Corp (EPC) of El Segundo, CA, USA, which makes enhancement-mode GaN-on Si (eGaN) power FETs used in power management applications, has appointed Dr David Reusch as its engineering team as director, Applications Engineering.

As a member of EPC's applications team, Reusch will focus on designing lower-loss and higher-power-density benchmark circuits that demonstrate the benefits of GaN transistors. His initial focus will be on their use in higher-voltage DC–DC converters and resonant, soft-switching converters. Reusch's research and experience in these applications will be shared with customers to accelerate their designs using high-performance eGaN FETs. EPC says his designs will demonstrate GaN transistors' superior performance over silicon MOSFETs.



Reusch has a doctorate in electrical engineering from Virginia Polytechnic Institute and State University (Virginia Tech), where he also earned bachelor's and master's

degrees. During his Ph.D. he was a National Science Foundation (NSF) Fellow at the Center for Power Electronics Systems (CPES).

Reusch is active in IEEE organizations and, in the last several years, has published papers at the Applied Power Electronics Conference (APEC) and the Energy Conversion Congress and Exposition (ECCE). He also has first-hand experience designing with GaN transistors to meet the demands for lower loss and higher power density in power converters.

EPC launches eighth brick DC–DC power converter demo board featuring eGaN FETs

EPC has launched the EPC9102, a fully functional eighth brick converter. The board is a 36–60V input to 12V output, 375kHz phase-shifted full bridge (PSFB) eighth brick converter with 17A maximum output current.

The EPC9102 uses the 100V EPC2001 eGaN FETs in conjunction with the recently launched LM5113 100V half-bridge gate driver from Texas Instruments (the first driver to optimally drive and fully release the benefits of E-mode GaN FETs, it is claimed). The EPC9102 demonstrates the performance capabilities of high-switching-frequency eGaN FETs when coupled with this eGaN driver, EPC says.

The whole converter is constructed within standard eighth brick footprint and height (2.300" x 0.900" x 0.400") requirements. Despite its small size, the board has peak power efficiency of 94.8% while delivering 10A of current with a 36V input.

The EPC9102 demonstration circuit was designed to showcase the size and performance that can be achieved at 375kHz operation using eGaN FETs rather than optimizing the design for maximum output power. The operating frequency is 50–100% higher than similar commercial eighth brick DC–DC power converters.

To assist the power system design engineer, the EPC9102 demonstration board is oversized to allow connections for bench evaluation. There are various probe points to facilitate simple waveform measurements and efficiency calculation. The board is intended for bench evaluation with low ambient temperature and forced air cooling.

EPC9102 demo boards are priced at \$306.25 each. A Quick Start Guide is included for reference and ease of use.

www.epc-co.com.

RFMD makes available GaN and GaAs foundry PDKs for Agilent's ADS EDA software

RF Micro Devices Inc of Greensboro, NC, USA says that its Foundry Services business unit has updated its process design kits (PDKs) for use with Agilent Technologies Inc's Advanced Design System (ADS) 2011 electronic design automation (EDA) software (released in February). The enhanced PDKs are available immediately to current and prospective Foundry Services customers for RFMD's gallium nitride (GaN) and gallium arsenide (GaAs) process technologies.

The PDKs support a complete ADS front- to back-end monolithic microwave integrated circuit (MMIC) design flow with scalable devices, a native design rule checker, and the layout capabilities in ADS 2011. The PDKs work seamlessly with ADS 2011, ADS 2009 Update 1 and ADS 2008 Update 2, enabling Foundry Services customers to take full advantage of the performance advantages of ADS 2011.

GaN and GaAs process technologies are available to Foundry Services customers, supported by what are claimed to be RFMD's cycle times. Foundry offerings include GaN1 (GaN for high power), a 0.5µm GaN-on-SiC process technology enabling 65V CW operation and optimized for maximum performance at 4GHz and below.

The GaN1 power technology provides a high breakdown voltage above 400V. Meanwhile, RFMD's GaN2 is a 0.5µm GaN-on-SiC process technology offering high linearity for high-performance communications systems. Both GaN technologies are manufactured in RFMD's fabrication plant in Greensboro (one of the world's largest III-V fabs).

The fab also manufactures HBT8D, RFMD's high-volume rugged InGaP technology for handset and mixed-signal applications, and IPC3, an integrated passive component technology that complements the firm's GaN technology portfolio with high-power compatibility.

Additional foundry offerings include FD25 (a low-noise, 0.25µm GaAs pHEMT technology) and FD30 (a high-power 0.3µm GaAs pHEMT technology), both of which support applications up through 25GHz. RFMD's technology portfolio also includes FET1H (a 0.6µm GaAs pHEMT technology) and FET2D (a 0.6µm GaAs E/D pHEMT technology). Each of the pHEMT

Mutual customers can now leverage the ADS 2011 product enhancements in RFMD's GaN and GaAs technologies

technologies is manufactured in the firm's fab in Newton Aycliffe, UK.

"The ADS 2011 release provides RFMD Foundry customers access to Agilent's latest multi-technology platform for our GaN and GaAs process technologies," says Dr Tom Joseph, manager of technology in RFMD's Foundry Services business unit. "By leveraging Agilent's new Library architecture and simulation enhancements, RFMD's foundry customers can improve their design efficiencies and reduce time-to-market for their end market products," he adds.

"Our mutual customers can now leverage the ADS 2011 product enhancements in RFMD's GaN and GaAs technologies," says Juergen Hartung, foundry program manager of Agilent's EEs of EDA organization. "With these PDKs, our customers can now enjoy the industry's most comprehensive multi-technology design platform using Momentum, the industry-leading 3D planar EM simulator, our integrated full 3D FEM [finite-element method] engine, the industry-proven design-for-manufacturing capabilities inside ADS, and an upgraded design rule checker," Hartung adds.

www.rfmd.com/foundry

www.agilent.com/find/eesof-ads

RFMD launches 225–1215MHz, 9W GaN wideband power amplifier

RF Micro Devices Inc of Greensboro, NC, USA has launched the RFHA1006, a wideband power amplifier designed for continuous-wave (CW) and pulsed applications including: class AB operation for public mobile radio; power amplifier stages for commercial wireless infrastructure; general-purpose Tx amplification; test instrumentation; two-way radios; and civilian and military radar.

Using a high-power-density gallium nitride HEMT process,

the amplifier achieves high power-added efficiency (PAE = 60%), flat gain (of 16dB), and large instantaneous bandwidth (225–1215MHz) in a single amplifier design. The input-matched GaN transistor is packaged in an air-cavity ceramic package for what is claimed to be excellent thermal stability through the use of advanced heat-sink and power dissipation technologies.

Ease of integration is accomplished through the incorporation of

an optimized 50Ω input-matching network within the package that provides wideband gain and power performance in a single amplifier. An external output match offers the flexibility of further optimizing power and efficiency for any sub-band within the overall bandwidth.

Operating from a 28V supply, output power is typically 9W (39.5dBm). The operating temperature is –40°C to 85°C. Large-signal models are available.

www.rfmd.com

NXP and Singapore's A*STAR to co-develop 200mm GaN-on-Si power devices

Work to be carried out in IME's MOCVD-equipped 200mm engineering fab

The Institute of Microelectronics (IME), a research institute of Singapore's Agency for Science, Technology and Research (A*STAR), and NXP Semiconductors N.V. of Eindhoven, The Netherlands, which provides mixed-signal and standard semiconductor products, have entered into research collaboration to develop a 200mm gallium nitride-on-silicon (GaN-on-Si) process and technology for high-voltage power devices to deliver highly efficient energy solutions in end applications such as computing and communications, aerospace and automotive applications.

The IME and NXP team will collaborate on the development of process technologies for the manufacturing of GaN devices on

200mm wafers, which is expected to bring about a considerable reduction in manufacturing cost compared to using smaller-size wafers. The work will be carried out in IME's 200mm engineering fab, which has GaN metal-organic chemical vapour deposition (MOCVD) capabilities for the production of GaN wafers.

"IME's GaN-on-Si research program can play a vital role in helping our partners achieve commercial success in GaN power electronics," says professor Dim-Lee Kwong.

"This collaboration is an important step in our strategy to address the need for dramatically improved efficiency in power conversion through innovative engineering solutions," says Dr Michael Bolt, director NXP

Research Asia Lab.

Gallium nitride is used as the key material for next-generation high-frequency, high-power transistors capable of operating at high temperatures. GaN-on-Si offers the key advantages of combining high operation voltage, high switching speed, low loss, and high integration level, on large-diameter Si wafers, says NXP. The CMOS-compatible device process - which leverages the economics of scale and compatibility with high-throughput and high-capacity 200mm Si-based wafer process technology - offers the opportunity for cost-efficient volume production, the firm concludes.

www.ime.a-star.edu.sg

www.nxp.com

Singapore's IME collaborating with Rolls-Royce on GaN-based power electronics

High-power-density converters to measure physical parameters at temperatures up to 300°C and environmental pressures up to 30kpsi

The Institute of Microelectronics (IME), a research institute of Singapore's Agency for Science, Technology and Research (A*STAR), has announced a collaboration with global power systems company Rolls-Royce for R&D on advanced power electronics devices.

The research collaboration aims to use gallium nitride (GaN) power devices for the development of high-power-density converters that can reliably measure various physical parameters at soaring temperatures of up to 300°C and at environmental pressure of up to 30kpsi.

The collaboration will be delivered through IME's Rugged Electronics program, which was set up to

support Singapore's drive to become a technology hub for the aerospace, oil and gas sectors.

The program's focus is to develop a wide range of solutions, from sensing, packaging, telemetry and non-volatile

This collaboration leverages IME's established competence and enables us to extend our research to innovate in new industries. More importantly, this strategic partnership offers an excellent opportunity for Singapore to build knowledge in this industry

memory to integrated circuits.

"This collaboration leverages IME's established competence and enables us to extend our research to innovate in new industries," says IME's executive director professor Dim-Lee Kwong. "More importantly, this strategic partnership offers an excellent opportunity for Singapore to build knowledge in this industry and move further up the value chain," he adds.

"IME's expertise, flexibility and positive approach makes them an excellent research partner," comments Dr Kurichi Kumar, director of Research & Technology — Asia, Rolls-Royce Singapore.

www.ime.a-star.edu.sg

www.rolls-royce.com

GaN Systems closes Series B funding after development milestones achieved ahead of schedule

Funding to speed commercialization of power transistors using island-based technology

GaN Systems Inc of Ottawa, Ontario, Canada, which is a fabless provider of gallium nitride (GaN)-based power switching semiconductors for power conversion and control applications, has closed its Series B financing round with existing investors Chrysalix Energy Venture Capital and RockPort Capital. This follows a Series A round of funding just last November and signals the achievement of the firm's initial development milestones months ahead of schedule.

"Since the company's Series A round, the market momentum for gallium nitride as a credible alternative to silicon for power devices has grown significantly, with devices becoming mainstream faster than we anticipated," says Chrysalix's managing director Mike Sherman. "This means commercial reality is closer and more tangible than expected," he adds.

"This significant financing round is a stamp of approval from our existing investors," says CEO Girvan Patterson. "It enables us now to accelerate commercialization of the GaN power devices that we have developed on our break-through island technology platform," he adds.

GaN Systems' transistors are

Since the company's Series A round, the market momentum for GaN as a credible alternative to silicon for power devices has grown significantly, with devices becoming mainstream faster than we anticipated... Commercial reality is closer and more tangible than expected

targeted at the next generation of highly efficient power conversion applications, the fastest-growing segment of the \$14bn-a-year power devices market. This includes high-growth applications such as solar inverters, server farms, and hybrid vehicles. Beyond the inherent advantages of GaN in efficiency, speed and temperature, GaN Systems says that its Cool Switching technology enables extremely compact, low-cost designs, and provides a seamless transition to foundry-independent GaN-on-silicon fabrication for flexible access to high-volume production resources.

"With these advantages, GaN Systems is uniquely positioned to drive broad adoption of gallium nitride as a superior alternative to conventional silicon power devices," comments RockPort Capital partner Daniel Hullah.

www.gansystems.com

Freescall unveils its first gallium nitride RF product for cellular infrastructure applications

Freescall Semiconductor of Austin, TX, USA, which provides RF power technology for cellular markets, has unveiled its first RF power amplifier fabricated using gallium nitride (GaN) technology. Products will initially target the cellular infrastructure market, with potential future applications including avionics, radar, ISM (industrial, scientific & medical)-band, and software-defined radio.

The first GaN product, the AFG25HW355S, is the latest addition to what is claimed to be the industry's most comprehensive portfolio of power amplifier (PA) solutions. Existing Freescall RF power products include 12V, 28V and 50V silicon LDMOS products, 5V GaAs HBT, 5V and 12V GaAs

pHEMT solutions, and high-frequency SiGe technology featuring operation up to 100GHz and beyond.

"Freescall's GaN RF power solutions underscore our technology-agnostic approach to the RF power market," says Ritu Favre, VP & general manager of the firm's RF Division.

"Working with GaN in development since the mid-2000s, we have established an ideal blend of cost efficiency, performance and reliability, and the time is now right to add GaN-based products to our broad array of RF power amplifier solutions."

The AFG25HW355S is a 350W, high-performance-in-package (HiP), 2:1 asymmetric device with the following features and performance targets: 2.3–2.7GHz operation;

56dBm peak power; 50% efficiency; 16dB gain; and NI-780 packaging.

Freescall says that advantages of using GaN technology in power amplifiers include smaller product form-factors, low parasitic loss, elevated power density, and higher-frequency operation. Potential GaN cellular applications include quasi-linear, high-efficiency (Doherty), high-powered pulsed (nonlinear) applications, broadband PAs, and switch-mode amplifier configurations.

The AFG25HW355S will be available soon to select customers in sample quantities, followed by full qualification and volume shipping by second-quarter 2013.

www.freescall.com

Cree launches X-band fully matched 50–100W GaN HEMT power transistors for commercial radar & satcoms

Cree Inc of Durham, NC, USA has launched high-efficiency X-band, fully matched gallium nitride (GaN) high-electron-mobility transistors (HEMTs) for commercial radar and satellite communications applications. Rated at 50W and 100W, the devices deliver power-added efficiency (PAE) and performance improvements compared with existing gallium arsenide (GaAs) metal-semiconductor field-effect transistors (MESFETs) or traveling wave tube (TWT) based amplifiers.

"The performance advantages of higher power ratings, higher linear efficiency and higher gain, combined with a reduced footprint, offer dramatic advantages when compared to GaAs MESFET transistors or TWT amplifiers," says Jim Milligan, director, RF and microwave. "This new product family will deliver comprehensive system benefits, including superior thermal management and significantly-reduced power supply load," he believes.



Cree's new 100W CGHV96100F2 GaN HEMT transistor.

"The new product family also offers a lower-cost alternative to TWT amplifiers and associated high-voltage power supplies and linearization systems while improving overall system reliability."

The X-band product family consists of four new GaN HEMT transistors: two 7.9–8.4GHz devices for satellite communications (the 50W CGHV96050F1 with 30% (linear) PAE and the 100W CGHV96100F1 with 30% (linear) PAE) and two 8.4–9.6GHz devices for commercial

radar applications (the 50W CGHV96050F2 with 50% (P_{sat}) PAE and the 100W CGHV96100F2 with 45% (P_{sat}) PAE). All four are offered in a small-footprint (0.9" x 0.7") package.

The efficiency advantages in using the new GaN devices can be up to three times greater compared with available GaAs MESFET transistors, Cree claims. Further, the wide video bandwidth of GaN HEMTs allows use in multi-carrier applications with two-tone spacing up to 70MHz.

The fully matched GaN HEMTs complement the previously released packaged MMICs CMPA5585025F and CMPA801B025F, which can also be used as drivers for the CGHV96050 or CGHV96100.

Cree exhibited the new devices at the 2012 IEEE International Microwave Symposium (IMS) in Montreal, Canada (17–22 June).

www.cree.com/rf

60W S-band GaN HEMT with 65% drain efficiency for radar

Cree has announced the sample release of a high-efficiency unmatched GaN HEMT for military and commercial S-band radar applications.

Rated at 60W for frequencies of 3.1–3.5GHz, the CGH35060 delivers what is claimed to be superior drain efficiency (approaching 70%) compared with conventional silicon or GaAs MESFET devices. Also, the combination of high efficiency and power density helps to minimize thermal management requirements and allows for reduced size and weight in commercial radar systems.

"The introduction of the new Cree S-band GaN HEMT devices gives our customers a complete portfolio of superior S-band GaN transistors and MMICs for use in high-power amplifier circuits for commercial

radar applications," says Jim Milligan, director, Cree RF and microwave.

"Their high efficiency allows for extended pulse capability along with superior signal fidelity, which in turn minimizes the thermal management requirements, enabling RF design engineers to dramatically reduce the size and weight of radar systems while increasing their range and lowering installation costs," he adds.

The new unmatched GaN HEMT transistor features a rating of 60W

Their high efficiency allows for extended pulse capability along with superior signal fidelity, which in turn minimizes the thermal management requirements

pulsed power (at a pulse width of 100μs), a power gain of 12dB and a 65% drain efficiency at 28V operation (50% higher than typical silicon LDMOS devices). The CGH35060 has been proven in high-power amplifier reference designs at S-band frequencies of 3.1–3.5GHz. Other performance characteristics include longer pulse and duty capability (<0.6dB) and what is claimed to be superior signal fidelity with extremely low power droop compared with GaAs and Si technologies.

The new GaN HEMTs are complemented by Cree's S-band product portfolio, which also includes the CGH31240F/CGH35240F fully matched 240W GaN HEMTs (2.7–2.9GHz/3.1–3.5GHz) and the CMPA2735075F two-staged packaged GaN HEMT MMIC.

Cree unveils 0.25 μ m, 40V and 0.4 μ m, 50V GaN-on-SiC RF MMIC foundry processes

Higher power to enable lower-cost, higher-performance telecommunications & radar systems

Cree Inc of Durham, NC, USA has announced the qualification and production release of two new GaN processes: G40V4 (a 0.25 μ m process with operating drain voltage up to 40V) and G50V3 (a 0.4 μ m process with operating drain voltage up to 50V). The increased operating voltage and RF power density of the new processes enable smaller die and more compact, higher-efficiency amplifiers than possible with conventional technologies. Both technologies are compatible with Cree's proven GaN MMIC technology on 100mm-diameter SiC wafers with a full complement of passive circuit elements and nonlinear models.

The new processes are now available for development and full-rate production. Cree says that, with these processes, it offers numerous foundry service options to facilitate the rapid development of custom circuits, including full and dedicated mask sets.

The G40V4 process has been qualified at both 28V and 40V operation with RF power densities up to 6W/mm of FET periphery with operation up to 18GHz. The G50V3 process has been qualified for 50V operation and RF power densities up to 8W/mm with operation through 6GHz.

Both of these processes are derivatives of Cree's previously released G28V3 28V, 0.4 μ m process that has been in production since 2006 and exhibits what is claimed to be one of the lowest field failure rates of any microwave technology in the industry (a Failure in Time rate of nine device failures per billion hours of operation).

Cree estimates that for a typical three-sector, multi-band LTE/4G telecom remote radio head (RRH) installation, simply switching to GaN from conventional transistor technology could reduce RRH power

consumption by up to 20%, translating directly into lower operating costs and reduced energy consumption. Beyond operational cost savings, there can also be a significant saving in the initial cost of the system. GaN's benefits of higher voltage and higher efficiency allow smaller heat sinks and enclosures, less complex RF amplifiers and lower-cost AC-to-DC and DC-to-DC converters. Systems that previously needed large fans for cooling can now be air cooled. All of these improvements can reduce the system bill of material cost by up to 10%, resulting in significantly lower system acquisition costs, Cree reckons.

Similar benefits are seen for military radar systems, where the improved efficiency from Cree's GaN processes can not only reduce operational power consumption but also improve system life-cycle cost via reduced maintenance. The G40V4 and G50V3 processes can operate at a junction (channel) temperature of 225°C with a median life-time of over 2 million hours (228 years). This reliability can dramatically lower the cost of radar system repair and upkeep over its operating life, claims Cree.

"Our customers have been asking for a reliable, higher-frequency process to exploit the advantages of GaN for applications greater than 6GHz, including satcom, radar and electronic warfare markets, and we believe our new G40V4 process successfully satisfies their needs," says Jim Milligan, director of RF & microwave. "To address our customers' need for lower-cost GaN solutions, the 50V operating voltage of our new G50V3 process has been specifically engineered to provide an extremely low price in terms of dollars per watt of RF output power," he adds. "The cost-performance of our G50V3 process is designed to rapidly accelerate the adoption of

GaN in extremely cost-sensitive markets such as telecom infrastructure, where GaN can now provide performance advantages not realizable in silicon LDMOS," he continues.

"The higher operating voltage and higher efficiency possible with these new processes are key to rapid adoption," says Dr Cengiz Balkas, VP & general manager power and RF. "Switching to GaN for upcoming LTE/4G macro-cell base-stations could save telecom operators over \$2bn annually in reduced energy costs," he reckons. "Fortunately, the telecom industry is beginning to recognize these potential savings." Cree aims to deliver over 75 million watts of GaN transistors into telecom base-stations this calendar year.

At 40V operation, Cree's G40V4 process exhibits up to 6W/mm P_{sat} (saturated output power) at 18GHz. Typical device characteristics at 10GHz are 65% power-added efficiency (PAE) and 12dB of small-signal gain. At 50V operation, the G50V3 process demonstrates up to 8W/mm P_{sat} at 6GHz. Typical device performance at 3.5GHz is 70% PAE with 12dB of small-signal gain. Both GaN processes are qualified for maximum operating channel temperature of 225°C with a median time to failure (MTTF) of greater than 2 million hours.

In addition, Cree is releasing MMIC design kits with proprietary scalable nonlinear high-electron-mobility transistor (HEMT) models suitable for operation with Agilent's Advanced Design System (ADS) and AWR's Microwave Office simulator platforms. The kits also contain a full suite of passive components — resistors, capacitors, spiral inductors and substrate ground vias that can be used to simulate full MMIC performance and provide significantly reduced design cycle times.

www.cree.com/rf

AWR Design Forum adds Taiwan to schedule

AWR Corp of El Segundo, CA, USA, a supplier of electronic design automation (EDA) software for designing RF and high-frequency components and systems, has added Taiwan (on 12 July) to the list of cities scheduled for the July tour of its AWR Design Forum (ADF).

ADF 2012 is an open event for designers of microwave and RF circuits and systems (such as MMIC, RFIC, RF PCB, modules and communication systems) to learn about AWR's latest products and technologies and how they can help solve both existing and future design problems. It also provides a chance to network and collaborate on industry issues and trends.

Agenda topics presented by AWR and partners National Instruments, WIN Semiconductor and Zuken may include:

- Optimizing the Design and Verification of 4G RF Power Amplifiers;
- Design of a Novel Multi-Slot Antenna Featuring EM Parameterization and Optimization Techniques;
- Simulating an NXP Doherty Power Amplifier with Digital Pre-Distortion;
- Electrical/Thermal Coupled Solutions for Flip Chip Designs;
- Design and Simulation of Modern Radar Systems;
- Fully Integrating 3D Electromagnetic (EM) Simulation into Circuit Simulation;
- System Simulation Featuring

Signal Processing Blocks;

- RF Link Prediction — A New and Novel Approach;
- Linking RF Design through to Test;
- RF Moving Beyond a Linear Datasheet;
- MMIC Design in AWR 2011; and
- The AWR Design Flow Advantage — Introduction to New Features and Capabilities.

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

Presentations will be available for download after the event from:

www.awrdesignforum.com

Cascade launches first fully automatic high-power device measurement probe system

Cascade Microtech Inc of Beaverton, OR, USA, which provides equipment for the precision contact, electrical measurement and test of ICs, optical devices (including LEDs) and other small structures, has launched the APS200TESLA. The turn-key system combines the proven capabilities of its Tesla on-wafer power device characterization measurement technology with Cascade's BlueRay production automation technology to deliver what is claimed to be the industry's first complete on-wafer production solution to address the test challenges of discrete power devices.

As power semiconductors grow with the demand for energy-efficient and environmentally friendly products, power device manufacturing will shift from silicon substrates to silicon carbide (SiC), gallium nitride (GaN), and gallium nitride on silicon (GaN-on-Si), says the firm. These new substrate technologies offer improved efficiency and enable higher levels of power, and faster switching, in many applications such as automotive and consumer electronics, electrical power distri-

bution and large data centers, which currently use silicon-based insulated-gate bipolar transistors (IGBTs) and MOSFETs.

Fast-growing applications in renewable energy and industrial power will challenge power device manufacturers to develop more efficient devices at a lower cost, driving the need for test solutions specifically designed for high-voltage/high-current probing, adds the firm. Cascade says it is meeting this challenge with what it claims to be the first fully automatic on-wafer probe system for high-power device measurement.

Rated up to 10kV/400A, the APS200TESLA delivers what is reckoned to be unmatched electrical performance for high-voltage and high-current device characterization at production levels. The system comes with a high-voltage/high-current probe card, a high-voltage/high-power chuck port, and the patent-pending MicroVac high-power chuck, which can handle wafer thicknesses down to 50µm, such as ultra-thin Taiko wafers. An optimized electrical connection easily integrates

the APS200TESLA with a variety of test instruments, and the interlock-enabled safety shield provides a safe environment for the operator. The arc-suppression feature allows the user to optimize device layout to achieve better yields. Auto-discharging and the unique probe-pin touch sensing capability prevent device damage due to high-voltage discharge during die-to-die moves. The APS200TESLA also offers advanced prober control software for automatic wafer and die stepping.

"The new APS200TESLA leverages our experience in achieving accurate on-wafer measurement," says president & CEO Michael Burger. "It is an advanced, turn-key power device measurement system that will help our customers improve cost-of-ownership, increasing test throughput and improving yields," he claims.

"It allows our customers to save time by avoiding unnecessary dicing and packaging prior to final test. By testing on-wafer in a production environment, the APS200TESLA enables our customers to reduce test costs and get their products to market faster."

www.cascademicrotech.com

Latest GoldenGate release speeds design verification

Agilent Technologies Inc of Santa Clara, CA, USA has announced GoldenGate 2012, the latest release of its RFIC simulation, verification and analysis software.

Raising the bar on performance and usability, the 2012 release offers RFIC designers a host of technology enhancements for accelerated design verification, extended design-for-manufacturing solutions and improved links to system design. Additionally, new licensing models offer users greater purchasing flexibility.

Agilent demonstrated GoldenGate 2012 — along with a range of solutions for everything from circuit-level modeling through system verification for general RF, microwave, 4G communications and aerospace/defense applications — at the Design Automation Conference (DAC 2012) in San Francisco (3–7 June). GoldenGate 2012 was

also demonstrated at the 2012 IEEE MTT-S International Microwave Symposium (IMS) in Montreal, Canada (17–21 June).

Agilent says that, since design verification can be a tedious and time-consuming task for RFIC designers, GoldenGate 2012 accelerates design verification through technology enhancements that allow users to set up distributed simulations, run them with unmatched performance, and display and analyze massive amounts of data.

The firm also offers an extended 'parallel simulation license' at a fraction of the cost of the base GoldenGate simulator license. The license is supported in any scenario launching a parallel simulation (and ADE-XL in Cadence Virtuoso).

A key feature of GoldenGate 2012 is the extraction of X-parameters (a mathematical superset of

S-parameters used for characterizing the amplitudes and relative phase of harmonics generated by nonlinear components under large input-power levels). The new GoldenGate 2012 X-parameters feature allows designers to capture the nonlinear behavior of active components such as amplifiers and to save the data for quick use in simulation models in RF system or circuit designs, while also hiding all intellectual property.

"We are very pleased to see the new X-parameters extraction support in GoldenGate," comments Alireza Shirvani, VP of engineering at Amalfi Semiconductor Inc. "We are using X-parameters to speed up design and co-simulation at the die-module interface, and to share an executable circuit model that encodes the proprietary details."

[www.agilent.com
/find/eesof-goldengate](http://www.agilent.com/find/eesof-goldengate)

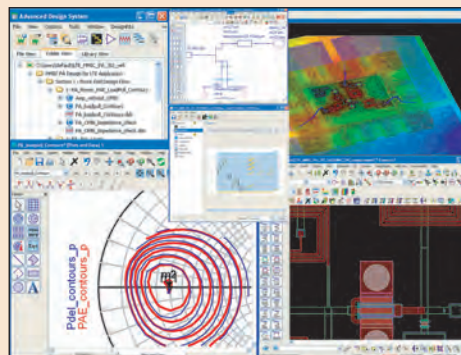
Agilent debuts new technologies in power amplifier module design for next release of ADS electronic design automation software

Agilent has unveiled new technologies and developments for RF power amplifier design that will be part of the next major release of its flagship Advanced Design System electronic design automation (EDA) software for RF, microwave and high-speed digital applications.

Agilent demonstrated ADS 2012 — along with a range of solutions for everything from circuit-level modeling through system verification for general RF, microwave, 4G communications, and aerospace/defense applications — at the 2012 IEEE MTT-S International Microwave Symposium (IMS) in Montréal, Canada (19–21 June).

Agilent's new developments for RF power amplifier design include:

- side-by-side finite-element method (FEM) electromagnetic simulation of different technologies to analyze electromagnetic interactions between ICs and



interconnects, wire bond and flip-chip solder bumps in typical multi-chip RF power amplifier modules;

- model support for the new artificial neural network-based Agilent NeuroFET model, extracted by IC-CAP device modeling software of Agilent's EEsos EDA division, which enables more accurate field-effect transistor (FET) modeling and simulation results (for high-power GaN FET amplifiers, for example);
- improved integration with Electromagnetic Professional software (three-dimensional EM compo-

nents from EMPro can now be saved as database cells for use directly in ADS);

- the immediate beta release of the new ADS electro-thermal simulator to select customers (based on a full 3D thermal solver natively integrated into ADS, this new capability incorporates dynamic temperature effects to improve accuracy in 'thermally aware' circuit simulation results);
- enhancements to the ADS Load Pull DesignGuide (such as adding mismatch simulation to indicate device or amplifier sensitivity to load VSWR or phase angle); and
- enhancements to the Amplifier DesignGuide (including extensive updates that make it easy to see amplifier performance at a specific output power or a specific amount of gain compression).

Agilent's ADS 2012 software release is due to ship in August.

www.agilent.com/find/eesof-ads

Element Six opens its first US synthetic diamond plant

Expansion a response to growing demand for commercial applications

Luxembourg-registered Element Six (which is part of the De Beers Family of Companies and is co-owned by Belgian materials group Umicore) has opened its first US manufacturing facility in Silicon Valley (in Santa Clara, CA), as part of its business developing and producing synthetic diamond materials.

The facility will house staff in the production, technical and customer service fields, and will serve to establish a direct connection to Element Six Technologies Division's customers and partners in the USA. The firm says that its continued expansion into the US market is in direct response to the growing demand and interest in synthetic diamond for commercial use in advanced technology applications.

Element Six says that technology developers using its synthetic dia-



Adrian Wilson, head of Element Six Technologies, presents its first US-grown polycrystalline diamond wafer.

mond can benefit from its unique extreme properties, including unparalleled hardness, thermal conductivity, and optical and electrochemical properties. For example, its thermal conductivity and electric insulator properties can result in step-change reductions in device operating temperatures, the firm

adds. Other applications include enabling environmentally friendly water treatment systems, quantum computing, magnetometry and biomedical sensors.

"With our new Santa Clara facility, we will build on our 25% year-on-year growth, and deliver innovative products which enhance productivity, reduce energy consumption and lower operational costs," claims CEO Cyrus Jilla.

With over 50 years of experience and on-going investment in R&D, Element Six claims its decades of process and material development experience give it unique insight into the properties of synthetic diamond and its applications. It also recently announced construction of the world's largest synthetic diamond materials R&D facility in Oxford, UK.

www.e6.com

IQE enhances test & measurement capabilities with Nanotronics automated wafer inspection tool

Epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK says that it has enhanced wafer inspection capabilities at its Cardiff facility by acquiring a new automated wafer inspection tool supplied by Nanotronics Imaging LLC of Cuyahoga Falls, OH, USA.

The nSPEC tool enhances existing manual microscopy inspection by allowing automated loading and scanning of III-V semiconductor wafer products including gallium nitride (GaN), gallium arsenide (GaAs) and indium phosphide (InP)-based materials. The tool has built-in intelligence to enable repeatable and quantifiable object recognition to identify, categorize and record wafer features in real-time.

The acquisition of the tool follows an extensive six-month evaluation where the reliability and repeatability was compared with existing

inspection techniques. This is the second nSPEC tool to be installed at IQE, the first unit having been commissioned and in use at the its manufacturing facility in Somerset, NJ, USA.

"The new automated inspection system offers a compelling alternative to manual microscope inspection, with greater repeatability and significantly reduced chance of human error," comments Eliot Parkinson, general

The new automated inspection system offers a compelling alternative to manual microscope inspection, with greater repeatability and significantly reduced chance of human error

manager of IQE's III-V manufacturing facility in Cardiff.

"Rapid inspection that gives repeatable and useful results needs to be thought of as a modern technology like the personal computer used to be, and the smart phone is now. What has traditionally been too expensive, too complicated, and provided too little relevant information now needs to have all required features and more, so that all companies using wafer inspection tools can have best-in-class technology that is affordable," says Nanotronics Imaging's CEO Matthew Putman. "We are at a point of technological convergence, where our engineers can develop such a tool. We are also pleased to have worked with a global leader like IQE to evaluate our tool in a high-volume semiconductor wafer manufacturing environment," he adds.

www.nanotronicsimaging.com



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5N Plus' revenue grows 8.5% in Q1/2012

Revised CdTe First Solar contract to hit profitability for two quarters

5N Plus Inc of Montreal, Quebec, Canada has reported results for first-quarter 2012, with numbers for the comparable period to end-February 2011 restated to reflect changes resulting from the implementation of IFRS (International Financial Reporting Standards) and adoption of the US dollar as the firm's functional and reporting currency.

5N focuses on specialty high-purity metals such as tellurium, cadmium, selenium, germanium, indium and antimony and also produces related II-VI semiconducting compounds such as cadmium telluride (CdTe), cadmium sulphide (CdS) and indium antimonide (InSb) as precursors for growing crystals for electronic applications, including solar photovoltaic, radiation detector and infrared markets. Also, in mid-April 2011, 5N paid \$317m to acquire MCP Group SA of Tilly, Belgium, a producer and distributor of bismuth and bismuth chemicals (with a 50% global market share) as well as other specialty metals (including gallium, indium, selenium and tellurium).

So, while up 8.5% on \$149.4m last quarter, revenue for first-quarter 2012 of \$162.2m was up 685% on \$20.7m for the quarter to end-February 2011.

"Sales returned to more expected levels, with contributions from both

business units reflecting healthy demand in their respective markets," says president & CEO Jacques L'Ecuyer. Compared with last quarter, the Eco-Friendly Materials business unit saw revenue rise by \$9m and bookings rise by 16%. Revenue also rose in the Electronic Materials unit but bookings fell, due mainly to the restructuring of the contract with 5N's main solar customer (CdTe PV module maker First Solar Inc of Tempe, AZ, USA). Although up on \$73.2m at the end of February 2011, during the quarter the backlog of orders (expected to translate into sales over the next 12 months) fell from \$223m to \$215.6m.

5N entered into a revised CdTe supply agreement with First Solar that came into effect on 1 April, replacing three existing supply agreements. In the new deal 5N will supply substantially all of the CdTe required by First Solar. However, pricing was adjusted downwards from the prior agreements, in line with more competitive environments in both the solar and material-feedstock markets.

Compared with an adjusted net loss of \$0.1m last quarter, net earnings were \$5m, but this is down on \$5.5m for the quarter to end-February 2011. However, before the amortization of intangible assets related to the

acquisition of MCP, net earnings were \$7.2m. EBITDA (earnings before interest, taxes, depreciation and amortization) has risen from \$6m for the quarter to end-February 2011 and from \$7.3m last quarter to \$16.9m.

Funds from operations were a record \$11.2m (up on \$10.3m last quarter and \$6.6m for the quarter to end-February 2011), "highlighting our ability to adjust working capital requirements to best match our long-term plan," says L'Ecuyer. "We were able to successfully reduce our inventory levels, increasing correspondingly our financial flexibility," he adds. During the quarter net debt fell from \$260.6m to \$232.1m.

"The accounting treatment related to the previously announced restructuring of our contract with our main customer in the solar market, which is effective from 1 April 2012 onwards, is expected to result in minimal profit being booked on this contract as long as the corresponding existing inventory has not been completely used up," notes L'Ecuyer. "The current sales outlook related to this contract is such that we expect this element to impact profitability for the next two quarters. Regardless, we continue to focus on strong cash flow generation and on debt reduction."

5N Plus completes \$40m equity financing

5N has completed a 'bought deal' public offering and private placement (announced on 16 May) of a total of 12,903,613 units at a price of \$3.10 per unit, for total gross proceeds of \$40m. Each unit consists of a common share plus half a share purchase warrant. Each full warrant (listed under the symbol 'VNP.WT' on the Toronto Stock Exchange) entitles the holder to buy an extra share at a price of \$5 for 24 months.

In the 'bought deal' offering, 5N issued and sold 6,452,000 units

(for gross proceeds of \$20m) to a syndicate of underwriters led by National Bank Financial Inc.

In the private placement, 5N issued and sold 6,451,613 units to Investissement Québec for gross proceeds of \$20m (with shares and warrants subject to restrictions on resale for four months under applicable securities legislation).

5N aims to use the net proceeds to reduce indebtedness incurred under its revolving credit facility with a syndicate of financial institutions.

Last quarter 5N Plus incurred impairment charges of \$45.6m, resulting mainly from the "current turmoil" in the solar market and the impact on the selling price of solar-related products and the value of fixed assets used to manufacture or develop such products. Specifically, the charges included total write-offs of fixed and intangible assets amounting to \$12.2m and total inventory write-downs of \$33.4m.

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IN BRIEF

IQE appoints Cardiff general manager

Epiwafer foundry and substrate maker IQE plc has appointed Eliot Parkinson as general manager of its III-V facility in Cardiff, UK, taking over from group business development director Adrian Meldrum (interim general manager).

With over 16 years manufacturing experience in operations leadership and management in the semiconductor industry, Parkinson joins from International Rectifier, where he was manufacturing director. He has also held manufacturing and operational management roles at Intel's IC fabrication plant in Ireland.

"Eliot brings a wealth of hands-on manufacturing management experience to the Group's Cardiff operation," comments Meldrum.

www.iqep.com

Riber sells Compact21 research MBE systems to labs in China and Japan

Riber S.A. of Bezons, France, which makes molecular beam epitaxy (MBE) systems as well as evaporation sources and effusion cells, has announced the sale of Compact 21 research MBE systems to laboratories in China and Japan.

A Compact 21 system will be installed in the new cleanroom suite at South Western University in Sichuan Province, China. The compound semiconductor group there will use what will be their first MBE installation to explore the fundamental properties of superlattice structures made from extremely thin layers of III-V materials deposited on a sub-nanometer scale.

Riber says that the system was selected by South Western University not just on its credentials in terms of the scientific achievements of Compact 21 customers worldwide but also on the basis of its ease of

use, ergonomic design features and proven reliability. South Western's Dr Chen also notes the importance of the presence of Riber China, equipped with expertise to support the installation as and when required.

Riber has also sold a Compact 21 system to what it describes as a "world famous" research lab in Japan.

Riber says the lab aims to modernize its fleet of MBE machines, while further strengthening its development capacities for designing III-V component-based nanostructures (quantum dots and photonic crystals for telecom and quantum information device applications).

"The Compact 21 MBE system is the world's top-selling research system and we need it to meet our demanding expectations for applied research on new compound semiconductor materials," says the lab.

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Indium Corp's Ploessl named Compounds product manager

Indium Corp of Clinton, NY, USA has named Robert Ploessl PhD as product manager for indium, gallium, germanium and tin compounds.

Dr Ploessl will work with Indium Corp's global team of engineering, sales, operations and R&D professionals to capitalize on the growth of LEDs, metal-organic precursors, power storage systems, fiber optics, and next-generation OLED displays.

Specifically, Ploessl will develop the firm's marketing strategies, while bringing insights learned from the technical team to further product development efforts. Indium Corp's compounds business includes indium trichloride (InCl_3), gallium trichloride (GaCl_3), germanium tetrachloride (GeCl_4), as well as a full range of oxides.

Ploessl joined Indium Corp in 2010. He holds a doctorate in physics from the University of Regensburg in Germany and an MBA from the S.C. Johnson Graduate School of Management at Cornell University. Ploessl is based at Indium Corp's global headquarters in Clinton, NY.

Indium Corp is a materials supplier to the global electronics, semiconductor, solar, thin-film, and thermal management markets. Products include solders, pre-forms, and fluxes; brazes; sputter targets; indium, gallium, germanium and tin compounds, and high-purity metals; and Reactive NanoFoil. Founded in 1934, the firm has global technical support and factories in China, Singapore, South Korea, the UK, and the USA.

www.indium.com

IN BRIEF

Enhanced CuInGa and CuGa targets

At Intersolar North America 2012 in San Francisco (10–12 July), Indium Corp is featuring enhanced copper-indium-gallium (CuInGa) and copper-gallium (CuGa) rotary sputtering targets, available in lengths up to 3.2m, and thicknesses of the monolithic source layer up to 22mm.

Targets are made by Indium's vertically integrated proprietary process using aerospace powder metallurgy technology, yielding a consistently homogeneous alloy with low-ppm contaminate levels and uniform density.

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IN BRIEF

Veeco presents at LED conferences

Veeco presented at two recent LED industry conferences:

- the 'LED Lighting Evolution Conference: From Sapphire to Lumens' on 6 June in Boston, MA, hosted by IMS Research, provided global LED industry leaders throughout the supply chain an opportunity to explore innovations shaping the future of lighting;
- the 'LEDforum 2012' on 11 June in Guangzhou, China, organized by LEDInside and Guangzhou International Lighting Exhibition, focused on future prospects for the LED industry, addressed key developments in LED manufacturing process and equipment, and provided analysis on the Chinese LED industry and global LED market.

Participating in both conferences, Jia Lee Ph.D. (senior director of marketing & business development for MOCVD) has held a variety of marketing positions covering the solar, foundries and semiconductor capital equipment industries. His presentation 'Enabling Solid State Lighting through Advancements in MOCVD Technology' provided an LED market outlook, with emphasis on improving manufacturers' production processes while reducing costs significantly.

According to IMS Research, Veeco's single-reactor TurboDisc K465i (launched in 2010) was the top-selling MOCVD tool that year, and the TurboDisc MaxBright Multi-Reactor GaN MOCVD system, launched in 2011, was the top seller in 2011. Veeco reckons that all its MOCVD systems provide the industry's highest production and lowest cost of ownership. Also, low-maintenance TurboDisc technology enables what is reckoned to be the highest system availability and throughput.

Veeco launches suite of GaN MOCVD systems for LED manufacturing

Three new models offer more compact version of MaxBright and high-performance versions of MaxBright and K465i

Epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA has introduced three new models of its TurboDisc metal-organic chemical vapor deposition (MOCVD) systems

for the production of Veeco's new TurboDisc MaxBright MHP system. high-brightness

light-emitting diodes (LEDs):

TurboDisc MaxBright M, TurboDisc MaxBright MHP and TurboDisc K465i HP.

MaxBright M is a modular and more compact version of Veeco's MaxBright multi-reactor system, providing easier serviceability and up to 15% improved footprint efficiency. It also features improved layout configuration flexibility to accommodate various fab spacing requirements.

MaxBright MHP is a high-performance version of the new modular 'M', providing as much as 20% within-wafer wavelength uniformity improvement over MaxBright. Higher yields are achieved from technology advancements that result in improved thermal and flow capability. The MHP also provides lower cost of ownership compared with MaxBright.

K465i HP is a high-performance option for Veeco's existing K465i single-reactor MOCVD system, delivering up to 20% within-wafer wavelength uniformity improvement as well as lower cost of ownership.

The new systems are available in 2", 4", 6" and 8"-wafer configurations. Existing MaxBright and K465i systems are easily field-upgradeable to the high-performance HP option. Veeco says that all of its MOCVD systems feature its low-maintenance



TurboDisc technology, which enables what is reckoned to be the highest system availability and throughput.

According to analyst firm IMS Research, the existing K465i (introduced in 2010) was the top-selling MOCVD tool that year, and the MaxBright (launched in 2011) was the top seller last year.

"This new suite of products provides our customers with tremendous flexibility to make the most of their capital investments and choose the system that works best in their unique production environment," says William J. Miller Ph.D., executive VP, Veeco Process Equipment. "The innovation in the MaxBright M, MaxBright MHP and K465i HP was accomplished by listening to our customers and focusing on system improvements that could drive their productivity and yield," he adds.

"This new product line-up, all based on our industry-leading technology and automation expertise, can help to accelerate worldwide adoption of LED lighting by reducing manufacturing costs," believes chairman & CEO John R. Peeler. "Veeco remains committed to providing the industry's highest-capacity, highest-throughput and lowest-cost-of-ownership MOCVD systems available."

www.veeco.com/maxbrightmhp

Dockweiler marketing MO precursors for III/V-on-Si under DOCK/CHEMICALS brand

Dockweiler Chemicals GmbH of Marburg, Germany, which supplies highly purified, liquid metal-organic (MO) compounds for chemical vapour deposition (CVD) applications, is now marketing its international full-service solutions under the brand name DOCK/CHEMICALS.

The firm has long-standing competence in manufacturing chemicals for III/V compound semiconductors on silicon. DOCK/CHEMICALS clients profit from efficient CVD deposition, faster time-to-market and enhanced semiconductor performance.

"After our intensive research in developing innovative precursor systems for the successful integration of compound semiconductors on silicon, we are now starting its international marketing," says CEO & co-founder Dr Arnd Greiling. With the fluid precursor system, Dockweiler Chemicals' innovation introduces a safer, higher-performing and cost-effective process, the firm claims.

"Use of TBAs [tertiarybutylarsine] and TBP [tertiarybutylphosphine] to realize these novel material systems offers enhanced material quality and device performance in addition to improved safety," says professor Wolfgang Stolz, co-founder of Dockweiler Chemicals and co-head of the firm's parent organization STRL (Structure and Technology Research Lab) at Philipps-University Marburg. The firm says that, to guarantee the purity and consistency of the chemicals, it has implemented the unique EPIGRADE quality program as an essential part of its total quality system.

Dockweiler Chemicals is an interdisciplinary spin-off from the Philipps-University in Marburg. The entire management team stems from the university, including third co-founder & chief technology officer Dr Andreas Salzmann, who is responsible for the entire site management.


Following the firm's full-service concept, in addition to the precursors DOCK/CHEMICALS offers equipment solutions and delivery systems — both optimized to the specific requirements of its clients. With a focus on customer processes, DOCK/CHEMICALS solutions also include the customization of chemicals, improving deposition processes and enabling next-generation semiconductor devices, the firm claims.

The firm also claims its international client base benefits from complete supply-chain and cylinder management, based on decades of experience handling ultrapure chemicals.

"DOCK/CHEMICALS is a disruptive high-tech solution, providing innovative semiconductor and solar industry companies a decisive step ahead in development, thus making DOCK/CHEMICALS Semiconductors Decision," says Dr Jörg Koch, physicist & chief marketing officer.

www.dockchemicals.com


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IN BRIEF

Sinoepi orders CRIUS II-L for nitride LED wafers

In fourth-quarter 2011 Aixtron received an order from new customer Sinoepi Co Ltd, a Chinese wafer materials manufacturer, for a CRIUS II-L MOCVD reactor in 69x2"-wafer configuration, to be used for the production of epi-wafers for ultra-high-brightness (UHB) GaN-based LEDs.

Founded in August 2010 in the Beijing Economic and Technological Development Area, Sinoepi's main products include InGaN UHB LED epiwafers and chips for applications including LCD TV back-lighting and solid-state lighting.

The new system will be delivered in second-quarter 2012. Aixtron's local service support team will install and commission it at Sinoepi's complex in Beijing.

"Although this is our first new piece of equipment from Aixtron, my team is already very familiar with CRIUS technology," says general manager Ye. "We are particularly impressed with its high performance-to-cost ratio compared to other systems, as well as the seamless and short process transfer," he adds. "The CRIUS II-L matches our requirements for very high throughput epitaxial growth of nitride-based wafer materials... It will enable us to develop our processes quickly and efficiently," he concludes.

"Sinoepi has opted for the CRIUS II-L after thoroughly evaluating all systems currently available on the market," says Aixtron's chief operating officer Dr Bernd Schulte. "The CRIUS II-L has already set new industry standards, which we back up with a service that provides everything our customers need to ramp up their production," he adds. "We look forward to expanding our relationship with Sinoepi."

www.sinoepi.com

Plessey orders Aixtron CRIUS II-XL reactor for GaN-on-Si LED production

Aixtron has received an order from UK-based Plessey Semiconductors Ltd for the first of a set of production-ready CRIUS II-XL MOCVD reactors in 7x6"-wafer configuration for the growth of HB-LED wafers based on GaN-on-silicon materials.

Aixtron's local support team will install and commission the first reactor in Plessey's cleanroom in Plymouth, UK by the end of June.

"We are on schedule for the production of a world-class LED that will become the high-performance lighting LED at the price breakthrough the market has been waiting for," reckons Plessey Semiconductors' chief operating officer Barry Denington. "We completed the acquisition of the University of Cambridge spin-off company CamGaN in February 2012 and are now installing the capability for the full commercial exploitation of GaN-on-Si technology. Furthermore, we will be in early prototype production before the end of third-quarter 2012 and in full production by Q2/2013," he adds.

"The CRIUS II-XL reactor will form the basis of our commencement of full production of materials for LEDs," says Neil Harper, HB LED program and product line director. Plessey's branded MAGIC (MANufactured on GaNICS) LEDs will be fabricated on large-area silicon substrates through the firm's 6" integrated circuit fabrication line in Plymouth. "Aixtron's

latest CRIUS technology has many advantages that meet our needs, such as the best cost-of-ownership for GaN epi-layer growth on 6" silicon substrates and eventually on 8" silicon substrates. In addition, we can draw upon the excellent support services in the UK from Aixtron Ltd. and Aixtron Europe," he adds.

"Plessey is a well-established name in the electronics industry and they are now accelerating the commercial exploitation of one of the most promising areas of epitaxial technology, GaN-on-Si," comments Aixtron's chief operating officer Dr Bernd Schulte. "Plessey technology has the potential to transform the LED industry by lowering the cost of LEDs, as demanded by the solid-state lighting industry," he adds.

Plessey Semiconductors develops and manufactures semiconductor products used in sensing, measurement and controls applications for a wide range of markets including communications, medical, defense, aerospace and automotive. Earlier this year, the firm announced its plan to bring to market low-cost 'MAGIC' HB-LED products (initially for the replacement incandescent bulb market) within the next six months. It also plans to develop a range of smart-lighting products incorporating Plessey's existing sensing and control technologies.

www.plesseysemiconductors.com

CRIUS II-XL technology wins Aurora Award

At the LEDforum in Guangzhou, China, Aixtron received the 2012 LEDinside Aurora Award in the 'Best MOCVD equipment' class (recognizing outstanding products in the LED industry) for its CRIUS II-XL (launched in November).

"Aixtron's MOCVD equipment has a very strong worldwide reputation in LED production, efficiency and yield rate, while the technology also provides stable performance

and flexible capacity expansion to LED manufacturers," said the jury.

"We are setting new standards of innovation and deliver competitive cutting-edge MOCVD technology, used for the production of LEDs for various applications, but also for memory or logic chips, lasers, and highperformance solar cells," says VP of marketing Dr Rainer Beccard.

www.ledinside.com

www.aixtron.com

LayTec's Pyro 400 GaN epi surface temperature measurement tool wins Aurora Award

On 11 June at the LEDforum 2012 in Guangzhou, China, LayTec AG of Berlin, Germany (which makes in-situ metrology systems for thin-film processes, focusing on compound semiconductor and photovoltaic applications) received the LEDinside 'Aurora Award 2012' for its Pyro 400 product in the category 'Best LED Test Equipment' (which recognizes outstanding products in the LED industry). At the award ceremony, the prize was presented to LayTec's general sales manager Tom Thieme.

Pyro 400 is LayTec's in-situ solution for the precise measurement of real surface temperature during gallium nitride (GaN) epitaxial growth. The near-ultraviolet (UV) pyrometry tool provides what is claimed to be a new quality of temperature control with unrivalled accuracy, and is of benefit in GaN-based LED and laser production because it directly correlates with the final device's emission wavelength.



LayTec's general sales manager Tom Thieme (left) receives award from Trendforce's chairman Dr C. L. Liu.

Pyro 400 can be combined with other LayTec in-situ monitoring systems for simultaneous measurements of GaN surface temperature with pocket temperature, reflectance and wafer curvature.

"I would like to thank all our customers who voted online for our product and the international prize committee for their decision," comments LayTec's CEO & president Thomas Zettler.

Lextar qualifies LayTec's Pyro 400 for GaN LED production

LED maker Lextar Electronics Corp of Hsinchu, Taiwan has qualified LayTec's Pyro 400 GaN surface temperature measurement pyrometry tool for GaN LED production.

"With Pyro 400 we can now better control the later emission wavelength of the LED already during growth," comments Lextar's Johnson Wang, department manager of Epi Engineering/Manufacturing, who was responsible for the qualification process for the Pyro 400 product, which uses using pyrometry at 400nm (at which wavelength GaN absorbs and thermally emits light). "The qualifications tests have proven that the surface temperature of the GaN measured by Pyro 400 at MQW [multi-quantum well] growth can be directly correlated with the later ex-situ PL emission wavelength. This tool is a quantum leap in wafer-to-wafer temperature control in LED production," he adds.

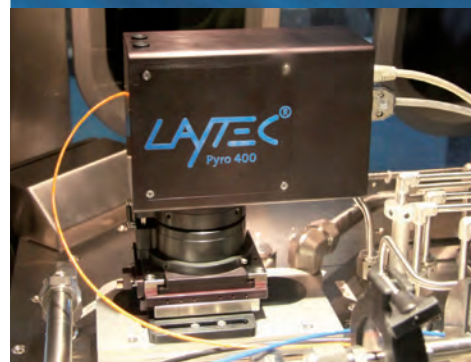
"The qualification of Pyro 400 by Lextar is a significant milestone for LayTec," says LayTec's director marketing & sales Dr Elisabeth Steimetz. "Through collaboration with this important and innovative customer we were able to further improve our product and qualify it for daily LED production application," she adds. "We could successfully demonstrate that precise surface temperature control gives room for even further LED yield improvement and cost reduction."

www.laytec.de

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Jenoptik expands high-power laser production with new AIX 2600G3 IC tool

In fourth-quarter 2011 Aixtron received an order for an AIX 2600G3 IC MOCVD reactor in 12x4"-wafer configuration from existing customer Jenoptik Diode Lab GmbH, which conducts semiconductor fabrication at its Adlershof campus in Berlin.

For delivery in second-half 2012, the new system will form the basis of a new capacity expansion for high-power semiconductor laser diode epitaxial materials at Jenoptik's Lasers & Material Processing Division. The Aixtron Europe support team will install and commission the new reactor in Jenoptik's new dedicated production facility in Berlin-Adlershof.

"Due to increasing demand as a result of high levels of customer satisfaction, particularly from Asia, it is likely that our existing production facility in Berlin will soon reach the limits of its capacity, and it is therefore being expanded," says a spokesman from Jenoptik Diode Lab. "As the new facility will more than double our production capacities, we need to introduce more MOCVD capability," they add. "Aixtron equipment has served us very well, and we now wish to bring in the AIX 2600G3 IC MOCVD reactor in order to better respond to high levels of customer satisfaction and demand."

From its own production facility in Berlin-Adlershof, which has been operating since 2006, Jenoptik has developed optoelectronic base materials in cooperation with the nearby Ferdinand-Braun-Institut, Leibniz-Institut for Ultra High Frequency Technology (FBH). Laser bars from Berlin-Adlershof are processed to create high-power diode lasers at Jenoptik in Jena as part of a complete technology chain through to laser systems for material processing. Jenoptik says that the new manufacturing facility will be automated and equipped with state-of-the-art production technology.

www.jenoptik.com

Aixtron appoints general manager of Aixtron China subsidiary

Deposition equipment maker Aixtron SE of Herzogenrath, Germany has appointed Tim Wang as general manager of its subsidiary Aixtron China Ltd.

Wang has worked in the semiconductor industry in the USA and China for many years and was most recently regional president of Novellus Systems in China.

"The Chinese MOCVD market has become increasingly important over recent years and China is expected to play a major role in future LED business," says executive VP & chief operating officer Dr Bernd Schulte. "We are therefore delighted to have Tim on board, to not only strengthen our local



Tim Wang.

strategic involvement, but also to underline China's significance as a key market within Aixtron," he adds.

"We have a clear commitment to China as

one of our largest markets; our mission is to provide our customers with the most productive and cost-effective technology and professional support, as well as to involve them in our future development," says Wang.

www.aixtron.com

CVD Equipment completes building sale prior to expansion

CVD Equipment Corp of Ronkonkoma, NY, USA (a designer and maker of equipment for developing and manufacturing electronic components, materials and coatings) has completed the sale of its facility at 979 Marconi Avenue, Ronkonkoma, NY, USA (comprising 63,275ft² in two buildings), where its Application Laboratory was located.

"During second-quarter 2012 we will be focusing on moving the company to our recently purchased building at 355 South Technology Drive, Central Islip, NY [a 120,000ft² facility, just 15 minutes away] and growing our CVD materials and equipment business," says president & CEO Leonard Rosenbaum.

CVD offers a range of chemical vapor deposition, gas control, and other equipment for the research, design and manufacture of semiconductors, solar cells, graphene, carbon nanotubes, nanowires, LEDs, MEMS, smart glass coatings, battery and/or ultra-capacitor materials, medical coatings, industrial

coatings, and equipment for surface mounting of components onto printed circuit boards.

"We expect additional growth opportunities for both equipment and materials, based on materials developed in our larger and enhanced Application Laboratory," Rosenbaum says. "After our relocation is complete, we will be able to

We expect additional growth opportunities for both equipment and materials

expand our (i) equipment manufacturing, (ii) nano material manufacturing, (iii) pilot-production process development and demonstration

for the transformation of nano materials to macro-sized materials, and (iv) joint business/technology developments for products enabled by nano materials that will be marketed through our wholly owned subsidiary CVD Materials Corp (formed last October)."

www.cvdequipment.com

Plasma-Therm ranked highly in VLSIresearch survey for 13th year

Plasma process equipment maker Plasma-Therm LLC of St Petersburg, FL, USA has been voted by market research firm VLSIresearch's 2012 Customer Satisfaction Survey as one of the world's best semiconductor equipment suppliers. This distinction is given to the top performers in this semiconductor segment and is based on being voted one of 10 BEST Focused Suppliers of Chip Making Equipment and one of THE BEST Small Suppliers of Wafer Processing Equipment. Plasma-Therm was also ranked first in Etch & Clean Equipment.

The recent VLSIresearch survey (measuring Customer Satisfaction in the semiconductor equipment sector) found that Plasma-Therm moved up five slots to the third

position, with a rating of 8.18. "Customers applauded this etch & clean supplier as the highest in commitment of all Focused Suppliers as well as tying in spares support," notes the market research firm.

"We are pleased that our continuous efforts and dedication to customer satisfaction and equipment performance are recognized in this prestigious survey by those that are most important — our customers," notes Rich Gauldin, director of Customer Focus at Plasma-Therm.

"Being acknowledged each of the last 13 years as being among the very best semiconductor equipment providers is motivating," he adds.

www.plasmatherm.com

IN BRIEF

SITE Services now Spintrac Systems

SITE Services of Santa Clara, CA, USA has changed its name to Spintrac Systems Inc.

"The nature of the company's business grew from being a service and training company (Semiconductor Industry Training and Electronic Services) to one that designs and builds its own line of photolithography coater and developer systems," says president Alan W. Kukas.

SITE Services' processing systems were initially targeted at silicon wafers but now extend to specialized substrates including compound semiconductors (InP, GaAs), sapphire and glass, from 2" to 320mm x 380mm plates.

www.spintrac.com

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IN BRIEF

Nanometrics announces \$20m share repurchase program

Nanometrics Inc of Milpitas, CA, USA (a supplier of process control metrology and inspection systems primarily for manufacturing semiconductors, high-brightness LEDs, data storage devices and solar photovoltaics) says that its board of directors has authorized the repurchase of up to \$20m of the firm's common stock.

The program follows completion a week previously of the \$10m repurchase program approved in November 2010, under which the firm repurchased a total of 667,000 shares at an average price of \$14.92.

"Our confidence in the continued strength of the company and positive free cash flow performance led us to complete the remaining \$5m of our prior stock repurchase program during May," says president & CEO Dr Timothy J. Stultz. "Given our continued outlook for strong cash generation, we believe the company has the financial position to meet our capital requirements to invest for future growth, while also minimizing shareholder dilution," he adds.

The \$20m program is effective immediately and will be funded using available cash.

As of end-March, Nanometrics had \$95.5m in cash and cash equivalents and about 23.4 million shares outstanding.

Share repurchases under the program may be made through open market and privately negotiated transactions, at such times and in such amounts as the firm's management deems appropriate.

www.nanometrics.com

SPTS wins PVD system order from Chinese GaAs RF device foundry

Plasma etch, deposition and thermal processing equipment maker SPTS Technologies Ltd of Newport, Wales, UK says that its Sigma fxP physical vapor deposition (PVD) system has been selected by a Chinese foundry dedicated to producing RF devices on gallium arsenide (GaAs) substrates. The system will be used to deposit front- and back-side metal layers, including integrated passives for producing monolithic microwave integrated circuits (MMICs). SPTS did not disclose the name of the customer.

SPTS adds that its production-proven Sigma fxP platform provides critical capabilities for GaAs-based RFIC fabrication, and is being used by the majority of the world's leading RFIC device makers.

The Sigma fxP is a single-wafer cluster tool designed for high-volume PVD processing, offering excellent process control with high throughput, says the firm. The highly flexible

system supports various process chamber configurations and combinations to address a large variety of specific applications. Deposition process modules are based on a standard design that enables simple technology upgrades. Key applications for the Sigma fxPM include, thick Al alloys for power device and next-generation CMOS bondpad, metal seeds for advanced packaging applications such as 3D-IC through silicon vias (TSV) and UBM/RDL, highly uniform aluminum nitride (AlN) for RF-MEMS devices, and processes for the compound semiconductor industry.

"SPTS is proud to be part of China's developing compound semiconductor device manufacturing industry," says executive VP & chief operating officer Kevin T. Crofton. "We look forward to contributing to our customer's success in their production ramp."

www.spts.com

Lake Shore features AC Hall-effect measurement system at EMC 2012

At the Electronic Materials Conference (EMC 2012) at The Penn Stater, Pennsylvania State University, State College, PA (20-22 June), Lake Shore Cryotronics Inc of Westerville OH, USA, which makes scientific sensors, instruments and systems for precise measurement and control, exhibited its new 8400 Series Hall-effect measurement system (HMS), along with its range of cryogenic and cryogen-free probe stations.

Also, senior scientist Dr Jeffrey R. Lindemuth presented on a Hall-effect measurement method that uses an AC magnetic field rather than the more traditional method that uses DC fields ('Sample Temperature Drift Effects in AC Field Hall Measurements', Paper Y3). The AC Hall-effect measurement provides better solu-

tions for researchers exploring the electronic and magneto-transport properties of low-mobility electronic materials, says the firm.

Lindemuth will discuss how Lake Shore's 8400 Series Hall-effect measurement system, which features an optional AC field measurement capability, can measure Hall mobilities down to $10^{-3} \text{m}^2/(\text{V s})$. DC field techniques are generally limited to measuring mobilities of about $1 \text{cm}^2/\text{V s}$ in DC magnetic fields produced by conventional laboratory electromagnets. Applications for the system include measurement of solar cell materials, organic electronics, transparent conducting oxides (TCOs), III-V and II-VI semiconductors, and magneto-resistors.

www.lakeshore.com

Metrology firm MicroSense acquires SigmaTech

Capacitance sensors to be integrated into metrology platforms

MicroSense LLC of Lowell, MA, USA, which provides high-resolution capacitive position sensors, metrology modules and high-sensitivity magnetic metrology tools, has added wafer inspection tools to its portfolio by acquiring SigmaTech Inc of Tempe, AZ.

MicroSense's patented capacitive sensors are used to make precise, high-bandwidth measurements of products such as solar wafers, air-bearing spindles and precision X-Y stages in equipment such as wafer lithography systems, solar wafer sorters, nanopositioning stages, and metrology tools.

SigmaTech offers automated metrology solutions for a broad range of standard and specific applications in the field of semiconductor wafers, materials and optics. In particular, the firm has developed high-sensitivity metrology tools for LED, MEMS (micro-electro-

mechanical system) and semiconductor manufacturing.

SigmaTech's systems integrate multiple sensing technologies such as optical spectrometry, interferometry and the firm's patented auto-positioning back pressure (APBP) technology. MicroSense aims to integrate its capacitance sensors into SigmaTech's metrology platforms.

"This acquisition makes excellent sense as it marries our leading capacitance sensing technology with SigmaTech's field-proven, highly reliable metrol-

SigmaTech's customers and prospects will continue to be supported by the existing SigmaTech employees, all of whom will stay with the combined business

ogy platform to provide highly stable and repeatable wafer metrology systems for targeted applications," says MicroSense's chairman & CEO James Pelusi. "SigmaTech's customers and prospects will continue to be supported by the existing SigmaTech employees, all of whom will stay with the combined business, and will also benefit from the additional resources, infrastructure and the decades of metrology experience that MicroSense will bring to the business," he adds.

"Their high-resolution capacitive sensor technology provides an ideal path to increasing throughput of our metrology systems and expanding the field of applications," comments SigmaTech's founder Jacques Fauque about MicroSense. Fauque will remain with the business and continue to lead its development.

www.microsense.net

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SÜSS MicroTec expands into projection lithography by acquiring Tamarack Scientific

SÜSS MicroTec AG of Garching, near Munich, Germany, a supplier of equipment and process solutions for microstructuring in the semiconductor and related markets, has acquired Tamarack Scientific Co Inc of Corona, CA, USA.

The deal involves the purchase of all of Tamarack's shares for a total price of \$9.34m, plus a variable earn-out component that depends on the development of revenues for the upcoming three financial years.

Founded in 1966, Tamarack develops and manufactures UV projection lithography systems, as well as laser micro-structuring tools for the advanced packaging, 3D integration, MEMS and LED markets. The systems are used in high-volume industrial manufacturing as well as in R&D. With the acquisition, SÜSS MicroTec says it is pursuing a consolidation strategy in the semiconductor backend equip-

ment industry by complementing its exposure technology portfolio with projection lithography.

The requirement for more functionality and higher performance in electronic devices is driving the increasing performance needs for semiconductor components and higher complexity at the simultaneously, says SÜSS MicroTec. This trend will prevail in the future, requiring the adoption of innovative technologies in backend processing, it adds. In the last two years necessary initiatives were undertaken to focus and reposition the firm to ensure that it remains in a position to respond to market and customer requirements in a fast and flexible manner.

"We enlarge our company's lithography segment by adding a new product line and core technology, both of which are highly complementary to our existing exposure

capability," says president & CEO Frank P. Averdung. "SÜSS MicroTec thereby becomes the leading backend lithography equipment and solution provider by offering the most comprehensive set of products and technologies to the market," he reckons. "This allows us to offer a broad product range to meet the different price and performance points required by the industry."

SÜSS MicroTec has a strong market position in semiconductor backend lithography, a global sales and service infrastructure, and a solid financial position, says Tamarack's chairman & CEO Courtney Sheets. "Together with SÜSS MicroTec, we can now expand our lithography and laser processing systems business faster and more successfully in our target markets," he adds.

www.tamsci.com

www.suss.com

EVG jumps from 15th to 4th in VLSIresearch's ranking of chip-making equipment suppliers

EV Group (EVG) of St Florian, Austria, a supplier of wafer bonding and lithography equipment for the MEMS (micro-electro-mechanical system), nanotechnology and semiconductor markets, says that, for the first time, its customers have ranked it as one of VLSIresearch's top-five 10 BEST Focused Suppliers of Chip Making Equipment companies in the market research firm's customer satisfaction survey results for 2012.

EVG was also awarded third place in VLSIresearch's 2012 THE BEST Small Suppliers of Wafer Processing Equipment ranking, with its product performance and customer service landing it on this list for the tenth consecutive year. Together, the rankings represent EVG's best showing to date in these annual surveys.

This year's VLSIresearch customer satisfaction survey represents feedback from more than 99% of the global chip market, garnered over a period of more than two months. Participants were asked to rate equipment suppliers among 15 categories based on three key factors: supplier performance, customer service, and product performance. EVG rose from the 15th in 2011 to 4th in 2012 in the 10 BEST Focused Suppliers category — the firm's first-ever appearance on one of the two most important, aggregated 10 BEST Suppliers of Chip Making Equipment lists.

In addition, its third-place ranking among THE BEST Small Suppliers of Wafer Processing Equipment was a three-position jump from last year's survey.

"EVG continues to innovate and introduce leading-edge equipment for 3D IC semiconductor applications, while expanding and strengthening its position in new markets, such as LED manufacturing and optoelectronics," comments VLSIresearch's CEO G. Dan Hutcheson.

"This year's achievements — a ranking in the top five of VLSIresearch's 10 BEST Focused Equipment Suppliers for the first time and again improving in THE BEST Small Suppliers of Wafer Manufacturing Equipment — reflect our commitment to ensuring all of our customers receive best-in-class service, support and solutions," says EVG's executive sales & customer support director Hermann Waltl.

www.EVGroup.com

Synova reorganizes into market-oriented business units

Synova SA of Ecublens-Lausanne, Switzerland has reorganized its business according to market segments, forming three business units: Diamonds, Semiconductor, and Industry. The aim is to focus on the specific customer and market needs of each business segment in employing the core Laser MicroJet technology application platform, while improving responsiveness and overall commitment to customers.

Since 1997 Synova has developed Laser MicroJet technology, which exploits the synergy of using laser power with water. The installed base of about 150 systems (including those used for dicing wafers) is supported by customer applications and testing in Ecublens-Lausanne plus Micro Machining Centers (MMC) worldwide. Sales and service uses the MMC infrastructure in addition to sales & service points worldwide.

Each new business unit will be staffed with dedicated resources in engineering, applications, and sales and services, enabling tailor-made product and service offerings for customers in each segment.

Head of Sales Jorg Pausch has been promoted to Head of Diamonds. Head of R&D Pedro Torres has been promoted to Head of Semiconductor. Heading the Industry division will be Frank Michels, who will join Synova in third-quarter 2012. His prior assignments involved long-standing experience in the equipment business. The business unit managers will report to the CEO.

In line with the business unit organization, Synova is also strengthening its sales & marketing presence in China, the Asia Pacific region, and the USA. Edward Chan has joined the firm as Head of

Business Development Asia and Managing Director China, based in Shanghai. He has a track record in the semiconductor capital equipment market and related industries. Chan works closely with P-J Broodbakker, who joined Synova earlier this year from ASML.

For the USA, Douglas K. Walker has assumed the post of director of US operations. He has long-standing experience in capital equipment markets for semiconductors and other electronic devices.

Synova is also increasing product test and demonstration capabilities in its MMC USA in Fremont, CA. Alexander Schreiner has been appointed as manager of the MMC.

To complement the new organization and business direction, Jeroen Hribar has joined the firm as head of business development.

www.synova.ch

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Imec spin-off EpiGaN starts production at new site 150mm GaN-on-Si offered; 200mm in development

In the presence of Flemish Minister Ingrid Lieten and Limburg Governor Herman Reynders, EpiGaN nv of Hasselt, Belgium has officially opened its new production site in Research Campus Hasselt (RCH) as the location for volume production of its gallium nitride (GaN) epitaxial material.

Incorporated in 2010, EpiGaN was founded by chief executive officer Dr Marianne Germain, chief technology officer Dr Joff Derluyn and chief operating officer Dr Stefan Degroote, as a spin-off of nanoelectronics research center imec in Leuven, Belgium. For more than 10 years, the founders jointly developed GaN-on-Si technology on 4" and 6" wafers at imec, part of which was licensed to EpiGaN. In July 2011 EpiGaN was joined by a consortium of investors formed by Robert Bosch Venture Capital, Capricorn CleanTech Fund and LRM, enabling installation of the new production facility.

EpiGaN says that its GaN-on-Si material will enable a new generation of power electronics (with performance beyond current silicon

electronics), which will be used for more efficient energy use: efficient power convertors, better power supplies for computers, motor drivers, inverters for solar energy technologies, and greener transport with smaller environmental footprint.

EpiGaN currently offers GaN epitaxial layers deposited either on Si up to 150mm or, for specific applications, on silicon carbide (SiC). Wafer diameters of 200mm are under development. The availability of large wafers that can be processed in existing Si CMOS fabs partly explains how GaN-on-Si technology excels at combining affordability with performance, says the firm.

EpiGaN's production unit at Research Campus Hasselt is located within the Eindhoven-Leuven-Aachen knowledge triangle, where the firm says it found the necessary framework for installing its cleanroom facilities. Also, the location in the heart of Europe allows the firm to establish its business at an international level, it reckons.

EpiGaN currently employs six people and is hiring more engineers and sales staff to support its growing production effort. Last year, EpiGaN sampled its first wafers to Europe, the USA and Asia. It is now taking a key step in ramping up capacity. "The current installation will allow us to better serve our customers and new-comers in the field of the GaN-on-Si market for electronics," says CEO Marianne Germain. "This is right at the time that device manufacturers are looking for getting access to this new technology, key for their future applications," she adds. This should enable EpiGaN to further expand its customer base, the firm reckons.

"IMEC has developed an innovative and state-of-the-art technology, the applications of which can lead to the solution of important challenges for society such as the energy issue and mobility," says Ingrid Lieten, vice minister-president of the Flemish Government. "Moreover, this spin-off has a beneficial effect on the employment," she adds.

www.epigaan.com

ARC Energy appoints Phil Yin as its VP & GM in China

Advanced RenewableEnergy Company LLC (ARC Energy) of Nashua, NH, USA, a provider of c-axis sapphire growth technologies and turnkey solutions for the LED solid-state lighting and other clean energy markets, has appointed Dr Philip C.S. Yin as VP & general manager, China region, based in its Shanghai office.

Yin will be responsible for building relationships and satisfying customer expectations, as well as directing the rapidly growing China organization, and helping to grow ARC Energy's business in the China region, says the firm.

Previously, Yin was chairman & CEO of AXT Inc of Fremont, CA, USA, which makes gallium arsenide,

indium phosphide and germanium substrates as well as raw materials. Prior to AXT, he was the US general manager for MOCVD equipment maker Aixtron SE.

"Rapid adoption of LEDs in lighting is increasing demand for large diameter sapphire, which in turn is driving up demand for ARC Energy's

Rapid adoption of LEDs in lighting is increasing demand for large diameter sapphire, which in turn is driving up demand for ARC Energy's cost-effective, highly automated CHES sapphire growth furnaces

cost-effective, highly automated CHES sapphire growth furnaces," says ARC Energy's senior VP Hap Hewes. "Phil is a true technology leader with significant operations, business, and LED expertise," he adds. "We look forward to working with him to expand our China operations so that we can continue to meet and exceed the needs of our rapidly growing customer base in China."

Yin has a Ph.D. in Material Science from Brooklyn Polytechnical Institute, and attended the executive education program at Stanford Law School. He is affiliated with the American Association for Crystal Growth (AACG) and Electro-Chemical Society (ECS).

www.arc-energy.com

Ultra-smooth tungsten crucibles

PLANSEE of Reutte, Austria (which makes refractory metals and composite materials) has launched new ultra-smooth tungsten crucibles for sapphire growth.

The Kyropoulos method (widely used to grow ultra-pure sapphire substrates for LEDs) involves melting a sapphire crystal in a heat-resistant crucible made from molybdenum or tungsten. A particularly critical stage during this process is when the sapphire crystal is extracted from the crucible. The easier the sapphire can be released from the crucible, the greater its yield and quality. If the surface of the crucible is too rough, the sapphire cannot be released or can only be partially released from the crucible's wall, resulting in cracks and faults in the crystal. Also, the crucible itself is damaged and has to be reworked or replaced earlier than planned.

PLANSEE says that its more than 90 years of experience in powder metallurgy, coupled with a fully automated manufacturing process, allow it to exercise precise control over the material properties of refractory metals such as tungsten and molybdenum. To cut the cost of sapphire growth, the firm has hence developed a special cost-saving pressed-sintered tungsten crucible with an ultra-smooth surface.

With surface roughness of less than $0.8\mu\text{m}$, the sapphire can be extracted from the crucible without difficulty and without damaging the surface of the crucible, it is claimed.

For sapphire producers, this results in less complex and expensive reworking of the surface of the crucible. The cycles run smoothly and deliver high-quality ingots, the firm adds. Also, the smooth surface is less susceptible to corrosion (caused by the aggressive melted sapphire), increasing the service life of the reusable tungsten crucibles.



PLANSEE's ultra-smooth tungsten crucibles.

In addition, crucibles with a low density and a large number of porous areas can shrink under the high process temperatures, becoming more dense during use and even becoming seriously deformed or breaking. PLANSEE says that it has finely adjusted the sintering process for the crucibles. Sintering is performed at very high temperatures and a uniform temperature distribution, giving the crucibles a very high material density of 93% coupled with an extremely homogeneous density distribution. Even under high temperatures and rapid changes of temperature, the crucible is guaranteed to retain its shape.

Finally, contaminants in plant components can be transferred to the sapphire in a way that is detrimental to its quality. Iron, titanium and chromium are particularly critical in this respect. To ensure that only flawless sapphire comes out of the crucible, PLANSEE has adopted an ultra-clean production process. Everything from the metal powder to the finished crucibles is manufactured in-house, so every step can be carefully monitored, resulting in crucible purity exceeding 99.97%.

PLANSEE says that, currently, crucibles large enough for 35–100kg of sapphire are commonplace. Yet the industry is already considering a new generation for up to 200kg of sapphire. The firm therefore notes that its extremely large sintering plants and processing machines mean that it is already geared up for this step.

www.plansee.com

IN BRIEF

Rubicon ranked 13th on Crain's 2012 'Fast 50 List'

Rubicon Technology Inc of Bensenville, IL, USA, which makes monocrystalline sapphire substrates and products for the LED, RFIC, semiconductor and optical industries, has been ranked 13th on Crain's Chicago Business' 2012 'Fast 50', an annual list of the fastest-growing public and private firms in the Chicago area.

Crain's ranks firms on the basis of five-year revenue growth. Rubicon has seen 546% growth, from \$21m in revenue in 2006 to \$134m in revenue in 2011.

"Throughout our 11-year history, Rubicon's focus on continuous innovation has helped us develop proprietary crystal growth technology that enabled us to be first-to-market with high-quality, large-diameter polished sapphire wafers," says president & CEO Raja M. Parvez. "We look forward to continued growth as LED technology is adopted in the general lighting market and as product developers find additional applications for commercial sapphire."

Rubicon claims to be world's largest provider of large-diameter sapphire wafers. As a vertically integrated supplier, it developed the process to grow large sapphire crystals from raw materials in custom-built, proprietary furnaces. The firm has hence been able to scale the growth of bulk crystal from 30kg to 85kg to 200kg without compromising high quality or high yield, it claims. Rubicon completes the final stage of vertical integration with high-precision core drilling, wafer slicing, surface lapping, large-diameter polishing and wafer cleaning in its Penang, Malaysia facility. To date, Rubicon has shipped over 230,000 large-diameter wafers to the LED and silicon-on-sapphire (SoS) markets.

www.rubicon-es2.com

Kyma demos 10" AlN-on-sapphire template

LED makers expected to look beyond 6" in next few years

Kyma Technologies Inc of Raleigh, NC, USA, which provides crystalline gallium nitride (GaN), aluminium nitride (AlN) and aluminium gallium nitride (AlGaIn) materials and related products and services, says that it has demonstrated a 10" diameter AlN-on-sapphire template.

Kyma's AlN templates are manufactured using its patented plasma vapor deposition of nanocolumns (PVDNC) technology, which provides GaN LED makers with throughput, cost and performance benefits, the firm claims, adding that the PVDNC AlN templates are chosen by manufacturers of blue, green and white LEDs as a replacement for bare and patterned sapphire substrates.

The 250mm (10") sapphire substrate was provided by Monocrystal Inc of Stavropol, Russia, which provides sapphire products and metalization pastes to the semiconductor, optical, and photovoltaic industries.

Until recently, the wafer diameter standard for GaN LED wafer manufacturing has been 50mm (2"). Recently, sapphire manufacturers have made much progress in increasing the size of sapphire



Kyma's new 10" diameter PVDNC AlN on sapphire template, along with smaller-diameter (6" & 4") products.

boules from which ever larger sapphire substrates can be sliced, with sapphire diameter demonstrations up to 12" being achieved by certain sapphire providers, says Kyma.

This has enabled some of the major GaN LED makers to begin transitioning to larger-diameter sapphire — up to 150mm (6") in some cases — to enhance manufacturing throughput and to achieve better economies of scale. While 10" sapphire based AlN templates are currently simply a demonstration, Kyma believes

that the LED community will begin looking beyond 150mm (6") diameter in the next few years.

In February 2011 Kyma announced the commissioning of its high-volume PVDNC AlN template manufacturing tool and the demonstration of the world's first 300mm (12") diameter AlN-on-silicon template suitable for high-quality gallium nitride (GaN) growth. Last November, Kyma announced customer qualification of products manufactured on that tool.

"Over the past year we have demonstrated several firsts in AlN template manufacturing, in each case leveraging Kyma's new volume-manufacturing tool, including customer qualification of our 2" sapphire-based product and large-diameter demonstrations on both silicon and sapphire," says chief technology officer Ed Preble.

"Together these results confirm the diameter scalability of the PVDNC AlN process as well as its robustness and flexibility for growth on different starting substrates," he adds.

www.kymatech.com

www.monocrystal.com

K-Slice diamond wire technology demonstrated on sapphire boules

Kyma has announced the improvement and successful application of its proprietary and exclusively licensed, patent-pending K-Slice diamond wire technology to the slicing of high-quality sapphire boules for LED substrate making.

K-Slice diamond wire uses a steel core and metal matrix approach that is claimed to have several advantages over competing diamond wire technologies. It is more durable than that produced using steel plus epoxy approaches, it is less costly than that produced using electroplating techniques, and it features high thermal conductivity and long wire lifetime, the firm adds.



First slices from a 2" LED-quality sapphire boule using K-Slice.

While Kyma has routinely used K-Slice diamond wire to slice such hard materials such as GaN and silicon carbide (SiC), initial attempts to slice sapphire (Al₂O₃)

boules indicated that there was an opportunity to further improve the K-Slice manufacturing process. Senior wafering engineer Dr Eugene Shishkin investigated how process could be modified to create a more sapphire-friendly wire. His efforts have helped Kyma to greatly improve the quality and speed of slicing 2"-diameter sapphire boules while maintaining low kerf loss and long wire lifetime.

K-Slice diamond wire is available on spools with wire lengths between 1km and 3km, and with an outer diameter of 220–225µm and diamond size of 20–30µm. Other wire diameters and diamond sizes are available upon request.

Nitride Solutions receives 6-month, \$150,000 SBIR grant

Nitride Solutions Inc of Wichita, KS, USA, which is developing substrates for LEDs, lasers and power electronics, has been awarded a US National Science Foundation (NSF) grant of nearly \$150,000 to commercialize its manufacturing technology. The Phase I Small Business Innovation Research (SBIR) award supports the firm's work to produce aluminium nitride (AlN) substrates at a high volume and low cost. The NSF selected just 10% of applicants for the 2012 Phase I award.

Founded in 2009, Nitride Solutions maintains strong ties to Kansas State University in Manhattan, with key employees and advisors hailing from the university, as well as University of California Santa Barbara (UCSB). To date, the firm has raised \$2.5m in funding from investors including Midwest Venture Alliance, NetWork Kansas, Mid-America Angels,

Nebraska Angels and Aurora UV.

Nitride Solutions' end product will be used to create more effective and more affordable water purification systems, consumer and industrial lighting, Blu-ray players, flat-screen TVs, and power systems for hybrid vehicles, says president & CEO Jeremy Jones. "Our process will bring nitride substrates — which will be critical in so many emerging applications — to commercial reality," he adds. "The NSF has recognized that this is potentially a breakthrough technology, and that our company has the capital, the team and the equipment to create it."

The project's principal investigator is the firm's R&D director Troy Baker Ph.D., who has

Our process will bring nitride substrates to commercial reality

experience in the growth of bulk aluminium nitride and gallium nitride substrates, having performed his doctoral work at UCSB under nitride-based LED and laser diode developer professor Shuji Nakamura.

Starting on 1 July, the six-month grant will support Nitride's move toward commercial production. Jones expects the firm to be selling its product by the end of this year. If Phase I results are deemed successful, the firm will be eligible for a Phase II grant of up to \$500,000 to further support its growth.

The SBIR program aims to encourage technological innovation and commercialization in small businesses. According to the NSF, SBIR programs are the single largest source of patents in the USA.

www.nitridesolutions.com

SETi receives Tibbetts Award at White House ceremony

Ultraviolet light-emitting diode (UV LED) maker Sensor Electronic Technology Inc (SETi) of Columbia, SC, USA has been honored with the Tibbetts Award for the role it has played in R&D for the US Government under the Small Business Innovation Research (SBIR) program.

In a ceremony held at the White House, the award was presented by Karen Mills (the US Small Business Administrator) to Dr Remis Gaska and Dr Michael Shur, who founded SETi in 1999 to develop III-nitride based electronic and optoelectronic devices.

Named after Roland Tibbetts (who was instrumental in developing the SBIR program), the Tibbetts Awards are presented to companies and individuals from all over the USA who are "beacons of promise and models of excellence in high technology". Winners are selected on the basis of the economic impact of their technological innovation, and on whether they have met federal R&D needs, encouraged diverse



(From left to right) Roland Tibbetts, Karen Mills (SMA Administrator), Remis Gaska, Sean Greene (Associate Administrator of Investment and Innovation), and Michael Shur.

participation in technological innovation, and increased the commercialization of federal research.

Under programs funded by SBIR and the US Defense Advanced Research Projects Agency (DARPA), SETi developed proprietary technology that led to the development of UV LEDs with peak emission wavelengths ranging from 230nm through 365nm. The firm has previously been honored for its inno-

vation by DARPA, when it was named in their 2007 Success Reports; it has also received the PRISM Awards, presented by SPIE and Photonics Media in 2009 for the Best Photonics Product; it has received the Best of Columbia award in 2009; and has twice been selected as a finalist in the IET Innovations awards.

SETi has more than 100 patents covering materials, devices and applications, many of which were the result of US government-backed development under SBIR funding. The firm says that it continues to further its device technology and develop new applications of UV LEDs through multi-agency programs. It recently announced external quantum efficiency (EQE) of more than 10% in a 275nm LED thanks to DARPA's Compact Mid-Ultraviolet Technology (CMUVT) program in collaboration with US Army Research Laboratories (ARL).

www.tibbettsawards.org

www.s-et.com

IN BRIEF

Seoul Semiconductor adds 3020 Series to mid-power LEDs family

At the Lightfair International trade show in Las Vegas (9–11 May), South Korean LED maker Seoul Semiconductor Co Ltd launched its 3020 Series, adding a smaller-footprint product with high light density to the existing mid-power family of LED products.

Featuring advanced packaging techniques, including high lumen output and improved thermal efficiencies, the 3020 series suits general illumination applications requiring distributed light, such as replacement lamps and linear strip lighting, says the firm.

The 3020 Series will be offered in the full range of ANSI white space, with standard binning and LM-80 testing. The entire family is general illumination class and comes with coloring rendering index (CRI) versions of 80 or 90 (minimum) and with luminous efficacies as high as 151lm/watt (cool white) and 136lm/watt (warm white).

Following the firm's 5630 package, the new LED is particularly suited to small fixtures and omni-directional bulbs, which demand the high efficacies and light densities of a small, mid-power LED solution, says the firm. The 3020 Series can also be used for fluorescent replacement tubes and linear strip products as well as panel and ceiling tile lighting.

The product will be available for sampling from Seoul's three distributors, Avnet Electronics Marketing, Digi-Key Corp and Mouser Electronics in second-quarter 2012, and available for mass production soon afterwards.

www.seoulsemicon.com/en

Lattice Power starts volume production of high-power GaN-on-silicon LEDs

Firm's production to be transferred to 150mm GaN-on-Si in 2013

China-based Lattice Power Corp has started volume production of its new-generation gallium nitride (GaN)-based high-power LEDs on silicon substrate. The firm reckons the development could set the stage for a sharp reduction in the prices of energy-efficient LED light bulbs.

Lattice Power claims to be the first firm in volume production of GaN-on-silicon LED chips, with products comparable to high-end chips that rely on conventional sapphire substrates. At an operation current of 350mA, the 45-mil product is capable of producing 130 lumens of cool-white light with an efficiency of 120 lumens per watt (lm/W) consumed. Moreover, silicon substrates are readily available in larger diameters and at a fraction of the cost of sapphire substrates, resulting in substantial cost reductions for downstream manufacturers.

The firm says that 20 strategic customers have received the LEDs and will incorporate them into indoor and outdoor lighting applications. The silicon substrate-based LED series encompasses four different chip sizes: 28mil x 28mil, 35mil x 35mil, 45mil x 45mil, and 55mil x 55mil. Chip power ranges from 0.5W to 2W.

Lattice Power says it has always invested heavily in R&D in silicon substrate-based LED technology, and that commercialization of its silicon substrate-based-power chip series represents a second milestone after the recent launch and volume production of its smaller-size silicon substrate-based LED chips used in display and signage.

Lattice Power says that using GaN-on-Si technology to make commercial-grade LEDs in the USA and Europe has shown promising laboratory results, but not at the

volume production levels that it has achieved in the past year. The firm says that, realizing its potential early on, it started to work on the technology before it became part of the mainstream industry perspective. Lattice Power has filed more than 200 international and domestic patents in this field.

"With the big growth of solid-state

Lattice Power is working on 150mm GaN-on-Si technology and is expecting to transfer its production in 2013

lighting and Lattice Power's introduction of high-power LED product family into the lighting market, the company has once again proven its cutting-edge development

and manufacturing capabilities," comments Sonny Wu, managing director of GSR Ventures and chairman of Lattice Power.

"Since its birth, Lattice Power has focused on high-efficiency, low-cost and high-reliability LEDs on silicon. To get to where it is now, Lattice Power has faced lots of hurdles and challenges and overcome many obstacles," says co-founder & CEO Dr Wang Min. "But we have persevered and gained enormous traction with customers."

The firm says industry experts now predict that future LED chip cost savings could be as much as 70% greater than with the current mainstream products when manufactured on larger-diameter silicon substrates. Lattice Power is working on 150mm GaN-on-Si technology and is expecting to transfer its production to the larger-diameter silicon substrates in 2013.

www.latticepower.com

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Seren wins £230k UK R&D grant to speed commercialization of LED technology

Second additive nano-particle technology to be developed to boost HB-LED efficiency

UK-based university IP commercialization company Fusion IP plc says that its LED technology portfolio company Seren Photonics Ltd (which was spun off from the University of Sheffield in February 2010) has won a £230,000 grant from the Technology Strategy Board (TSB), the UK government's national innovation agency. The grant will be used to fund a project based on nano-technology to further increase the amount of light emitted from high-brightness (HB) LEDs.

Developed by professor Tao Wang of the University of Sheffield, Seren's new processing technique can increase an HB-LED's luminous efficacy and reduce heat generation under normal running conditions. Demonstrations of the patent-pending technology have resulted

in a significant increase in light output compared to untreated devices, it is claimed, so that either much brighter lamps can be manufactured or the power consumption of lamps can be reduced.

The TSB grant will be used to develop a second additive nano-particle technology that will further increase the LED's efficiency. The technology, which has been demonstrated in a laboratory environment, will be developed into a process compatible with modern manufacturing techniques before being offered under license to Seren's future manufacturing partners. "The money will enable us to accelerate the transfer of Seren's latest nano-particle technology into a fit-for-purpose manufacturing process," notes CEO Dr Carl Griffiths.

Seren's technology is targeted at the large and fast-growing white-light HB-LED markets, such as back-lighting for laptops and TVs, signs and displays, as well as domestic and architectural lighting. This market is currently worth an estimated \$15bn and is set to grow to \$20bn by 2014, says Seren.

HB-LEDs are set to replace incandescent bulbs as governments around the world bring in legislation banning the manufacture and sale of incandescent lamps, and as concerns increase about the poor light quality and environmental contamination fears from compact fluorescents, the firm adds. The rate of adoption is expected to accelerate as the brightness of HB-LEDs increases and the cost of manufacture falls.

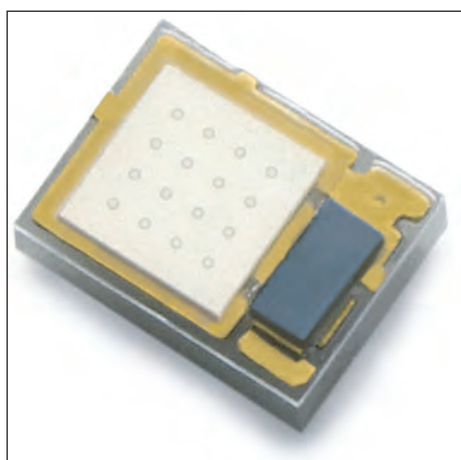
www.serenphotonics.co.uk

Lumileds launches LUXEON Z; smallest power LED with highest lumen density

Philips Lumileds of San Jose, CA, USA says that, with a size that is 80% smaller than traditional power LEDs, its new LUXEON Z is its smallest LED package to date.

With a total footprint of just 2.2 square millimeters and high lumen output across a full spectrum of colors of 440–670nm (including white), the LUXEON Z offers luminaire designers what is claimed to be the industry's highest commercially available lumen density. Also, its ultra-compact, non-encapsulated package enables new flexibility in packaging and optical designs, helping to push the boundaries of next-generation luminaire design.

Unlike other products on the market it is claimed, the LUXEON Z goes beyond the constraints of a



The new LUXEON Z, in Lumileds' smallest LED package to date.

typical 2x2 multi-chip package to enable the creation of specialized 2x2, 3x2 or 6x1 mono-color or multi-color luminaires. The multitude of configurations together with

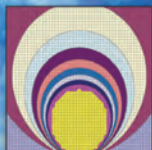
the ability to mount as many as 250 LUXEON Z in a 1 square-inch enable new levels of lumen densities, it is reckoned.

Simplifying development of products such as wall-washers, moving head entertainment spotlights, and even remote phosphor applications, the LUXEON Z can also give engineers in the entertainment, architectural and specialty lighting segments a modular approach to developing products, says Lumileds.

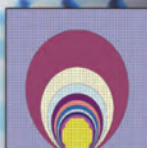
Also, the non-encapsulated chips are more readily adaptable to custom optics, eliminating the need for complex, inefficient secondary lenses.

The firm expects that a full line of semi-custom optics will also be available in the near future.

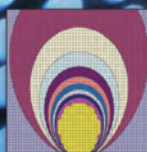
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IN BRIEF

Luminus' new LED packaging technology cuts thermal resistance by 30%

Luminus Devices Inc of Billerica, MA, USA, which makes PhlatLight (photonic lattice) LEDs for illumination applications, has launched its latest development in packaging technology, which uses proprietary processes and new specialty materials and equipment to achieve a 30% reduction in thermal resistance for its 'Big Chip' LED products. This, in turn, enables the LEDs to reach up to 20% higher brightness levels while maintaining reliability during operation, the firm says.

"This breakthrough allows for a simpler thermal design at the system level, and therefore chips to be driven at higher power in applications where maximum brightness is required, such as projection displays and entertainment," says VP of engineering Arvind Baliga. "The innovation will enable smaller and more cost-effective projector system designs, from small-form-factor to high-brightness data projectors in projection display market segments, as well as high-brightness wash lights and spot lights for entertainment," he adds.

"The new LED thermal technology is the result of continued focus on R&D, and it enables our customers to increase the brightness of our LEDs without lifetime or reliability concerns due to overheating," says Paul Panaccone, director of packaging technology.

Luminus is sampling products based on the new technology to several customers; production quantities will be available in the coming quarter.

www.luminus.com

LED light engine with embedded drive electronics and IP65 rating

At the Lightfair International trade show in Las Vegas (9–11 May), Luminus Devices announced the availability of its MD10 light engine.

The fully contained single-chip, high-lumen-density source is easy to integrate, claims Luminus. Designed for a variety of indoor and outdoor lighting applications, the MD10 is available in 800 and 1100 lumen output levels and color temperatures of 3000K and 4000K. For spot lighting applications, it can deliver more than 17,000 candelas into a narrow 9 degree spot beam angle. Other beam angles are medium, flood, wide flood and elliptical. Electrical inputs to the light engine include 24V_{DC} power and 0–10V dimming. Additionally, the light engine uses on-board smart controls for thermal protection to ensure long life and reliability.

"The MD10 substantially reduces the engineering design cycle for our OEM customers, and enables them to accelerate time to market for their newly developed LED lighting fixtures," claims Chuck DeMilo, global director of product marketing. "The MD10 provides our customers all the benefits of Luminus' 'Big Chip' LED technology in a plug and play solution," he adds.

With an Ingress Protection rating of 65 (IP65), the light engine can be designed into outdoor fixtures such as landscape, architectural and area lighting. Typical indoor applications include retail display spot and accent lighting. Patent-pending optics help to deliver the performance of a 50W halogen lamp for high-intensity spot lighting and applications where long-throw optical systems are required.

Luminus shipping 382–392nm UV LED

Production models of Luminus' largest UV LED device, the CBT-120-UV-C11, are now shipping in the 382–392nm wavelength range.

The firm says that applying its photonic lattice technology to UV wavelengths opens the single-chip 12mm² device platform up to many new applications. "We have already seen early customers in the fields of rapid prototyping, ink and adhesives curing, scientific & medical instrumentation plus purification benefit from engineering samples of this powerful new monolithic device," says Michael Lim, director of global industrial and new business. "By making this device available more broadly, we are excited to see how the highest power-density UV LED device will benefit additional customers and industries," he adds.

"The power density delivered by the CBT-120-UV, along with its capability for optimized coupling to high-performance DLP micro-mirror

systems, made this LED ideal for us," comments Roland Hoefling, president of optical metrology and scanning firm Vialux GmbH of Chemnitz, Germany. "We have implemented the Luminus UV light source in our LED-OM DLP Discovery 4100 module that is used in direct imaging maskless lithography, rapid-prototyping and CtcP printing equipment," he adds.

Also, engineering samples of the chip in 375nm and 405nm wavelengths are available on the same platform. "Luminus' successful implementation of their 'Big Chip' LED technology in the UV space will be complemented by the development of additional UV die sizes, wavelengths including 395nm, as well as work on different form factors," says Lim. "Our technology lets us offer UV integrators a monolithic, easy-to-integrate light source that is RoHS compliant, environmentally friendly and more efficient, with a median 12,000 hour lifetime."

Luminus' latest RGB chipsets boost projector performance by 40% on a year ago

Green LED brightness tripled in last five years; expected to double again

Luminus Devices Inc of Billerica, MA, USA, which makes PhlatLight (photonic lattice) 'Big Chip' LEDs for illumination applications, says that it has tripled the brightness of its semiconductor green LEDs over the last five years, and expects to at least double it again.

Green light is the major primary color that contributes to white light generation in systems with red-green-blue illumination, and the performance of green LEDs is considered by the industry to be the major limiting factor in replacing high-pressure mercury lamps in projection displays. Luminus says that, combined with its thermally enhanced packaging technology, its latest achievements in pure-green LED output allow its projection-optimized RGB chipsets to achieve new performance levels in projection system categories covering portable, home video, video walls and mainstream business and education.

For example, the firm's latest 5.4mm² green LED can output up to 3000 lumens at a current density

of 3.0A/mm². This chipset allows system makers to design portable LED projectors with performance in excess of 700 lumens (a 40% improvement over products introduced just a year ago).

"The rapid pace of improvement of our pure-green LEDs is a testimony to the large untapped potential of this technology," believes VP of engineering Arvind Baliga. "Alternative approaches such as phosphor conversion technologies rely on mature platforms with limited upside potential and also come with a broad spectrum that results in increased optical losses of up to 20%," he adds. "Our customers recognize that Luminus' projection chipsets enable the brightest projectors today and, more importantly, place them on a faster trajectory to transition their portfolio to a lamp-free model. Increased investment in R&D and rapid prototyping will dramatically accelerate our progress in reaching brightness targets needed to move into the business and education segments," he expects.

"Luminus' world's brightest green LED just got better, and the best testimony to this achievement is over 1 million consumer and professional lamp-free projection displays that have been deployed using our technology — a market that did not even exist only four years ago," says director of global product marketing Stephane Bellosguardo. "After virtually eliminating lamps in markets such as video walls, our technology is now gaining similar momentum in consumer video, education and business projection markets," he adds. "With RoHS exemptions for most high-pressure mercury lamps set to expire in 2015, these latest advancements in pure-green LED technology provide our customers with a path towards an environmentally friendly light source that combines cost effectiveness and performance."

At the InfoComm 2012 trade show in Las Vegas (13–15 June), Luminus featured a shootout between a 2200 ANSI lm-class lamp and the latest LED technology.

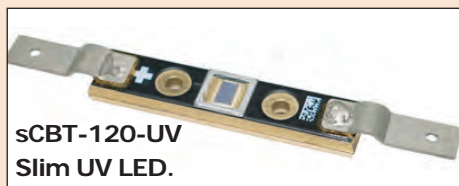
www.luminus.com

Luminus launches sCBT-120-UV Slim ultraviolet LED package for high-power-density line curing

Luminus Devices says that engineering samples are now available for the sCBT-120-UV Slim UV LED packaged chip, which has been designed specifically for printing and other line curing applications.

The firm claims the Slim UV LED packaged chip solution will provide maximum UV energy, superior performance, and long-term reliability while also improving workplace safety by eliminating harmful substances such as ozone and mercury that are by-products of UV mercury lamp use.

"The UV Slim was really designed as a LED light source for the appli-



sCBT-120-UV
Slim UV LED.

cation, rather than forcing the application to adapt to the light source," says Mike Lim, director of global industrial and new business.

Designed with graphic arts printing in mind, the UV Slim combines the advantages of Luminus' Big Chip LED technology, including improved thermal power density, simple optics and greater efficiency. The new packaging form factor makes

it possible to create a tight linear array that packs at three times the density of a regular CBT-102-UV chip, and also allows the UV Slim LED to be placed further from the substrate needing curing.

The new LED package has been designed to deliver more efficiency than traditional curing methods, ultimately lowering production costs and offering the longer life and higher brightness that is typical of LED performance.

Large-scale production of the sCBT-120-UV Slim UV LED is due to begin in third-quarter 2012.

www.luminus.com

Cree unveils technology centers in Shenzhen & Shanghai to help speed LED lighting product development

Cree has announced new technology centers in China, further expanding its Cree TEMPO (Thermal, Electrical, Mechanical, Photometric, Optical) Services in these key markets. The technology centers support demand for Cree products and services throughout China, with the aim of accelerating broader market adoption of LED lighting. TEMPO Services provide LED lighting manufacturers with a comprehensive suite of evaluation services for LED luminaires, ensuring that customers have the information needed to design and market quality LED products, says Cree.

The new technology centers will offer a range of TEMPO Services to meet the unique needs of lighting manufacturers in China, including

the TEMPO 21 and TEMPO Thermal Simulation Services. Cree says its experience indicates that many of the common quality issues and failure modes seen in solid-state lighting products are not detected by currently available standardized tests. TEMPO 21 examines critical aspects of quality that often go unchecked, such as chemical compatibility, driver spikes, dimmer compatibility and electrolytic capacitor analysis.

"Cree delivers our customers end-to-end development support," says Tang Guoqing, senior adviser, Cree Hong Kong Ltd. "TEMPO Services can give manufacturers competitive advantages by helping them avoid costly design mistakes and by providing access to a broad range of test environments that are, in many

cases, cost-prohibitive for them to build and operate," he reckons.

Effective LED luminaire thermal design is essential to ensure reliability and optimum performance, says Cree. TEMPO Thermal Simulation predicts the thermal behavior of LED-based fixtures, including junction temperature, heat-sink temperature, temperature profile and airflow profile. TEMPO SPOT gives customers access to complex, costly equipment to measure the photometric performance of luminaires and replacement lamps. Cree adds that every TEMPO Service delivers an accurate, easy-to-understand TEMPO report that includes all testing results and relevant performance data.

www.cree.com/tempo

Cree adds to TEMPO luminaire test services; NVLAP accreditation

Cree has added TEMPO 24 to its suite of services for LED luminaires.

Supplementing the Thermal Electrical Mechanical Photometric Optical (TEMPO) Services (launched last September), the new service combines IES LM-79-08 photometric testing with an extensive set of LED performance tests that, the firm claims, surpasses all industry testing parameters and can help to ensure total system design and quality.

Cree provides TEMPO Services out of its Cree Technology Centers in Durham, NC and Santa Barbara, CA. The Cree Durham Technology Center has now been accredited by The National Voluntary Laboratory Accreditation Program (NVLAP), furthering the firm's commitment to helping LED makers overcome design challenges and bring quality products to market faster.

"LM-79 is a necessary test and has become a requirement for doing business in the solid-state lighting [SSL] market," says Mark McClear, Cree's director of global applications engineering. "TEMPO 24 includes a

fully accredited LM-79 test, but goes well beyond this or any currently existing standards," he adds. "Cree has identified through our years of SSL experience nearly a dozen other potential problem sources of LED luminaire design. Our goal is the same as our customers — and their customers as well — quality SSL products that save energy. TEMPO 24 helps ensure this and gives customers the information they need to design and specify an SSL product with confidence," McClear continues.

TEMPO 24 provides LED luminaire tests that are not offered by any other third-party testing facility, Cree claims. In addition to LM-79 testing (an approved method for taking electrical and photometric measurements), TEMPO 24 testing includes binning and color point evaluation, chemical compatibility and TM-21 lifetime projection. It examines all aspects of an LED design and provides a true assessment of luminaire performance that can be used to promote and dis-

tinguish a product. Cree says each TEMPO service delivers an accurate, easy-to-understand TEMPO report that includes all testing results and relevant performance data.

Cree's Durham Technology Center NVLAP accreditation ensures that TEMPO measurements accord with the Illuminating Engineering Society (IES) approved method for electrical and photometric measurements of LED lighting — delivering lighting manufacturers consistent, accurate and repeatable measurements for luminaires. Accreditation signifies that a lab has shown it operates in accordance with NVLAP management and technical requirements pertaining to quality systems, personnel, accommodation and environment, test & calibration methods, equipment, measurement tractability, sampling, handling of tests and calibration items, and test & calibration reports. Cree laboratories also work to American National Standards Institute (ANSI) and National Institute of Standards and Technology (NIST) requirements.

SemiLEDs and Cree end patent infringement litigation

SemiLEDs agrees to one-time payment and injunction on import & sale of products in US

LED chip and component maker SemiLEDs Corp of Hsinchu Science Park, Taiwan and LED chip, lamp and lighting fixture maker Cree Inc of Durham, NC, USA have agreed to end their respective patent infringement litigation against each other.

As part of the settlement, SemiLEDs has agreed to make a one-time payment to Cree for past damages. It has also agreed to the entry of an injunction (effective 1 October) that prohibits the importation and sale of SemiLEDs' accused products in the USA. The parties have agreed to withdraw the remaining claims without prejudice to the right to assert their respective claims in the future.

"The resolution emphasizes the breadth and importance of Cree's

patent portfolio and its determination to ensure that Cree's intellectual property rights are respected," says the firm's chief intellectual property counsel Julio Garceran.

"The conclusion of the disputes between SemiLEDs and Cree will allow us to now focus our full resources on developing our business and serving our customers," says SemiLEDs' VP of business development & general counsel Adam Lin. "We continue to innovate and are introducing to the market an exciting, new line of LED products," he adds.

The parties have agreed to withdraw the remaining claims

www.semileds.com
www.cree.com

Cree's chief financial officer Kurtzweil resigns; McDevitt made interim CFO

LED chip, lamp and lighting fixture maker Cree Inc of Durham, NC, USA says that John Kurtzweil has resigned as executive VP-finance & chief financial officer in order to pursue other opportunities.

Michael McDevitt has been appointed CFO on an interim basis. McDevitt joined Cree in 2002 as corporate controller and previously served as interim CFO in 2006 during an earlier transition. He has also served as director of financial planning and as director of sales operations.

Cree has commissioned a search for a replacement through executive search consultants Russell Reynolds Associates. To assist with the transition of his responsibilities, Kurtzweil plans to continue as a Cree employee until 15 June. "The past six years have been personally rewarding," says

Kurtzweil. "At this point in my career, however, I decided to move to Extreme Networks, a smaller firm where I can have a more hands-on role in growing the business," he adds.

"We appreciate John's contributions in helping grow Cree from \$400m in revenues in fiscal 2007 to over \$1bn in annualized revenues today," says chairman & CEO Chuck Swoboda. "He has built a strong finance team and a foundation for future growth."

Swoboda also commented on Cree's previously announced business outlook for the fiscal quarter ending in June: "We are encouraged with our progress in growing the business through the first half of the quarter. At this point, we remain on track with our targets," he adds.

www.cree.com

IN BRIEF

Luminus launches network for design services, component production, and light engine development

Luminus Devices Inc of Billerica, MA, USA, which makes PhlatLight (photonic lattice) 'Big Chip' LEDs for illumination applications, has launched its Certified Solutions Partner Program to assist customers in integrating its LEDs into product designs. The network of independent partners provides expertise in optical, electrical, thermal, light engine development and production, reducing product development cycle time and expense while accelerating speed to market. Firms around the world are now certified by Luminus as having the technical capability and experience to deliver quality solutions to its customers.

"We are very pleased to be aligned with so many global partners with deep experience in developing components and system-level solutions using Luminus LEDs," says Chuck DeMilo, Luminus' global director of product marketing. "Luminus Big Chip LEDs are enabling the transition from traditional high-power, high-brightness lamp sources such as metal halide and xenon to solid-state illumination. Big Chip LEDs are unique optically, electrically and thermally when compared against 1mm² LEDs," he adds. "Luminus certified partners are experts in designing with Luminus LEDs and can quickly deliver optimized solutions to our customers... customers now have new reliable resources that will save time and money in the design and integration process."

www.luminus.com/resource/certified.html

DOE selects three projects for \$7.1m Solid-State Lighting Manufacturing R&D funding opportunity

In response to SSL Manufacturing R&D funding opportunity announcement (FOA) DE-FOA-0000561, the US Department of Energy (DOE) has announced the competitive selection of three projects for solid-state lighting (SSL), involving a total of \$7.1m in DOE funding plus an additional \$5m in private-sector funding from the three firms.

The two-year projects will focus on achieving significant cost reductions while maintaining quality by improving manufacturing equipment, processes, or monitoring techniques.

This is Round 3 of the DOE's investments in solid-state lighting manufacturing projects. The efforts are part of DOE's initiative to accelerate the adoption of SSL technology through improvements that reduce costs while maintaining product quality and performance. They are intended to play a key role in encouraging US-based manufacturing of SSL technologies — creating jobs, boosting exports, and promoting the USA's role as a global leader in energy efficiency.

The projects selected are as follows (final details are subject to negotiations):

● **Recipient:** Cree Inc of Durham, NC. 'Low-Cost LED Luminaire for General Illumination' aims to develop an optimized LED fixture design for efficient manufacture that can be readily integrated into buildings and outdoor applications and uses fewer raw materials — all without compromising the performance of the light source. The project builds on Cree's existing LED platform and has the potential to quickly reduce the cost of producing an already highly efficient LED fixture and allowing it to compete with existing fluorescent systems. The goal is to efficiently provide warm-white light over a minimum lifetime of 50,000 hours, while reducing the cost of manufacturing

the major components and assembled products.

● **Recipient:** KLA-Tencor of Milpitas, CA. 'High Throughput, High Precision Hot Testing Tool for HLED Wafer Level Testing' plans to remove one of the major barriers to the adoption of high-efficiency LED lighting — namely, the difficulty of providing low-cost white light that has consistent color quality and brightness.

Current practice is to separate LEDs according to color during the manufacturing process in order to maximize product yield, but this creates variation in light output and color quality of the product, leading to reduced performance and increased costs. KLA-Tencor seeks to improve the color consistency of LEDs by using a measurement tool during manufacturing that reduces the variation in LED quality, improving performance and reducing cost.

● **Recipient:** k-Space Associates of Dexter, MI. 'Optical Metrology for Volume OLED Manufacturing' plans to create a more efficient manufacturing process by building on k-Space Associates' existing optical monitoring technology to enable high-precision measurements of OLED layers during mass production (most monitoring of the OLED layers during the manufacturing process currently takes place after the fact; if problems are detected then there's little or no chance to change the production inputs). The tool will measure layer thickness and composition to ultimately control the efficiency, color and lifetime of OLEDs. This development will serve as a platform for future large-scale

KLA-Tencor seeks to improve the color consistency of LEDs by using a measurement tool during manufacturing

OLED production facilities, paving the way for a strong US presence in OLED manufacturing.

However, the DOE is not selecting or funding any projects in response to SSL Core Technology Research FOA DE-FOA-0000564 or SSL Product Development FOA DE-FOA-0000563 (Round 8 of both the SSL Core Technology Research and the SSL Product Development FOAs). SSL program funding for fiscal-year 2012 has been impacted by Congressional direction, which specifically targeted manufacturing R&D. Congress has also directed the DOE to use fiscal 2012 funds to fully fund the new multi-year projects, which further impacted the number of selections fiscal-year 2012.

Nevertheless, the DOE says that SSL program strategy and direction remain unchanged, and that it

The DOE is not selecting or funding any projects in response to the SSL Core Technology Research FOA or SSL Product Development FOA. SSL program funding for fiscal-year 2012 has been impacted by Congressional direction, which specifically targeted manufacturing R&D

continues to support SSL Core Technology Research and Product Development to improve the efficacy and quality of SSL. However, in light of these considerations, it will postpone the release of new solicitations for Core Technology Research and Product Development (which would normally be issued in summer 2012) until fiscal-year

2013, in order to gain a better idea of available funding.

www1.eere.energy.gov

Optogan opens Italian lighting sales office via distributor LEDisOne

European LED chip and luminaire maker Optogan has opened an LED lamp and luminaire sales office by signing a distribution agreement with LEDisOne srl of Varese, Italy (which operates in Northern Italy and the Tessin region of Switzerland).

At the grand opening in Varese, close to Milan, LEDisOne hosted more than 100 official guests, politicians, architects, and representatives of industry and universities. Founded in 2011, the newly certified distributor specializes in LED lighting and has a broad background in the semiconductor industry.

Founded in Helsinki, Finland in 2004 by Russian entrepreneurs and scientists from Ioffe Institute in St Petersburg, Optogan is a vertically integrated developer and manufacturer of HB-LEDs for applications including solid-state lighting. In addition to having an R&D facility in Helsinki, since founding Optogan GmbH in Germany in 2005 it has established epitaxy and chip R&D plus a pilot line in Dortmund and its Fab1 chip fabrication plant in Landshut. Also, after founding CJSC Optogan in Russia in 2009, in 2010 it acquired an industrial facility in St Petersburg, where it has established LED component and luminaire production lines.

Optogan says that its expansion to Italy has been a key target, since the country is considered to be the home market for architectural lighting. "Italy has always been one of the front runners in solid-state lighting and is traditionally first in adopting new technologies and trends of the indoor lighting industry," says Ove Sørensen, senior sales director & business development at Optogan GmbH. "The potential for LED-based lamps and luminaires in this country is on such a high level that we cannot afford to miss this strategic market."

Besides the architectural lighting and retrofit business LEDisOne will also focus on sportsfield and flood lighting. Regional sports clubs and associations have already expressed their interest, says Optogan.

"So far our customers are mainly designers, architects, industrialists and public authorities, but our long-term goal is to collaborate with the government since there are development projects concerning an energy-efficient re-design of cities," says LEDisOne's managing director Gabriele Demaria. "Within the next year we plan to set up the company structure in terms of additional locations and manpower."

LEDisOne is covering the Northern Italian region and aimed to open a new sales office in Lugano, Switzerland in June.

www.ledisone.it

www.optogan.com

Italy has always been one of the front runners in solid-state lighting and is traditionally first in adopting new technologies and trends of the indoor lighting industry



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Osram expands with new LED assembly plant in China

Back-end LED packaging plant in Wuxi to improve access to the world's largest lighting market

Germany's Osram AG has signed a contract with the Wuxi New District Administrative Committee to build an LED assembly plant in Wuxi (near Shanghai) the province of Jiangsu. LED chips will be packaged at the new back-end facility starting in late 2013; with Osram's front-end plants in Regensburg, Germany and Penang, Malaysia exclusively continuing to make the LED chips.

"The new assembly plant will improve our access to the world's largest single market in the lighting industry," says Aldo Kamper, CEO of the Osram Opto Semiconductors GmbH business unit in Regensburg. "Osram's new plant in Wuxi will definitely enhance the development of the LED industry in both Wuxi Municipality and Jiangsu Province," comments Lixin Huang, a member of the Standing Committee of Jiangsu Provincial CPC Committee and secretary of Wuxi Municipal

CPC Committee in China.

Osram says that, in the face of sharply rising demand for LED-based products, it opted to set up the plant in Wuxi to augment the capacity of its chip plants in Regensburg and Penang. When fully operational, the plant will be able to accommodate up to 1600 staff.

The new plant in Wuxi will augment the Penang plant's back-end LED assembly capacity by manufacturing general, automotive and industrial lighting products for key segments of the Chinese market. The firm reckons that the added back-end LED capacity should enable it to capitalize on China's fast-growing market.

Market analysts at IMS Research have predicted strong growth for optoelectronic semiconductors such as LED components and laser diodes, with average growth rates of about 5% worldwide in the com-

ing years. The fastest growth is expected to come in China, with an average growth rate of 10%.

However, this potential extends beyond components. According to a market survey conducted by McKinsey, the rapidly growing Asian region already accounts for about 35% of the existing global general lighting market, and should rise to 45% by 2020. Forecasts predict that the Chinese market alone, worth over €8bn now, will more than double by 2020.

In fiscal 2011, Osram generated about one fifth of its revenue in the Asia-Pacific region, where it employs more than 16,000 people. This workforce is larger than that of any other region, and roughly half are employed in China. Osram notes that it has marketed products in the region for about 80 years, covering the entire value chain from front-end to back-end.

www.osram-os.com

Osram launches Oslux LED for smartphone camera flash

Osram Opto Semiconductors GmbH of Regensburg, Germany has added to its Oslux family with a new LED designed specifically for the camera flash in smartphones, providing a high-quality white light that illuminates the target area. The firm says that, due to its specially shaped lens that allows it to be discreetly fitted into the device, design compromises for flash applications are eliminated, enabling a combination of design and function when it comes to using LEDs in smartphone camera flash applications.

Manufacturers of high-end smartphones often have to choose between design and functionality, says Osram Opto. A particular challenge is combining the actual camera with the lighting needed. In some designs the technical

components can look bulky and the recesses in the enclosure can also make the device less robust. Osram Opto says that, with the new Oslux LED for flash applications, it supports smartphone makers in their efforts to combine form and function.

The Oslux LED has two chips with an emitting surface of 1mm² each. The light-emitting area of the rectangular LED is optimized for the optics of the phone – the surface is flat and blends properly with the cover, so the LED can be installed inconspicuously. No additional covers or lenses are necessary. Also, due to its symmetrical emission, the Oslux LED can be installed vertically or horizontally.

Due to Osram Opto's UX:3 chip technology, the Oslux LED provides consistent illumination for

photos, the firm claims. At a distance of 1m, a brightness level of 150 lux is achieved (at a drive current of 320mA). The light is evenly distributed and covers the corners of the rectangular illuminated image. So, no hot spot is generated in the center, as would be the case with a conventional flash. As all the elements of the flash are combined in a single component, the LED is also easily integrated into the phone. In addition, due to its compact design, the LED is durable and resistant to shock and vibration. Its energy-efficient design makes also multiple consecutive flashes possible.

The new Oslux joins the existing Osram portfolio of flash LEDs with lenses. The Ceramos LED family offers components without lenses.

www.osram-os.com

Osram Ostar Projection Cube green LED doubles system brightness for embedded projection

Osram Opto Semiconductors GmbH of Regensburg, Germany has launched the Ostar Projection Cube green LED for embedded projection applications.

Osram Opto says that the next development for smart phones and cameras is an integrated miniature projector that can display images on a much larger surface than existing displays (i.e. embedded projection, using LEDs as the light source). However, the greatest challenge so far for lighting technology has been the limited efficiency of the green light-emitting diodes, since high brightness is essential if the projected image is to be seen with ambient light.

Efficient LEDs for red and blue light have been available for some time, but LEDs that produce green light with acceptable luminance have not been available. Osram claims that the Ostar Projection Cube now fills this gap by offering luminous efficiency of 110 lumens per watt (lm/W). This is claimed to be much more than other previously available green LEDs in the embedded projection sector, enabling sufficient output to be achieved in embedded projectors for the first time.

"The new LED almost doubles the brightness in smart-phone applications, so embedded projectors with a system brightness of up to 25 lumens are possible," says Wolfgang Schnabel, marketing manager, Projection, at Osram Opto. The image is hence clearly visible even without dimming and ambient lighting, says the firm. Also, due to the efficiency of LED technology, the projector can also be used in mobile applications with limited battery capacity.

The new green LED is available in two versions, with a 1mm or 0.75mm edge-length chip (providing a solution for all standard imager formats in mobile applications) producing 260lm at 700mA and 2.3W or 130lm at 350mA and 1.2W, respectively.

Such high luminance from a small surface area is made possible with the aid of encapsulation that sharply defines the light surface so that light is emitted without package reflections. With a footprint of 3.8mm x 4.1mm and a height of only 0.6mm, the new LED enables

extremely low-profile projection engines to be designed, suiting modern smart-phones and cameras. Also, the Ostar Projection Cube does not have a glass cover, so external optics can be placed very close to it, maximizing efficiency.

www.osram-os.com

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Sumitomo and Sony claim first 100mW true-green 530nm laser diode

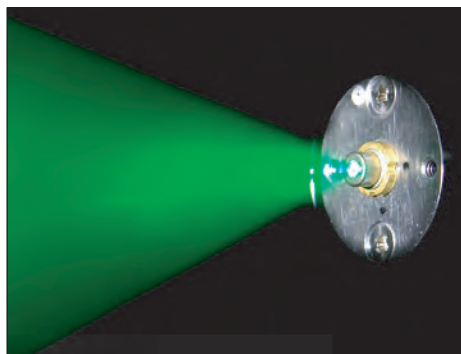
Luminosity doubled on conventional GaN green laser diodes

Tokyo-based compound semiconductor materials provider Sumitomo Electric Industries Ltd (SEI) and Sony Corp say that, by using a semi-polar gallium nitride (GaN) substrate and improving the production techniques, they have developed what is claimed to be the first semiconductor laser diode with an optical output power exceeding 100mW in the true-green region of the spectrum at a wavelength of 530nm.

The new laser diode features twice the luminosity compared with conventional GaN-based green laser diodes (emitting 60mW or less at a wavelength of 520nm or less), and a color gamut broadened by 182% based on the NTSC standard (CIE 1976 color gamut). As a result, it is reckoned that the laser diodes can significantly improve the performance of laser projectors and other display devices, allowing the reproduction of vibrant video and images.

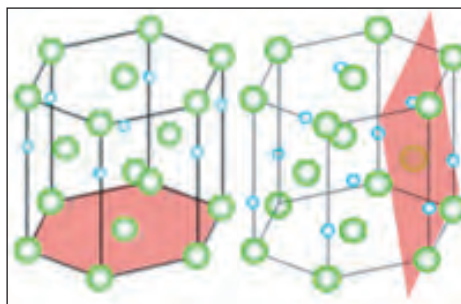
Of the primary red-green-blue (RGB) colors, red and blue laser diodes have been commercially available for some time, but there has been great need for high output green laser diodes to enable the development of high-performance laser projectors and display devices. Currently, green lasers are created by converting the wavelength of light from an infrared laser light source by using optical materials. However, such a green laser light source is large and expensive.

In addition, conventional GaN-based green diode lasers have difficulties achieving sufficient luminosity, as luminous efficiency declines in the green spectral region due to the internal field effects resulting from distortion in the crystal structure and the resultant internal polarization. Performance is limited to an

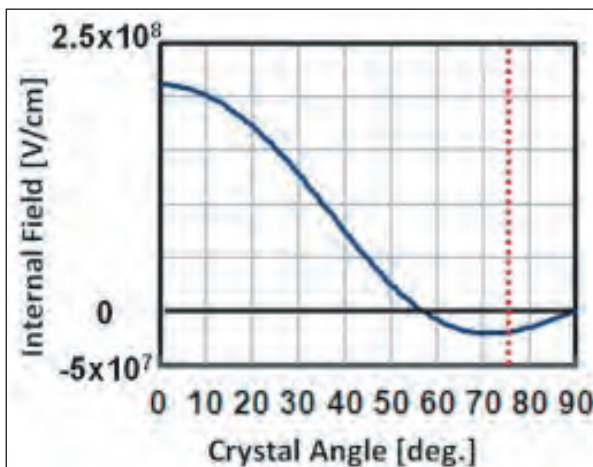


True-green laser emission.

output power of several tens of milliwatt at a wavelength of 520nm or less. It is possible to suppress the internal field effects by adopting semi-polar GaN substrates. This enables the sustainable production of homogenous indium-based active layers, allowing the growth of a high-quality light-emitting layer. However, for practical use of the laser, it is necessary to optimize the



Conventional c-plane (left) and semi-polar {20-21} plane. (right).



Internal polarization versus crystal angle.

entire laser production process.

Sumitomo Electric and Sony therefore collaborated on developing a true-green semiconductor laser by drawing on Sumitomo Electric's semi-polar GaN substrate oriented in the {20-21} plane (tilted 75° compared with the conventional GaN crystal c-plane), its crystal growth, and its wafer processing technologies, together with Sony's GaN-based laser technology (acquired through its Blu-ray development).

By introducing new techniques and improving the entire semiconductor laser production process (including structural design, crystal growth, wafer processing, and electrode configuration), Sumitomo Electric and Sony have hence been able to develop a true green laser with an optical output power of more than 100mW at a wavelength of 530nm. In addition, through optimization of the laser structure, impurity control in the crystal, and the minimization of electrode resistance, the firms have reduced the operating current and voltage. The laser is also highly reliable, with a wall-plug efficiency of more than 8%.

The development of a true-green laser diode completes the three basic colors for RGB laser light sources. Sumitomo Electric and Sony anticipate a wide variety of applications for the technology, such as incorporation into advanced laser projectors with high luminosity and broad color gamut, as well as compact, light, energy-efficient laser projectors.

The firms say that they will continue to jointly develop true-green laser diodes, aiming to achieve higher output power, efficiency, and laser quality.

<http://global-sei.com>

www.sony.net

New Focus launches first tunable, 461nm direct-diode blue laser

Photonics product maker New Focus (a division of Newport Corp of Irvine, CA, USA) has launched the Vortex Plus Blue TLB-6802 precision series, single-mode, finely tunable laser, which is claimed to be the first precision tunable blue laser operating at 461nm (the critical wavelength for next-generation atomic clocks currently being built by US National Labs and elsewhere). The blue Vortex Plus replaces complex resonant second-harmonic generation (SHG) systems, suiting research applications such as molecular and optical physics and other areas that require blue wavelength tunable lasers.

The Vortex Plus laser head delivers a narrower linewidth than prior versions. The new feature combines with the same reliable stability (1% over 1 hour) and true continuous-wave (cw), mode-hop-free operation offered by New Focus' legacy Vortex II product. For added flexibility, an industry-standard SMA port for direct-to-diode, high-speed modulation (useful for precise wavelength locking) is also included.



The Vortex Plus Blue TLB-6802 laser.

The compatible TLB-6700-LN controller is available as part of the Vortex Plus system or can be ordered separately. It features low-noise analog circuits that allow the user to precisely set critical operating parameters such as diode temperature and current. Designed to automatically recognize the laser head and to designate the ideal temperature and maximum current limit, the controller provides intuitive, easy setup for optimum performance results, says the firm. The TLB-6700-LN controller can be operated both manually or remotely via the USB interface.

www.newport.com/VortexPlus

VI Systems launches 40G VCSELs with HAB pad design for robust bonding and packaging

VI Systems GmbH of Berlin, Germany (a fabless spin-off of the Technical University of Berlin and the A. F. Ioffe Physico-Technical Institute in St Petersburg, Russia that provides laser and photo-detector chips and modules) has launched a new product line of high-speed VCSEL chips that operate with data rates of up to 40Gb/s.

The new generation of high-speed 850nm VCSELs and 1x4 and 1x12 VCSEL arrays feature an ultra-high -3dB modulation bandwidth of 20GHz. They also have a novel HAB

contact pad design which overcomes the problems of thick and soft planarization layers (characteristic to high-speed VCSEL designs) and which enables ultra-robust bonding and packaging.

VI says its novel manufacturing approach and array designs are in compliance with the standard 250µm device-to-device pitch (linear spacing), allowing systems developers to dramatically extend their capabilities in energy-efficient data communication. Die-level samples are available.

www.v-i-systems.com

IN BRIEF

Princeton Optronics launches 800nm IR VCSEL chips for consumer electronic 3D sensors

Princeton Optronics Inc of Mercerville, NJ, USA, has announced the availability of 800nm and near-800nm infrared VCSEL arrays with output powers from 100mW to over 10W peak power.

The devices are designed for consumer electronic applications such as gesture recognition, natural user interface and 3D content creation where near-infrared illumination is needed.

In 3D image sensing, the VCSEL arrays provide very low speckle, subnanosecond rise and fall times, and high electrical-to-optical conversion (>45%) efficiency. They are suitable for time-of-flight (TOF) or structured light applications, says the firm, and are preferred to LEDs and edge-emitting lasers because of their high efficiency, narrow and circular emission angle, short rise and fall times, and flat-top intensity profile. The devices also work at temperatures as high as 800°C.

VCSELs are being made in large quantities, ensuring both high reliability and competitive costs compared to LEDs and conventional edge-emitting lasers. Similarly to LEDs, for high-volume applications the chips can be packaged in various configurations. They do not require a hermetically sealed housing, reducing packaging cost. Chip sizes range from 0.5mm x 0.5mm to 3mm x 3mm, depending on output power. Also, the optics can be added to the package, creating greater options for beam handling in the illumination system. Sample chips are available at wavelengths in the 800nm range. Other wavelengths can be fabricated on request.

www.princetonoptronics.com

Mentor Graphics, ST and Leti launch NanoElec program

R&D to focus on 3D IC integration and integrated silicon photonics

ANR (the French National Research Agency) and CEA (the French Atomic and Renewable Energy Commission) have signed an agreement forming the Grenoble Institute of Technological Research (IRT): NanoElec Program.

Centered on Grenoble, the IRT partners aim to conduct R&D, and to share their research with all industrial sectors, especially small-, medium- and intermediate-sized enterprises, as well as to provide training in the necessary skills in these areas, specifically micro- and nano-electronics.

By bringing experts from manufacturers and public laboratories into close partnership, R&D activities will focus on 3D IC integration and integrated silicon photonics, in which Geneva-based chip maker STMicroelectronics (ST) and electronic design automation (EDA) software provider Mentor Graphics Corp of Wilsonville, OR, USA are the most involved.

Mentor Graphics' expertise in computer-aided design (CAD) tools will make the technical achievements of ST and CEA's Grenoble-based micro/nanotechnology R&D center Leti more accessible to system and applications designers, reckons CEA-Leti's CEO Laurent Malier. "Mentor Graphics has a long history of doing world-class electronics R&D in France," says the firm's president Gregory K. Hinckley.

The NanoElec IRT is supported by CEA-Leti in partnership with manufacturers like ST, Mentor Graphics, Soitec, Schneider, STEricsson, Bouygues, Presto Engineering and INEO, the Minalogic international competitive cluster, the Grenoble INP Institute of Technology teaching and research school, the Grenoble Ecole de Management school, Joseph Fourier university, INRIA (National Institute for Research in Computer Science and Control), CNRS (National Center for Scientific Research), the Laue Langevin Insti-

tute, and the ESRF (European Synchrotron Radiation Facility).

The semiconductor industry has followed a path defined by Moore's Law for 40 years, but transistor miniaturization is no longer enough to improve performance and reduce consumption, notes Leti. The concept of equivalent scaling and other changes to maintain that rate of progress have been defined as 'More than Moore'.

Most important of these is 3D IC integration, which aims to increase performance by stacking components. This additional approach combines with miniaturization to increase performance while reducing costs and delays in accessing the market.

However, the new approach requires many major innovations in design, modeling, simulation, manufacturing and testing. The lack of validated CAD tools to define effective architectures, as well as the lack of appropriate characterization methods and tools to predict reliability, are some of the obstacles that must be overcome before being able to validate the 3D IC integration approach.

Consequently, the main objective of IRT's 3D IC program is to validate an overall approach to 3D IC integration through a dedicated techni-

Integrated silicon-photonics technologies should first address data transmission and IT markets, then general public applications and sensors for markets such as environment and health. Technical developments are hence driven first by information and communications technologies applications

cal platform, taking into account the design, technological processes and characterization aspects.

Integrated silicon-photonics technologies should first address data transmission and IT markets, then general public applications and sensors for markets such as environment and health. Technical developments are hence driven first by information and communications technologies applications for data transmission, chip-to-chip links, and even intra-chip communication. As in other applications, silicon integration should lead to lower costs and smaller systems, says Leti.

However, there are still many technical challenges to be met before achieving photonic functions on a silicon circuit: providing CAD design tools, developing specific components such as laser sources, optical modulators, wide-bandwidth photo-detectors, passive waveguides, and wavelength multiplexers and demultiplexers. There is also a need to develop high-performance generic electronic circuit blocks to activate optical components, integrate photonic functions with electronic functions, and to implement low-cost testing and assembling techniques. The IRT's integrated silicon photonic program aims to develop critical technologies and techniques to bring photonic components to a sufficient level of maturity for their commercialization.

"As with 3D IC integration, silicon photonics has been the subject of joint work between the CEA and ST for several years," says Philippe Magarshack, ST's corporate VP, Design Enablement & Services. Due to the NanoElec IRT, the key players and all the design and technology resources can combine to accelerate development and open up applications, he adds.

www.mentor.com

www.st.com

www-leti.cea.fr

UGent and Imec release IPKISS open-source software platform to integrated photonics design community

Ghent University (UGent) and nanoelectronics research center Imec of Leuven, Belgium have launched their IPKISS software framework as an open-source software platform, available now free of charge to the wider integrated photonics design community.

The software platform is made available via a free-of-charge GPLv2-licensed code base, a custom developer license, and a custom commercial license, providing access to what is claimed to be a powerful and flexible software platform.

IPKISS was originally conceived in 2002 by UGent's Photonic Research Group and imec as a programmable generator of Mask Layouts (GDSII) written in Python, but has since then evolved significantly. Its main use is currently as a generic and modular software framework for the parametric design of photonic components and complex photonic integrated circuits (PICs). In IPKISS, a designer can quickly define photonic components, directly simulate them in electromagnetic solvers, and integrate them in a circuit on a photomask for fabrication. For this, IPKISS integrates easily with popular third-party simulators.

While most applicable to photonics, IPKISS is conceived as a generic and flexible framework, and can be

customized for use (and is already used) in many other domains related to micro- and nano-electronics (microfluidics, plasmonics, MEMS, etc).

IPKISS is based on scripting in Python, making it easy to learn and flexible in use, it is claimed. The user specifies in an analytical manner how a component is represented in terms of parameters. Internally, the component knows how to generate its layout, its input/output connections with other components, its internal circuit representations, etc. This ensures a separation between the formal specification of a component or circuit and different representations that can be derived (e.g. a mask layout in GDSII, a 2D or 3D model, a circuit model).

Components can be defined to accept outside technology information provided by the fab, effectively allowing a design that could be fabricated in different locations. Design kits for Imec's silicon photonics technologies are available via ePIXfab (a European foundry service for silicon photonics prototyping) and through Imec directly for customized photonic IC development.

Imec says that the IPKISS design approach is powerful and flexible as well as accurate, resulting in a productive design cycle with little margin for copy-and-paste errors. This contrasts with a design work-

flow that is static and cannot be influenced by the user, or where the user is limited to the functionality provided in a graphical user interface (GUI). Users of IPKISS will have access to a powerful and flexible software platform that can catalyze their research with a relatively small incremental effort, it is claimed.

The IPKISS framework is made available under different open-source licenses, as follows:

- **Community** — A GPLv2-licensed code base of IPKISS will allow access to the framework free of cost. The objective of this license scheme is to stimulate people in developing the IPKISS framework, so a thriving community can evolve around the framework.

- **Developer** — A custom license (at a modest annual fee) that allows the licensee to develop plug-ins and add-ons for distribution.

- **Custom commercial** — A license targeted at software developers wishing to incorporate IPKISS into a product and therefore bundle a (modified) version of the code base with their own additions. This license and its cost will be tailored to each individual case.

The platform was launched in April at SPIE Photonics Europe 2012.

www.ipkiss.org

<http://photonics.intec.ugent.be>

www.imec.be

POF transceiver maker Firecomms appoints CEO

Firecomms Ltd of Cork, Ireland, which makes transceivers (including its OptoLock technology, licensed worldwide) for consumer plastic optical fiber (POF), says that Hsin Chia has joined it as CEO. The firm adds that Chia has experience that should help to drive strategic expansion in target markets.

Prior to joining Firecomms, Chia led the cross-functional team at GLOBALFOUNDRIES Inc that developed that firm's strategic

direction and operational initiatives. He also developed the Industrial Fiber Product division at Avago Technologies Inc., and drove the product development and manufacturing of photonic products in the Optical Networking division of Agilent Inc.

"Since its foundation, Firecomms has opened new markets and developed highly innovative new products for plastic optical fiber," comments Chia.

Chia's immediate focus will be on China, where Firecomms has recently expanded its business (via a facility in Tongxiang), and in accelerating the release of innovative new products currently in the pipeline. These products will include the firm's recently announced new Gigabit transceiver (which is claimed to be a first for the POF industry) for coupling into POF and large-core silica fibers.

www.firecomms.com

Pacnet and Infinera first to demonstrate 500Gb/s optical super-channels in Asia

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 announced the completion of a collaborative effort demonstrating the transmission of more than 3Tb/s of capacity over 4500km of the C2C network of Hong Kong- and Singapore-based communications provider Pacnet. Infinera says that this marks another demonstration highlighting application of its 500Gb/s PIC technology to ultra-long-haul subsea super-channels.

The testing was conducted with Infinera's DTN-X platform (which began shipping this quarter) and also demonstrated the ability to use FlexCoherent technology to software select the modulation format in order to optimize fiber capacity and reach.

Pacnet owns and operates the leading pan-Asian submarine cable network, which touches 21 cable landing stations and extends from India to the USA. At the heart of this network is EAC-C2C, Asia's

largest privately owned submarine fiber-optic cable network, which spans 36,800km and serves customers globally.

"We are impressed with Infinera's DTN-X platform delivering 500Gb/s FlexCoherent super-channels and integrated OTN switching without compromise," comments Pacnet's CEO Bill Barney. "This successful test with Infinera demonstrates that Pacnet's network can scale up with the industry's latest high-speed optical technologies to deliver faster services," he adds.

"Long-haul-capable 500Gb/s super-channels are critical for carrier networks, especially in submarine applications such as Pacnet," says Infinera's CEO Tom Fallon. "The real value of Infinera's DTN-X goes well beyond its sheer size and bandwidth efficiency," he adds. "The true value is its ability to future proof our customer's most valuable asset, their fiber infrastructure, so they can continue to flexibly grow their network to accommodate wherever their customer demand takes them."

Infinera has developed super-channels embedded with FlexCo-

herent technology, and claims to be the first to demonstrate super-channels based on 500Gb/s PICs. A super-channel is a large unit of optical capacity created by combining multiple optical carriers into a single managed entity, so that optical networks can scale capacity without scaling operational cost and complexity. Infinera says that super-channels based on PICs enable operators to simply provision 500Gb/s of capacity with a single operational maneuver; FlexCoherent technology allows operators to optimize transmission performance across a range of applications using multiple software-programmable modulation formats. The DTN-X also offers integrated OTN (optical transport network) switching without compromise and — married with an automated GMPLS control plane — delivers Bandwidth Virtualization, which ensures that optical channels are efficiently utilized and enables service providers to rapidly deploy new services.

www.pacnet.com

www.infinera.com

Infinera 100Gb/s InP PIC named 'Best Component Product' at Next Generation Optical Networking 2012

Infinera Corp of Sunnyvale, CA, USA, a vertically integrated manufacturer of digital optical network systems incorporating its own indium phosphide-based photonic integrated circuits (PICs), says that its 100Gb/s PIC has been awarded 'Best Optical Component Product – 100G' at the Next Generation Optical Networking Awards 2012 in Monaco.

Infinera's first-generation PIC was recognized for the disruptive impact it has made in the optical network industry. Integrating more than 60 components onto a pair of chips, the 100Gb/s PICs are embedded into Infinera's DTN plat-

form and boasts more than 725 million hours of field operation without a known failure in live networks worldwide.

The firm is now shipping its DTN-X platform, which is based on 500Gb/s PICs. The DTN-X is believed to be the only platform on the market that delivers 500Gb/s long-haul super-channels, and the only platform to integrate 5 Terabits per second of optical transport network (OTN) switching in the same chassis.

The award was established to celebrate and recognize the achievements made by service providers and solutions providers in the opti-

cal networking industry. Infinera's award was accepted by VP of corporate marketing Michael Capuano.

Infinera says that its PICs power the DTN and DTN-X platforms, delivering to service providers globally a simple, scalable, efficient and reliable optical networking solution. "Our PICs change the dynamics of the optical networking industry by dramatically increasing optical transport network efficiency while reducing total cost of ownership," believes Michael Capuano.

<http://nextgenerationoptical.com/next-generation-optical-awards->

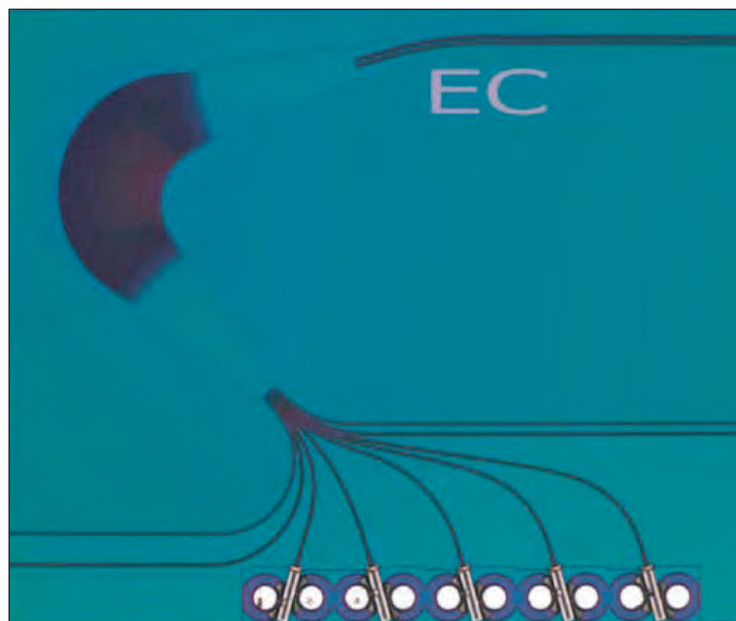
OneChip to sample PIC-based 40GBASE-LR4 and 100GBASE-LR4 receiver chips

At the IEEE Photonics Society Optical Interconnects Conference (OIC 2012) in Santa Fe, NM, USA, OneChip Photonics Inc of Ottawa, Canada, which develops and manufactures optical chips and transceivers based on monolithic photonic integrated circuits (PICs) fabricated in indium phosphide (InP) for access networks and other mass-market broadband applications, has announced that in second-half 2012 it will make available engineering samples of its PIC-based 40GBASE-LR4 and 100GBASE-LR4 receiver chips for partner testing.

The firm claims that the PIC-based receiver chips — which monolithically integrate, on a single indium phosphide (InP)-based chip, all of the active and passive optical components required to receive 40GBASE-LR4 or 100GBASE-LR4 signals — will enable transceiver manufacturers to address wide reach range (up to 10km), long-wavelength (around 1300nm) data communications applications, including high-density interfaces for next-generation data-center interconnects (NG DCI), more cost-effectively and efficiently than ever before.

“OneChip’s breakthrough PIC technology has proven to be a valuable solution for the very cost-sensitive, high-volume fiber-to-the-home [FTTH] market, and we now are extending that technology to the data communications market,” says founder & chief technology officer Dr Valery Tolstikhin. “By offering fully integrated receiver and transmitter PICs, we are demonstrating that InP-based wavelength division multiplexing (WDM) components can meet very aggressive cost and footprint points in the data communications market, overall, and in NG DCI applications, in particular,” he adds.

“The industry is in the midst of switching gears from raw device



OneChip’s 100GBASE-LR4 integrated receiver includes a spot-size converted input optical port, an arrayed waveguide grating (AWG) wavelength-division multiplexer and 4x25Gbps waveguide photo-detectors (WPDs) at its four output electrical ports, all monolithically integrated on a single InP chip.

speed to photonic integration, as optical interconnect speeds reach 40Gbps, 100Gbps and beyond,” comments Karen Liu, principal analyst for Components at market research firm Ovum. “PIC chips like OneChip’s offering will be critical to enable the required cost and density for transceiver and system solutions addressing exploding communications needs in a wide variety of applications,” she adds.

OneChip also expects to make engineering samples of its 40GBASE-LR4 transmitter optical components and 100GBASE-LR4 single-chip transmitter PICs available near the end of this year, after the release of

The industry is in the midst of switching gears from raw device speed to photonic integration, as optical interconnect speeds reach 40G, 100G and beyond

its PIC-based receiver chips. The 40GBASE-LR4 transmitter components will include spot-size converted distributed feedback (DFB) directly modulated lasers at 1271, 1291, 1311 and 1331nm wavelengths, with integrated monitor photo-diodes. The 100GBASE-LR4 transmitter PICs will integrate four DFB-EAM (electro-absorption modulator) externally modulated lasers

operating in the 1300nm window on 800GHz spacing at 25Gbps each, monitor diodes, a WDM combiner, and spot-size converter on a single chip.

OneChip claims that its PIC-based 40GBASE-LR4 and 100GBASE-LR4 integrated receiver chips will cost significantly less to package and manufacture than competing hybrid integration and silicon photonics solutions, and the chips will have the smallest footprint on the market. The firm anticipates that the PICs will enable LR4 transceivers cost effective enough to be used at short- and intermediate-range applications in the data center.

OneChip’s photonic integrated circuits are designed and manufactured using its Multi-Guide Vertical Integration (MGVI) platform — the firm’s unique, regrowth-free photonic integration technology — resulting in lower costs and higher yields than other implementation technologies, it is claimed.

www.onechipphotonics.com

GigOptix appoints Fabrinet chairman & CEO to its board

GigOptix Inc of San Jose, CA, USA (a fabless supplier of semiconductor and optical components for high-speed information streaming) has appointed David T. (Tom) Mitchell to fill a vacancy on its board of directors for an independent Class I director as the firm moves from an early-stage company to a "globally mature manufacturing organization".

Mitchell has over 33 years of experience in the electronics and semiconductor industries, while founding and co-founding two of the biggest manufacturing companies in the industry.

Currently, he is chairman, CEO & founder of Thailand-based Fabrinet Co Ltd (which provides optical, electro-mechanical and electronic contract manufacturing services to original equipment manufacturers of products such as optical communication components, modules and sub-systems, industrial lasers and sensors). He was also a co-founder

& president of disk-drive maker Seagate Technology, formerly Thailand's largest foreign employer.

GigOptix says that Mitchell is widely considered to be a pioneering force in the establishment of Asia as the pre-eminent manufacturing base for the hard-disk-drive industry. With his extensive experience in manufacturing of complex high-precision electronics, he leveraged his expertise into other vertical markets such as optical, automotive and industrial products. Many of the world's leading technology companies now look to Fabrinet for the manufacture of their products. Mitchell has also established high-volume, low-cost manufacturing bases in Singapore, Thailand, Malaysia, India and China.

Mitchell received his Bachelor of Science degree in Economics from Montana State University. He has also served as Captain in the US Marine Corp.

"His wealth and depth of experience, pioneering the Asia contract manufacturing industry, and building the leading CM [contract manufacturer] of high-speed optical components in the world, will certainly add a new level of professional and technical expertise to our team, as we continue to rapidly grow as a production trusted partner with our large number of industry-leading customers," says GigOptix's chairman, chief executive & president Dr Avi Katz. The firm now has a board consisting of five independent directors with diverse experience.

"This is the first time I have accepted such an offer to join a board of directors of a public company," notes Mitchell. "The future looks very promising for GigOptix based on their innovative products, aggressive execution and approach to business, primarily through partnering."

www.fabrinet.com

GigOptix's optical driver and receiver chipset used in high-speed interconnects for consumer HD information transfer

GigOptix's HXR/T4104 high-speed optical driver and receiver chipset is being used in the high-speed data interconnect module of a leading consumer electronics manufacturer for high-definition (HD) TV and next-generation HD information transfer. The devices enable much higher data transfer rates over longer distances and at lower costs compared with competing technologies, it is claimed.

The optical module is currently used in a high-definition camera, and the application is pushing the technology envelope from HD TV at 3.7Gbps to next-generation HD transfer speeds beyond 40Gbps, which will enable a four-fold increase in frame rate and support multi-view HD 3D imaging. The consumer electronics manufacturer has, for the first time, enabled a mass-production technology for VCSEL-based optical interconnect

modules by eliminating the need for lenses to couple the fiber to the VCSEL (vertical-cavity surface-emitting laser). This was enabled by the development of new assembly technology that connects the fiber with the VCSEL using a silicon interposer that allows fully automated assembly. The resulting module can transmit data at up to 40Gbps. This not only provides much higher data rates over longer distances but it is also more cost competitive compared to existing copper interconnect solutions.

The chipset consists of the HXT4104 4x10.3Gb/s parallel VCSEL driver and the HXR4104 4x10.3Gb/s parallel limiting transimpedance amplifier (TIA). These two devices address 40Gbps active cable and consumer applications. The chipset simplifies system design by being fully programmable via an industry-standard 2-wire

interface. This provides full control of signal peaking, modulation and average currents, in addition to providing access to temperature and output power monitoring on a channel-by-channel basis.

"Increasing amounts of data are used in modern consumer applications, and legacy copper-based interconnects are being challenged to transfer data at the speeds and at the low power being demanded by consumer applications," says GigOptix's senior VP & chief technology officer Andrea Betti-Berutto. "Optical communication has been less attractive for consumer applications to date due to the higher manufacturing costs. We are very excited to see a leading consumer electronics player solve this issue and enable optical communications in consumer applications."

www.gigoptix.com

GigOptix joins Russell Microcap Index

GigOptix joined the Russell Microcap Index on 25 June when Russell Investments (a subsidiary of The Northwestern Mutual Life Insurance Company) reconstituted its family of US indexes, according to a preliminary list of additions announced on 8 June.

Annual reconstitution of Russell Indexes captures the 4000 largest US stocks as of the end of May, ranking them by total market capitalization to create the Russell 3000 Index and Russell Microcap Index.

Membership of the Russell Microcap Index, which remains in place for one year, means automatic inclusion in the appropriate growth and value style indexes. Russell determines membership for its equity indexes primarily by objective, market-capitalization rankings and style attributes. Russell indexes are used by investment managers and institutional investors for index funds and as benchmarks for both passive and active investment strategies.

"Being included in the Russell Index is a validation of the progress we have made over the last five years," says GigOptix's chief financial officer Curt Sacks. "As we con-

tinue to execute on our growth strategy, we believe our membership will be a valuable tool to help

raise our investment profile in the financial community," he adds.

www.gigoptix.com

GigOptix rings NYSE's opening bell



GigOptix's founder, chairman, CEO & president Dr Avi Katz with company executives and guests at the New York Stock Exchange.

On 1 June, GigOptix's founder, chairman, CEO & president Dr Avi Katz, along with senior members of its management team, participated in the New York Stock Exchange (NYSE) opening bell ceremony, continuing the celebration of the firm's recent transfer from the OTCQX to listing on the NYSE MKT. GigOptix's

common stock began trading on the NYSE MKT on 25 April under the ticker symbol 'GIG'.

"This ceremony is a tribute to our employees, investors and partners, who continue to drive our success and position GigOptix for future success and growth," comments GigOptix's chief financial officer Curt Sacks.

Engineering samples made available for linear quad driver for 400G

GigOptix Inc of San Jose, CA, USA has begun engineering sampling of its GX62472, a surface-mounted technology (SMT) Mach-Zehnder modulator (MZM) quad linear driver designed with integrated GPPO outputs for 400Gbps DWDM metro and long-haul optical transmitters.

Key features include:

- data rates up to 32Gbaud for use in 400Gbps quadrature amplitude modulation (QAM) applications;
- coplanar differential inputs compatible with industry surface-mounted digital signal processors (DSPs);
- GPPO connectorized outputs compatible with market-leading

100Gbps DP-QPSK MZMs;

- low RMS jitter degradation;
- single ended output up to 6V_{pp};
- integrated temperature sensor and bias -T networks; and
- gain control and peak detector available.

"The solution integrates GigOptix's high-performance linear MMIC designs in a compact form factor suitable for use in both line-cards and transponders," says senior VP & chief technology officer Andrea Betti-Berutto. "The GX62472 integrates an SMT-to-GPPO transition in the package that simplifies customers' designs, shrinking the system size and saving costs by reducing the labor required to

manufacture the system," he adds. "Moreover, the coplanar differential inputs ensure excellent high-speed electrical signal integrity between the DSP and the driver, while the single ended GPPO connector ensures optimal coupling of the amplified electrical signals with the optical modulator."

The driver was developed in close cooperation with tier-1 customers and uniquely addresses the demanding requirements of 400G QAM application, the firm says. "We expect this new addition to GigOptix's high-speed driver portfolio to be a significant growth engine for the company going forward," it adds.

Alta discloses technologies behind flexible GaAs solar cells for adaptable form factors

Construction of pilot manufacturing facility targeting material availability by 2013

At the 38th IEEE Photovoltaics Specialists Conference (PVSC38) in Austin, TX (5–7 June), technology manager Dr Laila Mattos of Alta Devices in Sunnyvale, CA, USA presented details of key technologies that enabled it to reach a new record of 23.5% energy conversion efficiency for single-junction GaAs solar modules, as confirmed by the US National Renewable Energy Laboratory (NREL) and announced in February.

Founded in 2007, Alta is a development-stage company focused on improving the production economics of high-efficiency solar PV applications, as well as on making breakthroughs in both manufacturing and form factor. So far the firm has received \$72m in venture capital funding from investors including August Capital, Kleiner Perkins Caufield & Byers, Crosslink Capital, DAG Ventures, New Enterprise Associates (NEA), Presidio Ventures, Technology Partners, Dow Chemical, and Alberta Investment Management Corporation (AIMCo).

At PVSC, Alta described how its thin-film solar cells are interconnected into flexible sheets, creating what is claimed to be a new class of solar material. The material can be formed into different shapes and sizes, enabling new applications.

"Up until now, the applications of

relatively high-efficiency solar have been constrained to those that utilize large and heavy glass plates," says president & CEO Chris Norris. "But the technology being disclosed this week has the potential to change both the applications and economics of solar," he reckons.

Due to the high efficiency combined with its thin and flexible nature, Alta's solar material can be used differently from those that have been available, allowing meaningful power production anywhere the sun is shining, it is claimed. It can be deployed in many applications including: electric vehicles, aircraft and unmanned drones, portable power, roof tiles and other building-integrated uses. Because of the characteristics of the technology, the high cost of an entire solar energy system is reduced, the firm adds.

"When you are able to use solar in nearly any form, the applications broaden and the system complexity and cost are dramatically reduced and, ultimately, both the economic returns and human benefits increase," says Norris.

In addition to underscoring previously disclosed techniques for overcoming the cost and complexity of using GaAs, Mattos' presentation explained how Alta was able to maintain conversion efficiency

while creating flexible sheets that can be of nearly any size. Specifically, she revealed that Alta's solar cells are self-interconnected in a way that maximizes the light captured by the thin, flexible sheets.

"Traditionally, when solar cells are interconnected to form a module, conversion efficiency is compromised because active solar material is covered with metal busbars and wires, preventing some of the light from entering the cells," Mattos explains. "In addition, gaps between cells create areas of the module that are not able to convert incident light to electrical energy," she adds.

"The key to improving solar performance at the module level is to avoid these problems," continues Mattos. "Enabled by our cell flexibility, we use a self-interconnected technology that eliminates the wires, thus maximizing the cells' exposure to incident light. The self-interconnected cells form a flexible sheet with no gaps and that can be of any size or aspect ratio."

Construction of Alta's pilot manufacturing facility is underway, with expectations of material available by the beginning of 2013. "We take every step of our business systematically and don't underestimate the challenges," concludes Norris.

www.altadevices.com

Emcore completes sale of VCSEL product lines to SEI

Emcore has completed the sale of its vertical-cavity surface-emitting laser (VCSEL)-based product lines to optical and wireless communications product maker Sumitomo Electric Device Innovations USA Inc of San Jose, CA (SEDU, a subsidiary of Japan's Sumitomo Electric Industries Ltd, or SEI).

SEDU supplies optical components to the telecom, broadband and data communications markets, including transceivers, transmitters, receivers, lasers, and photodiodes for 10Gb/s up to 100Gb/s applications. It also provides a range of GaAs and GaN drivers and amplifiers for high-power RF wireless solutions.

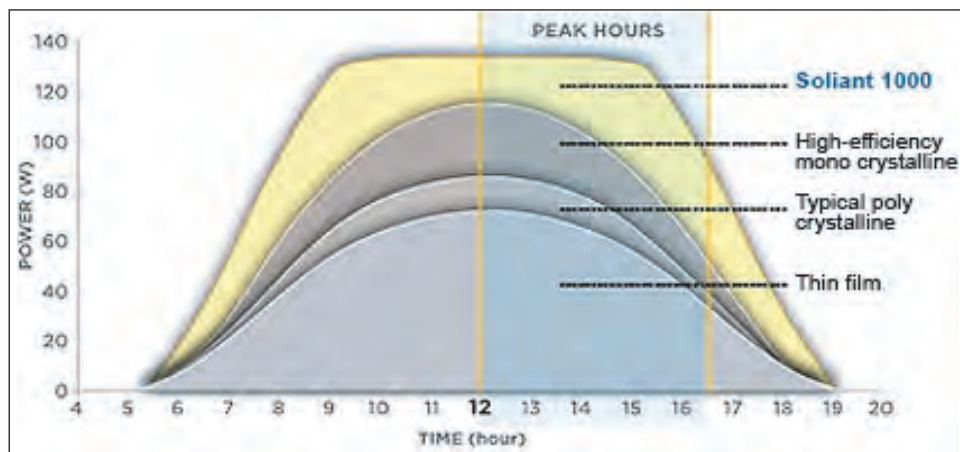
SEI is to pay \$17m for the fixed assets, inventory and intellectual property of the VCSEL-based product lines of Emcore's fiber-optics business. The product lines include VCSEL and photodiode components, parallel optical transceiver modules, and active optical cables (AOCs).

www.sei-device.com

Emcore launches commercial rooftop CPV system

Emcore Corp of Albuquerque, NM, USA, which makes components, subsystems and systems for the fiber-optic and solar power markets, says its Soliant 1000 commercial rooftop concentrator photovoltaic (CPV) system is now available for pre-production orders. The system was introduced and demonstrated in Europe for the first time at June's Intersolar Europe 2012 trade show in Munich, Germany.

The Soliant 1000 is designed to generate solar power for commercial buildings with high energy demands. It is claimed that the system offers one of the highest energy production densities of any available solar system, making it cost effective for commercial rooftops in regions with high direct normal irradiance (DNI). The Soliant 1000 generates more than 500 watts peak per panel (18 watts peak per square foot), requiring about 28% less rooftop area than polycrystalline and about 38% less rooftop area than thin-film solar panels, it is reckoned, to generate 1000MWh per year of energy output. The system combines Emcore's multi-junction solar cell technology with a patent-pending TipTilt Tracking system that tracks the sun's movement all day to maximize crit-



Daily energy output (CD) for 1m² of rooftop in Phoenix, AZ.

ical peak-hour energy output when utility energy is most expensive.

The Soliant 1000 panels are low profile, lightweight, non-penetrating and come fully assembled and ready to drop-in place. For developers, integrators and installers, more

projects can be completed in less time with lower labor and system costs, it is claimed. Commercial building owners can benefit from the lowest levelized cost of energy (LCOE, the final cost to produce a kilowatt-hour of solar power) along with a system that is designed for over 25 years of life, the firm adds.

"This announcement opens the door for Emcore to enter the estimated \$2bn annual rooftop solar market," says chief operating officer Christopher Larocca. "Production and deliveries are scheduled to commence later this year, and we look forward to addressing this new segment."

www.emcore.com



Emcore's Soliant 1000 CPV systems.

Emcore wins solar panel contract from JPL for NASA's Soil Moisture Active Passive mission

Emcore has been awarded a solar panel manufacturing contract by NASA's Jet Propulsion Laboratory (JPL) for its Soil Moisture Active Passive (SMAP) mission (for launch in late 2014). Solar panels populated with Emcore's most advanced third-generation triple-junction ZTJ solar cells will power the SMAP spacecraft and instrument suite in near-polar, sun-synchronous orbit for the duration of mission.

The SMAP mission will provide global measurements of soil moisture and its freeze/thaw state. The measurements will be used to

enhance the understanding of processes that link the planet's water, energy and carbon cycles, and to extend the capabilities of weather and climate prediction models. SMAP data will also be used to quantify net carbon flux in boreal landscapes and to develop improved flood prediction and drought monitoring capabilities.

"Emcore successfully delivered solar panels to JPL last year for the Mars Science Laboratory (MSL) mission and have delivered, or are in the process of delivering, solar panels for several other NASA mis-

sions, including the Lunar Atmosphere and Dust Environment Explorer (LADEE), Lunar Reconnaissance Orbiter (LRO), and the Magnetospheric Multi-Scale (MMS) missions," notes chief operating officer Christopher Larocca.

With a beginning-of-life (BOL) conversion efficiency nearing 30% and the option for a patented, onboard monolithic bypass diode, Emcore's multi-junction solar cells provide the highest available power to interplanetary spacecraft and earth-orbiting satellites, it is claimed.

<http://smap.jpl.nasa.gov>

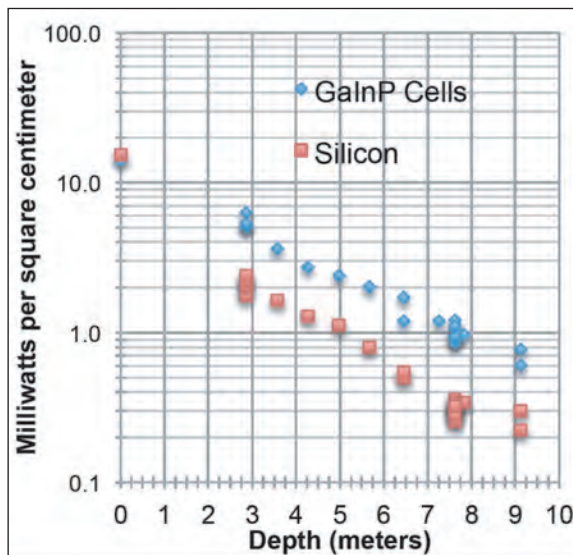
NRL developing high-bandgap GaInP solar cells for underwater autonomous systems

400–700nm (blue-green) absorption yields 7W/m² at depth of 9.1m

Scientists at the US Naval Research Laboratory (NRL), Electronics Science and Technology Division, are researching underwater photovoltaic technology to develop high-bandgap solar cells capable of producing sufficient power to operate electronic sensor systems at depths of 9m.

Underwater autonomous systems and sensor platforms are severely limited by the lack of long-endurance power sources. To date, these systems must rely on on-shore power, batteries or solar power supplied by an above-water platform. Attempts to use photovoltaics have had limited success, due primarily to the lack of penetrating sunlight and the use of solar cells optimized more towards the unimpeded terrestrial solar spectrum.

"The use of autonomous systems to provide situational awareness and long-term environment monitoring underwater is increasing," says Phillip Jenkins, head of NRL's Imagers and Detectors Section. "Although water absorbs sunlight, the technical challenge is to develop



Power density of GaInP and crystalline silicon cells, underwater, as a function of depth.

a solar cell that can efficiently convert these underwater photons to electricity."

Even though the absolute intensity of solar radiation is lower underwater, the spectral content is narrow and thus lends itself to high conversion efficiency if the solar cell is well matched to the wavelength range. Previous attempts to operate solar

cells underwater have focused on crystalline silicon solar cells and more recently, amorphous silicon cells.

NRL says that high-quality gallium indium phosphide (GaInP) cells are well suited for underwater operation, since they have high quantum efficiency at wavelengths of 400–700nm (visible light) and intrinsically low dark current, which is critical for high efficiency in low light conditions.

The filtered spectrum of the sun underwater is biased toward the blue/green portion of the spectrum and thus higher-bandgap cells such as

GaInP perform better than conventional silicon cells, states Jenkins.

Preliminary results at a maximum depth of 9.1m reveal output to be 7W/m² of solar cells, which is sufficient to demonstrate that there is useful solar power to be harvested at depths commonly found in littoral (near-shore) zones.

www.nrl.navy.mil

NREL's Kurtz wins Cherry Award from IEEE

At the 38th IEEE's annual Photovoltaic Specialists Conference (PVSC38) in Austin, TX, Sarah Kurtz — a principal scientist and group manager at the US Department of Energy's National Renewable Energy Laboratory (NREL) — received the Cherry Award from the Institute of Electrical and Electronics Engineers (IEEE).

Named in honor of William R. Cherry (a founder of the PV community), the award recognizes individual engineers or scientists who devoted a part of their professional life to the advancement of the science and technology of PV energy conversion.

Kurtz and NREL colleague Jerry Olson (who won the award in 2011) championed the early use of multi-

junction solar cells by showing that a top cell of GaInP and a bottom cell of GaAs can capture and convert photons into electricity more efficiently than other materials.

They showed that the multi-junction concentrator photovoltaic (CPV) cells not only use a fraction of the materials used by the thicker flat-plate cells, but that they can capture more light through the course of a day.

The development was embraced by NASA, which uses multi-junction solar cells to power most space satellites, as well as its Mars rovers.

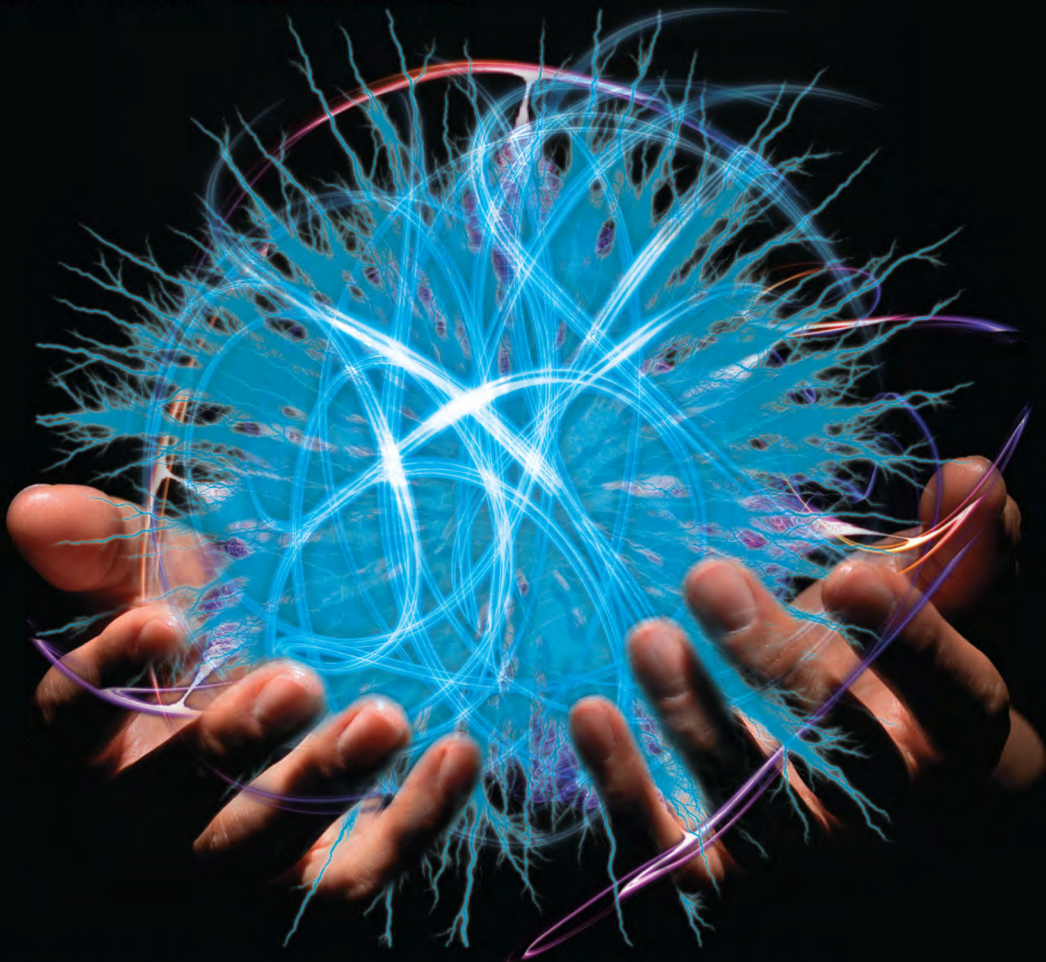
NREL says Kurtz's work helped to illuminate how to grow high-quality cells, how to measure multi-junction cells, and how their performance is

affected under various spectra. She has also looked at reliability issues of integrating such cells and solar PV in general into larger systems.

"The question on the street — how to predict the lifetime of modules — comes in different flavors," Kurtz says. "They come from people who are determining the warranties, customers who want to choose the most durable product, the investor trying to justify the investment of a billion dollars, and the insurance companies wanting to know how to set rates," she adds. "Service predictions, by site around the world, looking 20 or 30 years out, are quite challenging experiments to design."

www.nrel.gov

Hold Your Ground



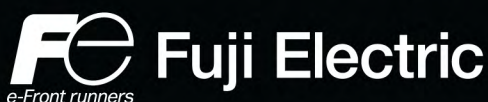
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OPEL cuts staffing as it refocuses from solar to POET

OPEL Technologies Inc of Toronto, Ontario, Canada — which makes high-concentration photovoltaic (HCPV) panels and solar tracker systems through its subsidiary OPEL Solar Inc and develops III-V semiconductor devices and processes through US affiliate OPEL Defense Integrated Systems (ODIS Inc) of Shelton, CT — has completed a staff reduction in the solar business as it continues to cut costs as part of an ongoing review and assessment of its solar division.

A core component of OPEL's strategy is to continue to develop its POET platform, which enables monolithic fabrication of GaAs integrated circuits containing both electronic and optical elements on a single wafer. The technology has been developed over 18 years by chief scientist Dr Geoff Taylor and his team. The firm has 37 patents issued and 13 pending in both its PV systems and for its semiconductor POET process.

OPEL continues to progress work with a third party in the validation of the technology (following independent validation of a critical component of the POET platform by BAE Systems in June 2011).

In support of the strategic direction, two special committees have been established by OPEL's board. The first will explore the divestiture of OPEL's Solar Division to interested parties that are now engaged in talks with the firm. The second will drive the monetization efforts of ODIS' POET platform technology.

OPEL's annual general meeting is scheduled for 21 August in Storrs, CT, USA, allowing shareholders to tour the ODIS facility. OPEL's president & CEO Leon M. Pierhal, execu-

tive chairman Mark Benadiba, executive director Peter Copetti, and board members Dr Samuel Peralta and John F. O'Donnell will be standing for election as directors.

OPEL restructures board of directors

OPEL has welcomed Mark Benadiba, Peter Copetti and Dr Sam Peralta to its board of directors.

Benadiba serves on the board of Cott Corp and will serve as executive chairman of OPEL's board. In late 2008, he was involved in helping Cott shift its strategy to refocus on its core business activities, and he has experience negotiating licensing agreements.

Copetti will serve as an executive board member. He has extensive capital markets and managerial experience and will be focused on rationalizing costs while defining the strategic direction of the firm with regard to its Planar Optoelectronic Technology (POET) semiconductor platform.

Peralta has rejoined the board of directors. After serving on OPEL boards since January 2007, all issues leading to his resignation this February have been resolved, says the firm. Until May he served on the board of Axiom NDT Corp, but stepping down from there allows him time to help renew OPEL's POET strategy. The firm says that Peralta has broad experience in the high-tech sector, and

brings a continuity of technological vision to its reformulated board.

Lawrence Kunkel and Tristram Collins have both decided not to stand for re-election to the board in order to pursue other opportunities. To allow for the new directors to join, they have both agreed to step down at this time.

Copetti, Peralta and Benadiba join CEO Leon M. Pierhal and O'Donnell at the board level in an "aggressive effort to drive down costs and maximize returns for all stakeholders".

● Benadiba and Copetti have each entered into a consulting agreement wherein they will each be paid \$8400 per month for one year with respect to their services as executive chairman and executive director, respectively. They will each be granted 2,500,000 stock options, and Peralta will be granted 500,000 stock options pursuant to the firm's incentive stock option plan. The options will be exercisable for a period of five years at a price of \$0.235 per share. The options vest 25% immediately and 25% every six months thereafter.

www.opeltechinc.com

Second, \$692,310 tranche of \$3m private placement completed

OPEL has announced a financing arrangement for IBK Capital Corp, to act as agent (on a best efforts basis) to conduct a private placement offering of up to 13,043,478 units at a price of \$0.23 each, to yield gross proceeds of up to \$3m. Each unit consists of one common share and one common share purchase warrant (allowing the holder to acquire one common share for a

period of three years at an exercise price of \$0.35 per share).

The private placement has been conditionally accepted by the TSX Venture Exchange. The securities being issued are subject to a hold period that expires four months and one day following closing.

After a first tranche of the financing of \$507,690 was completed on 8 June, a second tranche of

\$692,310 has been completed, making \$1.2m in total raised to date. The remaining \$1.8m will be closed by 30 July, says OPEL.

OPEL is paying a cash commission of 7% of the funds raised and 10% of the units sold in the form of broker warrants (each allowing the holder to acquire one common share at a price of \$0.23 for 48 months after the closing date).



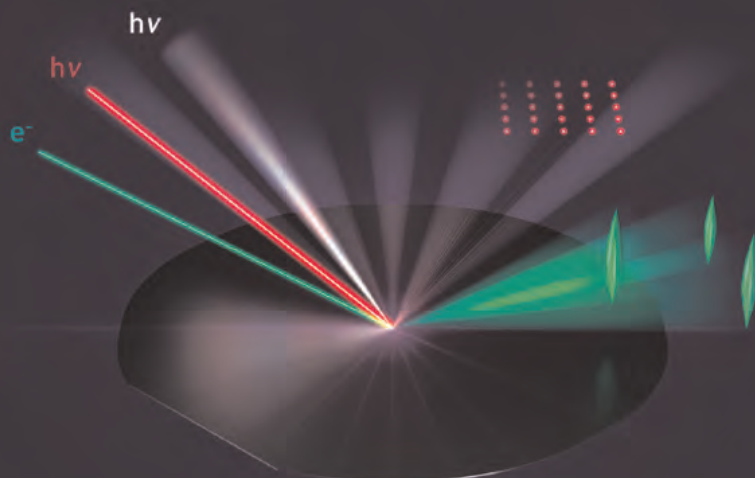
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Control Your Process!

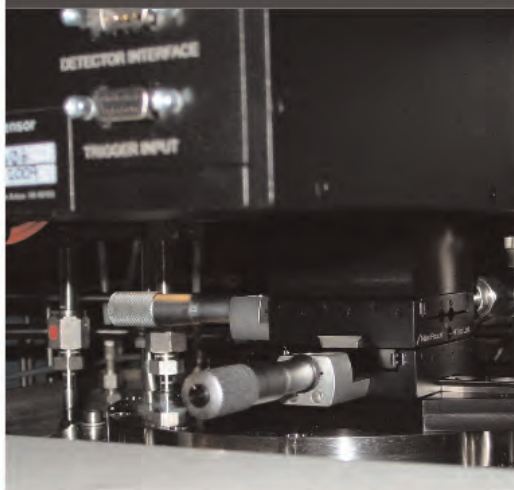
Real-Time Process Monitoring for MOCVD, MBE, Sputtering, and Thin-Film PV Deposition



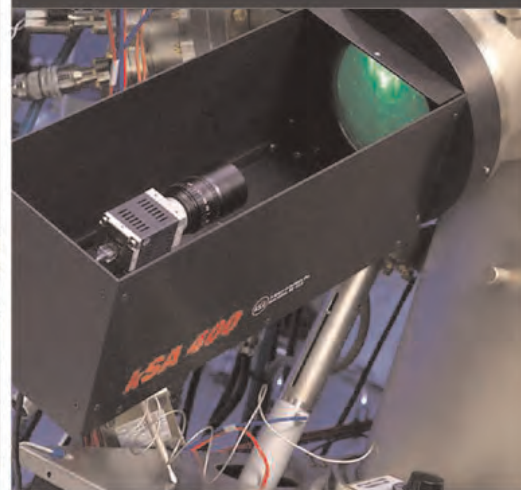
kSA BandiT Wafer Temperature



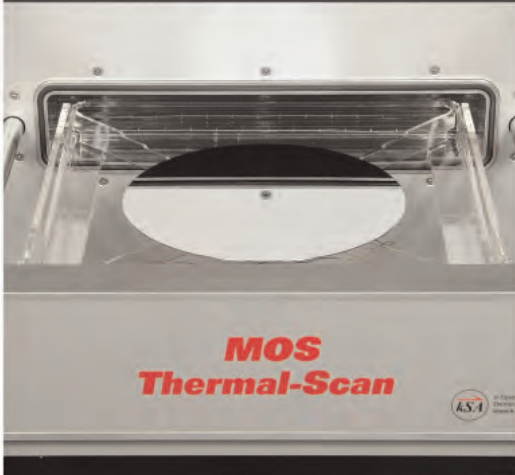
kSA MOS and kSA Mini-MOS Thin-Film Stress



kSA 400 Analytical RHEED



kSA MOS Ultra-Scan and Thermal-Scan Stress Mapping



kSA Rate Rat Pro Thickness & Deposition Rate



kSA BandiT PV Process Tuning

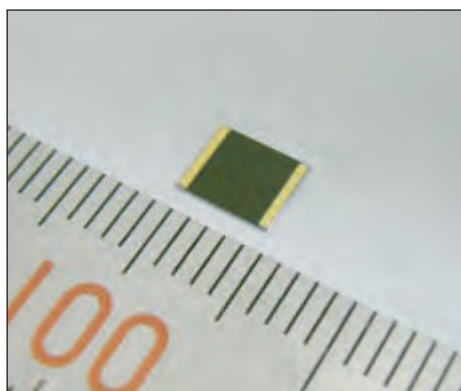


Sharp develops concentrator cell with efficiency of 43.5%

Efficiency equals record set by Solar Junction in March 2011

Japan's Sharp Corp has used a concentrator triple-junction III-V compound semiconductor photovoltaic cell to achieve a solar energy conversion efficiency of 43.5%, equaling the record for concentrating conversion efficiency set in March 2011 by Solar Junction of San Jose, CA, USA, a manufacturer of III-V multi-junction solar cells for concentrated photovoltaics (CPV).

Measurement of the value of 43.5% was confirmed in April by the Fraunhofer Institute for Solar Energy Systems (ISE) in Freiburg, Germany for a cell surface of about 0.167cm^2 under a light-concentrating magnification of 306x. One of several organizations around the world that officially certifies efficiency measurements in solar cells, ISE is one of seven European research establishments collaborating with Japanese partners in the 42-month-long EU-funded project 'NGCPV: A new generation of concentrator photovoltaic cells, modules and systems', which began in June 2011.



Sharp's concentrator triple-junction compound solar cell with conversion efficiency of 43.5%

The basic structure of the latest triple-junction compound solar cell uses Sharp's proprietary technology enabling efficient stacking of the three photo-absorption layers, with indium gallium arsenide (InGaAs) as the bottom layer.

Measurement of the value of 43.5% was confirmed in April by the Fraunhofer ISE

To achieve the latest increase in efficiency, Sharp capitalized on the cell's ability to convert sunlight collected via three photo-absorption layers. Sharp also optimized the spacing between electrodes on the cell's surface and minimized the cell's electrical resistance.

Sharp says its latest development arose through work that is part of the 'R&D on Innovative Solar Cells' project promoted by Japan's New Energy and Industrial Technology Development Organization (NEDO), which is one of the country's largest public management organizations for promoting R&D as well as for disseminating industrial, energy, and environmental technologies.

Because of their high conversion efficiency, compound solar cells have been used mainly for space satellites. However, Sharp's aim for is to apply this latest development in CPV power systems that can efficiently generate electricity using small-surface-area solar cells and make them practical for terrestrial use.

<http://sharp-world.com>

Solar Junction wins 5MW CPV cell order from SolFocus

Solar Junction of San Jose, CA, USA, a manufacturer of III-V multi-junction solar cells based on proprietary adjustable-spectrum lattice-matched (A-SLAM) materials for concentrated photovoltaics (CPV), has announced an agreement with CPV system maker SolFocus Inc of Mountain View, CA, USA for a 5MW order.

"Our multi-junction solar cell technology provides the pathway to higher efficiency, leading to higher performance for CPV system end users," says CEO Jim Weldon.

Solar Junction says that it continues to develop high-efficiency solar cells to enhance the competitiveness of CPV. An optimized cell directly correlates to module performance enhancements, and a higher-efficiency cell drives LCOE

(levelized cost of energy) towards grid parity, adds the firm.

"This order evidences SolFocus' confidence in Solar Junction and its cell technology, as the companies work to make CPV cost-competitive and sustainable with quality products," says SolFocus' president & chief operating officer Bob Legendre.

In March, SolFocus announced a 50MW project in Baja California, Mexico. The 50MW project is the first tranche of a planned 450MW capacity for the facility. Construction is scheduled to begin in late 2012.

Solar Junction's announcement follows a SUNPATH award from the US Department of Energy (DOE) as part of a \$21.5m program to increase its CPV cell manufacturing capacity. SUNPATH (Scaling Up

Nascent PV At Home) is part of the DOE's SunShot Program, which aims to increase PV manufacturing in the US through investments in technologies that are sustainable with competitive cost and high performance. SunShot investments are designed to help achieve \$1/Watt by 2020.

In February, Solar Junction announced a \$19.2m investment round, as well as an exclusive manufacturing agreement with epi-wafer foundry and substrate maker IQE plc of Cardiff, Wales, UK. The firm says that, coupled with the SUNPATH award, it is on a path to high-volume manufacturing of its A-SLAM cell.

www.sj-solar.com
www.solfocus.com

Soitec wins \$25m SUNPATH award from DOE for North American CPV module-making facility in San Diego

Soitec of Bernin, France says that one of its US solar energy subsidiaries has been selected by the US Department of Energy (DOE) to receive a \$25m award via SUNPATH (Scaling Up Nascent PV At Home), which aims to increase the USA's manufacturing competitiveness in the global solar market (falling under the DOE's SunShot Program). The funds will support the firm's new North American solar manufacturing facility in San Diego, CA.

Last December, Soitec acquired a 176,000ft² manufacturing center on 14.8 acres of land in San Diego to support over 300MW of well advanced projects throughout San Diego and Imperial Counties. The new factory will enable annual manufacturing capacity of 200MW (275MWp) of Soitec's fifth-generation Concentrix concentrator photovoltaic (CPV) modules, and will be the world's largest CPV manufacturing facility, the firm reckons. Representing an investment of over \$150m, the project is expected to create 450 on-site jobs and over

1000 indirect jobs at full capacity. Construction is underway, and the first phase is scheduled to be operational by fourth-quarter 2012.

"This SUNPATH award will accelerate the production and output of Soitec's first large-scale CPV module manufacturing facility in San Diego," says Clark Crawford, VP of sales & business development USA. "We are honored by this new partnership with the DOE and their support for CPV deployments in the US represented by this award," he adds.

"The decision of the DOE to award Soitec with the largest share of the SUNPATH award provides a strong endorsement of our CPV technology," says Gaetan Borgers, executive VP of Soitec Solar Energy Division. "The SUNPATH award adds support to our view that CPV is best-suited for regions with extremely hot ambient temperatures and dry weather conditions like the American Southwest."

CPV technology converts sunlight into electricity via concentrator optics and high-efficiency solar

cells, offering what is reckoned to be the best design for use in sunny regions, delivering low-cost (reliable, and environmentally friendly solar generated electricity). Soitec's fifth-generation CPV modules, to be manufactured at the San Diego facility, were developed to reduce installation costs while implementing improved system optics to further increase the efficiency levels of the modules. The fifth-generation Concentrix CPV modules provide a module efficiency of 30% (2–3 times the efficiency of conventional PV technology, it is reckoned).

Soitec says that high-volume CPV module production in San Diego will enable it to deliver renewable energy and economic development by expanding its solar power plant customers throughout Southern California and the American Southwest, and ultimately support export opportunities around the Pacific Rim.

The SUNPATH award will be finalized pending completion of contract negotiations with the DOE.

www1.eere.energy.gov/solar/sunshot

Grid connection completed on Italy's largest CPV plant

Soitec has completed construction and grid connection for the largest CPV solar power plant in Italy.

Located in the Belpasso municipality in Catania province in Sicily, the 1.17MWp facility is now ready to generate electricity for the local power grid, paving the way for other CPV plants to be developed in Italy, it is expected.

Equipped with 74 of Soitec's CPV trackers (each using 168 Concentrix CPV modules along with two central inverters of 500kW each to ensure reliable power distribution to the grid), local Italian construction companies provided engineering, procurement & construction (EPC) services for the solar power plant, while central-inverter technology was provided by global energy

management specialist Schneider Electric.

Fully owned and operated by Soitec, the utility-scale solar plant will supply electricity to Enel, Italy's largest power company. It will generate enough electricity to supply about 300 homes and should offset more than 125 tons of CO₂ emissions annually.

Operating at higher solar energy conversion efficiency than conventional solar PV panels, Soitec says that its systems maximize energy production throughout the day by incorporating multi-junction solar cells and dual-axis tracking systems that maintain an optimal angle to the sun, adding that CPV is the most attractive solar technology in high solar resource

regions around the globe.

"Completing this solar power plant marks a major milestone for Soitec in Italy while also demonstrating all of CPV's advantages in this part of the world," says Gaetan Borgers, executive VP of Soitec's Solar Energy division. "This project has allowed us to show that CPV's leading efficiency and ability to provide a steady, long-term energy supply without consuming excessive amounts of land and water make it exactly the right technology for Italy," he adds. "We are uniquely positioned with a cost-effective power generation technology at high levels of efficiency and committed to developing this market in Italy."

www.soitec.com

First Solar collaborating with Intermolecular to accelerate photovoltaic roadmap

First Solar Inc of Tempe, AZ, USA (the world's largest thin-film photovoltaic solar module maker) has announced a collaboration and licensing agreement with Intermolecular Inc of San Jose, CA, USA aimed at accelerating the efficiency roadmap for its cadmium telluride (CdTe) photovoltaic (PV) technology.

Under a newly signed collaborative development program, First Solar will leverage Intermolecular's High Productivity Combinatorial (HPC) platform in the development of its CdTe-based, thin film PV manufacturing technology. The program addresses new opportunities in certain critical materials and processes that may significantly influence the conversion efficiency of CdTe technology, reckons First Solar. Technical work is to be performed jointly

at Intermolecular's San Jose facility and in First Solar's R&D labs.

"Further improving our world-record CdTe conversion efficiencies remains a strong lever to reduce the cost of solar energy," says First Solar's chief technology officer Raffi Garabedian. "We evaluated Intermolecular's HPC platform and technical team in a trial collaboration, and this experience confirmed the suitability of the platform for our purposes," he adds.

In January, First Solar raised its record for CdTe PV module total area efficiency from 13.4% to 14.4%. In July 2011, the firm set a record for CdTe PV cell efficiency of 17.3%. Both records were confirmed by the US Department of Energy's National Renewable Energy Lab (NREL).

"Leveraging our HPC platform to accelerate the PV roadmap is central to our mission at Intermolecular," says Craig Hunter, Intermolecular's senior VP of global sales & marketing. The collaboration with First Solar represents "tremendous validation of that proposition, particularly given the extensive technical due diligence the First Solar team conducted prior to entering into this agreement," he adds.

Intermolecular says that its mission is to improve R&D efficiency in the semiconductor and clean-energy industries through collaborations that use its HPC platform, which allows R&D experimentation to be performed at speeds up to 100 times faster than traditional methods.

www.intermolecular.com

First solar panel installed on world's largest PV project

Less than two weeks after its official groundbreaking ceremony, MidAmerican Solar of Phoenix, AZ (a subsidiary of MidAmerican Renewables LLC) and cadmium telluride (CdTe) thin-film photovoltaic module maker First Solar Inc of Tempe, AZ have marked another milestone at Topaz Solar Farms in San Luis Obispo County, CA by installing the first solar panel on what is the largest solar project under construction in the world. When complete, the 550MW_{AC} project will include nearly 9 million solar panels.

The first solar panel was installed by Greg Abel, chairman, president & CEO of global energy services provider MidAmerican Energy Holdings Company of Des Moines, Iowa (the parent company of MidAmerican Renewables LLC), and Walter Scott Jr, who serves on the boards of directors for Berkshire Hathaway Inc and MidAmerican.

"It represents nearly five months of hard construction work put in by

a dedicated crew of craftspersons and on-site supervision, a large majority of whom live in the local area," says MidAmerican Solar's president Paul Caudill. "They are helping us achieve our goal of safely and reliably delivering energy to our customer, Pacific Gas and Electric Company [PG&E], all while adhering to our core value of respect for the environment," he adds.

On 3 May, MidAmerican Solar and First Solar held a ceremony at the project site to discuss the project's construction schedule, environmental values and community-centered plans for the future with local and state leaders and landowners.

The Topaz project will create about 400 construction jobs during its three-year construction period; will generate nearly \$417m in local economic impact (mostly during construction); and will provide California with renewable electricity. When complete, the project will

provide energy to power about 160,000 average California homes.

The Topaz project is owned by MidAmerican Solar and will be constructed, operated and maintained by First Solar. Construction began in late 2011 and is expected to be complete by early 2015. PG&E will purchase the electricity from the Topaz project under a 25-year power purchase agreement (PPA), helping California meet its mandate to generate 33% of its power from renewable sources by 2020. Electricity generated by the Topaz project will displace about 377,000 metric tons of carbon dioxide per year (equivalent to taking about 73,000 cars off the road).

"Solar projects such as Topaz will allow us to continue to deliver one of the cleanest energy portfolios in the nation to our customers and help the state meet its green energy goals," says John Conway, senior VP of energy supply for PG&E.

www.midamericanrenewablesllc.com
www.firstsolar.com

LA County approves module installation at AV Solar Ranch

The Los Angeles County Department of Public Works and First Solar have reached an agreement on the installation of solar modules at the Solar Ranch One photovoltaic (PV) power plant under construction in Antelope Valley (AVSR1).

The agreement enables First Solar to continue construction activities of the 230MW power plant that, when completed in 2013, will generate enough electricity to power 75,000 homes. Installation of the modules had been delayed while First Solar and Public Works worked to achieve agreement related to the module code certifications.

Dennis Hunter, deputy director of County Public Works, says the Department was responsible for ensuring that all applicable building codes were met by the project in order to protect the health and safety of county residents. "Following our discussions, we are now

confident in First Solar's ability to meet our health and safety requirements," he adds.

Work on the project began last August and is creating about 400 jobs during construction on the 2100 acre site. Los Angeles County supervisor Michael D. Antonovich said the AV Solar Ranch was one of the largest construction projects currently underway in the county and provided significant employment opportunities to the Antelope Valley community. "I am very pleased my office was able to facilitate resolution that helped towards finally resolving the permit issue involving the safety requirements of the AVSR1 project in the Antelope Valley," Antonovich comments. "This resolution will help those employees that have been furloughed to return to work as quickly as possible," he adds.

Jim Lamon, First Solar's senior VP

of engineering, procurement & construction and operations & maintenance, says the company greatly appreciates the collaboration and commitment from Public Works and 5th District staff to approve the module installation plan. "As the first utility-scale solar PV project in Los Angeles County, this was the county's first opportunity to apply its codes to a facility of this magnitude, which required significant time and effort for everyone involved," he adds. "After a very collaborative process, we are confident we have the county's support to keep the project moving to completion, and that this process has paved the way for future projects in the region, which has great potential for solar energy production."

First Solar expects to ramp up staffing for the project over the next several weeks.

www.firstsolar.com

First Solar grants National Park Trust \$48,000 for environmental education program in California and Nevada

First Solar has awarded the non-profit organization National Park Trust (NPT) of Rockville, MD, USA a \$48,000 grant that will expand its nationally recognized environmental education program 'Where's Buddy Bison Been?' to four schools in rural communities located near First Solar's utility-scale power plants in California and Nevada.

Now in its third year, the program has been recognized by US Department of the Interior Secretary Ken Salazar's Youth in the Great Outdoors office and First Lady Michelle Obama's Let's Move! Initiative and grew out of a need to encourage young people to visit America's parks. The program's goal is to cultivate the park stewards of tomorrow and to promote healthy living through increased activity and outdoor play. More than 30 schools across the country currently participate in the program.

"We welcome this support from First Solar that will engage underserved students from kindergarten through 8th grade in California and Nevada with their local parks, where they will learn about the unique history and science of the park, the fun outdoor recreation opportunities available, and their responsibility to protect and preserve these iconic places," says NPT board chair Bill Brownell.

Through the First Solar sponsorship, the Buddy Bison program will be launched this fall and will enable students to have hands-on experiences in the following California parks: Mojave National Preserve, Joshua Tree National Park and Antelope Valley California Poppy Reserve. The grant will also provide teachers with classroom toolkits that include educational resources about parks and other public lands and water, wildlife, sustainability, solar energy and healthy outdoor

recreation.

"Participating in programs like Buddy Bison is a key part of our community focus and a great way to further understanding of how renewable energy projects contribute to a sustainable world," comments Laura Abram, First Solar's director of Sustainability and Community Affairs.

First Solar associates supporting the development and construction of the AV Solar Ranch One, Desert Sunlight, Silver State South, and Stateline solar projects will work closely with NPT in the implementation of this year-long program by participating in classroom and park visits, as well as providing supplemental educational resources for the Buddy Bison classroom toolkits to help students understand the importance of sustainability and solar energy.

www.parktrust.org
www.firstsolar.com

Enbridge's Silver State North Nevada project completed

First Solar Inc of Tempe, AZ, USA, which manufactures thin-film photovoltaic modules based on cadmium telluride (CdTe) as well as providing engineering, procurement and construction (EPC) services, has announced completion of the 50MW_{AC} Silver State North Solar Project in Clark County, NV, which was acquired in March by energy distributor Enbridge Inc of Calgary, Alberta, Canada.

First Solar developed and constructed the facility, and will operate and maintain the project for Enbridge. It expects to recognize revenue from Silver State North in second-quarter 2012. The facility's output will be purchased by NV Energy under a 25-year power purchase agreement (PPA).

The plant has created more than 380 construction jobs, and will produce enough energy to power about 9000 Nevada homes, dis-

placing some 42,000 metric tonnes of CO₂ per year (equivalent to taking about 8000 cars off the road).

At a ceremony earlier in May near the community of Pimm, NV, US Secretary of the Interior Ken Salazar dedicated what is the first utility-scale solar facility built on public lands.

"As the first solar project on US public lands completed and ready to deliver energy to thousands of homes across Nevada, the Silver State North Solar Project is really at the forefront of our nation's clean energy economy," commented Salazar.

"I applaud the work and vision of many that have made this day a reality, including the Bureau of Land Management, the State of Nevada, First Solar and Enbridge," he added.

"Enbridge has invested almost \$3bn in wind, solar, geothermal, waste heat recovery, fuel cell and a host of other alternative energy technology projects that, together,

have the capacity to generate almost 1000MW of emissions-free energy," said Enbridge's president Al Monaco. "Along with our investment, Silver State North was made possible through the Nevada Government's Renewable Portfolio Standards Program, the Federal Government's incentive program under the 2009 American Recovery and Reinvestment Act, and the long-term contract that Enbridge has with NV Energy," he added.

"We are very pleased to bring on line the first utility-scale PV solar project on Bureau of Land Management (BLM) land in Nevada, which would not have been possible without support from the Department of the Interior and the hard work and dedication of county, state and BLM officials," said Frank De Rosa, First Solar's senior VP for business development, the Americas.

www.enbridge.com

First Solar to provide 159MW in Australia Solar Flagships Program

As part of Australia's Solar Flagships Program, First Solar is to design, construct and maintain two utility-scale solar power projects with annual capacity totaling 159MW_{AC} for AGL Energy Ltd (Australia's largest private owner and operator of renewable energy assets). AGL was selected in the program's solar PV category and will receive federal and state government funding to help it deliver on its commitment to greater investment in renewable electricity generation.

The Solar Flagships Program is one of a number of programs and market mechanisms providing what is claimed to be unprecedented support for the development of a broad range and scale of solar energy projects and technologies in Australia. The program is offering funding to support the construction and demonstration of large-scale, grid-connected solar (PV and thermal) power stations in Australia.

AGL will develop a 106MW_{AC} project in Nyngan and a 53MW_{AC} project in Broken Hill in New South Wales. First Solar will also maintain both projects for their first five years of commercial operation. Electricity produced will be sold under power purchase agreements (PPAs) to subsidiary AGL Hydro Partnership.

The projects will be supported by Australia's federal government and the state government of New South Wales under separate funding agreements.

"This is a significant step forward for the utility-scale solar industry in Australia — an order of magnitude increase in project size — and a testimony to the confidence our customers have in First Solar technology and its performance in some of the hottest and harshest conditions in the world," says CEO Jim Hughes. "These projects demonstrate First Solar's ability to apply its vertically integrated capabilities to deliver competitive,

comprehensive, utility-scale solar solutions in future sustainable markets," he adds. "We look forward to working with AGL on more projects like this in the future."

On an annual basis, the projects will produce enough electricity for at least 30,000 Australian homes (about 350GWh annually).

The projects should create about 450 jobs at peak construction, which should begin in 2014 (for commercial operation in 2015). AGL will be majority owner of the project.

"AGL is delighted to be working with the Commonwealth and New South Wales Governments, the people of Broken Hill and Nyngan, and our project partner First Solar," says managing director Michael Fraser. "These projects represent a tremendous opportunity for AGL and the broader solar industry to begin the roll-out of solar power as a meaningful source of generation supply in Australia."

www.agl.com.au

Calyxo raising annual capacity from 25MW to 85MW

Site targeted to be largest CdTe PV module production plant in Europe by end 2012

Cadmium telluride (CdTe)-based thin-film photovoltaic module maker Calyxo GmbH of Bitterfeld/Wolfen-Thalheim, Germany is investing in a second production line with annual capacity of 60MW. The firm has operated a 25MWp production line with more than 150 staff in Bitterfeld/Wolfen-Thalheim (known as Solar Valley in Saxony-Anhalt) since 2009, and will ramp total capacity to 85MW by the end of 2012.

Capital for the expansion will be provided by a bank loan and cash contributions from the technology inventor Solar Fields LLC of Toledo, OH, USA, which took over ownership of Calyxo in February 2011 from their former partner Q-Cells SE (which founded Calyxo in 2005). Solar Fields invented the technology while resident at the University of Toledo Incubation Center.

"Based on recent good results in production with modules of 80Wp and higher, we decided to increase the capacity of our low-cost atmospheric deposition process," says CEO Dr Florian Holzapfel.

"We are confident, that Calyxo will reach costs clearly below \$0.8/Wp by the end of 2012 and that CdTe production in the core of Europe will make sense for customers", he adds.

The production line will manufacture the firm's CX3 product (introduced in 2011), which was designed especially for hot and humid environments and is differentiated significantly from competing CdTe offerings, the firm claims, ensuring stable, long-term output even under extreme conditions. Under these conditions, due to the superior temperature behaviour of its modules, installation of the same rated capacity (in MWp or kWp) using Calyxo technology can provide up to 10% more energy than crystalline installations, claims the firm. "Recently we have published data showing the excellent performance and stability of the Calyxo product under hot and humid conditions based on our unique laminate design," says chief technical officer Michael Bauer.

The firm expects that these advances will lead to mid-term production costs of less than \$0.50/Wp, which may be the lowest in the world, it reckons. Costs this low allow for an LCOE (levelized cost of energy) forecast of less than \$0.10/kWh for electricity generated by Calyxo PV systems, the firm adds.

Based on current market information (and following the announcement in April that rival CdTe PV module maker First Solar Inc of Tempe, AZ, USA will close its manufacturing operations in Frankfurt (Oder), Germany in fourth-quarter 2012), Calyxo reckons that it will be the only meaningful CdTe producer in Europe from 2013 onwards, offering products to a wide range of customers (from small installers to large Megawatt installations). Besides the anticipated growth, Calyxo aims to maintain a complete set of services for all customers (simulation, project design, planning, installation and after-sales service).

www.calyxo.com

First Solar donates PV system as it joins KAUST's NEO testing & demonstration program in Saudi Arabia

First Solar Inc of Tempe, AZ, USA, which manufactures thin-film photovoltaic modules based on cadmium telluride (CdTe) as well as providing engineering, procurement & construction (EPC) services, has joined the New Energy Oasis (NEO) program of the King Abdullah University of Science and Technology (KAUST) in Thuwal (about 80km north of Jeddah), Saudi Arabia, which is a platform for introducing new and advanced technology to Saudi Arabia in the area of clean, alternative energy.

First Solar has donated a complete, integrated 3.2kWp PV system

including 40 solar modules, a ground-based mounting structure, an inverter, and weather-forecasting and performance-measuring equipment for the project.

KAUST and First Solar will work together to test the PV system under the extreme weather conditions of the Red Sea Coast, where summer daytime temperatures regularly reach 45°C (113°F).

"By providing platforms for testing and demonstrating

First Solar has donated a complete, integrated 3.2kWp PV system

PV technologies from leading companies such as First Solar, we can thoroughly test clean alternatives to traditional energy sources and ensure the best suitability to Saudi Arabian conditions," says Dr Raed Bkayrat, head of the KAUST Technology Application and Advancement Group.

"Supporting the NEO program enables us to showcase our capabilities in this important market, which has tremendous potential for sustainable solar power generation," First Solar executive vice president James Brown.

www.firstsolar.com

InGaAsSbN solar cells grown by MOCVD

A quinary layer has been developed for the 1eV component of GaAs-based multi-junction photovoltaics.

Researchers in the USA and Korea have grown heterojunction solar cells with lattice-matched indium gallium arsenide antimonide nitride (InGaAsSbN) base layers using metal-organic chemical vapor deposition (MOCVD) [T. W. Kim et al, Appl. Phys. Lett., vol100, p121120, 2012].

The aim of the work was to create layers with bandgaps around 1eV for incorporation into multi-junction solar cells grown on GaAs substrates. Multi-junction cells have a series of layers with different bandgaps responsive to different regions of the solar spectrum to increase efficiency.

The collaboration consisted of University of Wisconsin-Madison, The Aerospace Corporation, and MicroLink Devices Inc in the USA, and Ajou University in Korea.

Single-junction solar cells (Figure 1) were grown using metal-organic vapor phase epitaxy (MOVPE, also known as MOCVD). The antimony source was trimethyl-antimony (TMSb) rather than the more usual triethyl-antimony (TESb). Previous experimental work suggests that the use of TESb reduces the nitrogen incorporation in the InGaAsSbN structure. The resulting base regions were found to have compositions given by the formula $\text{In}_{0.065}\text{Ga}_{0.935}\text{As}_{0.9855}\text{Sb}_{0.0045}\text{N}_{0.01}$.

The collaboration's InGaAsSbN material was found to have a carbon background concentration ($9 \times 10^{18}/\text{cm}^3$) that was significantly higher than for InGaAsN grown under the same conditions. MOCVD growth of InGaAsN(Sb) tends to have 2–3 orders of magnitude greater background carbon. The carbon background could be reduced by using triethyl-gallium as opposed to the trimethyl-gallium used in the collaboration's structure.

The base region was also found to have a high hole concentration of $6.5 \times 10^{18}/\text{cm}^3$, preventing the use of a p-type/intrinsic/n-type (pin) diode structure. Instead, the researchers were forced to use a pn heterojunction.

The material was annealed in a two-step process to improve photoluminescence (PL) performance.

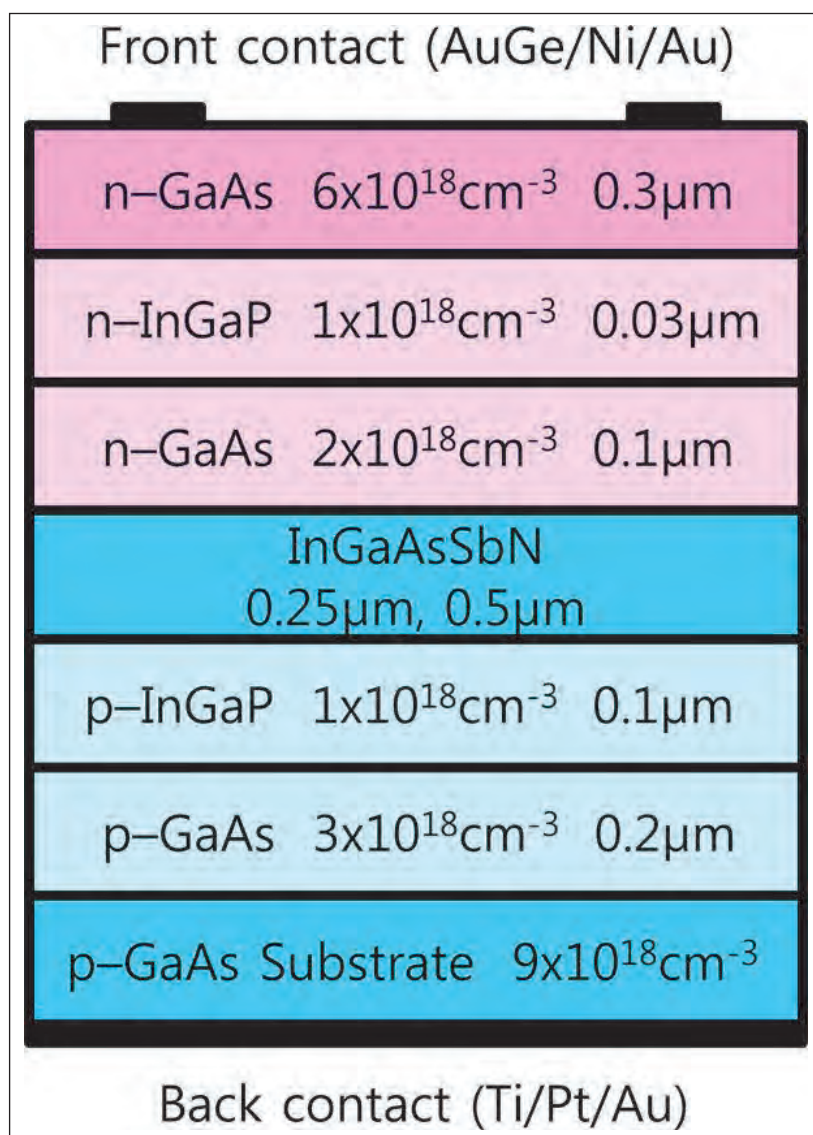


Figure 1. Schematic of InGaAsSbN heterojunction solar cell structure. Two different types of solar cells depend on thickness (sample A, 250nm; sample B, 500nm) of InGaAsSbN base layer.

Table 1. Characteristics of solar cells based on samples A (base layer 250nm) and B (500nm) under 1 sun AM1.5 direct illumination with entire spectrum range between 35 nm and 1200 nm.

Base layer	V_{oc}	J_{sc}	FF	Efficiency
250nm	0.69V	9.0mA/cm ²	76.3%	4.58%
500nm	0.59V	10.9mA/cm ²	67.0%	4.09%

The resulting PL spectral peak occurred at 1.04eV at room temperature.

Time-resolved PL was also performed to assess carrier lifetimes. The samples exhibited two decay components: a fast one of tens of picoseconds (78ps for A, 28ps for B), and a slow one of hundreds of picoseconds (576ps for A, 471ps for B). The source of the fast component is still under study but could be due to dislocations. The longer lifetime is consistent with domination by the Shockley–Read–Hall mechanism through trap states.

The 471–576ps lifetime range compares well with the 200ps achieved with InGaAsNSb structures grown using molecular beam epitaxy (MBE) and despite the MOVPE/MOCVD structure having higher background carbon content. MOCVD is preferred over MBE for low-cost manufacturing.

The estimated radiative and Auger recombination lifetimes are at the 5ns and 125ns levels, respectively. A long lifetime is desired to enable the photon-created carriers to be separated and to contribute to generating power. The combined lifetime is dominated by the shortest component — in this case the tens-to-hundreds of picoseconds mechanisms revealed in the time-resolved PL measurement.

Solar cells consisted of the epitaxial material with an active region of 0.2cm² between the n-type ohmic contact that was arranged in a 0.7μm metal grid with 250μm pitch. The p-type ohmic contact was applied to the back of the material. There was no anti-reflection coating to improve light absorption.

The characteristics of the device (Table 1) suggest that the thicker base layer device (sample B) has higher defect densities, as reflected in the lower open-circuit voltage (V_{oc}). On the positive side, sample B also has a higher short-circuit current (J_{sc}) due to the increased absorption length.

The researchers comment: “The MOVPE-grown InGaAsSbN solar cells reported here exhibit higher V_{oc} and FF (fill factor) values, compared with previously reported InGaAsN solar cells, although higher efficiencies (6.2%) and J_{sc} (26mA/cm²) have been reported for p-i-n homojunction InGaAsN solar cells.”

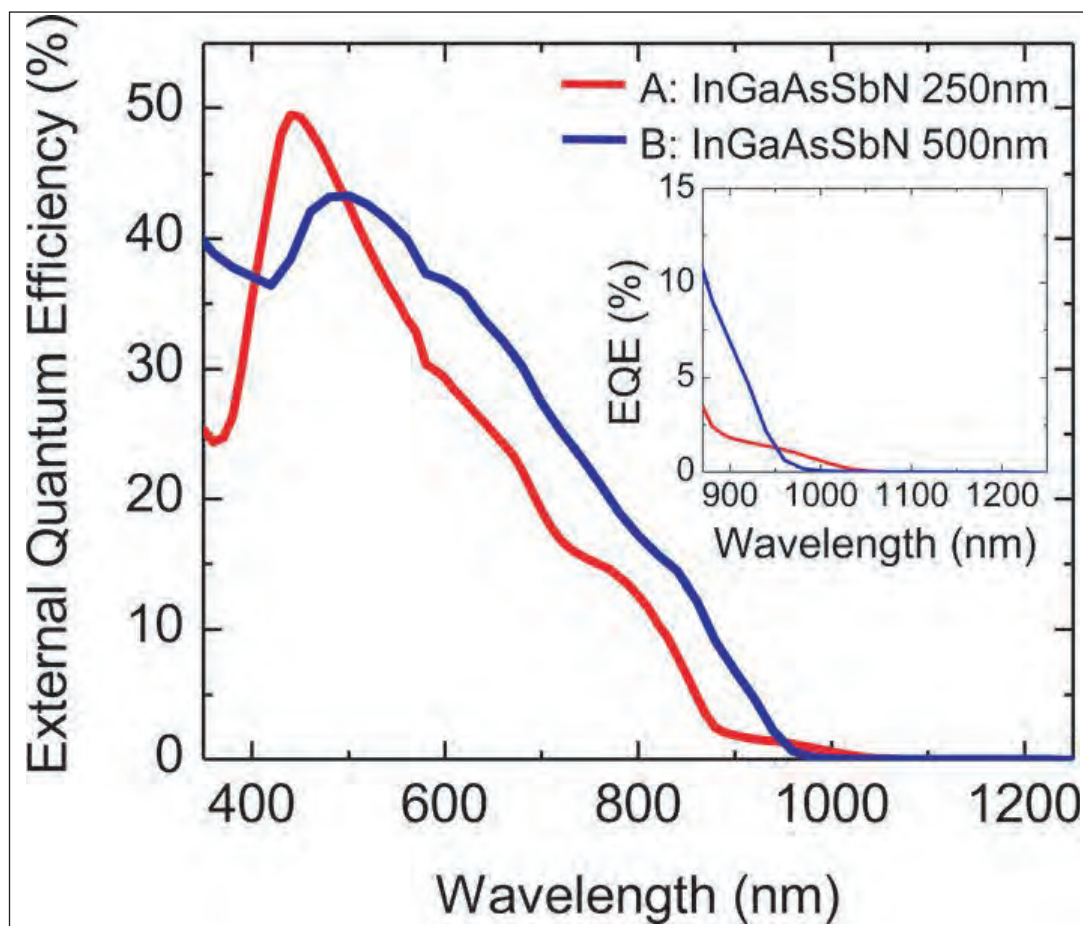


Figure 2. Measured spectral external quantum efficiencies of heterojunction InGaAsSbN solar cells with 250nm and 500nm base layers.

The external quantum efficiency (EQE) was also measured over the spectral range (Figure 2).

The researchers conclude: “Further optimization of the MOVPE growth conditions, including the use of alternate Sb sources, would be required to reduce the background carbon doping concentration in the InGaAsSbN base region and lead to further improvements in device performance”.

The work at UW-Madison was supported under the US Army Research Laboratory (ARL) and US National Science Foundation (NSF) Centers of Excellence for Materials Research and Innovation (CEMRI) finance. The work in Korea was supported by a Korea Institute of Energy Technology Evaluation and Planning Grant.

The Aerospace Corporation is a US Federally funded research & development center (FFRDC) that provides independent technical and scientific research, development, and advisory services to US national-security space programs. MicroLink Devices specializes in MOCVD growth of semiconductor structures for use in wireless communications devices, and the fabrication of advanced solar cells for space, unmanned aerial vehicle (UAV), and terrestrial use. ■

<http://link.aip.org/link/doi/10.1063/1.3693160>

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Author: Mike Cooke

First strained gallium nitride quantum well transistor with AlN barriers

Researchers at the University of Notre Dame have demonstrated the opportunities for scaling enhancement-mode/normally-off devices.

University of Notre Dame has realized the first strained gallium nitride (GaN) quantum well (QW) transistors with unstrained aluminium nitride (AlN) barriers [Guowang Li et al, IEEE Electron Device Letters, published online 12 March 2012].

One hope of using ultra-thin-body (UTB) structures such as QWs is to avoid the many short-channel effects that degrade transistor performance when scaled to smaller dimensions. Silicon devices have used amorphous dielectrics such as silicon dioxide to create UTB layers of silicon on insulator. However,

these materials are thermally insulating. Using epitaxial AlN as electrical insulator for GaN channels does not have this drawback since its thermal conductivity is high at 3.4W/cm-K. By contrast, the thermal conductivity of silicon dioxide is reduced from this by two orders of magnitude, at around 1.4W/m-K (0.014W/cm-K).

The nitride heterostructures (Figure 1) were produced using molecular beam epitaxy (MBE) on 1µm-thick semi-insulating metal-polar AlN templates on sapphire substrates. A further 210nm of AlN was grown as a

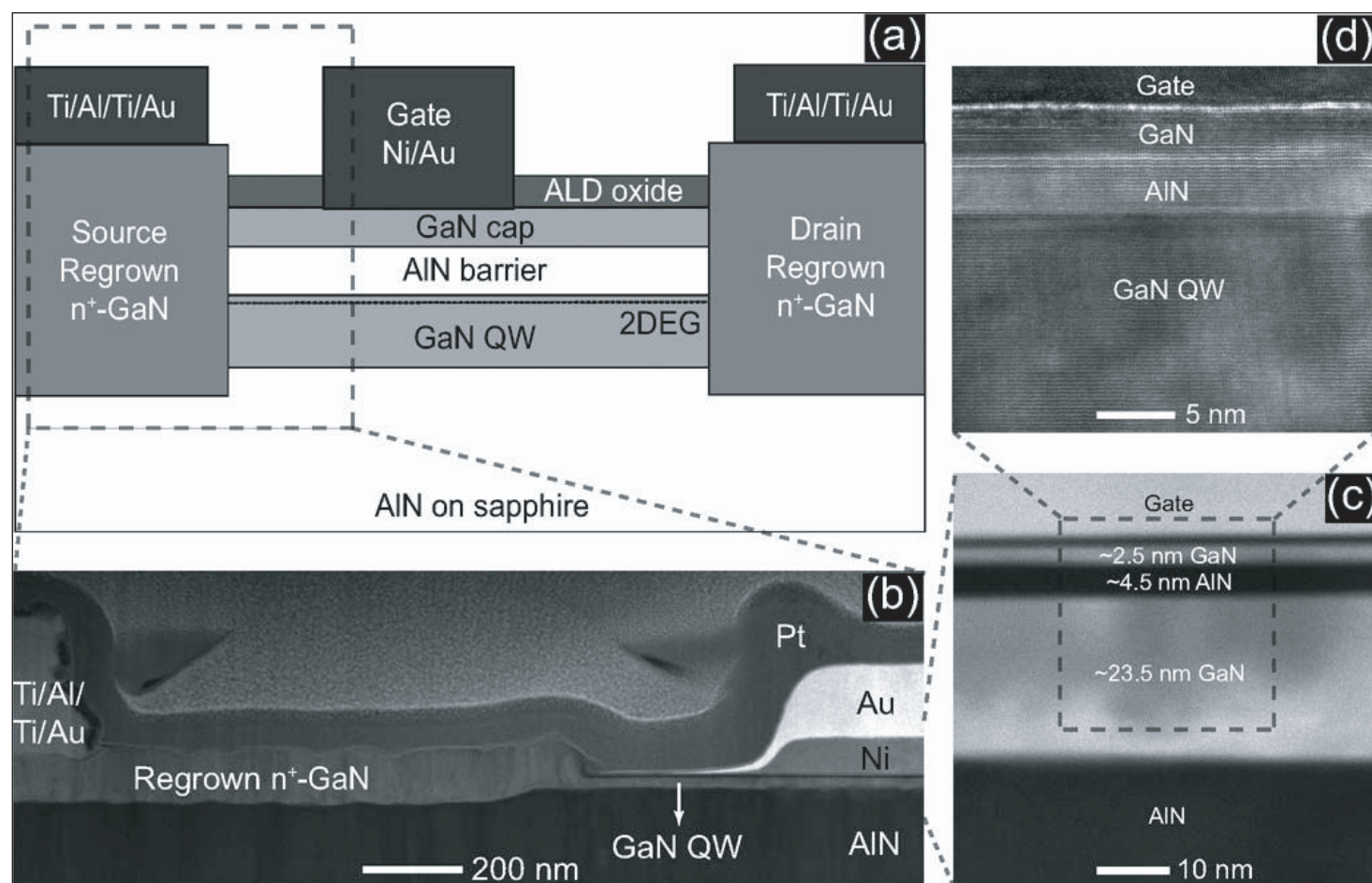


Figure 1. (a) Schematic of device structures (not to scale). (b) Z-contrast STEM image of gate-to-source regions, showing re-grown GaN connected to the GaN QW channel. (c) Z-contrast STEM image of active layers under the gate, resolving the sharp interfaces between binary III nitrides. (d) HRTEM image of top AlN/GaN QW interface at the 2DEG channel region.

buffer before the 23nm GaN quantum well layer. The final AlN barrier and GaN cap were 4.5nm and 2.5nm, respectively. The cap layer was designed in to protect the AlN surface from oxidation.

Hall mobility measurements on the structure give a rather low figure of $280\text{cm}^2/\text{V}\cdot\text{s}$. However, the researchers expect to be able to improve this by increasing the growth temperature and/or changing the growth rate.

The two-dimensional electron gas (2DEG) density of $1.77 \times 10^{13}/\text{cm}^2$ is lower than that usually achieved with 4.5nm/2.5nm AlN/GaN top barriers. The researchers say that this is due to the GaN layer on AlN being under compressive strain, which results in a piezoelectric polarization that opposes the spontaneous polarization. The negative polarization charge at the bottom GaN/AlN interface may also deplete the 2DEG.

The AlN back-barrier also has enhanced thermal dissipation compared with InGaN or AlGaIn, which are more often used in the nitride semiconductor heterostructures.

The source and drain regions of the transistor were formed by etching and re-growing 120nm GaN regions with heavy silicon doping to give high n-type conduction. Silicon dioxide was used as an etch mask. The re-growth was performed using MBE. Surface passivation was achieved with atomic layer deposition (ALD) of 1nm of aluminium oxide and 6nm of hafnium dioxide.

The gate was $2.1\mu\text{m}$ in length and $49.5\mu\text{m}$ wide. The gate-source and gate-drain separations were $0.4\mu\text{m}$ and $6.9\mu\text{m}$, respectively.

At 10V drain bias, the device pinched off at -2.4V with a drain current density of less than $1\text{mA}/\text{mm}$ (Figure 2). The saturated drain current at $+3\text{V}$ was $0.68\text{A}/\text{mm}$. The peak transconductance was $160\text{mS}/\text{mm}$. The drain-induced barrier lowering (DIBL) of $40\text{mV}/\text{V}$ (exhibiting a 'long-channel' behavior) was extracted from drain biases of 0.5V and 10V .

At a forward gate potential of 15V and a drain bias of 10V , the buffer leakage was $0.5\text{mA}/\text{mm}$ and the sub-threshold slope was $400\text{mV}/\text{dec}$. The poor subthreshold behavior was possibly due to unintended dopants and traps in non-optimal buffer layers.

The researchers comment: "Although the device performance lags current state-of-the-art GaN HEMTs, it is important to note that this is the first realization of a novel device structure that offers substantial opportunities for scaling. By scaling down the thicknesses of the GaN QW and/or top AlN barrier, an enhancement-mode operation can be a natural outcome in a self-

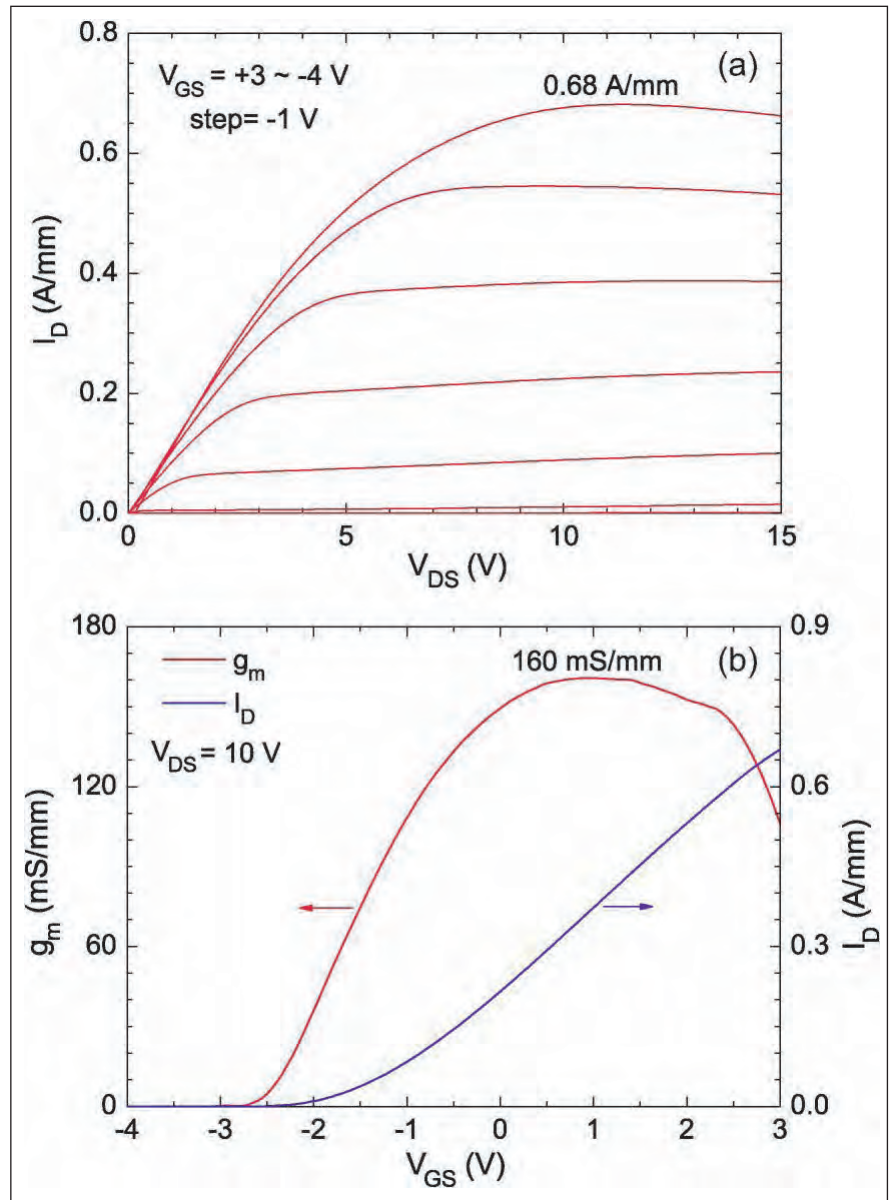


Figure 2. (a) Output characteristics of GaN QW device with gate length of $2.1\mu\text{m}$. (b) Transfer characteristics at 10V drain bias.

aligned device."

The researchers also believe that different QW channels with lower (InGaN) or higher (AlGaIn) bandgaps would allow scaling to high speed or high breakdown voltage, respectively. They also see the full benefit of the structure being achieved with the use of bulk AlN substrates rather than the demonstrated AlN template layers on sapphire.

The research was supported by the US Defense Advanced Research Projects Agency (DARPA) NEXT program ([www.darpa.mil/Our_Work/MTO/Programs/Nitride_Electronic_NeXt-Generation_Technology_\(NEXT\).aspx](http://www.darpa.mil/Our_Work/MTO/Programs/Nitride_Electronic_NeXt-Generation_Technology_(NEXT).aspx)), the US Air Force Office of Scientific Research (AFOSR) and the US Office of Naval Research (ONR) DATE program. ■

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Author: Mike Cooke

Improving InGaN channel for HEMT power amp/switching

Record mobility of 1290cm²/V-s achieved for In_{0.05}Ga_{0.95}N channel.

Epiwafer foundry Kopin Corp of Taunton, MA, USA and University of Notre Dame (UND) have developed record high-mobility indium gallium nitride (InGaN) channel layers in high-electron-mobility transistor (HEMT)-type epitaxial structures [O. Laboutin et al, Appl. Phys. Lett., vol100, p121909, 2012]. Kopin sees potential for improving the performance of next-generation power amplifiers and power switching converters.

The researchers are seeking ways to produce ultra-high-frequency operation through reduced-scale components. In particular, they want to reduce gate lengths and barrier thickness without short-channel effects that degrade performance.

Presently, nitride semiconductor HEMTs tend to use GaN channel layers but, as transistor dimensions reduce, such channels suffer from reduced electron densities due to the reduced polarization effect from thinner barriers.

Improvements have been seen from the use of aluminium indium nitride (AlInN) as opposed to aluminium gallium nitride (AlGaIn) barriers. Also, the use of a back-barrier underneath the channel can better confine the conduction electrons, boosting short-channel performance. However, producing high-quality structures with appropriate polarization fields to achieve this is a challenge.

An alternative is to use a narrower-bandgap material between the barrier and buffer that would naturally confine electrons. InGaN is such a narrow-bandgap material. However, InGaN is notoriously difficult to grow with smooth interfaces and uniform alloy composition.

The Kopin/UND HEMT epitaxial structures (Table 1) were produced in a close-coupled showerhead metal-organic chemical vapor deposition (MOCVD) reactor operating at low pressure on sapphire and silicon carbide (SiC). The optimized AlInGaN/AlN composite barrier was reported in the last year by researchers from Kopin, UND, and University of Florida.

During development of the new InGaN channel structure, the effect of increasing the growth temperature was studied. For an InGaN layer with 6% In molar fraction, an increasing trimethyl-indium flux of 1.5 up to 25µmol/min was needed as the growth tem-

perature increased from 710°C to 790°C. At the same time, the trimethyl-gallium flux was decreased from 18µmol/min to 6µmol/min, reducing the growth rate from 0.08nm/s to 0.03nm/s.

It was found that higher-temperature, lower-growth-rate deposition resulted in improved characteristics. In particular, root-mean-square surface roughness decreased from 0.8nm for 710°C growth to 0.5nm at 790°C. Such a reduction in roughness should lead to reduced interface scattering and hence improved mobility.

Photoluminescence experiments also suggest improved uniformity of the InGaN alloy. In particular, the InGaN peak is reduced in the lower-growth-rate, high-temperature sample. A large InGaN peak can be indicative of carrier localization at non-uniformities in alloy composition.

Using the low-growth-rate and high-temperature deposition process, full HEMT structures with InGaN channels with varying In composition in the range 0–10% were produced on silicon carbide and characterized (Figure 1). The mobility varied from 1690cm²/V-s for pure GaN down to 1070cm²/V-s for 10%-In InGaN channels. Such a decreasing trend is also observed in structures with more traditional AlGaIn barriers.

The researchers point out that despite the increased sheet charge (~2x10¹³/cm²), which is often associated with reduced mobility, “the electron mobility was higher than that in the AlGaIn structures within the entire In_xGa_{1-x}N compositional range.”

For the 5%-In sample, the record 1290cm²/V-s value produced an average sheet resistance value of 240Ω/square (~30% lower than the previous best published result for InGaN channels) with standard deviation of 4.2% across the 3-inch sample.

The work at Kopin was partially supported by the US Missile Defense Agency (MDA) via Small-Business Innovation Research (SBIR) funding. ■

Table 1. HEMT structure explored by Kopin/UND research.

AlInGaN/AlN	Composite barrier	11nm	750°C
InGaN	Channel	5–9nm	710–790°C
GaN	Buffer	1.9µm	
GaN or AlN	Nucleation		

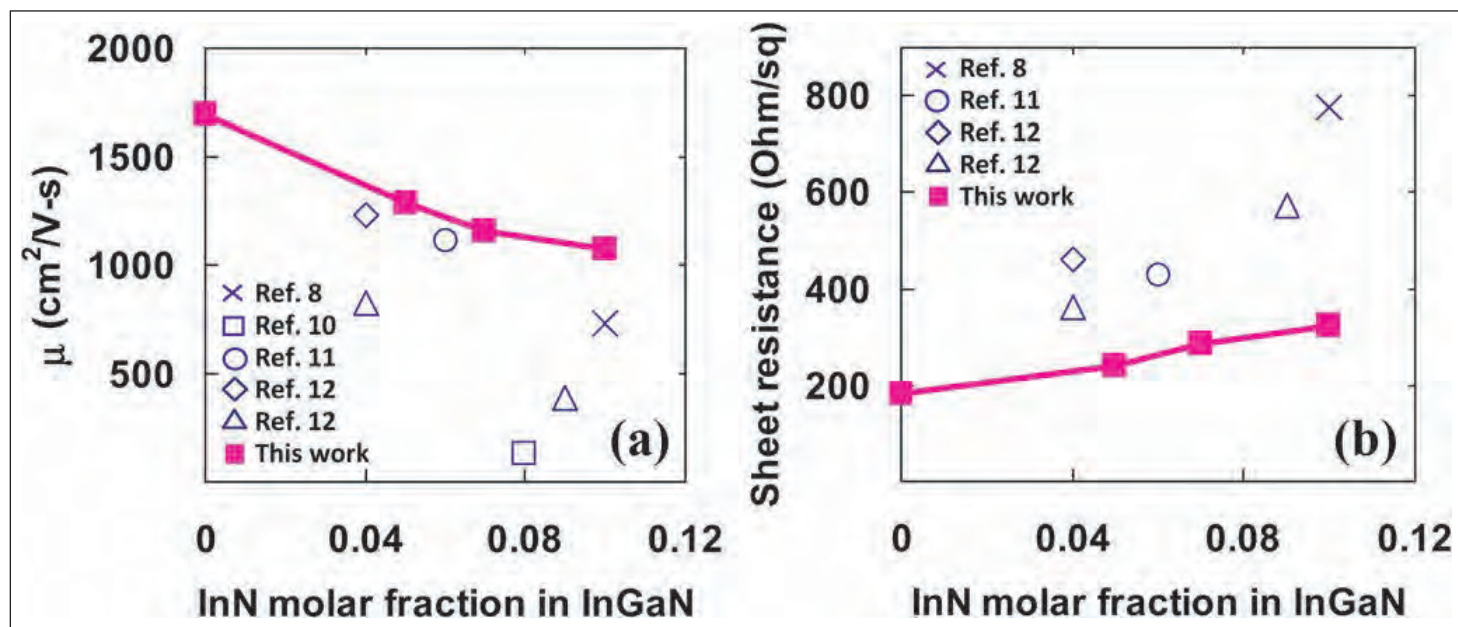


Figure 1. Electron mobility and sheet resistance as functions of $\text{In}_x\text{Ga}_{1-x}\text{N}$ channel composition for full HEMT structures. Further data points from literature with AlGaIn and InGaIn barriers and channel carrier concentrations include, respectively, $\text{Al}_{0.25}\text{Ga}_{0.75}\text{N}$ and $1.1 \times 10^{13}/\text{cm}^2$ (Ref. 8), $\text{Al}_{0.33}\text{Ga}_{0.67}\text{N}$ and $1.5 \times 10^{13}/\text{cm}^2$ (Ref. 10), $\text{Al}_{0.3}\text{Ga}_{0.7}\text{N}$ and $1.3 \times 10^{13}/\text{cm}^2$ (Ref. 11), for $\text{Al}_{0.24}\text{In}_{0.01}\text{Ga}_{0.75}\text{N}$ and $1.1 \times 10^{13}/\text{cm}^2$ (Ref. 12), $\text{Al}_{0.83}\text{In}_{0.17}\text{N}$ and $2.1\text{--}2.8 \times 10^{13}/\text{cm}^2$ (Ref. 12).

<http://link.aip.org/link/doi/10.1063/1.3697415>

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Polarization matching as a route to nitride transistor enhancement

Germany's RWTH Aachen and Fraunhofer-IAF have presented the first insulated-gate devices with an AlInGaN barrier.

Germany's RWTH Aachen University and Fraunhofer IAF (Institute for Applied Solid State Physics) have applied nitride-semiconductor polarization engineering to create enhancement-mode (normally-off) field-effect transistors [Herwig Hahn et al, Semicond. Sci. Technol., vol27, p055004, 2012].

There has been much recent research in shifting the thresholds of nitride transistors from negative to positive values, giving enhancement-mode rather than depletion-mode (normally-on at zero gate potential). Advantages of normally-off devices include lower power consumption and fail-safe behavior. The fail-safe characteristic is especially desirable for the high-power/voltage applications that are among the attractions of wide-bandgap nitride semiconductor devices.

RWTH and deposition equipment manufacturer Aixtron have recently developed quaternary aluminum indium gallium nitride (AlInGaN) barrier layers that can be polarization-matched to GaN buffers. This can allow normally-off conduction while maintaining a suitable conduction band offset, if the polarization-matched barrier is compressively strained. The compressive strain requires rather high indium contents. Previous work with AlInGaN in transistor structures contained only around 2% In.

The RWTH/Fraunhofer devices are the first compressively strained, nearly polarization-matched AlInGaN/GaN metal insulator semiconductor heterostructure field-effect transistors (MISHFETs) to be presented. The indium content of these devices was around 20%.

The epitaxial material was grown on c-plane sapphire using an Aixtron metal-organic chemical vapor deposition (MOCVD) reactor. A thin AlN spacer layer separated the 2µm GaN buffer from the compressively strained AlInGaN barrier. The barrier was grown at 716°C using

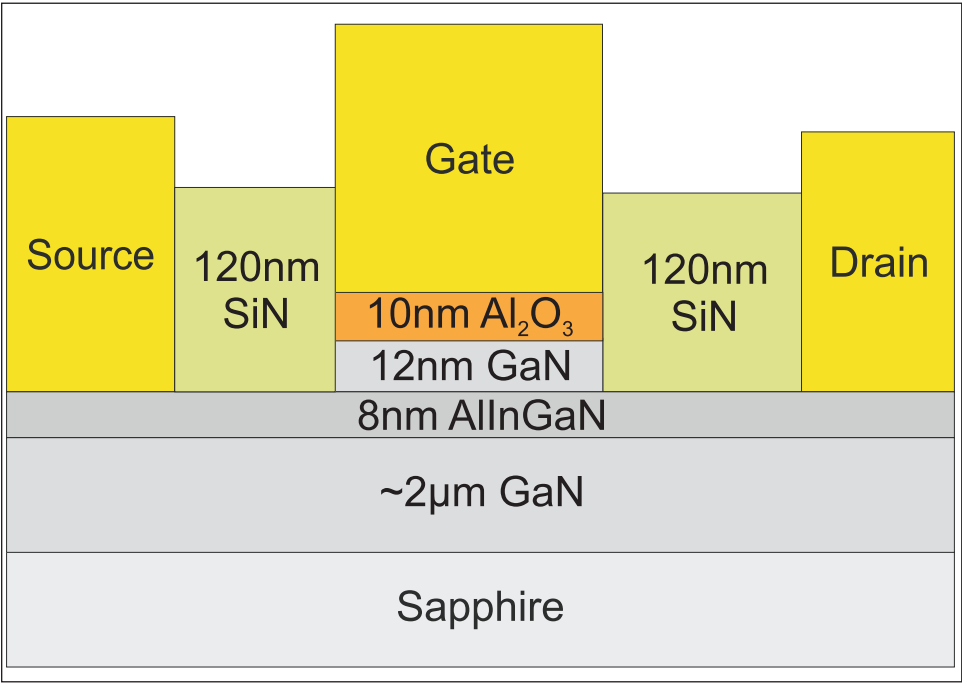


Figure 1. Structure of the gate-first processed samples.

continuous (sample A) and pulsed (sample B) methods. The pulsing of the Ga precursor resulted in enhanced indium incorporation. The barrier compositions were Al_{0.48}In_{0.18}Ga_{0.34}N and Al_{0.57}In_{0.23}Ga_{0.20}N for samples A and B, respectively.

To construct HEMTs (Figure 1), the epitaxial material was covered in aluminum oxide (Al₂O₃) before gate metallization. The Al₂O₃ was deposited using atomic layer (ALD) techniques. The gate metal was nickel. The gate was then used as a hard mask to etch down

Table 1. Data from calculations, van der Pauw, Hall and transmission-line model (TLM) measurements.		
Data	Sample A	Sample B
Contact resistance	~5Ω-mm	~5Ω-mm
Sheet carrier concentration	6x10 ¹² /cm ²	1.2x10 ¹² /cm ²
Sheet carrier mobility	450cm ² /V-s	215cm ² /V-s
Sheet resistance	2.2kΩ/sq	22kΩ/sq
Barrier/buffer polarization charge difference	0.0041C/m ²	0.0014C/m ²

to the AlInGaN layer away from the gate region. Ohmic titanium/aluminum/titanium/gold was used to provide source-drain contacts. Silicon nitride was then applied as passivation.

The device geometry consisted of 2x50 μm -wide, 1 μm -long gates. The gate-source distance was 1.5 μm and the gate-drain distance was 2.5 μm .

The drain currents at 4V gate potential and 10V drain bias were 115mA/mm and 27mA/mm for HEMTs based on samples A and B, respectively. The low current in HEMT B is attributed to high sheet resistance in the source-drain access regions (Table 1). The maximum trans-conductance values were 40mS/mm for sample A HEMTs and 10mS/mm for sample B.

The threshold voltages were positive in both cases, giving enhancement-mode, normally-off behavior. The HEMT A threshold was 0.56V, lower than that for sample B-based devices at 0.96V. The higher threshold from sample B was attributed to a reduction in polarization charge density from the polarization field between the buffer and barrier layers. A lower charge reduces the carrier density in the two-dimensional electron gas (2DEG) channel. This also increases the source-drain access sheet resistance.

The researchers comment: "Better results can be expected with optimizations concerning not only the mobility in the 2DEG, but also the improvement of the contact resistance".

The presence of the Al₂O₃ gate insulation reduces gate leakage currents (compared with normal Schottky-gate devices) at 4V gate potential to less than 1 $\mu\text{A}/\text{mm}$ for HEMT A and less than 100nA/mm for HEMT B.

The three-terminal off-state (0V gate) breakdown was 105V for HEMT A. This increased to 405V for a device with a gate-drain distance of 20 μm . The high values are attributed to the gate insulator and high buffer quality. Sample B devices had breakdowns up to 490V. "The values shown here are valid for devices without a field-plate. The addition of a field-plate and thus the reduction of the peak electric field would enhance the breakdown voltage even further," the researchers say.

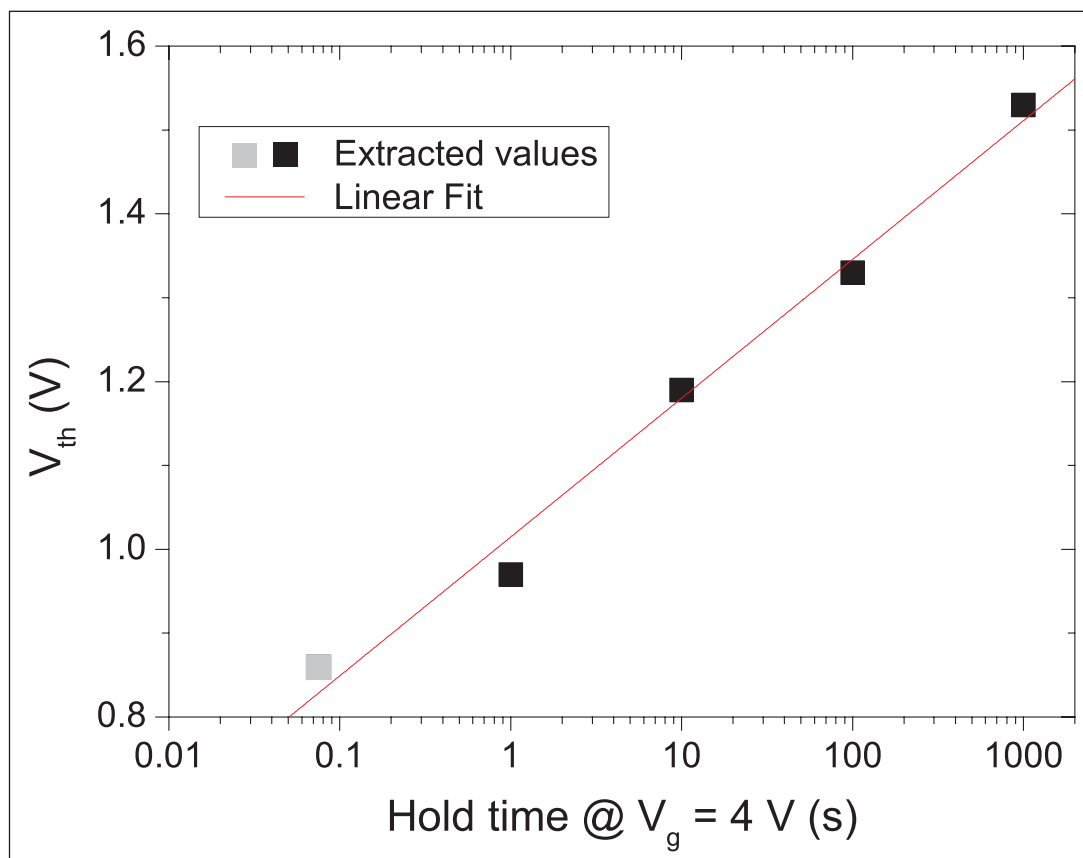


Figure 2. Dependence of threshold voltage on hold time, when devices are held at 4V gate potential. The 75ms time is estimated and indicated as a grey dot.

The stability of the threshold voltage was also studied for the better performance devices based on sample A. Sweeps in gate voltage in the negative (+4V to -8V) and positive (-8V to +4V) showed a small amount of difference in the subthreshold region that was more visible in the transconductance as opposed to the drain current.

Further tests involved applying stresses (+4V or -8V) to the gate for extended periods of time (up to 1000 seconds). The +4V, 1000s stress shifted the threshold up to +1.53V, while the -8V, 1000s stress shifted the threshold down to +0.35V. Despite the shift down, the threshold was still in the positive enhancement range.

The researchers suggest that the positive gate bias drives electrons into acceptor-like traps at the Al₂O₃ interface, depleting the 2DEG channel under the gate. The negative bias, by contrast, de-traps electrons in these states. A logarithmic dependence of the threshold shift on hold time (Figure 2) was seen by the researchers as being consistent with a tunneling process.

Before the devices become competitive, the researchers say that they will need to optimize the ohmic contacts and improve the 2DEG mobility. "Nonetheless, as quaternary nitride structures can be grown on large-diameter silicon substrates, this technology could pave a way for enhancement-mode high-power high-voltage GaN-based power switches," they conclude. ■

<http://iopscience.iop.org/0268-1242/27/5/055004/>

Author: Mike Cooke

More polarization engineering enhancement in nitride semiconductor HFETs

Researchers in Germany report using a InAlGaN barrier layer to reduce interface polarization charge and shift threshold voltage into the positive, enhancement region for normally-off operation.

German researchers have reported further results of their polarization engineering for nitride semiconductor heterostructure field-effect transistors (HFETs) [N Ketteniss et al, Semicond. Sci. Technol., vol27, p055012, 2012]. The aim of the work is to create HFETs with positive threshold voltages, therefore allowing normally-off (enhancement-mode) operation.

Normally-off devices are especially desired in power applications for fail-safety and for lower power consumption. Without special processing, such as gate recessing or fluorine plasma treatment, nitride semiconductor HFETs usually operate in 'depletion-mode' with normally-on behavior, where a current flows at zero gate potential.

In early April, RWTH Aachen University and Fraunhofer IAF (Institute for Applied Solid State Physics) reported on the use of quaternary indium aluminum gallium nitride (InAlGaN) as the barrier material for HFETs that allows lower interface polarization charge to be achieved with an underlying GaN channel/buffer layer (www.semiconductor-today.com/news_items/2012/APRIL/RWTH_100412.html). The lower charge shifted the threshold to the enhancement region.

There is also a further advantage in having reduced interface charge when producing metal-insulator-semiconductor HFETs (MISHFETs) to reduce gate leakage currents. When insulator is applied to the HFET structure, it tends to shift the threshold in a negative direction. The effect is proportional to the interface polarization charge.

The new report also involved RWTH Aachen University, along with Forschungszentrum Jülich GmbH and Jülich Aachen Research Alliance (JARA-FIT).

The epitaxial material was produced on sapphire in an Aixtron AIX 200/4 RF-S metal-organic chemical vapor deposition (MOCVD) system. An AlN nucleation layer was deposited at 780°C. The buffer consisted of 300nm AlN and 2.5µm GaN, grown at 1250°C and 1070°C, respectively. The further barrier layers (Figure 1) of AlN and InAlGaN were grown at 805°C.

Rutherford backscattering spectroscopy study of a thicker barrier than used for the transistors gave the composition of the quaternary InAlGaN barrier as 2% In, 16% Al, and 82% Ga. The researchers estimate that the residual interface charge density was 0.0075C/m², the bandgap of the barrier was 3.66eV, and that the conduction band offset was 0.24eV from

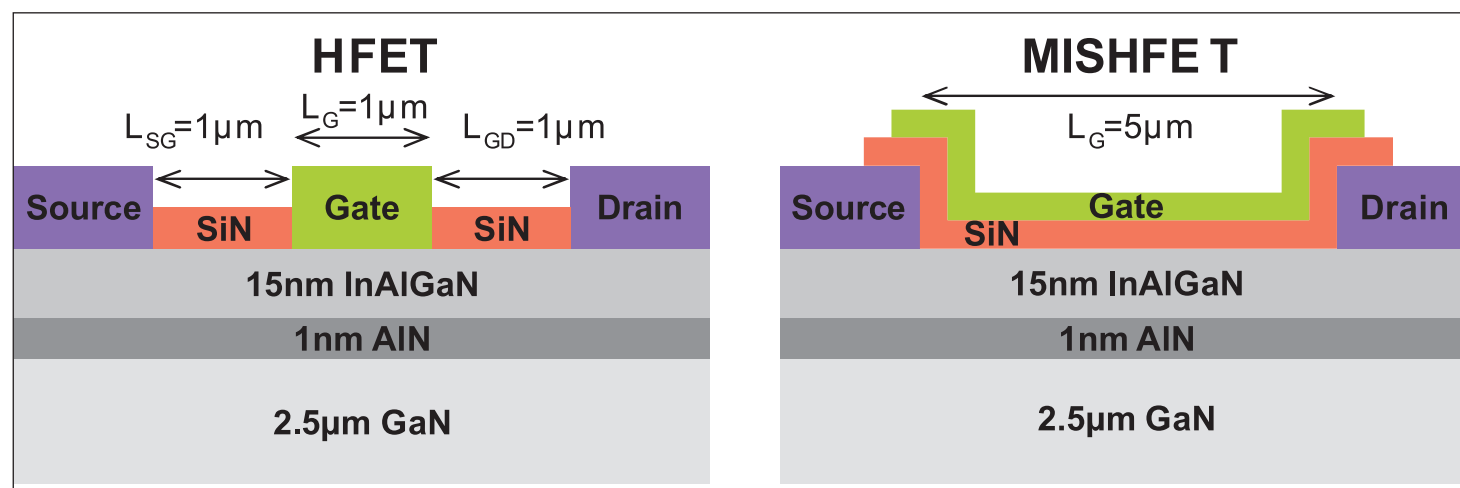


Figure 1. Schematic cross section of the investigated devices. Left: SiN passivation layer has a thickness of 120nm. Right: SiN gate insulator is 20nm thick.

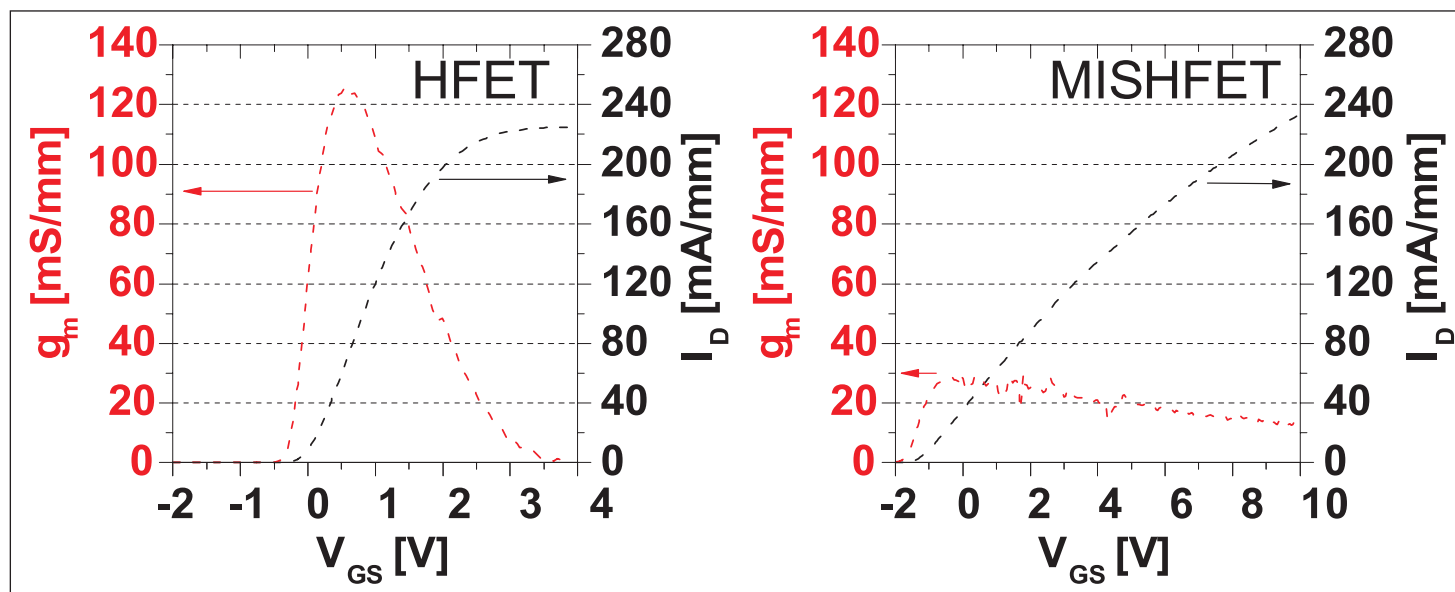


Figure 2. Typical transfer characteristics measured at 4V drain bias: left, for the HFET device; right, for the MISHFET device.

that of the GaN buffer layer.

This compares with a ternary AlGaN barrier with 10% Al that gives a structure with a residual interface charge density of 0.0063C/m^2 but a lower conduction band offset of 0.19eV . The researchers comment: "Keeping the conduction band offset reasonably high while reducing the interface charge σ_{pol} can only be realized in the quaternary material system. Hence, the In content in our devices helps us to reduce σ_{pol} while maintaining a specific bandgap."

The epitaxial material was processed into both HFETs and MISHFETs. Mesa isolation was realized using chlorine-based plasma etch. Ohmic source-drain contacts were 825°C -annealed titanium/aluminum/nickel/gold. Silicon nitride (SiN) was used as 120nm passivation for the HFET and 20nm gate insulation for the MISHFET. The gate metals were nickel/gold.

The HFET had a gate length of $1\mu\text{m}$ with $3\mu\text{m}$ source-drain separation. The MISHFET gate overlapped the source-drain contacts that were separated by $5\mu\text{m}$. The MISHFET gate overlap was designed to ensure carrier accumulation over the whole channel length and thus to reduce the on-resistance.

The transistors were tested at 4V drain bias (Figure 2). For the HFET, the drain current was 205mA/mm at 2V gate potential. The gate current was as low as

0.15mA/mm . The threshold voltage of the device was 0.05V , giving normally-off behavior. The peak transconductance was 130mS/mm .

The researchers see these as impressive results 'out of the box', commenting in addition that "A more sophisticated device structure and optimized barrier design will easily improve the device characteristics further and also provide a more positive threshold voltage."

The MISHFET had a negative threshold voltage shift of -1.3V , compared with the HFET. This is attributed to the heterostructure still having some interface charge. However, this shift is small compared with AlGaN/GaN MISHFETs with 8nm of SiN insulator that have shifts of more than -3V .

The researchers comment: "Choosing a barrier layer composition which is even closer to the polarization-matched case would prevent such a shift and enable even higher threshold voltages for both the HFET and the MISHFET concept."

Since the MISHFET has a longer gate of $5\mu\text{m}$, the transconductance is lower. Despite this, the device does achieve drain currents beyond 200mA/mm with less than 0.5mA/mm gate leakage at 7.6V gate potential.

The researchers expect improvements from using atomic layer deposited (ALD) aluminium oxide in place of the SiN gate insulation. They also believe that optimization of the MISHFET design is needed, since the metal-insulator-metal structure over the ohmic source-drain contacts is not ideal. Possibly, the polarization engineering technology with insulated gate could benefit from being implemented in a vertical device such as the current-aperture vertical electron transistor (CAVET) structure. ■

<http://iopscience.iop.org/0268-1242/27/5/055012>

Author: Mike Cooke

A more sophisticated device structure and optimized barrier design will easily improve the device characteristics further and also provide a more positive threshold voltage. The polarization engineering technology with insulated gate could benefit from being implemented in a vertical device

Crack-free nitride semi distributed Bragg reflectors

Peak reflectivity of 97.5% achieved at 400nm for 30-pair AlN/GaN distributed Bragg reflector on AlN templates.

Meijo University and Nagoya University in Japan have grown crack-free nitride semiconductor distributed Bragg reflectors (DBRs) on aluminium nitride (AlN) templates [Kouta Yagi, et al, Jpn. J. Appl. Phys., vol51, p051001, 2012]. This is the first use of AlN templates for nitride DBRs.

Although continuous-wave blue nitride semiconductor vertical-cavity surface-emitting lasers (VCSELs) have finally been produced in the past couple of years, these were based on oxide dielectric DBRs. However, in other material systems advantages have been found in having DBRs constructed from active semiconductor material.

A further attraction of aluminum nitride/gallium nitride (AlN/GaN) semiconductor DBRs would be improved thermal conductivity over typical dielectric structures. However, AlN/GaN DBRs grown on GaN templates tend to crack. The cracks result from the large 2.4% lattice mismatch between AlN and GaN and a large difference in thermal expansion coefficients.

Expected applications for blue VCSELs include white light sources, printers, and displays.

The Meijo/Nagoya DBRs were grown on AlN and GaN templates on sapphire substrates using low-pressure metal-organic chemical vapor deposition (MOCVD). The 1 μ m AlN template layer was grown directly on sapphire at 1250°C under a pressure of 26Torr. The comparison 2 μ m-thick GaN templates were produced using a low-temperature buffer grown at 550°C, followed by high-temperature GaN grown at 1070°C.

The DBR growth on the two types of template was performed simultaneously. The growth conditions were 1040°C temperature and 50Torr pressure. The DBRs were designed with a violet center wavelength of 400nm. The AlN/GaN pairs were optically a quarter-wavelength thick. Structures with 30 and 10 AlN/GaN pairs were produced for comparison. The structures began with quarter wavelength of AlN and ended with quarter wavelength of GaN.

A series of analyses of the structure were carried out using electron microscopy (Figure 1) and x-ray diffraction (XRD). The researchers estimated the thickness of

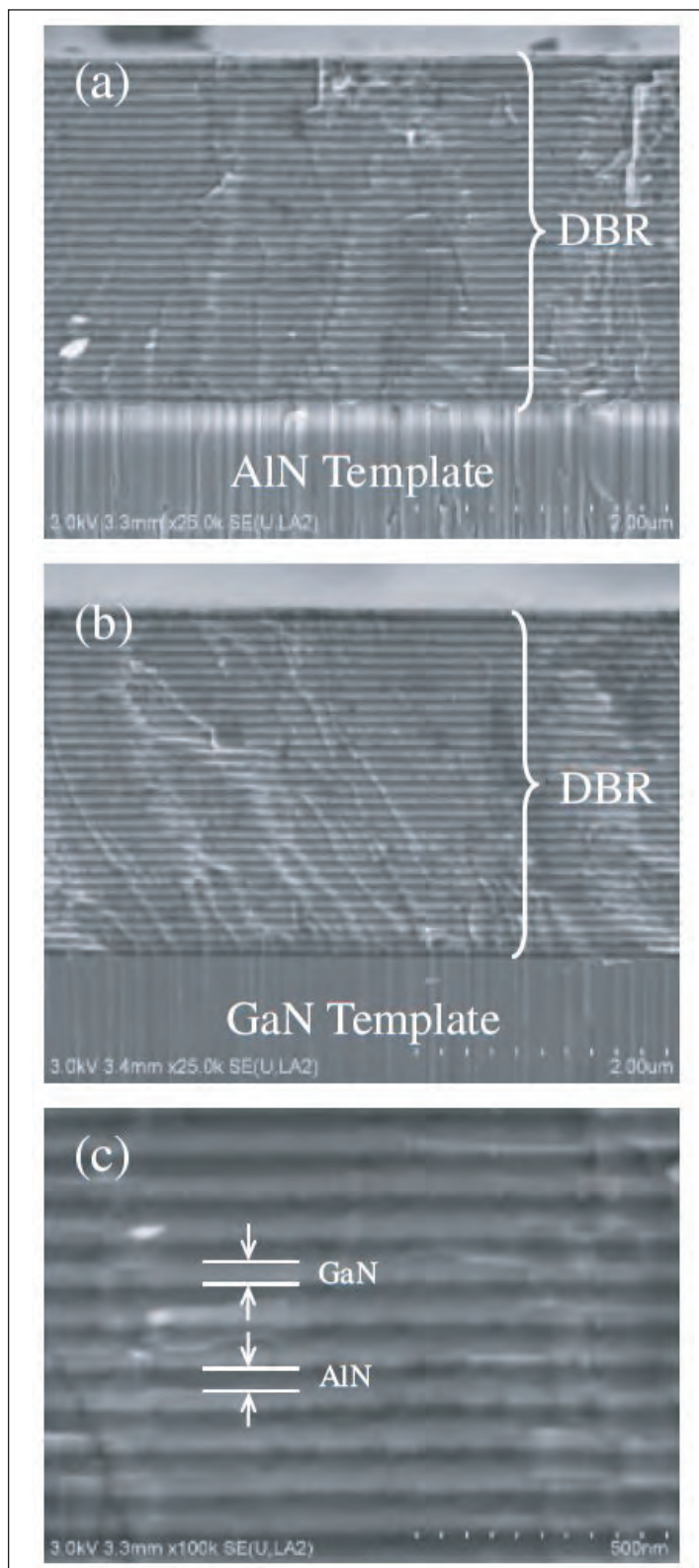


Figure 1. Scanning electron microscope cross-sections of 30-pair AlN/GaN DBRs on (a) AlN and (b) GaN. (c) High-magnification image of DBR on AlN.

the AlN and GaN layers at 40.1nm and 46.0nm, respectively, using XRD measurements. The top 20 AlN/GaN layers of the structure are estimated to be in balanced +1.1% (tensile) and -1.1% (compressive) stress, respectively. The lower 10 layers form the region where the materials relax from the stress imposed by the respective templates.

The use of an AlN template was found to result in DBRs without cracks, unlike with structures grown on GaN templates. This behavior is attributed to the different compressive or tensile stress given by the AlN/GaN templates, respectively. Tension

tends to lead to cracking as the main channel for stress relaxation. For compression, other relaxation paths have to be found, such as the generation of misfit dislocations.

The resulting peak reflectivities for the 30-pair DBRs on AlN or GaN templates were 97.5% at 400nm or 94.3% at 397nm, respectively (Figure 2). The stop bandwidths for 50% reflectivity were 28.2nm and 27.6nm for DBR/AlN and DBR/GaN, respectively.

The researchers comment: "Even though these values are still inferior to the expected values, most likely due to the surface and interface roughness, the crack-free AlN/GaN DBRs on AlN will be an important

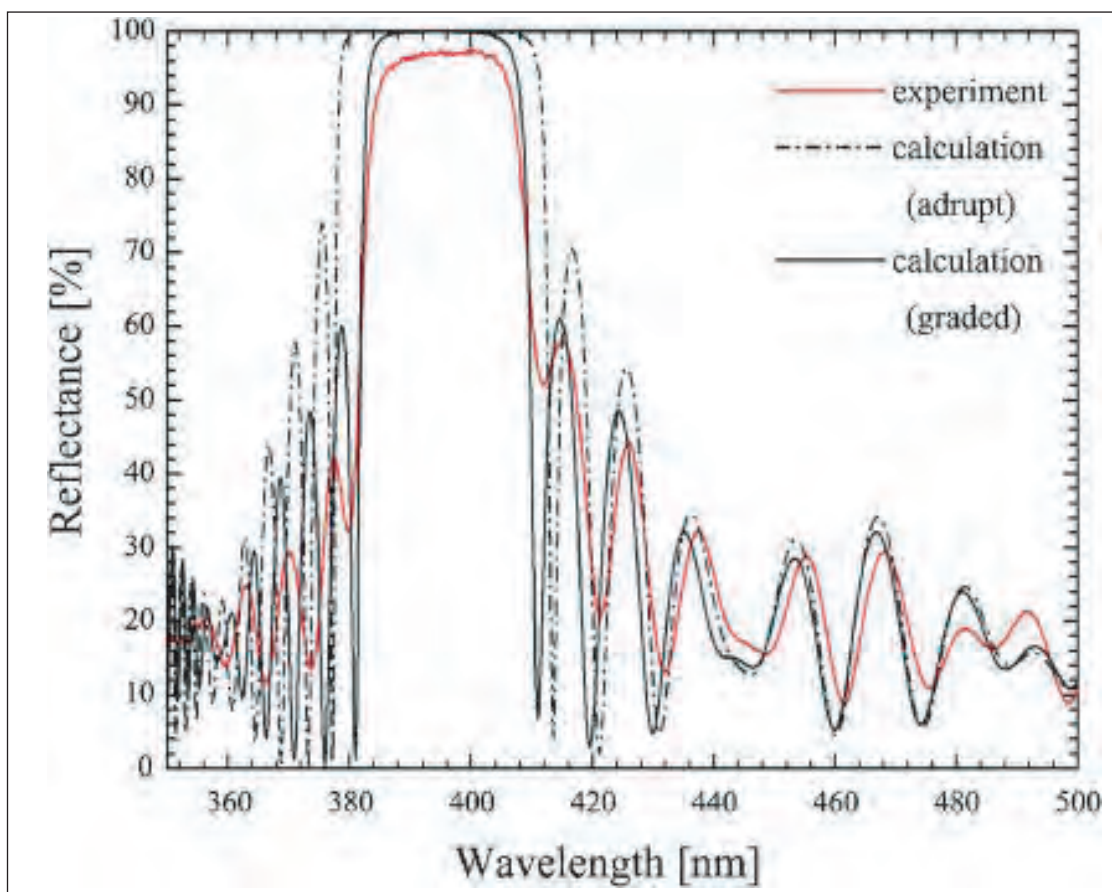


Figure 2. Comparison of measured and calculated reflectivity spectra of 30-pair AlN/GaN DBRs on AlN. Two calculation results are plotted with abrupt AlN/GaN interfaces and with 27nm graded AlGaIn layers.

structure for nitride-semiconductor-based blue VCSELs with a high yield."

The DBR surfaces were rough compared to normal GaN: atomic force microscopy gave 3nm root-mean-square roughness in a 10µm square; the corresponding figure for typical GaN surfaces is less than 1nm. The researchers believe that their measurements indicate a degree of AlGaIn grading between the AlN and GaN layers. ■

<http://jjap.jsap.jp/link?JJAP/51/051001>

Author: Mike Cooke

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Magnesium puzzle solving in nitride semiconductors

UCSB theorists untangle p-type dopant effects in gallium and other nitrides.

University of California Santa Barbara (UCSB) scientists have reported density functional calculations that shed light on the puzzling behavior of magnesium (Mg) as p-type (acceptor) dopant in nitride semiconductor materials involving the elements gallium (Ga), aluminum (Al) and indium (In) [John L. Lyons et al, Phys. Rev. Lett., vol108, p156403, 2012].

In particular, they explain some puzzles about the behavior of photoluminescence (PL) spectra, before and after annealing. Such spectra are important characterization tools, and correct identification of the sources of spectral lines should lead to improved technological development and production processes.

The development of Mg-doping in gallium nitride (GaN) during the 1980s was one of the most important ingredients leading to the present applications of nitride semiconductors in visible and ultraviolet light-emitting devices.

In GaN, the Mg atoms tend to substitute for the Ga in the crystal structure (symbolized as Mg_{Ga}). The addition of Mg in the crystal structure is known to create conditions where electrons can be grabbed from the valence band, leaving holes. Unfortunately, the activation energy for this ($\sim 200\text{meV}$) is quite high when compared with typical thermal excitations at room temperature ($\sim 26\text{meV}$). By contrast, silicon doping creates n-type behavior in GaN much more easily, donating electrons to the conduction band with activation energies around 20meV .

In photoluminescence experiments, there are two extra peaks in Mg-doped GaN: one is an ultraviolet emission with a photon energy of 3.27eV ; the other is a blue peak of energy 2.8eV . Naively, one might attribute the 3.27eV emission to electrons from the conduction band falling into the Mg-state near the valence band. If Mg behaves as a shallow acceptor, then this

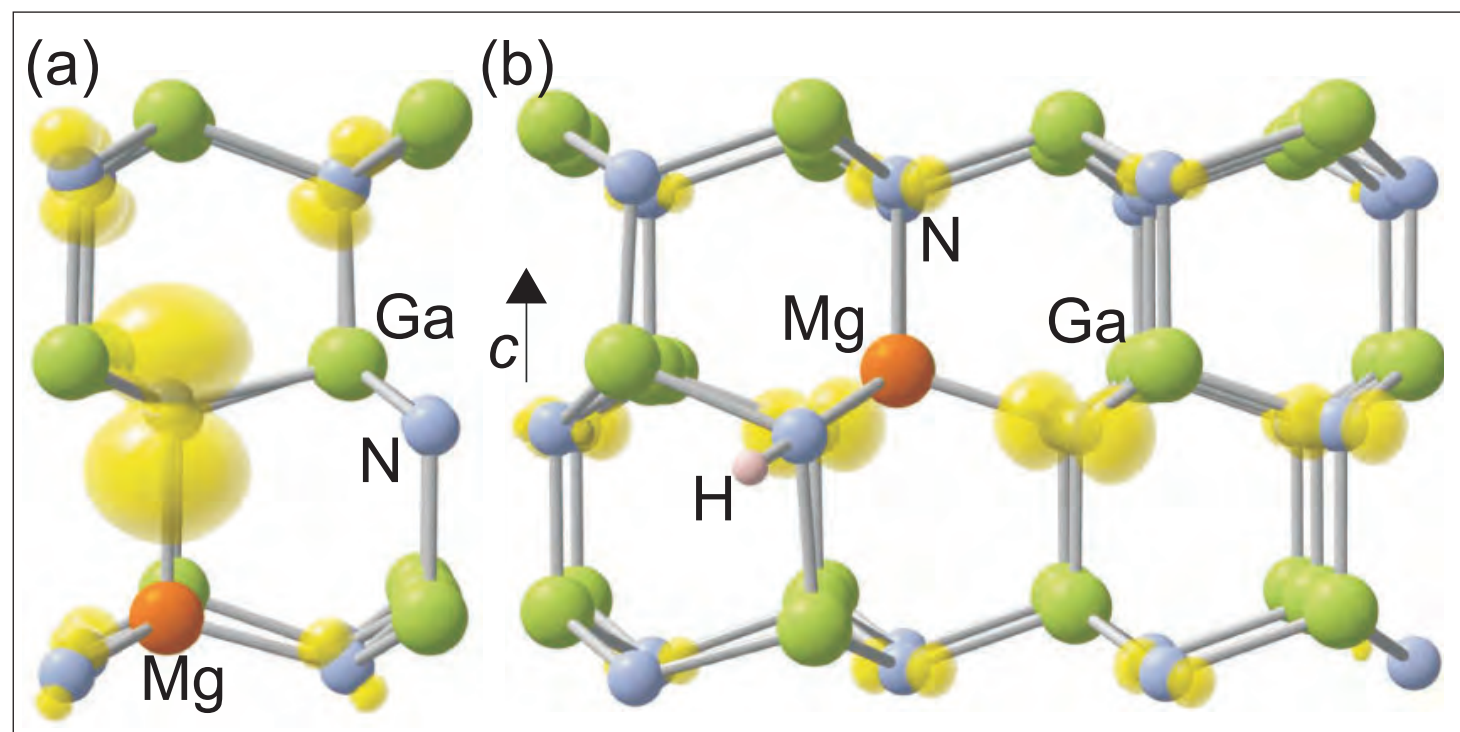


Figure 1. (a) Local structure showing distortion around neutral Mg acceptor in GaN. Localization of hole on axial nitrogen neighbor is illustrated by spin-density iso-surface (yellow), set to 5% of maximum. (b) Structure of Mg-H complex in GaN in positive charge state. The spin density shows the more delocalized nature of the complex. Large green spheres denote Ga atoms, medium light blue spheres denote N atoms, and orange (darker) sphere denotes Mg_{Ga} .

emission should indeed occur at an energy close to the 3.5eV bandgap. In this model, the blue emission would be associated with (unidentified) compensating donors induced by Mg.

However, the UV signal is reduced when such samples are annealed to improve their p-type properties, which would suggest that the peak is not associated with Mg itself, but with Mg-H complexes, since the annealing is expected to drive off hydrogen (H) from the sample. The blue emission would then be related to the acceptor mechanism of Mg proper. However, if Mg is an acceptor with activation energy around 200meV (0.2eV), which is relatively close to valence band maximum, how can blue light be emitted from transitions from the conduction band?

In their calculations, the researchers find that the bound hole (Mg^0_{Ga}) is highly localized, with most of its charge on the nearest-neighbor axial nitrogen (Figure 1a). Normal shallow acceptor behavior consists of a delocalized hole only loosely bound to the negative charge acceptor core.

In addition to the hole charge being localized on the neighboring nitrogen atom, the crystal lattice is distorted by a 15% lengthening of the bond between the Mg and axial N atoms, compared with the bulk Ga-N bond. The configuration where the hole is localized on the planar N atoms has an energy level that is 0.03eV higher. The researchers add: "Careful investigations reveal that there are no other metastable configurations, in contrast to previous theoretical work."

The localized nature of the hole in the bound state suggests to the researchers that its use as a shallow acceptor is an accident of nature. When the hole is freed (Mg^-_{Ga}), the lattice is no longer asymmetrically distorted and only 'breathing relaxations' of the nearest neighbors occur to accommodate the Mg in the crystal.

The researchers explain the blue transition as being due to recombination of an electron with an Mg^0_{Ga} state, creating an Mg^-_{Ga} state. However, the optical transition tends to result in a state that is initially asymmetrically distorted, and so has higher energy than the Mg^-_{Ga} state at 260meV above the valence-band maximum referred to above.

Representing the distortion asymmetry by a generalized coordinate, the researchers give an energy diagram (Figure 2b) with an emission peak around 2.70eV. The energy for relaxation to the symmetric

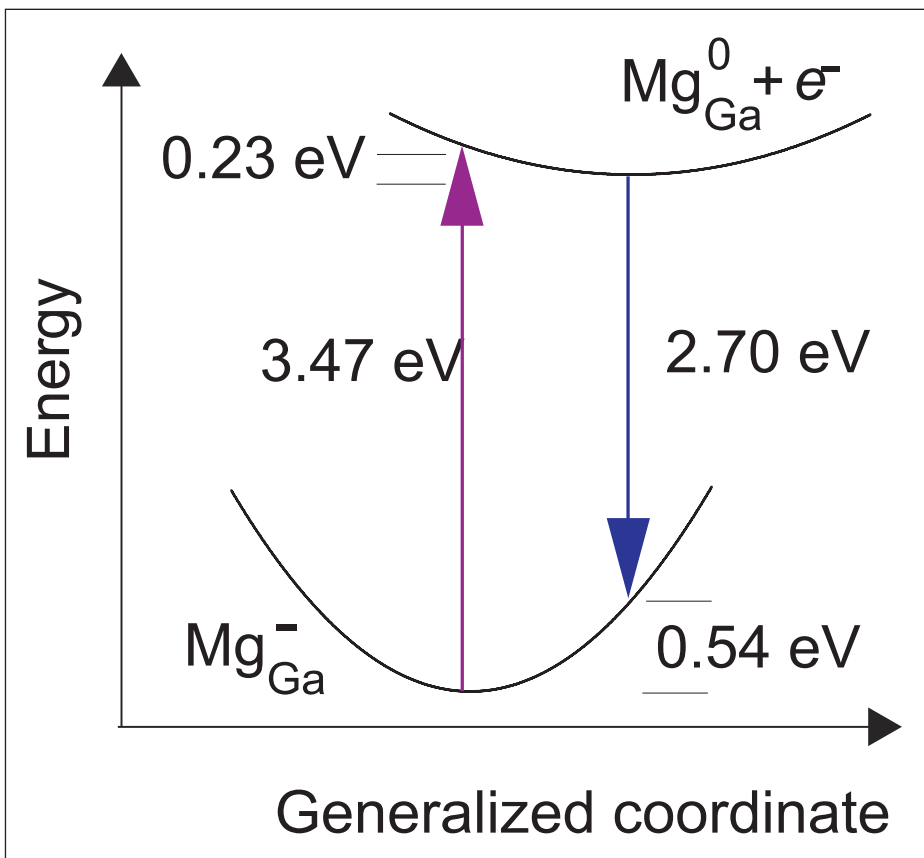


Figure 2. Configuration-coordinate diagram illustrating optical processes related to Mg in GaN. Recombination of an electron at conduction-band minimum with Mg^0_{Ga} leads to emission peaking at 2.70eV, explaining the blue line emission in GaN.

breathing state is about 0.54eV. The large value of 0.54eV indicates that the photoluminescence should be broad, as seen experimentally.

The researchers also considered the way in which interstitial hydrogen atoms affect the Mg acceptors in GaN. They find that the H^+ forms a neutral bound state with Mg^-_{Ga} , with a binding energy of 1.02eV. Also, when the Fermi level is close to the valence-band maximum, there is a stable positively charged state 130meV above the valence-band maximum (Figure 1b).

One effect of the H-interstitial is to reduce the lattice distortion. In particular, the distinct axial character of the distortion disappears. The positive charge state also gives a route for an ultraviolet transition from the conduction band, with a predicted peak around 3.32eV. The researchers would associate this with the experimental ultraviolet emission around 3.27eV.

The electrical effect is two-fold. The neutral state inactivates the Mg-acceptor; the positive state is a compensating center that removes a hole from the valence band. The researchers comment: "Thus, these complexes are doubly detrimental in reducing free hole concentrations in Mg-doped GaN. Combined optical and electrical experiments to assess the presence and role of these complexes in Mg-doped GaN are called for." ➤

► The ultraviolet line is especially strong in samples that have not been annealed. "Confirmation of our proposed attribution could be obtained by monitoring the intensity of the UV line in material that is first activated and then intentionally hydrogenated: the formation of Mg-H complexes should lead to an increase in the intensity of the UV line," the researchers add.

The researchers made similar calculations with InN and AlN. In AlN, in addition to the negative and neutral states, a positively charge state (Mg^+_{Al}) forms that is stable when the Fermi level falls below 0.36eV, relative to the valence-band maximum. In addition to a greater axial distortion of 18%, the positive state indicates that it is more difficult to exhibit p-type conductivity in Mg-doped AlN (and by implication AlGaN). The poor conductivity of p-AlGaN/p-AlN is already well known experimentally and theoretically.

By contrast with GaN and AlN, the researchers find genuine shallow acceptor behavior with Mg-doped InN. There are no asymmetric distortion or hole localization effects. The researchers give an energy transition for transitions between the MgOIn and Mg-In states as

190meV, consistent with experimental values.

The researchers believe that the behavior of Mg as an acceptor in nitride semiconductors is linked to the character of the valence band. Deep, flat bands (with implied higher hole effective mass) promote hole localization on the acceptor. AlN has the largest bandgap (~6.15eV in the UCSB calculation), the deepest valence band and highest hole effective mass of the nitride semiconductors, leading to the highest acceptor ionization energy. InN has the smallest bandgap of the nitride semiconductors (~0.65eV, according to calculation), with a high valence band and smaller hole effective mass.

The researchers comment: "Our results resolve experimental results for GaN that have remained puzzling for almost two decades: Mg_{Ga} is responsible for the widely observed blue luminescence, and the Mg-H complex is responsible for 3.27eV PL. Mg_{In} in InN is found to behave as a shallow, effective-mass acceptor, with the lowest ionization energy among the nitrides." ■

<http://prl.aps.org/abstract/PRL/v108/i15/e156403>

Author: Mike Cooke

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Mechanical release of nitride semiconductors from sapphire using a boron nitride layer

A new mechanical process takes just seconds to separate nitride semiconductor layers from the sapphire substrate with minimal damage.

NTT Basic Research Laboratories in Japan has developed a new method to release nitride semiconductor layers from sapphire substrates [Yasuyuki Kobayashi et al, *Nature*, vol484, p223, 2012]. Normally, slower methods such as laser-lift off or wet etching are used to achieve this.

The new technique uses a thin layer of hexagonal boron nitride (h-BN) between the nitride semiconductors and the sapphire growth substrate. The h-BN has planes of boron and nitrogen bonded in an analog to the sp²-hybridized configuration of carbon (i.e. graphite with strong in-plane bonds but weak plane-plane bonds). This allows for a relatively simple mechanical release of the nitride semiconductor material from the substrate in mere seconds.

The hexagonal BN (h-BN) is deposited first using metal-organic vapor-phase epitaxy (MOVPE or MOCVD) on sapphire. Triethyl-boron and ammonia (NH₃) were used as

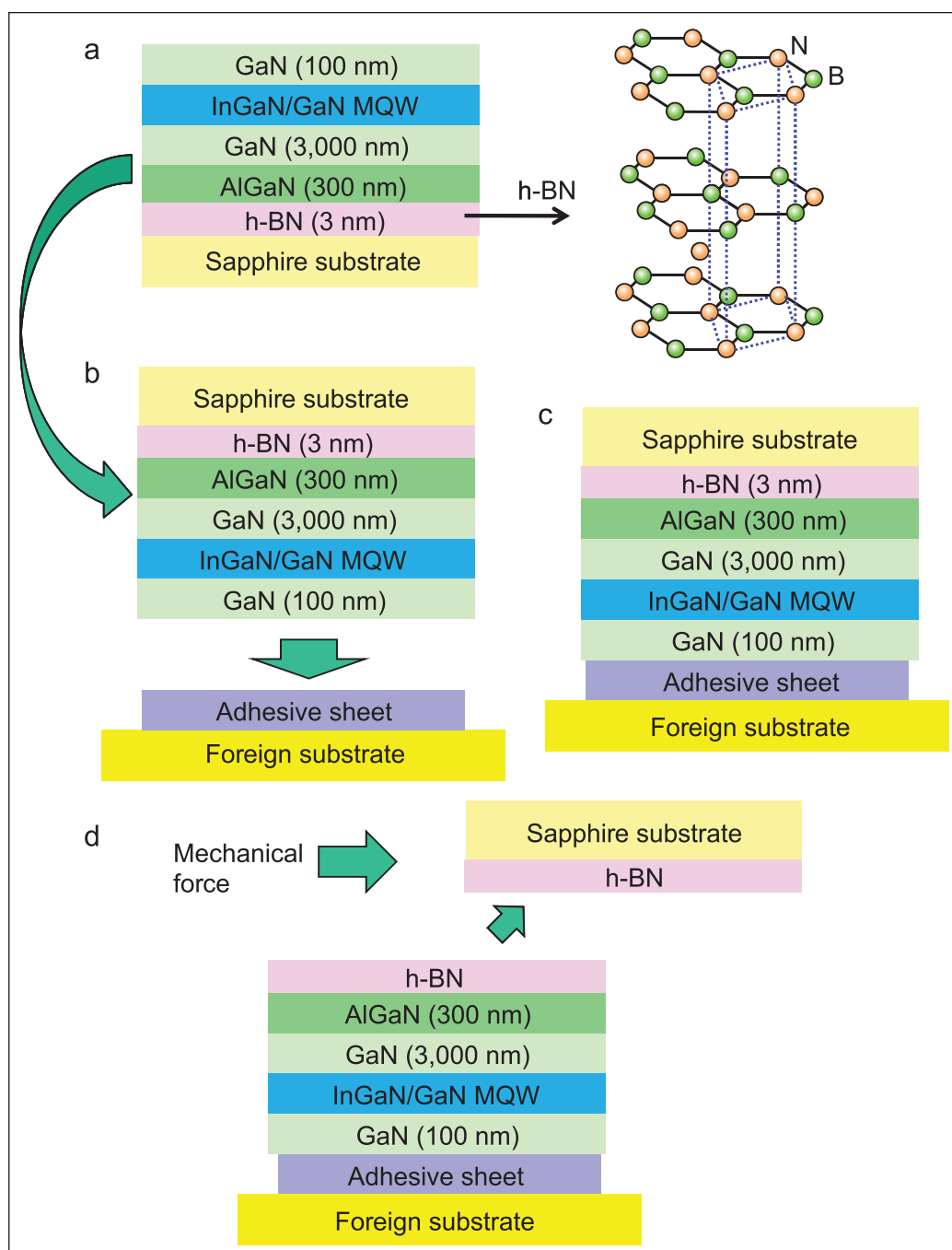


Figure 1. a, Single-crystal h-BN release layer growth on a sapphire substrate, followed by growth of wurtzite AlGaIn layer and MQW structure. On right, crystal structure of h-BN. Dotted lines mark unit cell dimensions of h-BN. b, MQW structure is flipped upside down and placed on foreign substrate via adhesive indium sheet. c, MQW structure attached to sheet is heated to a temperature sufficient to heat-seal indium, and the structure is released from host sapphire by mechanical force and transferred to foreign substrate (d).

precursors for the respective elements of h-BN.

Further layers deposited on the release layer (Figure 1) included a 10-period multi-quantum well structure of InGaN in GaN barriers. The wells were found to be 5.5nm thick with an indium molar content of 15%. The structure was then flipped onto an adhesive indium sheet on a foreign substrate. The combination was then heated to seal the adhesive bond. Finally, the sapphire substrate was separated from the nitride layers using mechanical force. The separation occurs in the h-BN layer and is due to the relative weakness of the plane-plane V an der Waals bonds.

The researchers comment: "In this way, MQWs and other types of nitride devices can be transferred to all kinds of substrates, such as silicon, polycrystalline metal, glass and transparent plastics."

It has been found that AlGaIn or AlN deposited on the h-BN is needed before the GaN layers to improve the crystal structure and surface properties. Direct growth of GaN on h-BN tends to result in rough, irregular island shapes and polycrystalline structures. On effect of AlGaIn/AlN layers on h-BN is as a dislocation filter, reducing the number of threading dislocations in later layers.

The release process takes mere seconds, unlike alternatives such as laser lift-off. The researchers add: "No cracks were observed in the transparent AlGaIn/GaN structure up to maximum size of about 1cm square, suggesting that the mechanical release process using the h-BN layer ensures minimal crack formation."

Blue LEDs were produced from the structure with comparable or better than LEDs grown on sapphire with AlN buffer (Figure 2).

Since the new process does not require specialized lift-off equipment or chemical etchants, the researchers see it as leading to considerable cost

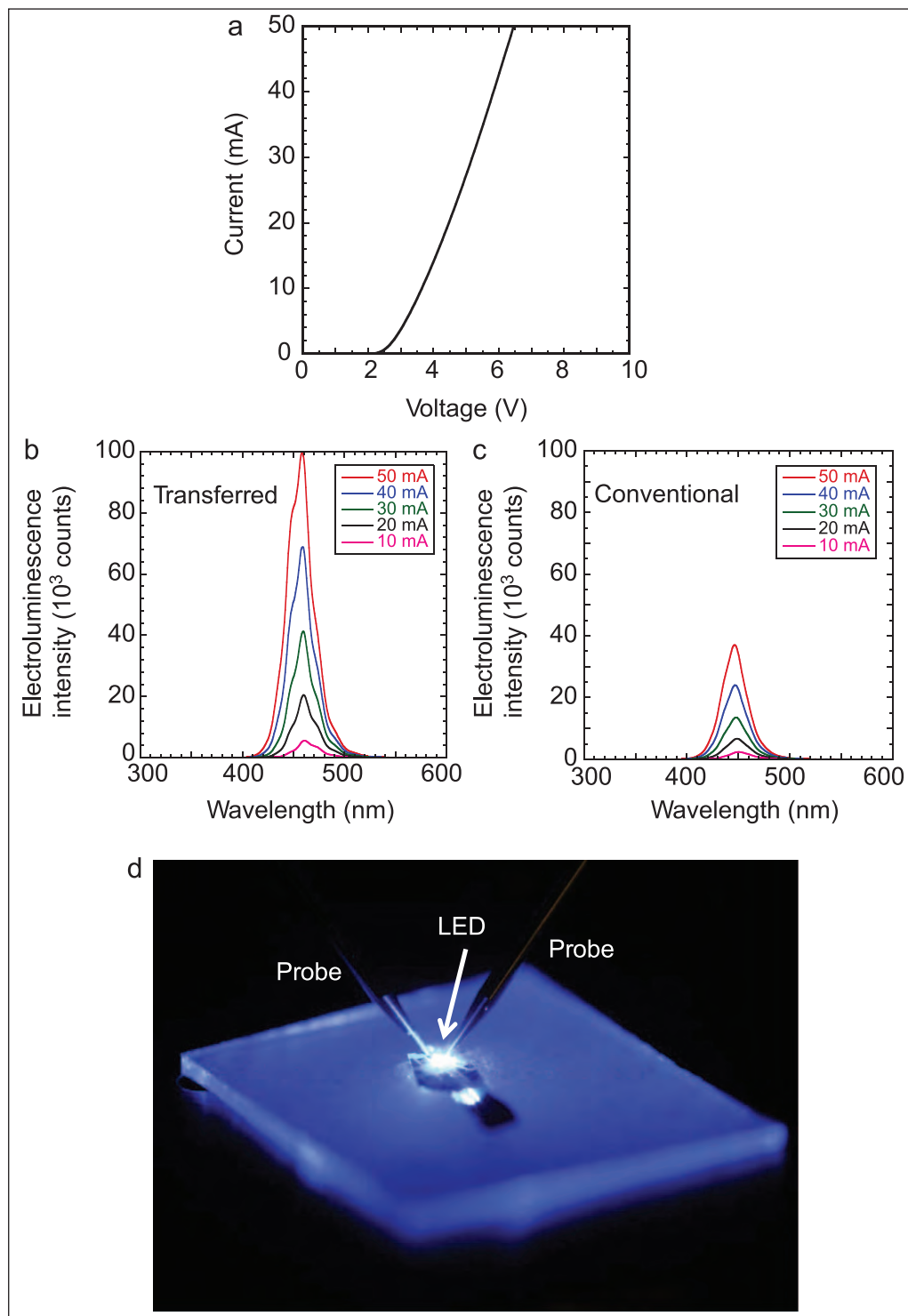


Figure 2. a, Current–voltage characteristics of transferred LED. b, Electroluminescence spectra from transferred LED. c, Electroluminescence spectra from conventional LED. d, Optical image of blue electroluminescence from transferred vertical-type LED.

reduction. Also there is no post-process cleaning, as is needed for laser lift-off. The new mechanical release process leaves a flat surface with root-mean-square roughness of 1nm, considerably lower than laser techniques. ■

www.nature.com/nature/journal/v484/n7393/full/nature10970.html

Author: Mike Cooke

Reversing polarization to tackle overshoot and droop

Double quantum-well nitride LED shows almost no droop in luminous efficiency under a pulsed current up to 400A/cm².

Ohio State University has suppressed overflow and droop effects in nitride semiconductor LEDs by reversing the polarization of the material [F. Akyol et al, Appl. Phys. Lett., vol100, p111118, 2012].

Usually nitride semiconductor LEDs are grown in the c-direction (0001) on Ga-face gallium nitride templates, which leads to strong polarization fields that affect LED performance. One effect is that the more mobile and plentiful electrons tend to overshoot the active region where light-emitting electron-hole recombination is desired. Such overflow reduces the luminous efficiency of the device.

The overshooting can be reduced by including aluminium gallium nitride (AlGaN) electron-blocking layer (EBLs). However, such layers also reduce hole injection into the active region, impacting efficiency adversely.

Simulations have suggested that devices grown on material where the polarization is reversed could benefit from improved performance. However, experimental reports have been few because such growth and/or substrates are not as mature as those obtained by more traditional methods.

The new Ohio devices used free-standing N-face silicon-doped GaN substrates supplied by Lumilog. LEDs with single quantum wells (SQW) and double quantum wells (DQW) were produced (Figure 1). The semiconductor material growth was carried out using a Veeco Gen 930 nitrogen-plasma-assisted molecular beam epitaxy (MBE) system. The quantum-well growth temperature was 570°C. There was no electron-blocking layer.

The p-electrode of the LED devices consisted of semi-transparent nickel/gold (4nm/6nm). The material was then

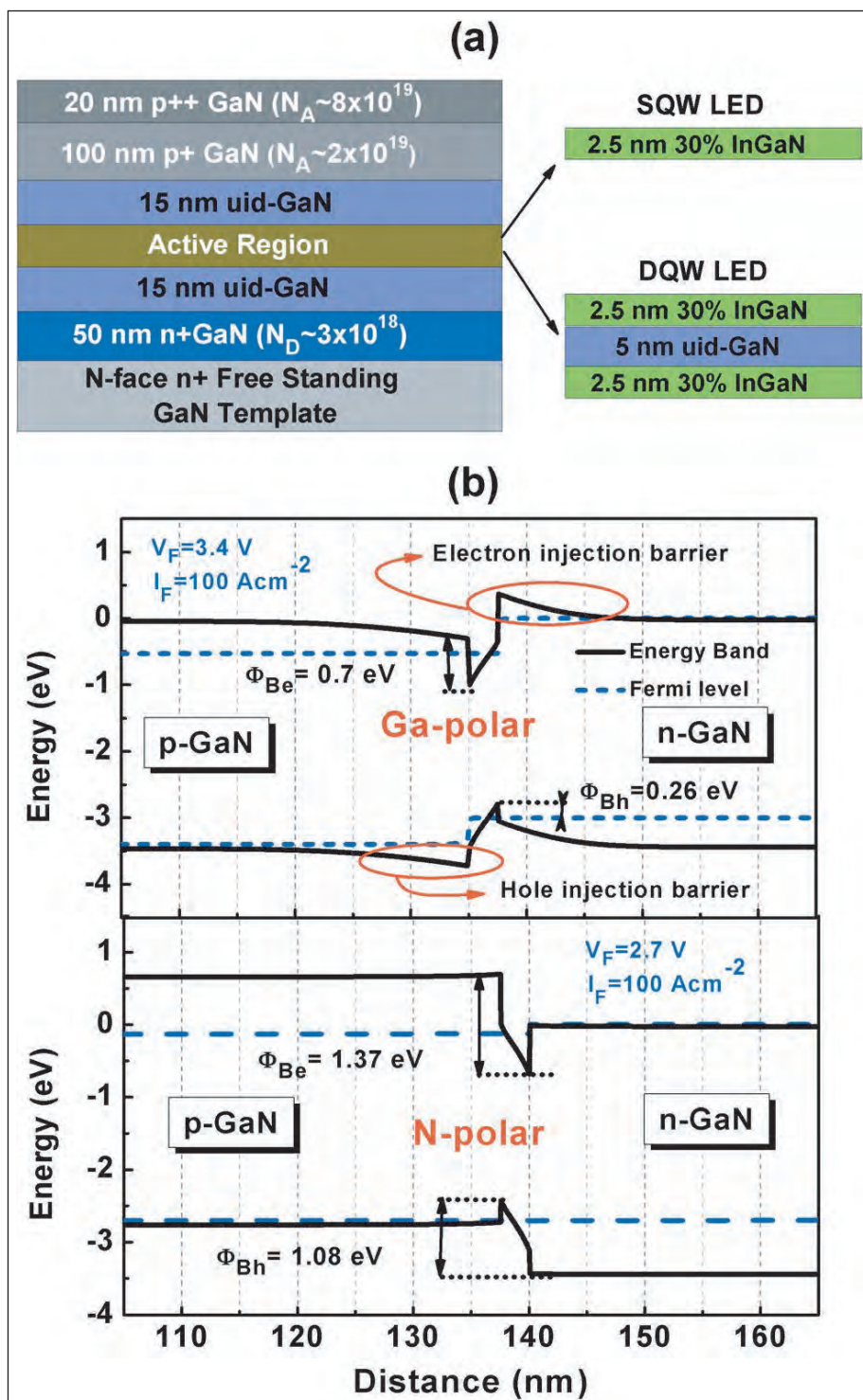


Figure 1. (a) Epitaxial structure of the SQW and DQW LEDs. (b) Simulated energy-band diagrams of Ga- and N-polar SQW LEDs at 100A/cm² current density.

etched to provide mesa isolation to create $250\mu\text{m} \times 250\mu\text{m}$ devices. The n-contact consisted of titanium/gold (20nm/300nm). The p-contact pad/current spreader consisted of thick gold. Electrical and light-emission measurements were performed on-wafer, without dicing or packaging.

The devices had a low turn-on voltage of $\sim 2.3\text{V}$, attributed to "decreased electron and hole potential barriers in N-polar devices", as expected from Ohio's previous simulations. The SQW device showed higher leakage under reverse bias, which may be due to increased inter-band tunneling of electrons and holes across the thin N-polar active region.

The spectral position of the emission peaks blue-shifted with increasing current ($16\text{A}/\text{cm}^2$ to $192\text{A}/\text{cm}^2$): from 558nm to 535nm for the SQW LED and from 565nm to 535nm for the DQW LED. The shift is attributed to polarization screening at low currents and band-filling at higher currents. The full-width at half maxima (FWHM) for the green peaks were 78nm and 67nm for the SQW and DQW devices, respectively.

The SQW LED also had an ultraviolet peak around 385nm when the current density exceeded $50\text{A}/\text{cm}^2$. By contrast, the DQW was without such a peak up to $400\text{A}/\text{cm}^2$. Such a peak can be attributed to electron overflow into the p-GaN layer.

The researchers comment: "Thus, it could be concluded that, while one quantum well with the given thickness may be insufficient to prevent electron overflow, the insertion of a second quantum well provides an efficient built-in potential barrier to electron overflow in our N-polar device".

External quantum efficiency (EQE) measurements (Figure 2a) indicated conventional droop effects in the SQW device with a peak at a current density of

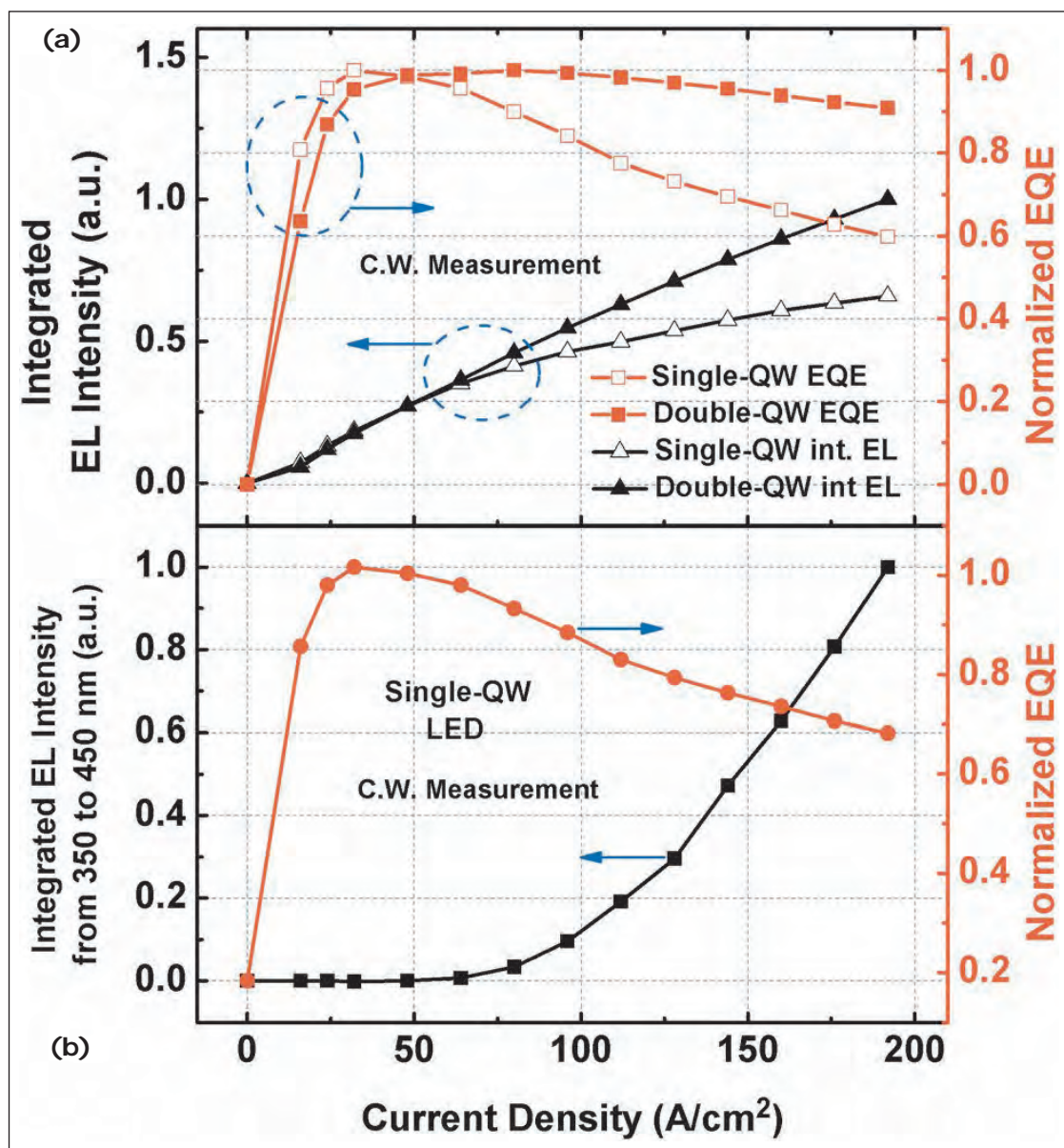


Figure 2. (a) Integrated EL intensity and normalized EQE variation of SQW and DQW LEDs with continuous wave (CW) forward current. (b) Integrated UV-blue (350–450nm) EL intensity and normalized EQE as a function of CW current density.

$30\text{A}/\text{cm}^2$. The DQW had a much improved droop character with the peak occurring at $96\text{A}/\text{cm}^2$ and a small drop of 7% from this at $192\text{A}/\text{cm}^2$. The researchers also compared the onset of droop with the rise of the UV parasitic peak (Figure 2b).

The DQW LED was also tested under pulsed currents. The device then showed almost no efficiency droop. Pulsed currents are used to avoid self-heating effects that also degrade LED performance.

The researchers comment: "We have thus not only established the direct correlation between electron overflow and efficiency droop but also demonstrated how to overcome it by using DQW in N-face orientation".

The devices were not optimized, so the absolute performance fell below that of state-of-the-art devices. ■

<http://link.aip.org/link/doi/10.1063/1.3694967>

Author: Mike Cooke

Integrating multispectral capability into III-V detectors

Mike Cooke reports on some recent developments in creating multi-band photodetection for more compact, lighter equipment.

Electromagnetic radiation is full of information, if only we can detect and analyze it. Apart from spatial information, humans and other animals have well-developed multi-spectral capabilities in the visible range that allow them to discriminate between objects such as ripe and unripe fruit. More recently, humans have discovered and exploited radiation with frequencies and wavelengths over some 20 orders of magnitude, while visible light covers a mere factor of two (about a third of an order of magnitude).

Multispectral detection has applications ranging from military and environmental sensing to failure analysis and medical imaging. Desirable characteristics for such equipment are small size, low weight, and simplicity. There is a number of ways to achieve such aims.

Much of the interest for applications centers on mid-wavelength (MWIR) and long-wavelength (LWIR) infrared in the range 3–15 μ m for which there is a number of atmospheric transmission windows. Also in this range, terrestrial objects (including human beings) emit radiation with distinct spectral signatures. These wavelengths allow chemical sensing, environmental monitoring and natural resources surveys to be carried out. In defense, one of many applications is the detection of heat sources such as rocket emissions from missiles.

Particularly attractive for semiconductor detection is hetero-structure integration using techniques similar to photovoltaic multi-junction solar cells where light is absorbed in bands given by the bandgaps of the various materials. In the upper layers of such devices, the high-frequency/energy radiation is absorbed/converted, while lower-frequency/energy photons are transmitted to be absorbed/converted in the layers beneath.

Using a similar principle for detection would eliminate the need for the bulky, heavy, and complex optical assemblies that are presently needed to observe in multiple bands, thereby enabling compact, lightweight imagers. Arranging such vertically, monolithically

integrated sub-detectors in focal plane arrays (FPAs) with multicolor capability could reduce pixel size and thus increase image resolution.

Vertically integrated systems do exist in commercial form. Hamamatsu has a device that consists of a wafer-bonded indium gallium arsenide (InGaAs) p-i-n diode and silicon (Si) photodiode, giving two-color responses covering ultraviolet (UV > 0.32 μ m) to infrared (IR < 2.57 μ m) wavelengths. The company sees applications as being spectrophotometers, laser or flame monitors, and radiation thermometers.

Another company, Foveon, markets vertical multi-spectral detection that uses the different absorbance of red, green and blue light in silicon to create image sensors for multicolor visible light cameras.

There is a wide range of semiconductor materials that are popular in various frequency bands, such as mercury cadmium telluride alloys (HgCdTe, also known as MCT), but here we will focus on recent developments using III-V materials.

The direct bandgaps of most of these materials allow efficient detection of radiation, while the extensive research in light/laser emission and photovoltaic devices has created a large palette of energy gaps that can be exploited.

Visible/NIR combo

Ohio State University has been a keen developer of multispectral devices based on gallium arsenide (GaAs) substrates. In late 2011, researchers from Ohio described an optically aligned visible/near-infrared (NIR) photodetector based on indium gallium phosphide (InGaP) and InGaAs subdetectors [K. Swaminathan et al, J. Appl. Phys., vol110, p063109, 2011]. Funding for the work came from US Air Force Office of Scientific Research and US Army Research Office.

The researchers grew metamorphic materials (Figure 1) on n-type (100)-oriented GaAs substrates, intentionally off-cut 6° toward the nearest (111)A direction in a modified Varian GEN II solid-source MBE system with

valved P_2 and As_2 cracker sources. The back-to-back structures were doped to be p-type in the middle region and n-type at the top and bottom (n-i-p/p-i-n).

The three-step InGaAs buffer layers, with In-contents of 6%, 12% and 18%, were designed to bridge the ~1% lattice mismatch metamorphically between the GaAs substrate and the photodetector layers of $In_{0.14}Ga_{0.86}As$ and $In_{0.61}Ga_{0.39}P$.

The 6%-InGaAs buffer layer was grown at 550°C, while subsequent InGaAs layers were grown at 515°C.

Phosphide layers were grown at 475°C.

Square photodetectors with active regions with 300µm sides were created using photolithography and plasma etching to create mesa and via trenches. The common p-type ohmic contact consisted of chromium/gold and the two n-type ohmic contacts were nickel/germanium/gold. A 4 minute 400°C treatment was used to anneal the n-type contact. No anti-reflective coating was used to improve performance.

The detector was designed so that both sub-detectors could be operated simultaneously and independently without the need for active bias control to select band sensitivity.

The dark currents at a reverse bias of -2V were $4 \times 10^{-8} A/cm^2$ for the InGaAs detector and $7 \times 10^{-12} A/cm^2$ for the InGaP detector. The InGaP detector was designed to absorb all photons above its bandgap, allowing lower-energy photons to be detected in the InGaAs region beneath.

The optical isolation was tested at -2V reverse bias, with the device showing overlap of detection in a relatively narrow wavelength range of 690–720nm (Figure 2). This cross-talk is attributed to near-bandgap photons that have a smaller InGaP absorption coefficient and

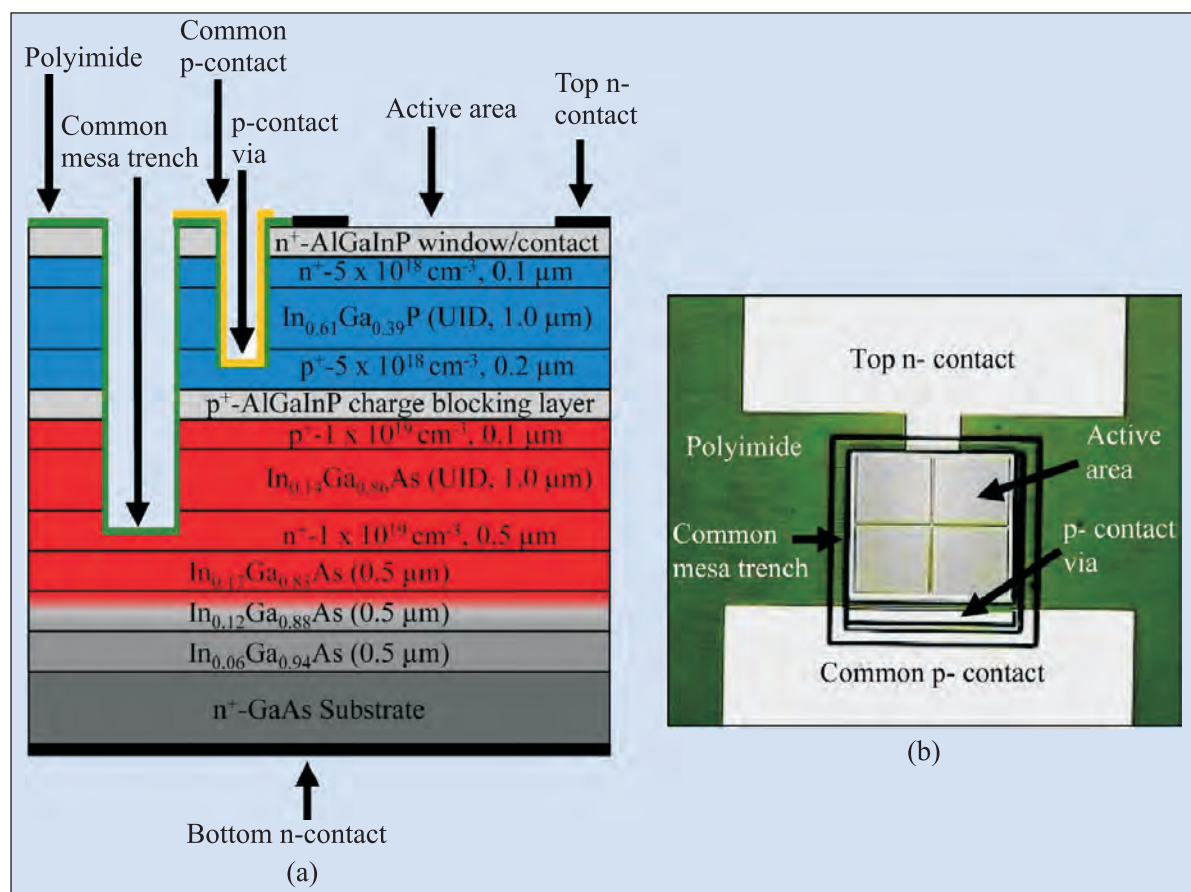


Figure 1. (a) Cross-sectional schematic of Ohio State University device (not to scale) of a fabricated n-i-p/p-i-n $In_{0.61}Ga_{0.39}P/In_{0.14}Ga_{0.86}As$ dual-photodetector with AlGaInP window and charge-blocking layers (0.1µm each). (b) Top-view photograph of a fully fabricated $In_{0.61}Ga_{0.39}P/In_{0.14}Ga_{0.86}As$ dual-photodetector.

thus leak through to the InGaAs device. This effect could be reduced by increasing the InGaP thickness.

There was no detectable effect of photo-generated carriers recombining to produce new photons, which is an effect sometimes seen in high-quality multi-junction solar cells. The absence of this effect is attributed to the 0.2µm p^+ -InGaP layer limiting the number of freely diffusing photo-generated carriers.

The responsivity and specific detectivity at -2V bias were, respectively, 0.30A/W and $2.0 \times 10^{14} cmHz^{1/2}/W$ at 680nm, and 0.41A/W and $8.6 \times 10^{11} cmHz^{1/2}/W$ at 980nm.

The researchers comment: "The use of properly designed $In_xGa_{1-x}As$ (and/or $In_zGa_{1-z}P$) graded buffers should enable the extension of the metamorphic detector platform across the entire lattice constant range between GaAs and InP, providing access to multi-band photodetectors with tunable bandgaps from 0.74eV to 1.9eV."

Extension to even shorter wavelength could be achieved with Al-containing alloys. InAsP could be used for longer-wavelength detection. The researchers have also produced back-to-back diodes with opposite polarity (p-i-n/n-i-p) that were sensitive to wavelengths with cut-offs at 650nm and 870nm.

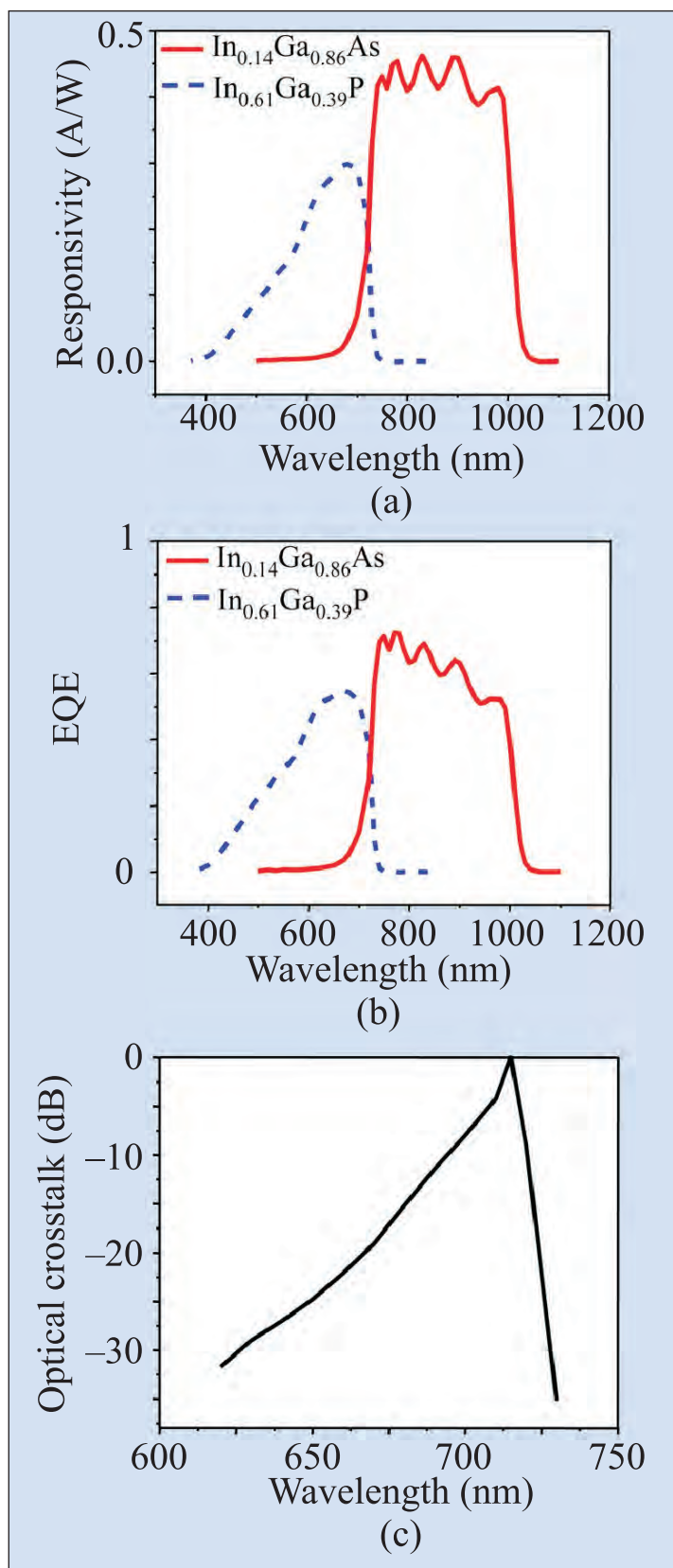


Figure 2. (a) Room-temperature spectral responsivity simultaneously measured by Ohio State University for both $\text{In}_{0.61}\text{Ga}_{0.39}\text{P}/\text{In}_{0.14}\text{Ga}_{0.86}\text{As}$ sub-detectors at -2V bias, demonstrating high responsivities and very low optical cross-talk between sub-detectors. (b) EQE values for both subdetectors calculated from the corresponding responsivity values shown in (a). (c) Relative inter-detector optical cross-talk as a function of wavelength.

Optical switching

Arizona State University and Sandia National Laboratories have developed two-terminal devices capable of detecting NIR and LWIR [O. O. Celtek et al, Appl. Phys. Lett., vol100, p241103, 2012]. This is achieved by optical switching between the two IR bands. The need for only two terminals allows denser packing of detectors in FPAs and the use of simpler read-out ICs. "These devices enable the use of only a single indium-bump per pixel for multi-band image sensor arrays to have maximum fill factor," the team writes.

A previous proof-of-concept consisted of a triple-junction device with visible, NIR and SWIR bands. The detection band was selected by illuminating the device with wavelengths for the non-selected bands. The new device (Figure 3) extends the idea to

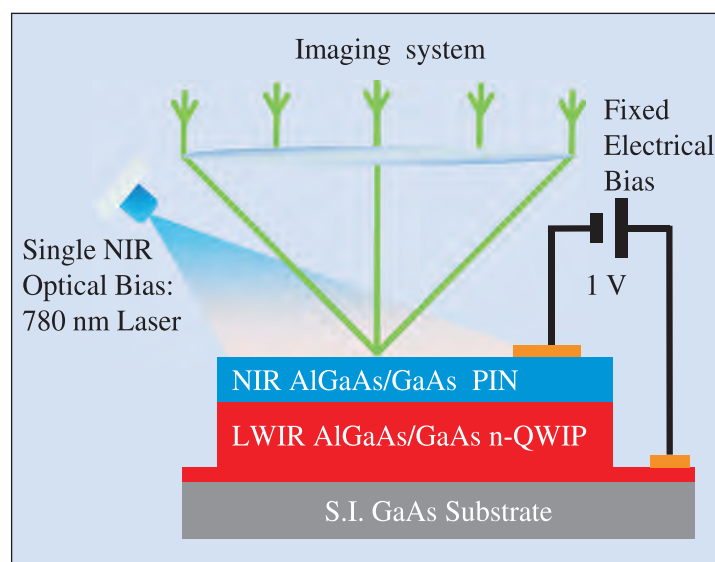


Figure 3. Schematic of Arizona State University/Sandia NIR/LWIR optically addressed photodetector using single optical bias source.

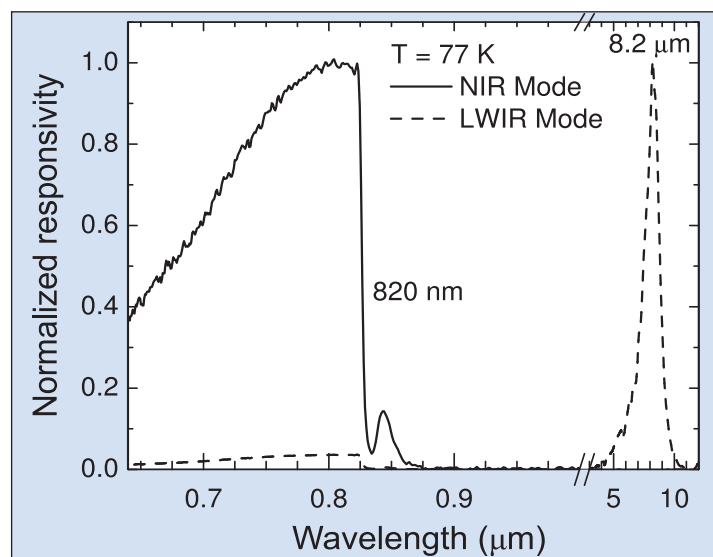


Figure 4. Spectral response in NIR and LWIR modes of operation at 77K measured by Arizona State University/Sandia with different beam splitters in an FTIR system.

NIR/LWIR dual-band detection. To avoid the use of tunnel junctions as used in the original concept, the new design couples a unipolar quantum well infrared photodetector (QWIP) with a p-i-n bipolar detector. In operation, the p-i-n NIR detector is reverse biased.

The epitaxial layers are produced using molecular beam epitaxy (MBE). Mesa isolation ($150\mu\text{m} \times 150\mu\text{m}$) was achieved through etching. Conventional ohmic contacts were used. The optical bias was supplied by a 780nm laser diode.

The device has a $0.82\mu\text{m}$ cut-off for NIR and a $8.2\mu\text{m}$ peak for LWIR response (Figure 4). The quantum efficiency for NIR radiation is 65% and the specific detectivity is $2 \times 10^9 \text{cmHz}^{1/2}/\text{W}$ in the LWIR band at 68K. The cross-talk is better than 25dB.

The researchers comment: "Further addition of more detection bands is possible by using different active layers grown on the same substrate and by adding more corresponding optical bias sources."

Five-band detection

Multispectral infrared and ultraviolet detectors are also being developed at Georgia State University. In 2010 [G. Ariyawansa et al, Appl. Phys. Lett., vol97, p231102, 2010]. Georgia State University reported a five-band device that consisted of two back-to-back p-i-n diodes with InGaAs/GaAs and GaAs/AlGaAs-based quantum wells integrated within the n-regions (Figure 5). The bias polarity was used to select responses at 80K from two groups of three bands: $0.6\text{--}0.8\mu\text{m}$, $3\text{--}4\mu\text{m}$, and $4\text{--}8\mu\text{m}$ ranges in one group and $0.8\text{--}0.9\mu\text{m}$, $0.9\text{--}1.0\mu\text{m}$, and $9\text{--}13\mu\text{m}$ ranges in the other. The polarity puts one of the diodes into reverse bias. Illumination creates carriers in the reverse biased device, giving a photo-current (Figure 6).

Although the device incorporated a middle contact for testing purposes, the aim of the work was to have wavelength selection from biasing only the top and bottom contacts.

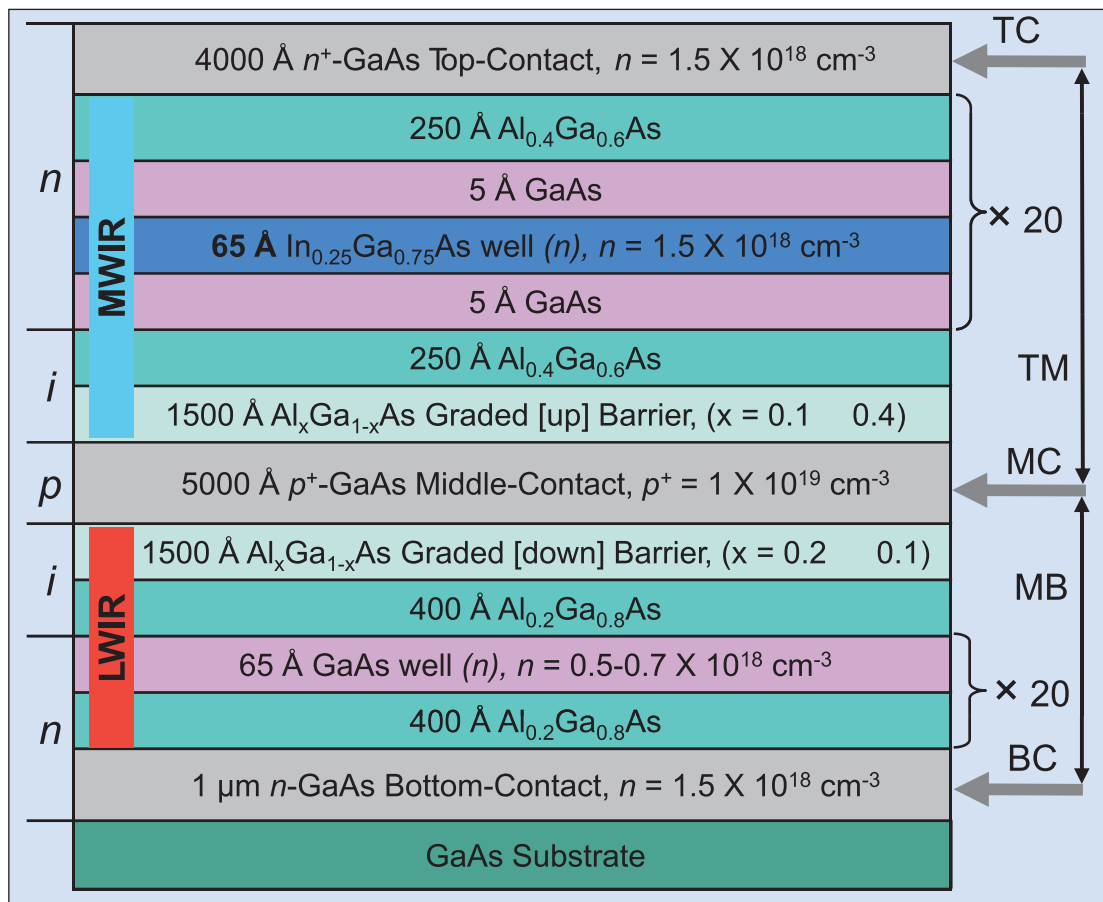


Figure 5. Schematic diagram of Georgia State University n-p-n-QWIP, as-grown. Three doped layers (TC, MC, and BC) separate two major active regions; one containing InGaAs MWIR quantum wells and the other containing GaAs LWIR quantum wells. Three different measurement configurations (TM, MB, and TB) are also indicated.

Nitride quantum cascade detector (QCD)

Quantum cascade (QC) structures consisting of large numbers of steps through which electrons flow have been widely studied for laser emission and photo-detection in the far- and mid-infrared spectral regions, using arsenide- and phosphide-based semiconductors.

Researchers in France and Switzerland have recently used nitride semiconductor QC structures to detect two-color short-wavelength infrared light [S. Sakr et al, Appl. Phys. Lett., vol100, p181103, 2012]. The team was based variously at University of Paris-Sud (UPS) and Ecole Polytechnique Fédérale de Lausanne (EPFL).

The nitride semiconductor structure enabled detection of the shortest wavelength so far of $1\mu\text{m}$ for QC detectors. This raises the possibility of use with infrared fiber-optic communication systems.

QC detectors (QCDs) have advantages over other techniques such as low noise at zero bias due to the absence of dark current. Further attractions include high-frequency operation due to short electron transit times and easy tuning of detected wavelengths with quantum well thickness.

The UPS/EPFL device contained active quantum well (QW) regions consisting of seven monolayers (1ML =

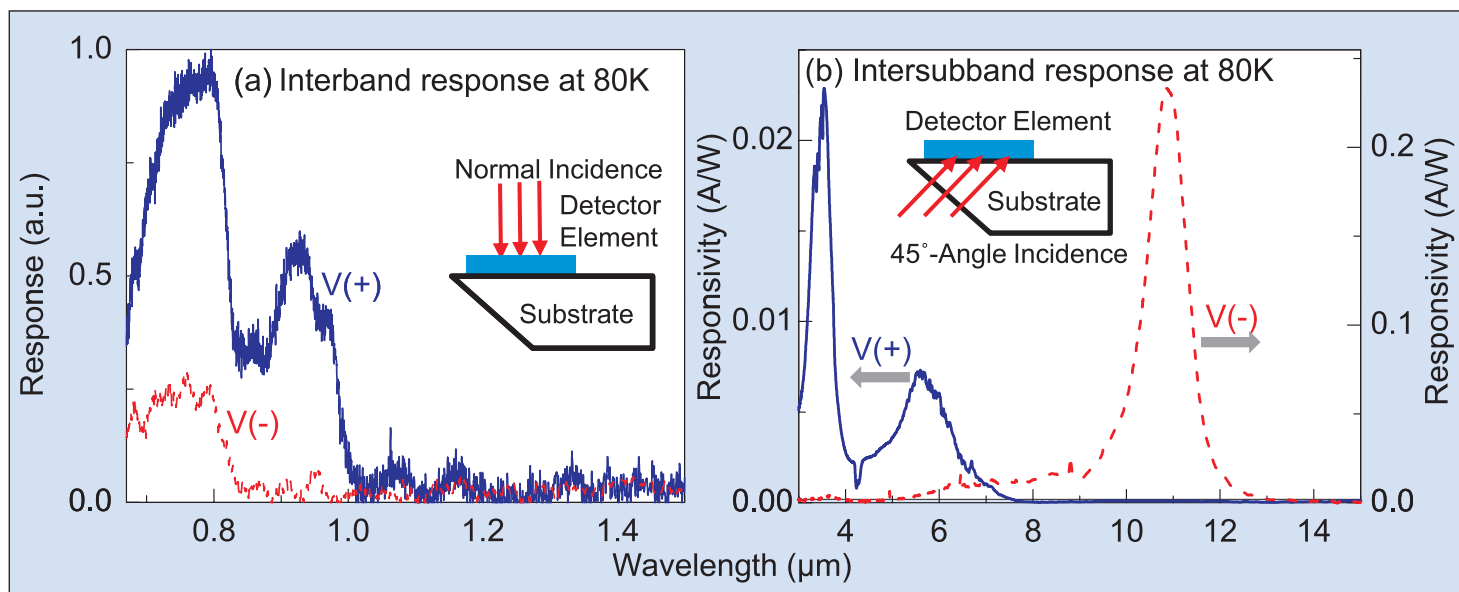


Figure 6. (a) Interband response of Georgia State University n-p-n-QWIP measured with front-side illumination. (b) Intersubband spectral response measured with 45° back-side illumination at 80K for positive (left scale) and negative (right scale) bias voltages indicated by V(+) and V(-). When the detector is coupled with a grating, both interband and intersubband responses can be measured with normal incidence light.

0.26nm) of n-type gallium nitride (n-GaN). These QWs were separated by extractor regions (Figure 7) composed of four repetitions of undoped AlN/Al_{0.3}Ga_{0.7}N (4ML/6ML). These structures were grown as a 50-period cascade.

The QC arrangement was simulated to have three bound states (e_1 , e_2 , e_3) between which transitions could be excited by infrared illumination. The energies for intersubband (ISB) transitions from the ground state (e_1) were 0.7eV (e_2) and 1.3eV (e_3). The extrac-

tor structures were tuned to encourage transfer to the next period via scattering with the GaN longitudinal optical phonon of energy 92meV.

The QC structure was sandwiched between n-Al_{0.3}Ga_{0.7}N cladding layers. The material was grown on AlN on c-sapphire templates using ammonia-source molecular beam epitaxy. The active-region growth temperature was 800°C.

For electro-optic measurements, the material was formed into 700μm x 700μm mesas by etching; then titanium/aluminum/titanium/gold top and bottom contacts were applied. The center of the top layer was unmetallized to allow illumination into the device.

The current-voltage curves of the devices were more symmetric than expected, given the polarization electric field in the structure (giving the triangular wells/barriers in Figure 7 simulation), suggesting that perhaps dislocations were creating parasitic conduction channels. The polarization electric field was part of the design of the device, allowing transitions to the second excited state (e_3) through symmetry breaking.

The photovoltage and absorption spectra were measured in a Fourier transform infrared (FTIR) spectrometer (Figure 8). The absorption of the active region was measured in

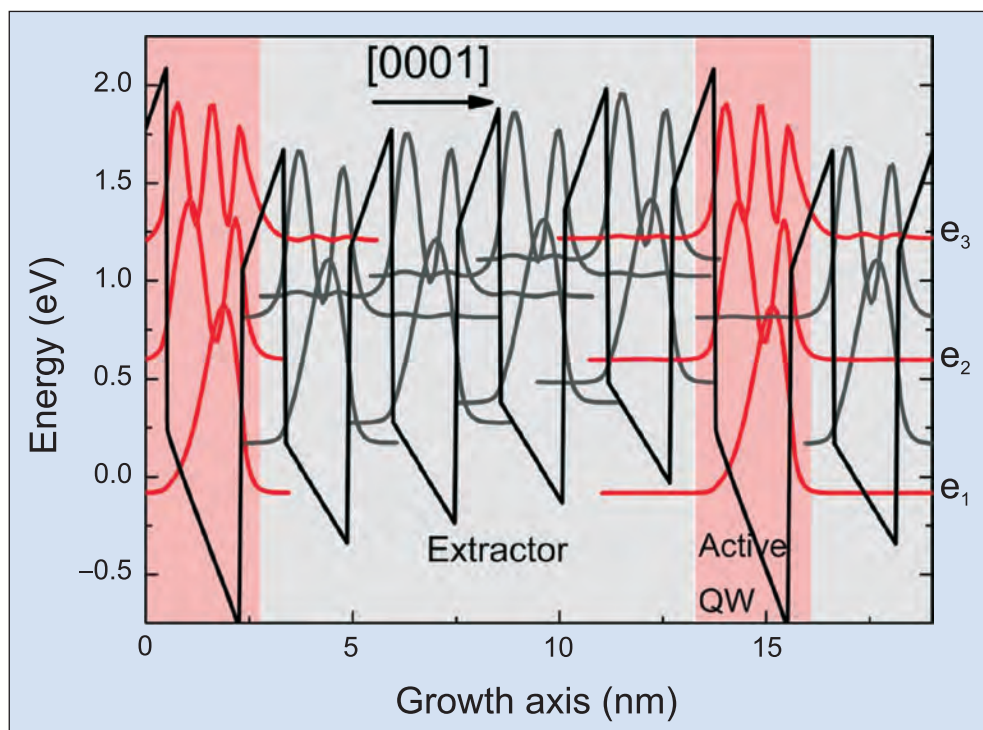


Figure 7. Conduction-band diagram of one period of UPS/EPFL QCD with adjacent active QW. The red and grey regions correspond to active QW and extractor stages, respectively.

scans across facets at 45° to the substrate. Both photovoltage and absorption spectra showed peaks at $1.7\mu\text{m}$ (0.71eV). The $1\mu\text{m}$ (1.25eV) peak was only seen in the photovoltage measurement.

The peaks were only seen with p-polarized light (i.e. with the field direction parallel to plane of incidence) and not with s-polarized (perpendicular) light. This is taken as a "clear indication that they originate from ISB transitions".

The researchers comment: "It should be noted that the $1\mu\text{m}$ peak detection wavelength is the shortest value ever reported for an ISB detector."

The response at 77K was 1.6x that at room temperature. The $1.7\mu\text{m}$ peak had a response of 0.1mA/W at 77K; the value for the $1\mu\text{m}$ peak was 0.008mA/W .

The researchers believe that the response could be improved by reducing the material defects in the active region. Longer-wavelength devices could be produced with lower-Al-content alloys.

Although only detecting a single band, a recent report from Boston University [Faisal F. Sudradjat et al, Appl. Phys. Lett., vol100, p241113, 2012] is of far-infrared (FIR) intersubband photodetectors based on double-step nitride semiconductor quantum wells. The detected FIR at 20K was centered around 54meV photon energy ($23\mu\text{m}$, 13THz). The responsivity of the device was estimated to be 7mA/W at the same temperature.

The Boston device was designed to virtually eliminate the internal electric fields that are common in nitride semiconductor material structures. The double-step

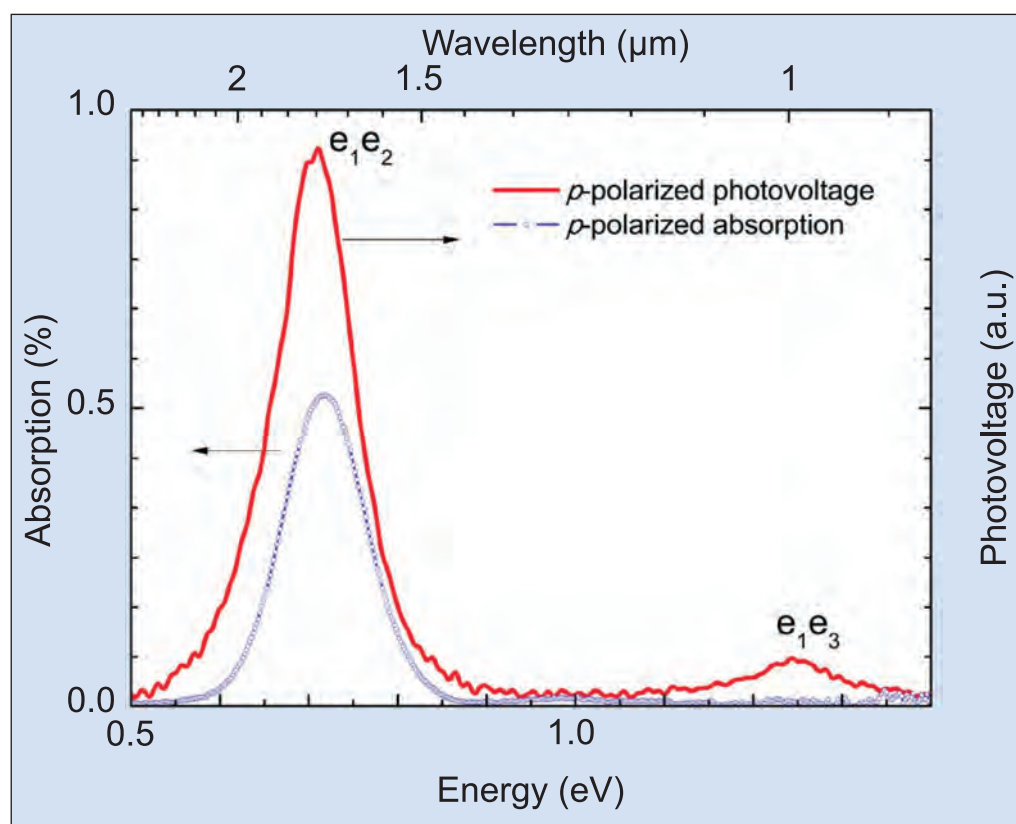


Figure 8. Absorption (solid lines with a square) and photovoltage spectra of UPS/EPFL QCD under p-polarization.

well was repeated 20 times. The structure was grown on free-standing GaN using rf-plasma-assisted molecular beam epitaxy.

The researchers see potential applications in biomedical sensing, explosive and drug detection, security screening, industrial process control, and spectroscopic imaging for astronomy and space physics. The large longitudinal optical phonon frequency (22THz in GaN versus 9THz in GaAs) suggests that such devices could eventually be operated at room temperature. ■

The author Mike Cooke is a freelance technology journalist who has worked in the semiconductor and advanced technology sectors since 1997.

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San Diego, CA 92127,
USA
Tel: +1 858 674 4676
Fax: +1 8586 74 4681
www.quikpak.com

18 Chip foundry

Compound Semiconductor Technologies Ltd

Block 7, Kelvin Campus,
West of Scotland, Glasgow,
Scotland G20 0TH,
UK
Tel: +44 141 579 3000
Fax: +44 141 579 3040
www.compoundsemi.co.uk

United Monolithic Semiconductors

Route departementale 128,
BP46, Orsay, 91401,
France
Tel: +33 1 69 33 04 72
Fax: +33 169 33 02 92
www.ums-gaas.com

19 Facility equipment

MEI, LLC

3474 18th Avenue SE,
Albany, OR 97322-7014,
USA
Tel: +1 541 917 3626
Fax: +1 541 917 3623
www.marlerenterprises.net

20 Facility consumables

W.L. Gore & Associates

401 Airport Rd,
Elkton, MD 21921-4236,
USA
Tel: +1 410 392 4440
Fax: +1 410 506 8749
www.gore.com

21 Computer hardware & software

Ansoft Corp

4 Station Square, Suite 200,
Pittsburgh, PA 15219,
USA
Tel: +1 412 261 3200
Fax: +1 412 471 9427
www.ansoft.com

Crosslight Software Inc

121-3989 Henning Dr.,
Burnaby, BC, V5C 6P8,
Canada
Tel: +1 604 320 1704
Fax: +1 604 320 1734
www.crosslight.com

Semiconductor Technology Research Inc

10404 Patterson Ave., Suite 108,
Richmond, VA 23238,
USA
Tel: +1 804 740 8314
Fax: +1 804 740 3814
www.semitech.us

22 Used equipment

Class One Equipment Inc

5302 Snapfinger Woods Drive,
Decatur, GA 30035,
USA
Tel: +1 770 808 8708
Fax: +1 770 808 8308
www.ClassOneEquipment.com

Brumley South Inc

422 North Broad Street,
Mooresville,
NC 28115,
USA
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Fax: +1 704 664 9246
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24 Consulting

Fishbone Consulting SARL

8 Rue de la Grange aux Moines,
78460 Choisel,
France
Tel: + 33 (0)1 30 47 29 03
E-mail: jean-luc.ledys@neuf.fr

25 Resources

SEMI Global Headquarters

3081 Zanker Road,
San Jose, CA 95134, USA
Tel: +1 408 943 6900
Fax: +1 408 428 9600
www.semi.org

Yole Développement

45 rue Sainte Geneviève,
69006 Lyon,
France
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www.yole.fr

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10–12 July 2012

SEMICON West 2012

Moscone Center, San Francisco, CA, USA

E-mail: semiconwest@xpressreg.net

http://semiconwest.org

31 July – 1 August 2012

The LED Show

Rio All Suite Hotel & Casino, Las Vegas, NV, USA

E-mail: jamesh@pennwell.com

www.theledshow.com

12–16 August 2012

SPIE Optics + Photonics 2012

San Diego Convention Center, CA, USA

E-mail: customerservice@spie.org

http://spie.org/optics-photonics.xml

12–17 August 2012

Defects in Semiconductors: Gordon Research Conference

University of New England, Biddeford, ME, USA

E-mail: Evan.Glaser@NRL.navy.mil

www.grc.org/programs.aspx?year=2012&program=defects

22–24 August 2012

LED Tech Korea 2012 & Optical Expo 2012

KINTEX, Seoul, Korea

E-mail: led2100@naver.com

www.korealed.org

27–30 August 2012

Compound Semiconductor Week (CSW 2012), including:

39th International Symposium on Compound Semiconductors (ISCS 2011) and 24th International Conference on Indium Phosphide and Related Materials (IPRM 2011)

Santa Barbara, CA, USA

E-mail: wmorris@housing.ucsb.edu

http://csw2012.ece.ucsb.edu

29–31 August 2012

IEEE's 9th International Conference on Group IV Photonics (GFP 2012)

Holiday Inn on the Bay Hotel, San Diego, CA, USA

E-mail: r.bankowski@ieee.org

www.gfp-ieee.org

2–6 September 2012

9th European Conference on Silicon Carbide & Related Materials (ECSCRM 2012)

St Petersburg, Russia

E-mail: yuri.makarov@ecscrm-2012.org

www.ecscrm-2012.org

6–9 September 2012

14th China International Optoelectronic Exposition (CIOE 2012)

Shenzhen Convention & Exhibition Center, China

E-mail: cioe@cioe.cn

www.cioe.cn

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10 September 2012

**PV Technology Conference – North Africa 2012:
Solar Energy for the Region**

Hyatt Regency Casablanca, Morocco

E-mail: severine.scala@solarpraxis.de

[www.solarpraxis.de/en/conferences/
pv-technology-conference-north-africa-2012](http://www.solarpraxis.de/en/conferences/pv-technology-conference-north-africa-2012)

10–13 September 2012

Solar Power International 2012

Orange County Convention Center, Orlando, FL, USA

E-mail: spi@experient-inc.com

www.solarpowerinternational.com

10–14 September 2012

**42nd European Solid-State Device Research
Conference (ESSDERC-2012) and
38th European Solid-State Circuits
Conference (ESSCIRC-2012)**

Bordeaux, France

E-mail: cor.claeys@imec.be

www.esscisc.org

18–20 September 2012

Strategies in Light Europe

M.O.C. Event Centre, Munich, Germany

E-mail: jamesh@pennwell.com

www.sileurope.com

23–27 September 2012

**IEEE Photonics Conference 2012 (IPC-2012),
formerly the IEEE LEOS Annual Meeting)**

Hyatt Regency San Francisco Airport, Burlingame, CA, USA

E-mail: m.hendrickx@ieee.org

www.ipc-ieee.org

23–28 September 2012

**17th International Conference on Molecular
Beam Epitaxy (MBE2012)**

Nara Prefectural New Public Hall, Japan

E-mail: secretary@mbe2012.jp

<http://mbe2012.jp>

23–28 September 2012

**37th International Conference on Infrared,
Millimeter, and Terahertz Waves (IRMMW-
THz 2012)**

University of Wollongong, Australia

E-mail: daniel@rice.edu

www.irmmw-thz.org

24–26 September 2012

**2012 International Semiconductor
Conference Dresden-Grenoble (ISCDG)**

MINATEC Campus, Grenoble, France

E-mail: iscdg2012@insight-outside.fr

<http://iscdg2012.insight-outside.fr>

24–27 September 2012

**SPIE Remote Sensing 2012 and
SPIE Security & Defence 2012**

Edinburgh, Scotland, UK

E-mail: customerservice@spie.org

<http://spie.org/security-defence-europe.xml>

<http://spie.org/remote-sensing-europe.xml>

24–28 September 2012

**27th European Photovoltaic Solar Energy
Conference and Exhibition (EU PVSEC 2012)**

Frankfurt, Germany

E-mail: pv.conference@wip-munich.de

www.photovoltic-conference.com

25–27 September 2012

LED Japan/Strategies in Light

Pacifico Yokohama, Yokohama, Japan

E-mail: jamesh@pennwell.com

www.sil-ledjapan.com

30 September – 5 October 2012

**37th International Conference on
Infrared, Millimeter, and Terahertz Waves
(IRMMW-THz 2012)**

Wollongong, Australia

www.irmmw-thz.org

7–10 October 2012

**International Semiconductor Laser
Conference (ISLC)**

San Diego Mission Valley Marriott, CA, USA

E-mail: m.hendrickx@ieee.org

www.photonicsconferences.org

7–12 October 2012

222nd Electrochemical Society (ECS) Meeting

Hawaii Convention Center, Honolulu, Hawaii, USA

E-mail: meetings@electrochem.org

www.electrochem.org/meetings/biannual/fut_mtgs.htm

9–11 October 2012

SEMI CON Europa 2012

Messe Dresden, Germany

E-mail: eweller@semi.org

www.semiconueuropa.org

14–17 October 2012

**IEEE Compound Semiconductor Integrated
Circuit Symposium (CSICS 2012)**

Hyatt Regency Hotel, La Jolla, CA, USA

E-mail: customer.service@ieee.org

www.csics.org

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