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COMPOUNDS & ADVANCED SILICON

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Nitride HEMTs on silicon Nitride LED developments

Aixtron opens China subsidiary • JDSU acquires QuantaSol
News from IMS 2011 • 3Sun opens Italy's largest PV fab

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p26 SemiSouth's SJDPI20R045 SiC JFET, chosen by electronic power module maker Vincotech.



p54 GT Solar's expanded sapphire production facility in Salem, opened in June for production.



p63 President Obama tours Cree's plant in Durham, NC, USA.



Cover: Osram Opto Semiconductors has supplemented its TOPLED Black Series 60° beam-angle portfolio of red and yellow LEDs (which feature integrated lenses in black packages) by adding the three new colors blue, green and orange, suiting use in displays in travel and roadway environments. **p64**

Silicon forming basis for nitride device growth

In this issue we focus on technical developments in nitride-based devices on silicon substrates, both microelectronic devices such as high-electron-mobility transistors (HEMTs) and light-emitting diodes (LEDs).

In the former case, on pages 110–113 we focus on recent developments by France's Institute of Electronic, Microelectronic and Nanotechnology (IEMN), which has used ultrathin aluminium nitride (AlN) barrier layers to maximize carrier densities in the HEMT's channel, reducing on-resistance and enabling improved high-frequency performance on low-cost substrates.

Similarly, on pages 108–109, we report how a team of researchers at Switzerland's ETH-Zürich and France's CRHEA-CNRS have fabricated AlGaIn-barrier HEMTs on high-resistivity (HR) silicon substrates oriented in a direction compatible with mainstream CMOS integrated circuits, claiming the first report of the DC and RF performance of short-gate-transistor AlGaIn/GaN HEMTs grown on (110)-oriented HR silicon, rather than (111) silicon, which has poor properties in terms of CMOS circuit elements.

Likewise, on pages 114–117, we report from this year's International Conference on Compound Semiconductor MANufacturing TECHNOLOGY (CS MANTECH) in Palm Springs, at which several presentations discussed work on nitride HEMTs. These included further work by Colombo Bolognesi's Millimeter-Wave Electronics Group at Switzerland's ETH-Zürich demonstrating the feasibility of millimeter-wave interconnects on GaN-on-Si epilayer stacks and hence the viability of a low-cost AlGaIn/GaN HEMT MMIC technology on high-resistivity silicon substrates.

On pages 28–35, we report news from June's IEEE International Microwave Symposium (IMS 2011) focusing on nitride microelectronic device product developments from the likes of RFMD, Cree, TriQuint, M/A-COM Tech, Fujitsu, Toshiba, Renesas, Integra, Microsemi, and NXP. Although most of these are based on silicon carbide substrates, Nitronex has launched further products using its GaN-on-Si technology, while silicon wafer maker Siltronic has just joined Imec's GaN-on-Si industrial affiliation program (IIAP).

At MANTECH, Eric Higham of market research firm Strategy Analytics forecast how the non-optoelectronic GaN device market will grow from just 1.6% the size of the GaAs market in 2010 to 7% in 2014 (from just \$75m to \$376m). In particular, market research firm Yole Développement adds that, based on the expected price erosion of 6" GaN-on-Si epiwafers, the GaN substrate market alone should exceed \$100m in 2015, driven by consumer and IT applications at 0–900V.

Similarly, on pages 102–104 we cover work by Korean researchers to boost light output power from GaN-on-Si LEDs. One of the organizations involved — the Korea Photonics Technology Institute (KOPTI) — has also just agreed to collaborate on LED lighting technology with Korea's Samsung LED.

US-based LED maker SemiLEDs blames its further quarterly revenue decline on pricing pressure and end-demand weakness (see page 60), while Cree is also suffering in the lull before the expected LED lighting uptake. Although silicon substrates may ultimately provide the low cost required for mass-market adoption for lighting, this may only add to pricing pressure.

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

Regular issues contain:

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

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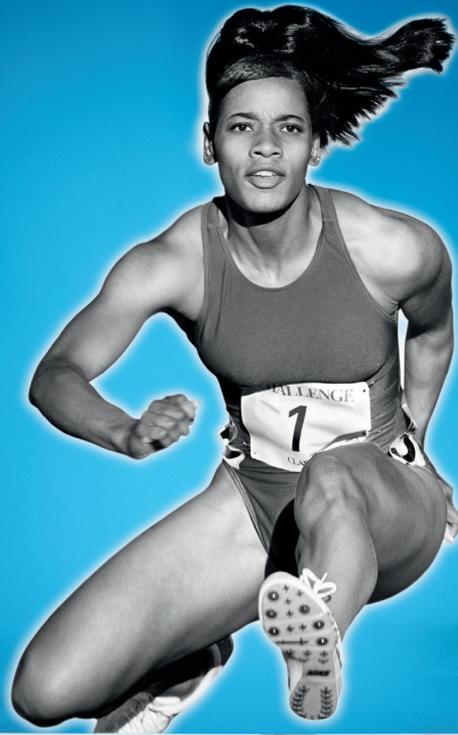
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AIXTRON started in 1983 and is today a leading provider of deposition equipment to the semiconductor industry. With our advanced solutions customers worldwide build components for electronic as well as opto-electronic applications. As pacemaker in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

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Electronic gases market recovers to 2008 levels Gas business forecast to reach \$3.2bn by 2012

After a 14% decline to \$2.37bn in 2009, the electronic gases market grew 16% year-on-year to \$2.74bn in 2010 (exceeding the forecast 11%), according to 'Gases for Semiconductor Device Processing 2011, A Techcet Group Critical Materials Report'. The outlook is for 11% growth overall in 2011, with the electronic specialty gases segment leading the way with 12% growth to \$1.9bn. The combined electronic gases market is expected to exceed \$4.1bn by 2015, forecasts market research firm Techcet Group LLC.

Sales of specialty gases correlate very closely with silicon wafer consumption, and rode the roller-coaster down and back up with the

semiconductor business through the 2009 recession. Bulk gases do not track as closely with wafer starts because the gas volumes attributed to other electronic applications are large in comparison to IC bulk gas.

Driven by consumer spending in lieu of vacations and travel, manufacturing of thin-film transistor (TFT) displays boosted bulk gas consumption in 2010 by 55% over 2009, leading overall gas revenues back to 2008 levels. Vigorous growth in bulk gases is expected to continue with projections of annual market expansions of 10% for ICs and TFTs, 8.5% for LEDs and 24% for photovoltaics over the next several years.

The electronic gas market share leadership position is now a three-way contest between Air Products, Taiyo Nippon Sanso and Air Liquide (each with just under a quarter of the market), followed by Praxair, BOC/Linde, OCI and others.

The report discusses global issues affecting the market dynamics and supply chain stability for He, NF_3 , ion implant and other dopant sources, and specialty gas compounds affected by the supply chain impacts on rare-earth metals which are critical to electronics manufacturing. The outlook for future gas usage — as shaped by environmental concerns, legislative changes, and geopolitical issues — is also discussed.

www.techcet.com

Energy efficiency drives power management IC demand Power semiconductors showing trend to the use of GaN instead of SiC

Power management integrated circuits (PMICs) accounted for 3.5% of the \$298.3bn global semiconductor market in 2010, according to a new report 'Power Management Integrated Circuits (IC) Market to 2020 - Alternative Energy Markets and Energy Efficient Portable Gadgets to Drive Sales Growth' from Companiesandmarkets.com. PMIC market growth is driven by consumer interest in portable devices such as smartphones, and their need for energy-efficient technologies. PMIC sales are being boosted by increasing consumer spending in Asia in particular.

PMICs have applications in the communication, IT, industrial, automotive, medical, defence and electronics sectors. A factor encouraging growth is the interest in energy-efficient technologies, in order to combat rising energy prices and consumer adoption of portable electronic devices.

Alternative energy technologies used to harness solar and wind power are driving demand, as power semiconductors use power management integrated circuits to minimize energy wastage and ensure efficient power distribution. The PMIC report indicates that energy-efficient technologies could reduce global electricity usage by up to 30% by 2025.

The report highlights a trend for the use of gallium nitride (GaN) instead of silicon carbide (SiC) in power semiconductors (which use PMICs), as it enhances power density, breakdown voltage, switching frequency, resistance and system efficiency

Manufacturing companies are seeking improvement opportunities for their power devices, and substrate technology is of interest. The report highlights a trend for the use of gallium nitride (GaN) instead of silicon carbide (SiC) in power semiconductors (which use PMICs), as it enhances power density, breakdown voltage, switching frequency, resistance and system efficiency.

Thermal management is another opportunity to minimize cost and improve efficiencies of power management semiconductor PMICs. Improvements to packaging systems will equip PMICs to cope with fluctuations in current, and subsequently enhance energy management.

Key firms profiled in the report include: Infineon Technologies AG, Linear Technology Corp, National Semiconductor, STMicroelectronics N.V. and Texas Instruments.

www.companiesandmarkets.com

Dedicated LED packaging gear to drive \$2bn investment in 2011–2016

Up to now, LED packaging houses have relied mostly on using retrofitted equipment and materials from IC fabs to improve LED cost of ownership and performance, but what was once a cost-saving and field-proven option is becoming too far removed from the specific needs of LED devices and is now constraining the LED industry, reckons Yole Développement in its market research report 'LED Packaging 2011', which covers the market for capital equipment, packaging trends, and LED manufacturing capacity expectations through 2016.

Although LEDs can have long-term cost benefits over traditional lighting technologies for example, their upfront costs have been inhibiting widespread adoption, notes Yole. However, with packaging accounting for 20–60% of the packaged LED's total cost, this stage of the manufacturing process represents the biggest area for cost reduction.

In particular, the LED market has now gained enough momentum and reached a critical mass to entice equipment and material providers into developing dedicated solutions for LED fabrication and packaging, Yole says. Many dedicated solutions are emerging from both existing and new players that can allow a significant reduction in LED manufacturing costs through improved yields, throughputs and material efficiency.

Consequently, over 2011–2016 more than \$2bn will be invested in new equipment for LED packaging, including laser lift-off (LLO), permanent wafer/die bonding, singulation and testing, reckons Yole.

However, growth in the LED industry will not be straightforward, as a few mini down/up-turn cycles will occur through 2016, reckons Yole. In particular, with the general lighting market scheduled to reach \$20bn by 2020, no LED makers want to get caught short of capacity. The consequent rush to add capacity

for the anticipated spike in demand led to an unprecedented cycle of investment that started around the end of 2009 and is expected to extend through early 2012.

This cycle, initiated in Korea, is now essentially fueled by subsidies and other incentives in China, as the country is aggressively trying to position itself as a future leader in solid-state lighting. New entrants are investing heavily to displace existing manufacturers. This will lead to a global averaged overcapacity that will briefly exceed 50% for some tools (i.e. a capacity utilization rate of less than 50%) by mid-2012.

The over-investment in LED packaging equipment in the last 2 years and the resultant absorption of this overcapacity will create a short 12–18 month down-cycle, starting in early 2012 and extending through mid-2013, forecasts Yole. This may cause some consolidation, predicts Yole, before utilization rates return to the more usual 80% range. By mid-2013, a new investment cycle will begin, fueled again by increasing demand for general lighting. However, this may lead to another, shorter period of excess investment to be absorbed in 2016.

In contrast, material and component suppliers will enjoy a smoother ride, with regular growth at a compound annual growth rate (CAGR) of 27.6% between 2011 and 2016, forecasts Yole.

In particular, package substrate makers will see the fastest growth, with a CAGR of 45% through 2016. Phosphors will experience strong price pressure but will still enjoy double-digit growth, with a CAGR of 12%. However, there is still a lot of room for innovation in this field, which could pay off in capturing more added value, reckons Yole. For such products, it remains paramount that the solution offers an overall reduction in cost of ownership (\$/lumen) to LED makers.

www.yole.fr

Microelectronic revenue continues strong growth

Quarterly growth tops 24% at TriQuint, WIN, Hittite, Skyworks, Microsemi and Soitec

Recent financial reports from companies in the microelectronics segment of the compound semiconductor industry indicate continued sharp revenue growth, notes the Strategy Analytics GaAs and Compound Semiconductor Technologies Service (GaAs) viewpoint 'Compound Semiconductor Industry Review April 2011: Microelectronics'.

The viewpoint from market research firm Strategy Analytics summarizes April's technology, product, contract, financial and employment developments from major microelectronics firms such as RF Micro Devices, Skyworks Solutions, Fairchild, Fujitsu, Hittite Microwave, TriQuint Semiconductor, Soitec and WIN Semiconductors addressing commercial and military applications using gallium arsenide (GaAs), gallium nitride (GaN), silicon carbide (SiC), and complementary metal-oxide-semiconductor (CMOS) technologies.

"The strong revenue reports which Strategy Analytics saw in April show continued compound semiconductor market expansion," notes Eric Higham, director of the Strategy Analytics GaAs and Compound Semiconductor Technologies Service. "Growth in this industry is broad-based as both gallium arsenide (GaAs) and silicon manufacturers are showing strong year-on-year revenue gains," he adds.

"Increasing data consumption is driving development in consumer electronics and networks," comments Asif Anwar, director, Strategy Analytics Strategic Technologies Practice.

www.strategyanalytics.com

IN BRIEF

Anadigics ships dual-band PA for Samsung's first 4G LTE smart-phone

RF and mixed-signal semiconductor maker Anadigics Inc of Warren, NJ, USA says it is shipping production volumes of its AWC6323 dual-band High-Efficiency-at-Low-Power (HELP3E) power amplifiers (PAs) to Korea's Samsung Electronics for its first 4G LTE smart-phone, the feature-packed Droid Charge (which has a 4.3-inch AMOLED display, rear-facing 8 megapixel camera, front-facing 1.3 megapixel camera, and Android 2.2 operating system).

"The Samsung Droid Charge raises the bar for 4G Android smartphones, by delivering an exceptional multimedia experience," says Michael Canonico, Anadigics' senior VP of worldwide sales. "Anadigics has forged a strong relationship with Samsung Electronics by providing power amplifiers with industry-leading efficiency, linearity, and integration," he claims. "We look forward to supporting Samsung through each successive generation of mobile connectivity."

As part of its HELP3E product family, the AWC6323 PAs use Anadigics' exclusive InGaP-Plus technology to achieve optimal power-added efficiency across low-range and mid-range output power levels (via three different mode states) and to provide low quiescent current of 4mA.

Also, integrating an RF coupler and internal voltage regulation together with independent PCS and cell-band PAs in a single package, the compact 3mm x 5mm footprint reduces printed circuit board (PCB) space by 25% compared with current-generation single-band solutions, it is claimed.

www.anadigics.com

Anadigics expands family of small-cell wireless infrastructure PAs

Anadigics has launched the AWB7223, expanding its portfolio of wireless infrastructure power amplifiers (PAs) optimized for small-cell base-station applications, including microcells, picocells and femtocells.

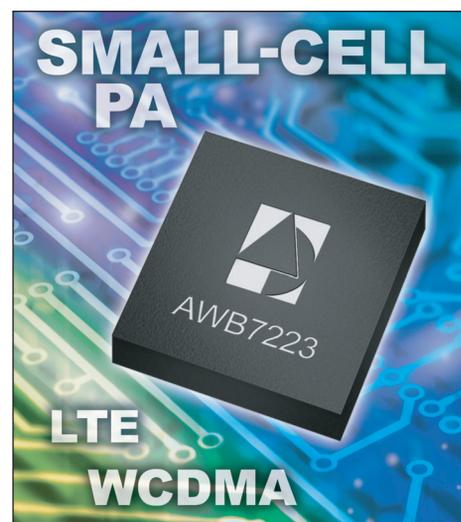
A report from market research firm Mobile Experts forecasts shipments of such equipment to grow from 2.6 million devices in 2011 to over 20 million in 2014, stressing the need for small-cell solutions to support the growing capacity requirements of mobile broadband networks.

"Rising demand for mobile broadband will be the catalyst for a rapid deployment of small-cell wireless infrastructure devices," says Glenn Eswein, director of product marketing for broadband RF products.

"The AWB7223 power amplifier delivers optimal performance for a new generation of microcells, picocells and femtocells that will enable high-data-rate connectivity for a larger base of subscribers," he adds.

"Anadigics' new wireless infrastructure power amplifiers provide the ideal combination of output power, power-added efficiency, and linearity required to produce highly reliable, high-performance small-cell base-stations," claims Joseph Cozzarelli, senior director of broadband RF products.

Supplied in a compact 7mm x 7mm x 1.3mm surface-mount package,



Anadigics' AWB7223 power amplifier.

the AWB7223 provides what is claimed to be best-in-class power-added efficiency (PAE) of 15% at rated output power for WCDMA, HSPA and LTE small-cell base-stations operating in the 1930–1990MHz band, with output power of +27dBm and linearity of -50dBc ACPR @ ±5MHz (WCDMA). Anadigics says this combination of critical performance parameters extends the range of small-cell base-stations while enabling solutions that are more thermally efficient and consume less power.

Engineering samples of the AWB7223 are available now, as are pre-production samples of the AWB7123, AWB7127 and AWB7227.

Anadigics receives award from Huawei

Anadigics has received Huawei's Cooperation and Support Award for outstanding service.

The award was presented to CEO Ron Michels by Derek Luo, Huawei's terminal parts CEG senior business manager. "Anadigics has been recognized for providing exceptional support in responding to Huawei's ramp-up of 3G smart phones in the second and third quarters of 2010," says Luo. "The level of cooperation and support demon-

strated by Anadigics during a critical period in our manufacturing process was significant in ensuring our success in the highly competitive wireless handset market," adds Victor Chu, Huawei's business director terminal parts CEG.

"This award recognizes our commitment to deliver service and support that exceeds customer expectations and reinforces our dedication to growing our partnership with Huawei," says Michels.

Skyworks launches low-power LNAs for diverse 1.5–3.0GHz wireless markets

At the IEEE International Microwave Symposium (IMS 2011) in Baltimore (7–9 June), Skyworks Solutions Inc of Woburn, MA, USA, which makes high-reliability analog and mixed-signal semiconductors, has launched the first in a series of ultra-low-current, general-purpose low-noise amplifiers (LNAs) for diverse wireless applications including satellite receiver set-top boxes, Bluetooth headsets, medically prescribed hearing aids, advanced meter reading devices, and 2.4GHz wireless local area networks. The firm says that the high-performance LNAs deliver enhanced receiver sensitivity and wide dynamic ranges, facilitating improved signal reception, increased design flexibility and reduced part counts.

“Our new low-noise amplifiers enable Skyworks to enter new markets — driving intense diversification beyond our proven front-end solutions for mobile devices,” says David Stasey, VP of analog components.



Skyworks' new SKY67014-396LF LNA.

Manufactured in a compact (2mm x 2mm), 8-pin dual flat no-lead, RoHS-compliant, surface-mount technology package, the SKY67014-396LF is a GaAs pHEMT enhancement-mode LNA with an integrated active bias and on-die

Our new low-noise amplifiers enable Skyworks to enter new markets — driving intense diversification beyond our proven front-end solutions

stability structures enabling simple external matching and stable performance over temperature.

Skyworks' enhancement-mode pHEMT process allows the device to offer return loss of 15dB typical, stable gain (12dB), low noise (<1dB) and high linearity (+18dBm OIP3) while drawing <6mA of bias current. The SKY67014-396LF offers the designer the ability to externally adjust the supply current to further optimize the amplifier linearity performance for the chosen application. The supply voltage is applied to the RF_{OUT}/V_{DD} pin through an RF choke inductor and through the V_{BIAS} pin through an external resistor. The supply voltage is adjustable over a range of 1.5–5V.

The device is the first in a series of high performance, low-power LNAs targeting broadband wireless applications. Additional footprint-compatible LNAs for the 100–700MHz and 700–1500MHz bands will be launched later this year.

www.skyworksinc.com

Skyworks unveils first stand-alone, high-dynamic-range power detectors for 3G and LTE smart-phones and data-cards

Skyworks has expanded its product portfolio by adding high-dynamic-range power detectors for smart-phones and data-cards.

Skyworks claims that its RF detectors are an industry first and address the need for small, stand-alone solutions that are compatible with various baseband architectures and accommodate multiple 3G and LTE band combinations. In addition, the devices have been designed to work with the SKY7770X and SKY7772X series of 3G and 4G power amplifiers to expand the compatibility of the integrated daisy-chain coupler for the majority of basebands and transceivers.

The detectors' small size (1.2mm x 1.5mm) minimizes board space requirements, while higher

dynamic range increases power control and improves total radiated power performance. Their low current consumption enables both longer standby and talk times, and their high off-state impedance level is particularly beneficial for today's demanding, high-end 3G smart phones, claims the firm.

“Skyworks' new power detectors are highly compatible with other solutions from our portfolio and allow us to offer our customers a full end-to-end solution for smart-phones and data-cards,” says Gregory L. Waters, executive VP & general manager of front-end solutions.

The SKY77002 is designed for use in smart-phones and data-cards in conjunction with Skyworks'

power amplifiers in 3G and LTE applications. The stand-alone, high-dynamic-range power detector is fabricated using Skyworks' GaAs HBT process, offering reliability, temperature stability and ruggedness. The detector circuit technology is optimally aligned for transceivers that require external detection for power control. Temperature and voltage compensation maintains accuracy over extreme operating conditions. The detector presents high off-state impedance to the transceiver to minimize loading other detectors connected to the input line.

The SKY77002 is packaged in a quad flat no-lead package and is compliant with current restriction of hazardous substances requirements.

RFMD showcases new RF components at IMS 2011

RF Micro Devices Inc of Greensboro, NC, USA showcased its portfolio of products and technologies for the wireless and wired broadband markets at the 2011 IEEE International Microwave Symposium (IMS) in Baltimore, MD (6–8 June).

The firm highlighted products for a wide range of end-market segments including: broadband transmission, defense & aerospace, point-to-point microwave radio, WiFi, wireless infrastructure, wireless consumer products, WiMAX and SmartEnergy.

Products displayed span the firm's portfolio, including:

- a variety of gallium nitride (GaN)-based products, including high-power transistors and ICs;
- the RFMD2080/81 IQ modulators with integrated LO oscillators, designed for point-to-point and other software-defined radio applications;
- point-to-point products including up/down-converters, MMIC voltage-controlled oscillators (VCOs) and other products addressing the RF and IF functions of the point-to-point radio transceiver;
- the new RFSA2714 and RFSA2724 digital step attenuators and the RFSA2013 and RF2023 voltage-controlled attenuators, optimized for cellular 3G/4G/LTE and WiMAX markets;
- RFMD's portfolio of highly integrated multi-chip modules (MCMs) for wireless infrastructure applications.

RFMD also introduced its 2011–2012 Product Selection Guide, which features specifications for more than 900 products including over 90 recently released products targeting multiple end-market applications. The 63-page guide allows cross-referencing and searching of products using end-market application diagrams.

Staff presenting papers, chairing sessions and hosting proceedings at the symposium represented RFMD's Broadband Components, Defense and Power, Wireless Connectivity, Wireless Products, and Foundry Services business units.

Narrowband MMIC VCOs with integrated dividers for P2P radio

RFMD has expanded its multi-market product portfolio to include the RFVC1831–RFVC1844 family of MMIC voltage-controlled oscillators.

Covering 7.2–15.1GHz frequencies, the 14 new narrowband VCOs are optimized for the point-to-point (P2P) radio market, with cellular backhaul the leading application. They are also suited to satellite communications, test & measurement, aerospace & defense, and other defense and commercial applications.

The P2P radio market is growing rapidly, as the proliferation of smart-phones and the increasing demand for mobile data are forcing cellular operators to expand capacity in cellular backhaul networks.

RFMD says that its new narrowband MMIC VCOs satisfy operators' capacity expansion requirements by delivering what is claimed to be industry-leading phase noise performance and minimal power consumption. The VCOs also feature monolithic construction and exhibit superior performance related to temperature, shock, and vibration, the firm adds.

"RFMD's RFVC1831 through RFVC1844 MMIC VCOs complement our existing RFUV and RFRX product families of integrated up-converters and down-converters and extend our commitment to providing the industry's most comprehensive and most technically advanced product portfolio for point-to-point microwave radio applications," says Jeff Shealy, general manager of RFMD's Defense and Power business unit.

The phase noise performance of the VCOs enables the development of next-generation high-capacity radios using complex modulation schemes. They also have a common footprint, providing radio designers extra flexibility in designing outdoor base-station units (ODUs) covering discrete radio bands of 6–38GHz. Finally, the VCOs have integrated dividers that can be disabled if not required in particular applications.

Highly linear monolithic VCAs for wireless and wired markets

RFMD has launched the RFSA2013 and RFSA2023 voltage-controlled attenuators (VCAs), which operate from 5V and 3V supplies, respectively, cover a wideband frequency range of 50–4000MHz and satisfy a wide range of applications across end markets.

The fully monolithic VCAs have high linearity, with a third-order intercept point of more than 50dBm over a 30dB gain control range. The devices incorporate a new circuit architecture that provides what is claimed to be industry-leading overall performance in linearity, attenuation range, DC current and bandwidth, as well as a linear attenuation profile versus control voltage. The VCAs also employ internal temperature compensation to provide a stable attenuation profile over an operating temperature range from –40°C to +85°C.

RFMD claims that competing VCAs, typically using PIN diodes, have poor attenuation over tempera-

ture and a nonlinear attenuation profile versus control voltage. To correct such performance shortcomings, they need further off-chip calibration and correction circuitry, which consumes valuable board space, adds cost and requires additional DC power. RFMD says that, by comparison, its products provide a complete monolithic solution in a small 3mm x 3mm QFN package.

"RFMD's new attenuator products help customers significantly reduce cost by lowering the overall component count and reducing power consumption for the attenuator application," claims John Pelose, general manager of RFMD's Wireless Products business unit, adding that they can not only lower overall system cost but increase end-product performance. ▶

► RFMD launches P2P radio chipsets for cellular backhaul

RFMD has expanded its multi-market product portfolio to include several point-to-point (P2P) radio chipsets targeting the growing cellular backhaul market. The highly integrated radio chipsets combine multiple RF/microwave radio front-end components and expand the portfolio to encompass all critical RF and IF functions in the P2P radio transceiver.

RFMD says its highly integrated P2P radio chipsets help to satisfy operators' capacity expansion requirements by optimizing each front-end component for next-generation high-capacity 3G/4G radios using complex modulation schemes. The front-end components deliver what is claimed to be industry-leading narrowband performance. Also, their broadband nature enables radio designers to maximize design flexibility and simplify inventory bill-of-material control, RFMD claims.

"RFMD is rapidly expanding our product portfolio in support of the point-to-point microwave radio

market," says Jeff Shealy, general manager of RFMD's Defense and Power business unit. "With the launch of these highly integrated radio chipsets, RFMD enables our customers to develop high-reliability, next-generation point-to-point radio solutions while reducing design time requirements and lowering overall bill-of-material costs."

Each P2P radio chipset is available in a surface-mount QFN package. The integrated up-converters include an LO amplifier (with x2 multiplier where applicable), IQ mixer, VVA and driver amplifier in a single package. The integrated down-converters use 0.15µm GaAs technology to deliver what is claimed to be industry-leading IIP3 and noise figure performance. Finally, the integrated MMIC VCOs also exhibit what is claimed to be industry-leading phase noise performance coupled with flat output power over the frequency tuning bandwidth. To complement the new radio chipsets, RFMD also offers a portfolio of converters and gain blocks for the radio's IF section.

Low-power IQ modulators with integrated local oscillators

RFMD has extended its portfolio of broadband components with two low-power IQ modulators with integrated fractional-N synthesizers and VCOs.

The RFMD2080 and 2081 can generate output frequencies from 45MHz to 2700MHz, and suit satellite communications, point-to-point radio, software-defined radio, and other applications needing QPSK/QAM modulators. The broadband nature of the components and integration of the local oscillator offer a competitive combination of functionality, versatility and size, claims RFMD.

The 2080 has a baseband interface incorporating programmable filtering and gain control. Optimized for low-power operation, current consumption is just 150mA from a 3V supply, allowing more environmentally friendly systems with reduced power consumption. Offered in QFN 5mm x 5mm packages, both the 2080 and 2081 are programmable using a simple 3-wire serial interface.

www.rfmd.com

RFMD launches RF6555 ZigBee FEM for smart energy

RFMD has unveiled its latest ZigBee front-end module (FEM), the RF6555, optimized for smart energy/advanced metering infrastructure (AMI) applications providing utilities and consumers more control over how they monitor and save energy.

ZigBee is a global low-power wireless networking standard for monitoring and control of applications including energy management, safety and security, home automation, lighting and electrical appliances.

The highly integrated RF6555 combines the power amplifier (PA), harmonic transmit filtering and low-noise amplifier (LNA) with bypass mode in a single 5mm x 5mm x 1mm package, enabling users to shrink product footprint, accelerate product time-to-market, lower bill of material (BOM) costs, and reduce power consumption for smart energy and home-area network (HAN) applications, RFMD claims.

As well as battery-operated smart grid and smart energy applications (such as smart meters, demand response, and HAN devices), the RF6555 also suits industrial and other wireless sensing and control applications requiring low power consumption, high performance, and proven reliability, the firm adds.

The RF6555 operates with the EM300 Series chips from Ember Corp of Boston, MA, USA: the EM351 and the EM357 — in both system-on-chip (SoC) and network co-processor modes — as well as with the EM250 SoC and EM260 network co-processor.

"Industry analysts forecast global smart energy deployments will continue to grow rapidly, with particular demand anticipated in low-power wireless networking technologies like ZigBee," notes Bob Van Buskirk, president of RFMD's Multi-Market Products Group (MPG).

Ember's ZigBee networking systems — chips, ZigBee protocol software and tools — simplify the complexity of integrating embedded software, networking and RF for developing low-power, wireless products in smart energy, connected home and other remote monitoring and control applications. Since its inception, Ember has been the most deployed ZigBee platform in the market.

The EM300 Series is Ember's next-generation ZigBee chip family, and the world's foremost ARM Cortex-M3 based ZigBee SoC, packing what's claimed to be the industry's highest wireless networking performance and application code space into the lowest-power-consuming chip set. The EM250 and EM260 are the most deployed family of ZigBee semiconductors.

www.ember.com

TriQuint's new base-station RFICs integrate protection for data-intensive mobile networks

TriQuint Semiconductor Inc of Hillsboro, OR, USA, which provides RF front-end product maker and foundry services to mobile device, networks, and defense & aerospace markets, has released the first members in a new family of integrated RF products that lower power consumption while protecting mobile networks from disruption and service failures. Its newest base transceiver station (BTS) network devices join 12 other new power and filter infrastructure solutions introduced in first-half 2011.

"Consumer demand for smartphones and tablets means more bandwidth through the network. That leads to the requirement for greater linearity in the RF chain," says vice president Brian P. Balut. "At the same time, our customers want to minimize power consumption, and they want devices that withstand spikes and other stresses that may occur in the field," he adds. "These two new products uniquely address all these needs."

TriQuint says it is focused on bringing performance innovation to essential building blocks in the global network. This network is fraught with demand; by 2015, the amount of mobile data traffic contributed by tablets alone is expected to equal that of mobile data traffic from all devices combined in 2010, according to the 2011 Cisco Visual Networking Index.



TriQuint's new 0.25W TQP7M9101 base transceiver station network device.

The new base-station devices start with the 0.25W TQP7M9101, which provides high gain and linearity with very low current consumption — just 88mA in a typical 5V design. The 0.5W TQP7M9102 is also now available, providing highly linear performance, low current consumption and greater gain.

TriQuint's patent-pending integrated protection features include means to guard against ESD and DC over-voltage electrical spikes. The firm also integrates RF overdrive protection, which reduces the chance of damage from high signal levels often seen in systems employing digital pre-distortion linearization techniques commonly used to meet 3G/4G BTS system requirements. Unlike other linear driver amplifiers available, the

TQP7M9101 also integrates matching circuits that eliminate the need externally. TriQuint says that these integration benefits reduce the overall bill of materials (BOM) and provide easier-to-use solutions that are especially important when fast time-to-market is a key manufacturer strategy.

"TriQuint regularly releases new amplifier and linear gain blocks that offer useful improvements. They appreciate that design requirements change all the time," comments Alexander Kopp, RF designer at Andrew Wireless Systems/CommScope in Buchdorf, Germany. "A more linear RF signal is very important, and with very low current drain, we can reduce a system's thermal dissipation," he adds. "The TriQuint team has offered us great support."

TriQuint's two new amplifiers are suited to 3G/4G wireless infrastructure applications including base transceiver stations, repeaters, boosters, tower-mounted amplifiers (TMAs), remote radio heads (RRHs), defense/aerospace and other wireless systems requiring high linearity and gain with low power consumption.

TriQuint's base-station, microwave and defense/aerospace developments were displayed at the IEEE MTT-S International Microwave Symposium (IMS 2011) in Baltimore, MD, USA (5–10 June).

TriQuint launches 10–12GHz, 2W linear amplifier

TriQuint Semiconductor Inc of Hillsboro, OR, USA, which provides RF front-end product maker and foundry services to mobile device, has launched the TGA2535-SM, a high-linearity power amplifier designed using the firm's GaAs power pHEMT production process to operate at 10–12GHz.

The TGA2535-SM typically provides 43dBm of OIP3 (output

third-order intercept point) at 20dBm $P_{out}/Tone$, 25dB of small-signal gain, 33dBm of P1dB (output power at 1dB gain compression), and saturated power of 34.5dBm at a quiescent bias condition of 6V and 1300mA. The input and output of the amplifier are matched to 50Ω with a typical return loss of 15dB.

Available in a low-cost, surface-

mount 24-lead 5mm x 5mm QFN package, the amplifier is best suited to 10GHz and 11GHz point-to-point radio applications and X-band communications, and is pin compatible with the TGA2533-SM (12.7–15.4GHz) amplifier.

Evaluation boards are available upon request.

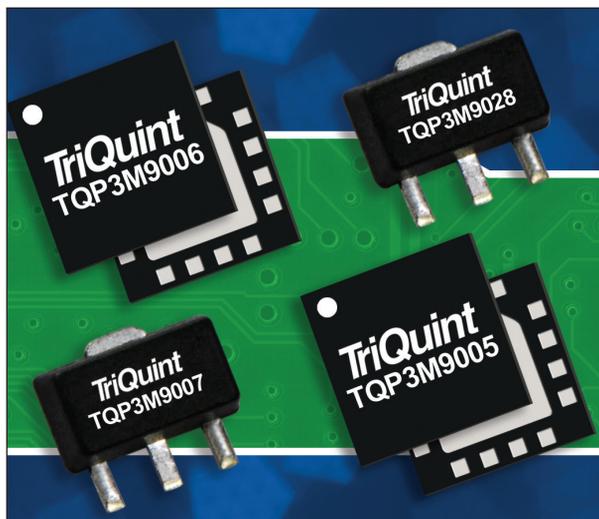
www.triquint.com

TriQuint broadband LNAs eliminate matching components & deliver linear performance

TriQuint Semiconductor Inc of Hillsboro, OR, USA, which provides RF front-end product maker and foundry services to mobile device, networks, and defense & aerospace markets, has launched four new linear low-noise amplifiers (LNAs) that eliminate matching components in a wide range of high-performance broadband applications including 3G/4G base-station networks.

TriQuint comments that the global network is fraught with demand that continues to grow; by 2015, the amount of mobile data traffic contributed by tablets alone is expected to equal that of mobile data traffic from all devices combined in 2010 (according to the 2011 Cisco Visual Networking Index).

"Consumer demand for smartphones and tablets means more bandwidth through the network, which leads to the need for greater RF chain linearity," says Brian P. Balut, TriQuint's vice president Networks. "Our customers want to integrate functions for simplified design and greater efficiency," he adds. "TriQuint solutions deliver by leveraging our unique technology portfolio and experience meeting worldwide network RF design



TriQuint's four new linear low-noise amplifiers.

requirements."

TriQuint's new LNAs are part of a wide-ranging portfolio created to provide flexible, highly efficient linear solutions for broadband markets including mobile network base-stations, repeaters, point-to-point radios, test and other high-performance applications. Available in cost-effective standard surface-mount packages, the cascadable 50Ω LNAs consume as little as 50mA of electrical current and offer gain options of 15–19dB; all operate on a single positive power supply (3–5V) and are unconditionally stable.

The new products include:

- TQP3M9005, which has a low 0.8dB noise figure and provides 15dB of gain at 1.9GHz; P1dB RF output is 22.3dBm; OIP3 is 34dBm; electrical current consumption (I_{dd}) is 50mA.

- TQP3M9006, which has a low 1.0dB noise figure and delivers 13.5dB gain at 1.9GHz; P1dB RF output is 22.4dBm; OIP3 is 38.5dBm; electrical current consumption (I_{dd}) is 90mA.

- TQP3M9007, which is a gain block that operates with a low 1.3dB noise figure while delivering 13dB gain at 1.9GHz; P1dB RF output is 23.6dBm; OIP3 is 41dBm; electrical current consumption (I_{dd}) is 125mA.

- TQP3M9028, which has a low 2.0dB noise figure and provides flat gain (± 0.2 dB) across a wide bandwidth; it delivers 14.7dB gain at 1.9GHz. The device's P1dB RF output power is 21dBm; OIP3 is 40dBm; electrical current consumption (I_{dd}) is 85mA.

Samples and evaluation boards are available.

www.triquint.com

TriQuint appoints general manager of Defense & Aerospace unit

TriQuint Semiconductor says that James L. Klein has joined it as VP & general manager of its Defense and Aerospace business, based in TriQuint's facility in Richardson, TX and reporting to president & CEO Ralph Quinsey. Klein will work closely with Tom Corder, current VP & general manager of Defense & Aerospace, as Corder supports the transition and prepares to retire.

"Tom has done a wonderful job building our business," says Quinsey. About Klein, he adds: "His



James L Klein.

experience and deep industry knowledge will be invaluable in helping us take our defense & aerospace business into the next decade".

Klein has more than 20 years of industry experience in RF, most recently with Raytheon's Space and Airborne Systems division, responsible for the design and

manufacturing of RF and microwave subsystems and components. Previously, he held various positions with Texas Instruments, where he focused on MMIC and Transmit/Receive module engineering. He holds both Bachelor and Master of Science degrees in Electrical Engineering from Texas A&M University.

"TriQuint's commitment to technology innovation and customer service make it an ideal place to define the next generation of RF solutions," comments Klein.

Avago launches first WiMAX coexistence FEM for simplified design of mobile electronics

Avago Technologies has launched a complete RF front-end module (FEM) for WiMAX radios in mobile handset or portable PC applications.

The AFEM-S257 module is designed specifically for coexistence operation of WiMAX with other cellular and WiFi radios in the same device. It features two receive ports and a single transmit port (with 25dB of TX/RX isolation and RX1/RX2 isolation) in a small 5mm x 7mm x 1mm package that suits space-constrained mobile applications in the 2.5–2.7GHz frequency range, providing up to 25% space savings over discrete WiMAX solutions.

With all RF ports matched to 50Ω, the module integrates multiple high-performance technologies to reduce PCB board footprint, while simplifying design and manufacturing and shortening time to market, Avago claims. Using the firm's proprietary 0.25μm GaAs enhance-

ment-mode pHEMT process and film bulk acoustic resonator (FBAR) filtering technologies, the module delivers what is claimed to be superior performance across voltage and temperature levels. FBAR technology delivers steep roll-off and low insertion loss, resulting in extended battery life and talk-time and better signal quality. With high noise rejection of 35dBc, the module enables fewer interference issues between IEEE 802.16 WiMAX and other radios. The AFEM-S257 achieves 24dBm of WiMAX-compliant output power, while maintaining an error vector magnitude (EVM) of 2.5% at 16 quadrature amplitude modulation (QAM). With a 3–5V power supply for TX path and 18% power-added efficiency (PAE), TX gain is 34dB. The noise figure (NF) from antenna to RX is 3.5dB.

"The AFEM-S257 front-end module provides a complete, compact solu-

tion that can be easily and quickly designed in to mobile WiMAX applications, which is demonstrated in the top three reference designs addressing this market," says James Wilson, senior director of marketing for wireless products. "With Avago FBAR filtering technology delivering unparalleled out-of-band rejection, the module offers the performance major smartphone makers demand," he adds.

The AFEM-S257 WiMAX coexistence front-end module is available in a 28-lead MCOB package and is priced at \$9.50 each in 10,000-piece quantities.

Avago gave a live demonstration of the AFEM-S257 module, and exhibited its complete RF and microwave portfolio, at the 2011 IEEE Microwave Theory & Techniques Society (MTT-S) International Microwave Symposium (IMS) in Baltimore, MD, USA (7–9 June).

Integrated switch/LNA modules for TD-SCDMA & -LTE base-stations

Avago Technologies has launched a series of high-power switch low-noise amplifier (LNA) modules for use in front-end receiver designs of TD-SCDMA and TD-LTE base transceiver station (BTS) applications.

The small-footprint ALM-12x24 modules replace existing three-piece discrete solutions, providing significant board-space savings (especially critical for BTS designs with eight transceiver channels in a single radio card). The fully matched solutions also shorten design cycle time by eliminating the need for tuning with external matching circuitry, says Avago. The modules deliver what is claimed to be best-in-class noise performance, high gain and high linearity from a compact package.

The new modules integrate a high-power 50W single-pole, double-throw (SPDT) switch, a

first-stage LNA and a second-stage high-linearity amplifier in a lead-free 8mm x 8mm package (with 50dB isolation between the first- and second-stage amplifiers, enabling external addition of an attenuator or RF filter without affecting the overall module performance).

Constructed with an Avago low-distortion silicon PIN diode, the SPDT switch prevents the LNA from damage by high-power signals potentially leaking over from the transmit chain in conditions where the antenna is mismatched.

The LNA and high-linearity amplifier leverage the firm's proprietary 0.25μm GaAs enhancement-mode pHEMT process to achieve robust RF performance.

The wireless infrastructure industry must provide optimum coverage with the best signal quality in a crowded spectrum, says Avago. Receiver sensitivity is the most crit-

ical requirement in a BTS receiver's design, and LNA selection greatly affects the receiver's performance, it adds. For front-end design architectures, low noise figure (NF) is a key design goal. Another key design factor is linearity, which affects the receiver's ability to distinguish between wanted and spurious signals that are closely spaced. The ALM-12124 covers 1880–2025MHz with 0.80dB NF and typical linearity performance of 36.4dBm OIP3 at 1900MHz in receiver mode. The ALM-12224 covers 2300–2400MHz with 0.99dB NF and 38.5dBm OIP3 typical performance at 2400MHz in receiver mode. The ALM-12x24 modules also have a high power-handling capability of 47.5dBm.

The ALM-12x24 modules ship in a 24-pin MCOB package. The ALM-12124 and -12224 are priced at \$8.58 in 10,000-piece quantities.

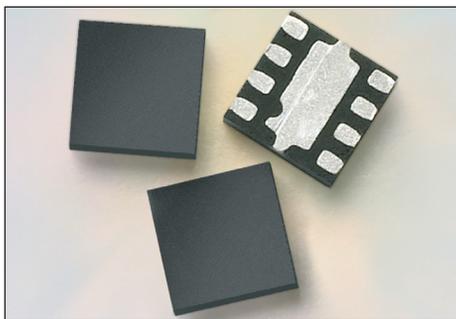
www.avagotech.com

Avago adds two LNA series to RF & microwave portfolio for cellular infrastructure

At the IEEE International Microwave Symposium (IMS 2011) in Baltimore, MD, USA (7–9 June), Avago Technologies Ltd announced an expansion of its portfolio of RF and microwave components for cellular infrastructure applications with two new series of low-noise amplifiers (LNAs). Featuring what is claimed to be best-in-class noise performance and high linearity, the new MGA-63xP8 LNAs and ALM-11x36 fail-safe bypass LNA modules deliver improved receiver sensitivity for base transceiver stations (BTS) and tower mounted amplifiers (TMA) applications.

The MGA-63xP8 devices and ALM-11x36 modules expand Avago's LNA portfolio for BTS applications, which leverage the company's proprietary 0.25 μ m GaAs enhancement-mode pHEMT process to deliver low noise figure and high linearity. As opposed to a broadband approach, Avago offers series of LNAs with each device optimized for superior end performance at specific frequency operation ranges. Both new LNA series exemplify this philosophy. Reflecting the portfolio's emphasis on integration, the ALM-11x36 modules can replace large discrete and surface-mount component counts in conventional designs, shortening design cycle time and providing board space savings.

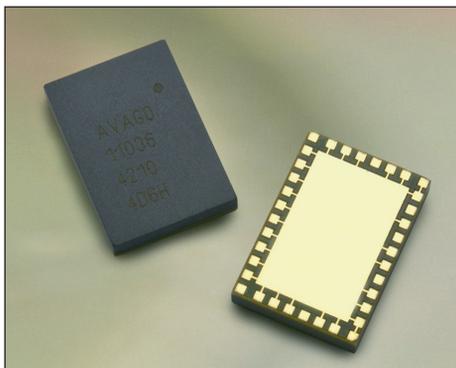
"These two new LNA series, along with the other high-performance products we have introduced leading up to IMS 2011, demonstrate our commitment to extend our leading LNA portfolio for the wireless infrastructure market and raise the bar for noise figure and overall performance," said James Wilson, senior director of marketing for wireless products. "We continue to work with our customers to develop highly-integrated solutions that streamline the design process and help them to keep up with continuously evolving cellular standards."



Avago's MGA 63xP8 LNAs.

At IMS 2011, Avago exhibited its complete RF and Microwave portfolio for cellular infrastructure applications. In addition to LNAs, the portfolio includes Film Bulk Acoustic Resonator (FBAR) filters, gain blocks, driver amplifiers, and WaferCap amplifiers and detectors, as well as modules that integrate multiple technologies. Avago also presented live demonstrations of its recently announced AFEM-S257 RF front-end module (FEM) for WiMAX coexistence in mobile handset or portable PC applications.

The high-linearity MGA-63xP8 LNA series integrates active bias circuitry and a power down function, simplifying design by eliminating the need for external discrete components to perform the same functions. The series offers high-gain performance consistent across 700–2600MHz, with the MGA-636P8 device operating from 450–1500MHz, while the MGA-637P8 and -638P8 operate from 1500–2500 and 2500–4000MHz, respectively. The series thus sup-



Avago's ALM-11036 LNA.

ports all major cellular bands for GSM, CDMA and UMTS, as well as the next-generation LTE bands. The LNAs are housed in a common footprint miniature package measuring 2.0mm by 2.0mm by 0.75mm. With a shared pin-out and layout of external matching network, the LNAs provide a common PCB layout for customers when used at different frequencies, simplifying design. The performance and features of the series make them ideal to be used as second or third stage LNAs for cellular BTS radio cards, TMAs, combiners, repeaters and remote or digital radio heads.

The ALM-11x36 LNA modules are equipped with a fail-safe bypass function, which is especially critical for TMA applications to enable the LNA bidirectional bypass path during the absence of DC power supply. Their superior bypass isolation eliminates the possibility of oscillation issues, and the modules also feature low bypass insertion loss and high input and output return loss. All matching components are fully integrated within the modules and the 50 Ω RF input and output pins are already internally AC-coupled. This makes the modules easy to use, as the only external parts required are DC supply bypass capacitors. The series delivers optimum performance across a wide range of bands, with the ALM-11036 module covering 776–870MHz, the ALM-11136 module covering 870–915MHz, the ALM-11236 module covering 1710–1850MHz and ALM-11336 module covering 1850–1980MHz. All the modules share the same compact 7.0mm by 10.0mm by 1.5mm package and pin-out configuration and are thus suited to common platform designs.

The MGA-63xP8 LNAs ship in a surface-mount 8-lead QFN package. The ALM-11x36 LNA modules ship in a 36-lead MCOB package.

www.avagotech.com

IN BRIEF

Mouser distributing for M/A-COM Tech

Semiconductor and electronic component distributor Mouser Electronics Inc of Mansfield, TX, USA is now selling products for M/A-COM Technology Solutions Inc of Lowell, MA, USA (which makes semiconductors, components and subassemblies for RF, microwave and millimeter-wave applications).

Products provide functionality such as signal conditioning, frequency conversion, amplification, limiting, attenuation, signal generation, transmission, and reception. Target applications include cellular base-stations and infrastructure, military communications, avionics, radar, medical equipment, point-to-point and broadband radios, and broadcast equipment.

M/A-COM Tech has more than 60 years' experience in designing and manufacturing RF product solutions. Mouser has more than 40 years of distribution experience. "Together, we will bring advanced RF technologies to engineers worldwide, helping them get their designs to market faster," says Russell Rasor, Mouser's VP of advanced technology.

"Having Mouser Electronics as our authorized global distributor offers us the opportunity to address our customers' needs for time-critical design cycles," comments Jim Dempsey, director of M/A-COM Tech distribution.

Mouser offers 17 global support locations. Its website is updated daily and searches more than 8 million products to locate over 2 million orderable part numbers from over 400 manufacturers, available for online purchase. Mouser.com also has an interactive catalog, data sheets, supplier-specific reference designs, application notes, technical design information and engineering tools.

www.mouser.com

OMMIC launches 10 new MMICs for telecom and radar applications

At the 2011 IEEE International Microwave Symposium (IMS) in Baltimore (7–9 June), III-V foundry OMMIC SAS of Limeil-Brévannes, near Paris, France launched 10 new MMICs for telecom and radar applications, including low-noise amplifiers (LNAs), power amplifiers and control functions from 5 to 160GHz.

OMMIC has reduced the noise figure for commercially available LNAs covering the 5–7, 18–26, 25–43, 13–15 and 110–160GHz bands to 0.5, 1.1, 1.5, 1.5 and 4.5dB via the new CGY2120XUH, CGY2121XUH, CGY2122XUH, CGY2125AUH and CGY2191UH MMICs, respectively. In addition, the CGY2178HV is a new plastic-packaged version of the space-qualified CGY2178UH MMIC, providing more than 30dB of gain and 1dB noise figure over the 5–6GHz frequency band.

In power amplifiers, OMMIC has launched the CGY2138UH, a 5W MMIC operating in the 27.5–31GHz band with 19dB of gain under 5V bias and 5.6A current. The MMIC suits VSAT and point-to-point/point-to-multipoint applications.

OMMIC has also launched new products in its control function family of devices. The CGY2179UH and CGY2179HV are bare die and QFN plastic-packaged versions of a 4-bit phase shifter and LNA combination operating in the 10.7–12.75GHz band, providing 12dB of gain and a 1.9dB noise figure. An on-chip serial-to-parallel converter simplifies the interfacing to the MMIC and in particular allows easy daisy chaining with a minimum number of interface lines and bonding pads. The CGY2174UH is a 6-bit phase shifter designed for the 13–16GHz frequency range and is suited to both space-based and terrestrial Ku-band telecom antennas.

"These new products demonstrate OMMIC's commitment to bring to market products that have outstanding and unique specifications based on OMMIC's set of leading-edge but commercial technologies — from the 70nm MHEMT to the enhancement/depletion-mode PHEMT processes," says marketing & sales director Derek Smith.

www.ommic.com

M/A-COM Tech promotes Dempsey to director of global distribution

M/A-COM Technology Solutions Inc of Lowell, MA, USA has promoted James (Jim) Dempsey to director of global distribution, reporting to VP of sales Jack Kennedy.

Dempsey has 25 years of industry experience, with a background in wireless data and infrastructure, aviation radar and military products. Most recently he was deputy director of distribution at M/A-COM Tech, but previously he has held leadership roles at Skyworks Solutions Inc, Alpha Industries and Herely Micro-Dynamics. Dempsey received a B.S. degree in Electrical Engineering from Wentworth Institute of Technology, while also earn-



Jim Dempsey.

ing a certificate from the MIT Sloan School of Management in the Greater Boston Executive Business Program.

"Jim's product knowledge and previous experience with our distributor network is a true benefit to M/A-COM Tech," says Kennedy. "Jim's primary goal is to further develop product introduction initiatives and drive new product sales," he adds.

www.macomtech.com

M/A-COM Tech launches LNAs for RF & microwave applications

M/A-COM Technology Solutions Inc of Lowell, MA, USA (which makes semiconductors, components, and subassemblies for RF, microwave and millimeter-wave applications) has launched the MAAL-01070X family of low-noise amplifiers (LNAs) for cellular infrastructure applications.

The firm claims that the GaAs-based LNAs facilitate easy implementation in multiple RF and microwave front-end circuits including GSM, CDMA, WCDMA and LTE base-stations and repeaters, meeting the performance requirements of telecom equipment makers optimizing for minimum system noise figure and increased receiver sensitivity.

"The low noise figure coupled with high gain and OIP3 make these LNAs ideal for first- and second-stage 3G and 4G receivers," claims David Richardson, market director of M/A-COM Tech Infrastructure Products.

The MAAL-010705 and -010706 are highly linear LNAs with low noise figure (0.5dB and 0.6dB, respectively), high gain (21.0dB and 17.5dB) and good input return loss (19dB and

20dB) and output return loss (19dB and 16dB) designed for operation at 0.5–1.6GHz and 1.4–4.0GHz, respectively. The two amplifiers share the same pin out and are packaged in an RoHS-compliant leadless 2mm x 2mm DFN package. The bias current and gain can be set with external resistors, allowing customization of the current consumption and gain value to fit the application.

The MAAL-010704 is a versatile broadband LNA in a SOT-363 package which operates at 0.1–3.5GHz. Gain is 14.0dB, noise figure is 0.8dB, input return loss is 12dB and output return loss is 20dB. The bias current can also be set externally via the use of a resistor.

The LNAs all feature an integrated active bias circuit allowing direct connection to a 3V voltage supply while minimizing variation over temperature and process.

Production quantities and samples of the MAAL-010705 and -010706 are available from stock. The MAAL-010704 will be available for sampling and production later this summer.

www.macomtech.com

Director of aerospace & defense appointed

M/A-COM Tech has appointed Glen Fields as director, aerospace & defense (A&D), reporting to Suja Ramnath, VP & general manager of the firm's market-facing businesses. Fields is now responsible for leading aerospace & defense initiatives.

A 10-year veteran at M/A-COM Tech, Fields was most recently area director for Asia Pacific and New Territory sales, leading business development and sales operations for these high-growth regions. Previously, he contributed to sales management in M/A-COM Tech's Pacific Northwest, Midwest, Canada, Southern California and Arizona sales territories. His lead-



Glen Fields.

ership and understanding of this market is expected to enable further A&D market penetration by M/A-COM Tech. "His many years of experience in this market will greatly benefit the company," says Ms Ramnath.

Fields received a B.S. in Systems Engineering from the US Merchant Marine Academy, and an MBA from University of San Diego. He is also a Commander in the US Naval Reserve, with 17 years of service.

Ocampo joins RFAxis' advisors

Fabless semiconductor firm RFAxis Inc of Irvine, CA, USA, which was founded in January 2008 to design RF semiconductors and embedded antenna solutions for the wireless connectivity and cellular mobility markets, says that John Ocampo is to join its board of advisors.

Ocampo is co-founder & president of Silicon Valley-based semiconductor private equity fund GaAs Labs LLC and (since acquiring it from UK-based Cobham plc in March 2009) chairman of its portfolio company M/A-COM Technology Solutions Inc. He also serves on the board of directors for Ubiquiti Networks Inc, which designs and makes broadband wireless solutions worldwide.

Prior to creating GaAs Labs, Ocampo co-founded Sirenza Microdevices Inc of Broomfield, CO, USA, serving in key roles including president & CEO, chief technology officer, and chairman. After leading Sirenza through an IPO and eventual sale to RF Micro Devices Inc of Greensboro, NC in 2007, Ocampo served on RFMD's board of directors.

Prior to Sirenza, Ocampo was general manager at RF component maker Magnum Microwave, and engineering manager at telecoms engineering firm AvanteK (later acquired by Hewlett-Packard).

"John is a well-respected semiconductor operations & technology executive and financier who brings to RFAxis a wealth of advisory experience in increasing growth trajectory, profitability and market leadership," says RFAxis chairman & CEO Mike Neshat. "As a private equity investor, John is very savvy with respect to business development, and he has a proven track record of success in driving and closing major deals," he adds.

"I am very impressed with RFAxis' RF and CMOS innovations," comments Ocampo. "I look forward to helping RFAxis achieve its market and strategic objectives."

www.rfaxis.com

New features and productivity enhancements of AWR 2011 design suite showcased at IMS

At the 2011 IEEE International Microwave Symposium (IMS) in Baltimore (7–9 June), high-frequency electronic design automation (EDA) software tool provider AWR Corp of El Segundo, CA, USA showcased the latest release of its design suite.

AWR 2011 adds new features and productivity enhancements to every product in the suite, including Microwave Office high-frequency design software, AXIEM 3D planar electromagnetic (EM) analysis software, Visual System Simulator (VSS) communication system design and optimization software, and Analog Office RFIC design software.

The new features are as follows:

Microwave Office & Analog Office

- Design sharing (group design) makes it simple to manage data (schematics, layouts, EM analysis, and measurements) and to resolve conflicts as sub-designs are combined and merged into a module or subsystem.

- Simulation state management (SSM) allows large amounts of simulation results from optimization runs, swept simulations, or Monte Carlo analyses to be efficiently

managed in Microwave Office and Analog Office as well as in AXIEM software at all stages of the design process.

- Yield analysis allows parameterized, graphical geometry manipulation directly in AWR's unified data model (UDM) architecture, ensuring that the entire design remains synchronized with respect to parameterized geometry.

- RF Aware short/open checker makes it possible to detect and eliminate errors in wiring and layout early in the design flow.

- AWR Connected for CapeSym SYMMIC lets MMIC designers to capture and view the interdependencies between thermal and electrical properties and to address them throughout the design process.

- Floating windows allows any window (layout, 3D views, measurements, etc) to be pulled outside the run-time window for analysis.

AXIEM

- Asynchronous EM simulation allows users to keep working while EM analysis is being performed transparently in the background on multi-CPU computers.

- User-defined parameterized models enables both parameterized cells (pCells) or 'static' shapes to be accessed and manipulated to define an EM parameterized model that can be defined by the user and simulated on demand, allowing the designers to use the actual shape in a highly accurate EM analysis.

- EM yield, sweeps, and optimization automatically integrates yield analysis, sweeps, optimization, and DFM seamlessly into the design flow.

Visual System Simulator

- Envelope simulator lets designers simulate circuit-level, time-variant phenomena such as memory effect in digital pre-distortion (DPD) configurations so they can focus on final performance metrics such as EVM and ACPR earlier in the design.

- System-level RF subcircuit parameters allows nonlinear circuits in Microwave Office to share the same hierarchical parameter-passing as blocks within VSS software.

- RF Budget Analysis spreadsheet wizard brings the power of VSS RF Budget Analysis to spreadsheet enthusiasts.

www.awrcorp.com

Analog Office RFIC PDK for Lfoundry's 0.15µm RF CMOS process

AWR has announced the availability of a process design kit (PDK) for the LF150 process of LFoundry GmbH of Landshut, Germany (a foundry for analog, mixed-signal and specialized technologies).

LF150 is a modular 0.15µm RF CMOS process, offering up to six levels of aluminium plus thick metal (2–6µm), optionally a MIM capacitor, a polyimide passivation and I/O voltages of 1.8V, 3.3V and 5.0V. This new PDK targets customers designing RFICs for telecom, automotive, industrial and energy-saving applications.

The Analog Office design kit includes a full set of RF devices, along with a set of standard

devices that will expand to include more options as customer demand warrants. The PDK includes fully scalable models covering temperature effects, process corners, and Monte Carlo statistical behavior.

Analog Office supports PowerDRC/LVS and Calibre verification flows, both of which are offered in the new PDK. It also includes all electromagnetic (EM) stack-up information pre-configured to perform EM analysis and/or RLCK parasitic extraction from within the Analog Office design environment using AWR's EM Socket interface.

"We are currently working with one of our European customers in tapping out a design using our advanced

LF150 process together with AWR's Analog Office software," says LFoundry's chief technology officer Gerhard Spitzlspenger. "This PDK combines LFoundry's LF150 0.15µm RF CMOS process with AWR's innovative software and technologies, giving our mutual customers many benefits and advantages to successfully complete designs," he adds.

"LF150 provides an excellent fit with Analog Office's customer requirements," comments AWR product manager Graeme Ritchie. "With RF MOS f_Ts of up to 90GHz, LF150 is ideal for circuits operating up to 10GHz and beyond, enabling a wide variety of RF applications to be addressed."

UMS expands EM analysis support using Agilent's ADS 2011 EDA software

United Monolithic Semiconductors (UMS), which designs and produces RF, microwave and millimeter-wave components and ICs for the telecom, space, defense, automotive and ISM sectors at its facilities in Orsay, France and Ulm, Germany, has announced the availability of the majority of its design kits for various process technologies for use Advanced Design System (ADS) 2011.01 electronic design automation (EDA) software, which was released in March by Agilent Technologies Inc of Santa Clara, CA, USA.

"Agilent worked closely with us to make sure our PDKs now support complete EM [electromagnetic] analysis," says Eric Leclerc, manager of UMS' foundry business department. "This is a key requirement of most of our customers that use ADS for their MMIC designs support, the kit itself being a major step forward in simulation accuracy, validation, and ease of use," he adds.

"In addition to circuit simulation, EM analysis has become the norm when simulating and verifying MMIC/RFIC designs," says Juergen Hartung, foundry program manager of Agilent's EEs of EDA division

(which supplies EDA software for microwave, RF, high-frequency, high-speed digital, RF system, electronic system-level, circuit, 3D electromagnetic, physical design and device-modeling applications). "This past year we collaborated with UMS to enable advanced EM analysis natively within its kits by leveraging the latest ADS 2011 product enhancements. The new kits work seamlessly with ADS 2011, as well as ADS 2009 Update 1," he adds.

The UMS PDKs support a complete ADS front-to-back-end MMIC design flow with scalable devices, dedicated EM analysis, native design rule checker (DRC), and the latest layout capabilities in ADS 2011.

"With these kits, our customers can enjoy the industry's most comprehensive multi-technology design platform using Momentum, the industry-leading 3D planar EM simulator, as well as our integrated full 3D FEM engine, industry-proven Design-for-Manufacturing (DFM) capabilities inside ADS, and the recently upgraded DRC," says Hartung.

www.ums-gaas.com
www.agilent.com/find/eesof-ads

EDA software tool supplier AWR completes merger with National Instruments

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 completed its merger with National Instruments Corp (NI) of Austin, TX, USA (which provides automated test equipment and virtual instrumentation software).

As announced on 23 May, AWR will continue to operate as a wholly owned subsidiary of NI under the leadership of the existing manage-

ment team.

"We are pleased to have progressed through the final phase of this merger with relative ease," says AWR's CEO Dane Collins. "Now we are ready to take advantage of the synergies between AWR's design validation software and NI's test and measurement product portfolio to further increase customer productivity and satisfaction," he adds.

www.awrcorp.com
www.ni.com/nati

OMMIC PDKs offer front-to-back flow support for Agilent's ADS 2011 software

At the 2011 IEEE International Microwave Symposium (IMS) in Baltimore (7-9 June), III-V foundry OMMIC SAS of Limeil-Brévannes, near Paris, France announced the availability of process design kits (PDKs) for use with Agilent Technologies' Advanced Design System (ADS) 2011 EDA software. The kits work with ADS 2011, ADS 2009 Update 1 and prior ADS releases, enabling mutual customers to take advantage of ADS 2011.

"Customers expect an integrated tool flow to meet their RF and microwave design challenges and to achieve first-time-right designs," says president Marc Rocchi. "Leveraging the latest ADS 2011 capabilities in our PDKs, we are now able to provide our mutual customers a complete front-to-back flow within a single environment including DRC sign-off. This is an integral part of OMMIC's Fab+ Foundry Service," he adds.

"We are very happy with the expanded PDK support from OMMIC, as we see a strong and growing demand for ADS 2011 support in our customer base," says Juergen Hartung, foundry program manager of Agilent's EEs of EDA organization. "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 engine, industry proven design-for-manufacturing capabilities inside ADS, and an upgraded design rule checker," he adds.

The OMMIC PDKs for the ED02AH (PHEMT), D01PH (PHEMT), D01MH (MHEMT) and D007IH (MHEMT) processes support a complete ADS front-to-back end MMIC design flow with scalable devices, native design rule checker and the latest layout capabilities in ADS 2011.

www.ommic.com

TowerJazz teams with DARPA's GRATE program BiCMOS for 200–300GHz then 300–400GHz and 400–500GHz HBTs

Jazz Semiconductor of Newport Beach, CA, the US subsidiary of specialty foundry Tower Semiconductor Ltd of Migdal Haemek, Israel (collectively TowerJazz), has unveiled a cost-sharing collaboration with the US Defense Advanced Research Projects Agency (DARPA) to advance its roadmap for high-frequency silicon germanium HBT devices.

The DARPA program GRATE (Gratings of Regular Arrays and Trim Exposures) aims to use grating masks combined with conventional photolithography to achieve very fine dimension features as an alternative to more costly lithography techniques such as immersion lithography. The grating masks will be used in combination with the standard masks currently used in volume semiconductor device manufacturing.

The TowerJazz roadmap includes BiCMOS platforms which have both

CMOS and bipolar devices on a single wafer and are offered monthly on a foundry basis in multi-project wafer (MPW) runs. The existing BiCMOS platforms are based on 350nm, 180nm and 130nm CMOS nodes, and the variants include HBT device performance at 60, 150, 200 and, most recently, 260GHz. In the multi-year GRATE program, TowerJazz will develop methods for implementing grating and trim exposures in its existing BiCMOS platforms in three stages: to target 200–300GHz devices, 300–400GHz devices, and finally with research on 400–500GHz HBT devices.

TowerJazz has partnered with the University of California, San Diego (UCSD) for novel circuit demonstrations using the new technology platforms and for teaming on extremely high-frequency test and characterization of HBT devices as well as interconnect and passive

components such as microstrip lines and MIM capacitors. This high-frequency data and modeling will be the basis for millimeter-wave (mmWave) design kits that enable customers to design and simulate mmWave circuits and products.

TowerJazz also says that it will bring its pure-play specialty wafer foundry approach to the program through MPW runs to allow select, early access to the technology.

"Our team has demonstrated abilities to print sub-90nm features with very good depth of focus, and we are applying these methods to our SiGe BiCMOS technologies," says TowerJazz executive director David Howard (primary investigator for GRATE). "We look forward to demonstrating novel capabilities and offering these technologies to our customers through our MPW infrastructure."

www.darpa.mil

SWID selects TowerJazz as strategic foundry for RF ICs

Fabless IC design firm Southwest Integrated Circuit Design Co Ltd (SWID) of Shenzhen, China (which provides ICs and other electronic circuits for mobile communication, modules and systems, circuit design, circuit production, circuit test, and circuit marketing) has selected TowerJazz's SiGe BiCMOS process technologies to develop its latest RF ICs. SWID is announcing availability of an integrated walkie-talkie chip (XN239) and a low-noise amplifier (XN255) to complement its existing fully integrated RF tuner.

SWID's XN239 is manufactured using TowerJazz's SBC35 process and is a multi-functional transceiver chip. It includes a built-in power detector as well as an MPU to perform functional control through a serial interface that can significantly reduce the need for other discrete components and reduce the total bill-of-materials (BOM) cost of the walkie-talkie.

XN239 realizes a good noise figure for the transmission and receiver design of audio-frequency walkie-talkies, it is claimed; its radio frequency is 460MHz; its first-order IF (intermediate frequency) is 21.7MHz; and its 2nd IF is 450kHz or 455kHz, which can support dual-frequency conversion.

SWID's XN255 is fabricated using TowerJazz's SBC18 process and is a low-noise amplifier (LNA) for GPS applications. SiGe BiCMOS technology enables both the high gain and low noise required for sensitive GPS receivers. With XN255 placed at the front-end of a GPS receiver, it can increase the sensitivity of the signal receiver so the GPS can be used in many different environments. XN255 can be operated with a 2.7–3.3V voltage source, and its current consumption is only 3mA, with an idle current of less than 10µA which allows very low power consumption.

"They offer very reliable technologies, extremely accurate models and excellent technical support, which enables us to achieve first-time silicon success and to reduce our design cycle time," comments SWID's president Lin Fan about TowerJazz. "We look forward to continuing to work together on several other products," he adds.

"SWID leverages our SiGe BiCMOS process to enable better noise performance over standard CMOS and better integration of RF functions," says Dr Marco Racanelli, senior VP & general manager, RF and High Performance Analog Business Group, TowerJazz. "SWID is a very important customer and an RF communication applications leader as well as a significant company within the Chinese region, and we will continue to support them as their strategic foundry of choice for SiGe solutions."

www.swid.com.cn
www.towerjazz.com



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UHB LED Solid State Lighting
BiFET/BiHEMTs



Strained Layer & Quantum Well
Multi-junction CPV Cells

Agilent simulation & modeling for TSMC's 65nm, 60GHz CMOS wireless RDK

Agilent's SystemVue, GoldenGate and Momentum RFIC solutions have been included in the 65nm, 60GHz RF Reference Design Kit (RDK), version 3.0, of Taiwan Semiconductor Manufacturing Company, the world's largest silicon wafer foundry. The solutions link RF system, subsystem and component-level design and analysis as part of a comprehensive design flow.

Developed using Agilent's simulation and modeling solutions, the kit provides silicon correlation results; extracted S-parameter models for various interconnects, transmission lines and transformers; simulation test benches, and a flow tutorial that helps customers design high-frequency, high-bandwidth wireless ICs with confidence.

"Agilent collaborated closely with us on RF and electromagnetic design enablement," says Suk Lee, TSMC's director of design infrastructure marketing. "We want to deliver a comprehensive simulation and modeling solution crossing system, millimeter-wave circuit and interconnect-as-component boundaries," he adds.

"Until recently customers developing 60GHz CMOS wireless gigabit link or radar ICs had to create and maintain their own millimeter-wave CMOS process design kits (PDKs)," says Paul Colestock, RFIC planning & marketing manager for Agilent's EEs of EDA organization. "TSMC and Agilent have connected the dots for customers by providing a certified millimeter-wave-ready RDK for evaluation, which includes a 60GHz CMOS reference design and a tutorial along with Agilent's comprehensive millimeter-wave CMOS design solutions for the Cadence Virtuoso platform," he adds.

www.agilent.com/find/eesof

TowerJazz assisting TecnoPolis del Sur with R&D in Argentina

Specialty foundry TowerJazz has signed an agreement with Public and Private Consortium TecnoPolis del Sur (TecnoPolis del Sur) of Buenos Aires, Argentina to help foster research and technological development in Argentina, with the aim of enabling product competitiveness in the international market.

The terms of the agreement include training the R&D groups of TecnoPolis del Sur by TowerJazz on process design kits (PDKs) and technology, and TowerJazz will provide discounted multi-project wafer (MPW) space in its fabs. In exchange, TecnoPolis del Sur will grant TowerJazz the right to use its facilities in Bahía Blanca, helping TowerJazz enter a new region and expand its global reach into South America. The program will use the broad spectrum of technologies that TowerJazz offers, including power management, RF CMOS and silicon germanium (SiGe).

TecnoPolis del Sur promotes the economic and technological development of Argentina, mainly through design, prototyping and testing of high-added-value electronic systems, and builds on the capacities of Universidad Nacional del Sur (Argentina's leading academic institution for IC design), INTI (National Institute of Industrial Technology), UIBB (Industrial Union of Bahía Blanca) and the infrastructure of the Trade Free Zone (TFZ) Bahía Blanca — Coronel Rosales. TecnoPolis del Sur is located in the Trade Free Zone area of Bahía Blanca and Coronel Rosales counties in the province of Buenos Aires. The location in Bahía Blanca will be built next to the airport and the location in Coronel Rosales is already located next to the seaport, providing close proximity to air and sea and easy access for product trade.

A ceremony to sign the agreement was held on 6 June at the Flags Room of the Ministry of Science,

Technology and Productive Innovation (Ministerio de Ciencia, Tecnología e Innovación Productiva — MINCyT) in Buenos Aires city, presided over by MINCyT Director of International Relations, Eng. Agueda Menvielle. Also present were representatives from the Israel Embassy.

MINCyT was created to incorporate science and technology for economic and social development of Argentina. This goal required a series of innovations with respect to organizational structure and financing instruments, e.g. an initial private and public investment of US\$8.6m by MINCyT in TecnoPolis del Sur. The MINCyT-sponsored initiative aims to produce Argentina's first scientific park specializing in electronics.

"TecnoPolis del Sur is a platform to empower Argentine talent by enabling conception, design and prototyping of high-added-value electronic systems," says TecnoPolis del Sur's principal investigator Dr Pedro Julian (who was awarded the MINCyT Houssay Prize in Engineering in 2010). "We are strategically located in a Trade Free Zone with access to air and sea, offering optimal conditions to target niche electronic product markets... TecnoPolis del Sur and TowerJazz share common roots: we both base our value on specialty solutions," he adds.

"South America is a growing market," comments TowerJazz's VP of sales Dani Ashkenazi. "By working with TecnoPolis del Sur and the exceptional engineers in Argentina, TowerJazz will contribute to the expansion of their ecosystem of technology development by providing the essential components of manufacturing excellence and innovation, and in turn we will greatly expand our global reach by gaining access to this important region."

www.tecnopolisdelsur.com.ar

www.towerjazz.com



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Silicon-on-sapphire IC firm Peregrine's co-founders receive IEEE award for Emerging Technologies

At the 2011 IEEE International Microwave Symposium (IMS) in Baltimore on 6 June, the 2011 IEEE Daniel E. Noble Award for Emerging Technologies was presented to IEEE members Mark L. Burgener and Ronald E. Reedy, who in 1990 co-founded Peregrine Semiconductor Corp of San Diego, CA, USA, a fabless provider of RFICs based on silicon-on-sapphire (SOS).

Sponsored by the Motorola Foundation, the award recognizes them for basic R&D of SOS technology culminating in high-yield, commercially viable ICs that have impacted the wireless communications market.

IEEE says Burgener and Reedy stood by SOS technology that, despite great promise, had initially been abandoned by semiconductor market leaders. The advantages of using sapphire as a substrate for ICs include its high resistance to radiation and insulating properties that prevent stray currents from



Mark L. Burgener and Ronald E. Reedy.

spreading to other circuits. First discovered in the 1960s, SOS technology presented manufacturing problems that prevented firms from pursuing commercialization. The persistence of Burgener and Reedy during the 1980s and '90s overcame these obstacles, making SOS commercially viable and enabling it to penetrate the wireless communications market. The emerging technology produces ICs with improved speed, lower power consumption and more isolation compared with bulk silicon circuits.

Even after demonstrating viable

SOS circuits, Burgener and Reedy had to erase the stigma associated with the earlier problems before SOS could become commercially accepted, says IEEE. Funding was difficult to obtain, engineers were wary of becoming involved with the technology, and technical hurdles at fabrication facilities needed to be solved based on the unique requirements of producing SOS circuits. To spur commercialization efforts, they co-founded Peregrine in 1990, and developed the UltraCMOS process, which solved the critical manufacturing issues and made SOS cost-effective. After an initial shipment of 100 chips in 1995, Peregrine has now sold more than 500 million UltraCMOS ICs.

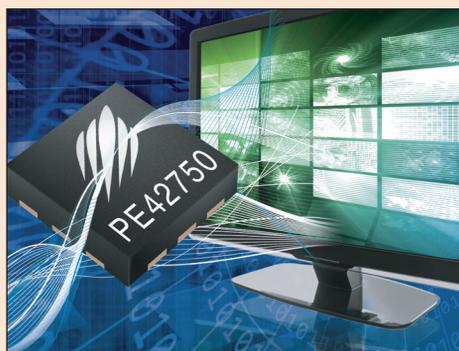
Burgener holds 22 patents on SOS and related IC technologies. He is VP of advanced research at Peregrine. Reedy holds 18 patents on SOS and optoelectronics technologies. He is chief operating officer.

RF switch addressing FCC 15.115 isolation spec for broadband TV

Peregrine has made available the RoHS-compliant PE42750 75Ω RF switch for broadband consumer use including cable TV, digital TV, multi-tuner digital video recorders, set-top boxes, PCTVs and video game consoles.

Manufactured on Peregrine's UltraCMOS technology, the HaRP-enhanced single-pole, double-throw (SPDT) device have high linearity and isolation performance in both powered and unpowered states, addressing the stringent broadband requirements of the FCC 15.115 specification.

The PE42750 RF switch features isolation of 63dB at 1GHz (typical). Isolation levels are maintained in the unpowered state in compliance with the FCC 15.115 standard for CATV-to-antenna isolation. During unpowered operation, the ports are terminated to prevent reflected



Peregrine's PE42750 RF switch.

signals between the terrestrial and cable antennas. This high level of isolation is a key feature to ensure high performance in consumer TV applications, says Peregrine.

"Until now, manufacturers of these types of products have used mechanical relays or multiple solid-state switches in their designs for high-isolation switching," says Mark Schrepferman, marketing

director for Peregrine's HPS business unit. "The PE42750 is an elegant alternative that not only meets the FCC isolation specification, it does so in a solution that is smaller, more cost-effective, more reliable, and easier to implement in the design," he adds.

The switch spans a frequency range from 5MHz to 2200MHz with a single positive supply and CMOS control, and delivers low insertion loss (0.7dB @ 5MHz and 1.0dB @ 1000MHz); high IIP3 (47.5dBm at 5–2200MHz); and ESD performance of 2000V HBM on all ports.

The PE42750 is supplied in a 3mm x 3mm 12-lead QFN package priced at \$0.57 in 10,000-quantity orders. Samples are available to qualified customers through global sales representatives and its worldwide distribution partners.

www.psemi.com

GCT launches first 4x4 MIMO WiMAX 2 single-chip

GCT Semiconductor Inc of San Jose, CA, USA, a fabless designer of CMOS-based RF transceivers and system-on-chip (SOC) integrated circuits for 3G and 4G wireless communications, has announced the GDM7225 WiMAX 2 (IEEE 802.16m) single-chip, which integrates RF, MAC and PHY functions.

Designed for the growing demands of the WiMAX broadband market, the monolithic WiMAX 2 single-chip offers a 4x4 Multiple Input Multiple Output (MIMO) system, enabling high-speed wireless broadband communications 4–5 times faster than existing WiMAX technology. The GDM7225 allows for higher data rates and provides backward compatibility with existing 16e mobile WiMAX (IEEE 802.16e) requirements. With the new WiMAX 2 single-chip, GCT is collaborating with Japan's UQ Communications Inc to enhance their 4G WiMAX network.



GCT's GDM7225 WiMAX 2 single-chip.

"As the demand for wireless broadband continues to grow exponentially, UQ Communications Inc is committed to advancing and improving our mobile WiMAX capacity," says its president Akio Nozaka.

"Cooperation with GCT enables us to take full advantage of the potential of mobile WiMAX 2 in Japan," he adds.

"WiMAX 2 is the natural next-generation option for WiMAX operators to improve network performance cost-effectively," says GCT's president

& CEO Dr Kyeongho 'KH' Lee. "Our new WiMAX 2 single-chip will power the terminal devices needed by operators that are upgrading their networks," he adds. "The announcement of GDM7225 demonstrates our continuing efforts to advance the 4G ecosystem and provide market-proven 4G SoC solutions to our WiMAX and LTE customers."

GDM7225 has a complete transceiver that supports full coverage of the 2GHz WiMAX band in Japan and other countries, and offers what is claimed to be the first 4x4 MIMO performance enabled by four independent RF receivers. With its proprietary MIMO modem technology, GDM7225 enables performance at speeds of up to 150Mbps downlink and 50Mbps uplink. It also supports multi-carrier operation (10MHz + 10MHz) up to 20MHz bandwidth.

www.gctsemi.com

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Cree launches 1200V Z-Rec SiC Schottkys

Cree Inc of Durham, NC, USA, which makes silicon carbide (SiC) substrates as well as power devices, has launched a new family of seven 1200V Z-Rec SiC Schottky diodes optimized for price and performance and available in a range of amperages and packages. The firm aims to advance the adoption of SiC power devices into mainstream power applications by introducing a comprehensive family of SiC diodes with a wide range of amperage ratings and package options.

"To develop the next generation of power electronics, design engineers are looking for the unique performance advantages of SiC Schottky diodes – zero reverse recovery losses, temperature-independent switching losses, higher-frequency operation – all with a lower EMI signature," says John Palmour, Cree co-founder & chief technology officer, Power and RF. "This new family of diodes allows a higher current density and increased avalanche capability over previous-generation SiC

Schottky diodes with no penalty in performance," he adds. "Cree's recent innovations in device design and commitment to continuous process improvement are allowing us to offer significantly higher amperage ratings at lower cost per amp."

Cree's Z-Rec diodes feature zero reverse recovery, resulting in a reduction in switching losses of up to 50% versus comparable silicon diodes. They also exhibit consistent switching performance across their entire temperature range, simplifying circuit design and reducing the need for complex thermal management, the firm claims. When used in conjunction with Cree's 1200V SiC power MOSFETs (launched in May), the Schottkys enable the implementation of all-SiC power electronic circuits with the capability to operate at up to four times higher switching frequencies compared with conventional silicon diodes and insulated-gate bipolar transistors (IGBTs), says the firm. This enables a reduction in the size, complexity and cost

of inverter circuitry, while achieving extremely high system efficiency, Cree claims. Finally, the new family has the additional benefits of higher surge ratings and avalanche capabilities than the previous generation of SiC Schottky diodes, helping to increase overall system reliability.

The devices are suitable as boost diodes and anti-parallel diodes in solar inverters and 3-phase motor drive circuits, as well as in power factor correction (PFC) boost circuits in power supplies and UPS (uninterruptible power supply) equipment. They can also be used in applications where engineers typically parallel many devices to address higher-power requirements.

Devices now released are rated for 2A [C4D02120x], 5A [C4D05120x], 10A [C4D10120x], 20A [C4D20120x] and 40A [C4D40120x]. Dependent on amperage ratings, the parts are available in standard or fully isolated TO-220 and standard TO-247 packages.

www.cree.com/power

SemiSouth SiC diodes and JFET chosen by power module maker Vincotech

SemiSouth Laboratories Inc of Starkville, MS, USA, which designs and manufactures silicon carbide (SiC) power devices and electronics for high-power, high-efficiency, harsh-environment power management and conversion applications, says that its Schottky diodes and junction field-effect transistors (JFETs) have been selected by electronic power module maker Vincotech GmbH of Unterhaching, Germany.

Vincotech's modules are used for applications including motion control, renewable energy, and industrial converters, as well as switched-mode power supplies (SMPS) and uninterruptible power supplies (UPS). The datasheet for the recently launched flowSOL0-SiC module acknowledges the value



SemiSouth's SJD120r045 SiC junction field-effect transistor.

that SemiSouth's SiC diodes and normally-off JFETs add to the modules' performance.

Vincotech's flowSOL0-SiC PZ12NMA025FN (MNPC topology with split output)/PZ12B2A025FN (dual booster) modules are rated for 1200V/25mΩ operation. Targeting high-efficiency solar inverters, UPS, and DC-DC

converters, the modules combine multiple 10A diodes and 100mΩ JFETs.

SemiSouth offers the only normally-off SiC JFETs available in the world, claims director of sales Dieter Liesabeths. "By combining both products [Schottky diodes and JFETs] in SiC technology, the end customer will be able to increase switching frequency and reduce losses, neither of which would be possible with conventional silicon MOSFETs," he adds.

Vincotech's new modules are available for sampling, with mass production due to begin in third-quarter 2011. SemiSouth's SiC diodes and JFETs are immediately available in production quantities.

www.vincotech.com
www.semisouth.com

Anvil to develop SiC power semiconductor switches

Further funding round later this year to target prototype devices

The firm Anvil Semiconductors Ltd has been launched at the UK's University of Warwick, created by its technology commercialization subsidiary Warwick Ventures Ltd. It aims to develop smaller, more efficient power converters using silicon carbide (SiC) power semiconductor switches.

Anvil has received an investment of £25,000 from the Early Advantage Fund of West Midlands-focused privately owned commercial fund manager Midven Ltd, as well as £125,000 from private investors Minerva (the Midlands network of entrepreneurs, venturers and angels). The firm has also since (in June) been awarded an R&D grant from the UK's national innovation agency Technology Strategy Board for the project 'Commercial SiC Power Electronics'.

SiC devices are able to withstand higher voltages and currents and are 10 times faster than traditional silicon devices, says Anvil. However, they are also currently 10 times more expensive to produce, which has prevented the material being widely adopted.

The semiconductors being developed by Anvil are expected to enable significant improvements in operating efficiency, size and cost when used in power converters such as those found in electric cars, photovoltaic cells and wind turbines. The market for such devices

is estimated to be \$25bn world-wide.



Left to right: Ward, Mawby, Marks and Stuart LeCornu (lead investor from Minerva).

Anvil's technology has been developed by CEO Dr Peter Ward and professor Phil Mawby's team at the University of Warwick's School of Engineering. The firm will be using five patents licensed from the university to refine and commercialize the devices. It will also be the first private company to use the £10m semiconductor cleanroom funded through the Science City Research Alliance (SCRA) of the universities of Birmingham and Warwick. SCRA is funded by the Birmingham Science City initiative (a region-wide partnership of public sector, businesses and the research base), via Advantage West Midlands (AWM)

and others.

"Semiconductors have such a vast array of uses in electronic equipment. The technological advances we are introducing to their design have huge potential to reduce our overall energy consumption, through improving the efficiency of electric cars, renewable power generation and the Grid," says Mawby. "Now Anvil gives us a route to get this technology to market," he adds.

"Two factors have stopped the introduction of silicon carbide into the market place: the cost of the substrate and the production of a high-quality switch," notes Warwick Ventures' business development manager Kevin Marks. "Anvil's technology offers potential solutions to both these barriers," he adds.

"Anvil builds on the impressive research track record of Phil Mawby and the substantial investment made in the Science City Cleanroom," says Dr Andrew Muir, a director of Midven and investment director of the Early Advantage Fund. "Our investment, alongside the Minerva business angels, will support the progress of this business, which has great growth potential and the ability to become a world leader," he believes.

Anvil will be launching a further funding round later this year as it moves towards producing prototype devices.

<http://anvil-semi.co.uk>

RF & power electronics opportunities for GaN market

Last year marked the start of a ramp-up of GaN microelectronic products from multiple vendors for commercial applications, including cable TV and power management, according to market research firm Strategy Analytics.

Early market pioneers that have targeted high-value RF applications have recently been complemented by companies offering both D-mode and E-mode GaN-on-silicon

products aimed at power conversion applications, Strategy Analytics adds.

"While initial commercial offerings for RF applications focused on lower-frequency applications (in the L-, C- and S-bands), we expect to see additional opportunities emerging for higher-frequency application, with commercial satcoms a potential prime target," comments Eric Higham, director

for Strategy Analytics' GaAs & Compound Semiconductor Technologies Service.

Defense markets will also continue to command a significant proportion of the early market for GaN devices, with development on next-generation radar, electronic warfare and communications systems providing continued demand, the firm concludes.

www.strategyanalytics.com

RFMD's GaN1 technology now qualified for 65V operation High-reliability process available via Foundry Services business unit

RF Micro Devices Inc of Greensboro, NC, USA says that it has qualified its GaN1 power semiconductor process technology for 65V operation.

The high-reliability power semiconductor process technology supports RFMD's GaN-based power semiconductor product designs and is also available to foundry customers through the firm's Foundry Services business unit.

Previously, RFMD's GaN1 power semiconductor process technology had been qualified for 48V operation. The increase in operating voltage from 48V to 65V enables miniature, 0.5kW power devices with high operating efficiency for L- and S-band military and civilian radar applications.

"The qualification of our 65V GaN1 power process technology enables RFMD to target multiple higher-voltage market opportunities across MPG's diversified markets while helping our foundry customers to design smaller-periphery die for high-power applications," says Bob Van Buskirk, president of RFMD's Multi-Market Products Group (MPG). "RFMD continues to optimize our game-changing GaN process technology for both foundry customers and proprietary RFMD product designs, with particular emphasis on higher peak efficiency, lower power consumption and higher linearity," he adds.

The 48V GaN1 process technology is established in the high-power semiconductor industry, and the

65V GaN1 process technology raises the performance level. The 65V GaN1 process demonstrates a mean-time-to-failure (MTTF) of 43 million hours with a channel temperature of 200°C at power densities of 10W (an industry performance benchmark, it is claimed). The high-reliability power semiconductor process is suited to higher-voltage operations in next-generation military, radar, and public/defense mobile radio applications.

RFMD showcased its foundry services offerings at the IEEE Microwave Theory & Techniques Society (MTT-S) International Microwave Symposium (IMS 2011) in Baltimore, MD, USA (6-8 June).

www.rfmd.com

First 100V half-bridge gate driver for E-mode power FETs

National Semiconductor Corp of Santa Clara, CA, USA has made available samples of what is said to be the first 100V half-bridge gate driver optimized for use with enhancement-mode (E-mode) GaN power FETs in high-voltage power converters. The LM5113 is a highly integrated, high-side and low-side GaN FET driver IC that cuts component count by 75% and shrinks PCB area by up to 85% versus discrete driver designs, the firm adds.

Designers of power bricks and communications infrastructure equipment require high power efficiency in the smallest form factor, Nat Semi says. Enhancement-mode GaN FETs enable new levels of efficiency and power density compared with standard silicon MOSFETs due to their low on-resistance ($R_{ds(on)}$) and gate charge (Q_g) as well as their ultra-small footprint, but driving them reliably presents significant new challenges. The LM5113 driver eliminates these challenges, it is claimed, enabling power designers to realize the ben-

efits of GaN FETs in a variety of popular power topologies.

Meeting the stringent gate drive requirements of E-mode GaN FETs requires multiple discrete devices and significant circuit and PCB design effort. The fully integrated LM5113 driver greatly reduces circuit and PCB design effort and delivers what is claimed to be industry-best power density and efficiency.

"National's LM5113 bridge driver helps designers unleash the performance of eGaN FETs by simplifying the design," says Alex Lidow, co-founder & CEO of Efficient Power Conversion Corp (EPC) of El Segundo, CA, USA, which makes E-mode GaN power FETs based on its proprietary GaN-on-Si technology for power management applications. "The LM5113 dramatically reduces component count, and paired with our eGaN FETs, enables a tremendous PCB area savings and higher level of power density versus equivalent MOSFET-based designs," he adds.

Using proprietary technology, the LM5113 regulates the high-side

floating bootstrap capacitor voltage at about 5.25V to optimally drive E-mode GaN power FETs without exceeding the maximum gate-source voltage rating. It also features independent sink and source outputs for flexibility of the turn-on strength with respect to the turn-off strength. A low-impedance pull-down path of 0.5Ω provides a fast, reliable turn-off mechanism for the low-threshold-voltage E-mode GaN power FETs, helping to maximize efficiency in high-frequency power supply designs.

The LM5113 has an integrated high-side bootstrap diode, further minimizing PCB real estate. It also provides independent logic inputs for the high-side and low-side drivers, enabling flexibility for use in a variety of both isolated and non-isolated power supply topologies.

Offered in a 10-pin 4mm x 4mm LLP package and costing \$1.65 each in quantities of 1000, production quantities of the LM5113 will be available in September.

www.national.com

NXP launches GaN for high-efficiency RF power amplifiers

Engineering samples to lead to volume production by end 2011

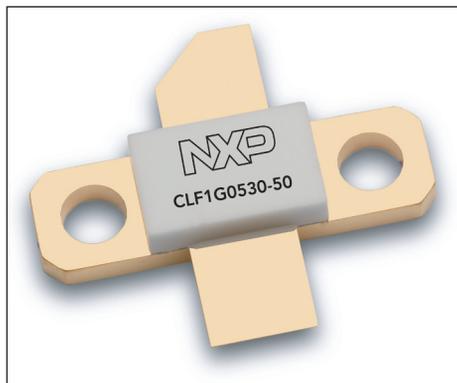
At the IEEE Microwave Theory & Techniques Society (MTT-S) International Microwave Symposium (IMS 2011) in Baltimore, MD, USA (7–9 June), NXP Semiconductors N.V. of Eindhoven, The Netherlands, which provides mixed-signal and standard product solutions, is showcasing a live demonstration of its next-generation products based on gallium nitride (GaN) technology, manufactured on silicon carbide (SiC) substrates for enhanced RF and thermal performance. NXP says that it is now uniquely positioned as the largest semiconductor firm to offer both LDMOS (silicon) and GaN solutions.

NXP has developed its high-frequency, high-power GaN process technology in collaboration with the Fraunhofer Institute for Applied Solid State Physics (Fraunhofer-IAF) in Freiburg, Germany and United Monolithic Semiconductors (UMS), which designs and produces RF, microwave and millimeter-wave components and ICs at its facilities in Orsay, France and Ulm, Germany.

The demonstration includes the CLF1G0530-50, a 50W wideband amplifier covering 500–3000MHz; 2.1GHz and 2.7GHz Doherty power amplifiers for base-stations; and the CLF1G2435-100, a 100W amplifier covering 2.5–3.5GHz.

Target end-user applications for NXP's GaN include cellular communications, wideband amplifiers, ISM (industrial, scientific & medical), PMR (private mobile radio), radar, avionics, RF lighting, medical, cable television (CATV) and digital transmitters for cellular and broadcast.

In particular, with its high power densities, GaN has the potential to expand into applications such as high-power broadcast applications, where solid-state power amplifiers built with vacuum tubes are still the norm.



NXP's CLF1G0530-50.

Also, while most base-station power amplifiers are limited to specific applications, NXP says that its new GaN process technology supports a roadmap towards a 'universal transmitter' that can be applied in multiple systems and frequencies, simplifying transmitter production and logistics, and allowing operators to switch between frequency bands to instantly meet demands in a base-station's coverage area.

"As GaN continues to gain traction, the entry of major semiconductor companies such as NXP helps to validate GaN as a 'technology of choice' for RF power semiconductors, and will help to accelerate broader adoption," comments Lance Wilson, director at market analyst firm ABI Research.

Engineering samples of NXP's first GaN broadband power amplifiers are available now, with volume production expected at the end of 2011.

"As we release new products based on GaN, we'll also be working with our partners to build a European supply chain that optimizes costs at every step in the value chain, and continue to offer our customers choice when it comes to selecting the best alternatives — LDMOS or GaN — for high-efficiency applications," says John Croteau, senior VP & general manager, high-performance RF.

www.nxp.com

IN BRIEF

Cree ships 10m Watts of commercial RF power transistors and high-power MMIC amplifiers

Cree Inc of Durham, NC, USA says that, as of April, its RF business unit had shipped commercial GaN-on-SiC RF power transistor and MMIC products with combined RF output power of over 10 million Watts, demonstrating the consistency, reliability and proven performance of its GaN HEMT and MMIC technology. The figure includes only commercial RF products and excludes an additional 1.5 million Watts shipped for GaN MMIC foundry services.

Cree says it attained the milestone while maintaining a return rate of less than 1 part per million and a failure-in-time (FIT) rate of less than 10-per-billion device hours (up to 80% lower than the typical FIT rates for other RF technologies, it is reckoned).

"We have achieved more than 1.4 billion total hours of field operation for our GaN-on-SiC devices, coupled with reliability that surpasses other high-voltage silicon or GaAs technologies," says Jim Milligan, Cree's director of RF. "This is the largest known body of fielded data accumulated by any domestic GaN supplier to date, and includes not only discrete transistors but complex multi-stage GaN MMICs as well," he adds.

"The 10 million Watt milestone is a testament to the rapid adoption of our GaN technology — not only for military applications, but for telecom base-stations, wide-band test equipment, civil radar and medical applications as well. If our expansion into these new market segments continues at the current rate, we have the potential to double the 10 million Watt milestone by the end of calendar 2011."

www.cree.com

First GaN HEMT T/R module operating in C–Ku band

12mm x 30mm module operates across 6–18GHz with output of 10W

At June's IEEE MTT International Microwave Symposium (IMS 2011) in Baltimore, MD, USA, Fujitsu Laboratories Ltd of Kawasaki, Japan presented the development of what is claimed is the first transmitter/receiver (T/R) module using GaN HEMT technology that operates across a wide bandwidth range of C-band, X-band and Ku-band (C–Ku-band) radio frequencies (6–18GHz).

By combining the what are claimed to be world's best performing GaN power amplifier (PA) — announced last year at IMS 2010 — with a newly developed GaN low-noise amplifier (LNA), the researchers have achieved a compact T/R module that generates a high output of 10W.

The firm says that the technology enables the integration of multiple types of communications equipment — each currently operated at a different frequency range — into a single module, allowing the development of smaller, lighter radar equipment and wireless communication systems.

In line with an increasingly network-based society, radio wave demand in wireless systems is expected to increase even further, says the firm. For example, aircraft radar typically switches between the C-band (which can detect distant objects and works well in rain) and the X- and Ku-bands (which can measure physical objects with high-precision).

Currently, this demand for multiple frequency ranges requires different communications equipment, each suited to its respective frequency band. However, a single T/R module capable of covering the entire C–Ku-band range would meet a variety of needs, allowing systems to become more compact.

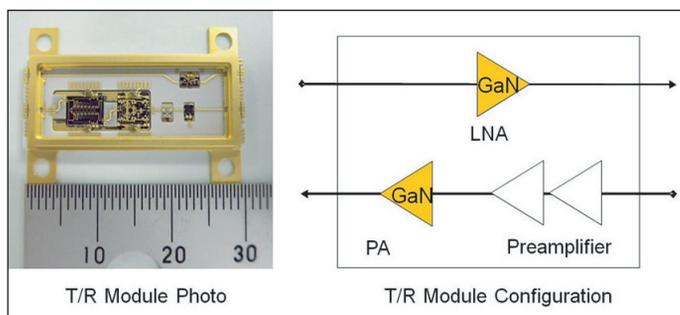


Figure 1: Photo and structure of GaN wide broadband T/R module.

T/R modules are vital for operating multi-functional radar over a broad spectrum. Users hence demand they have wide-band features capable of operating across multiple frequency ranges, plus high-output performance in order to cover a wide area. To develop a module with 10W-class output over a wide broadband range (such as the C–Ku-band), not only is a wideband PA and LNA required, but it is critical to improve the module's heat dissipation characteristics, as heat generation intensifies in tandem with higher output levels.

It is also necessary to reduce signal losses in the input/output terminal to maintain frequencies up to 18GHz, since at higher frequency ranges input/output signal losses rise in the terminal portion of the T/R module.

By adopting a GaN HEMT, Fujitsu has developed a compact, high-output GaN HEMT T/R module that covers the ultra-broadband C–Ku spectrum (6–18GHz). Key features of the new technology are as follows:

1. Fujitsu has developed an embedded heat-sink structure that efficiently dissipates the heat generated at high output levels. The heat-sink is built into the T/R module's multi-layer alumina ceramic substrate.

Compared with previous designs, heat dissipation has improved by a factor of five times, enabling high output levels of 10W.

2. Fujitsu Laboratories has devised an ultra-broadband terminal structure that reduces the input/output terminal signal loss that occurs at higher frequencies. With the new terminal structure, high-frequency signals passing through the module can be transmitted at up to 40GHz, three times the frequency levels of previous designs.

3. In addition to the GaN HEMT PA featuring the record output performance developed by the firm last year, the researchers have developed a new LNA using GaN HEMTs. The compact 2.7mm x 1.2mm LNA achieves a gain of 16dB across 3–20GHz and noise figures of 2.3–3.7dB (claimed to be record performance levels).

The new technology has enabled Fujitsu Laboratories to develop a compact T/R module measuring just 12mm x 30mm. The firm says that the new technology will enable a single T/R module to operate at multiple frequencies, paving the way for further system integration in broadband communications and radar systems that use various frequencies, meaning more compact and lighter equipment.

Fujitsu Laboratories targets the technology at a wide range of applications that require compact modules with high output across wide bandwidths, including wireless communications and radar systems.

<http://jp.fujitsu.com/labs/en>

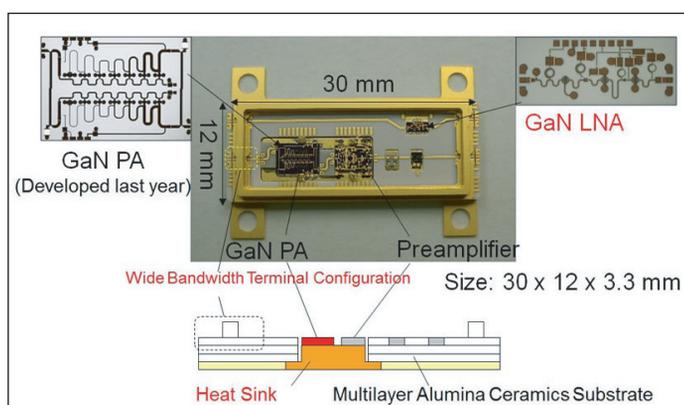


Figure 2: Photo and cross-sectional diagram of GaN wide broadband T/R module.

TriQuint reports GaN development milestones at IMS GaN foundry available on 100mm wafers in limited release

At the IEEE MTT-S International Microwave Symposium (IMS 2011) in Baltimore, MD, USA (5–10 June), TriQuint Semiconductor Inc of Hillsboro, OR, USA announced several milestones related to its ongoing gallium nitride (GaN) developments. The firm says that, together with customers and various US Government agencies, it is working to define the future of RF, where it believes GaN will play a key role.

"We have standard products available today and continue to enhance the reliability, manufacturability and performance of our GaN process technology," says vice president Thomas Cordner. "We intend to set a high bar for what customers should expect of GaN technology, customer service and semiconductor material experience," he adds.

Together with researchers from the University of Notre Dame, TriQuint has put its GaN NEXT Process (which is being developed with funds from DARPA and is not yet commercially available) through stringent performance tests. The results — presented in the paper 'State-of-the-Art E/D GaN Technology Based on an InAlN/AlN/GaN Heterostructure' by Saunier et al at the 36th Annual GOMACTech Conference in Orlando, FL, USA in late March — demonstrated a threshold frequency (f_T) of more than 240GHz, which is twice that of the record of 120GHz claimed recently by University of California Santa Barbara (UCSB). The paper also details enhancement/depletion integration with record DC and RF performances.

TriQuint's commercial GaN foundry offering is now available on 100mm wafers in limited release, for well-qualified customers with available resources prior to becoming a Full Release process. The latter will include the full complement of associated models, tools and support traditionally offered to customers.



TriQuint's T1G4005528-FS, a 55W, 28V discrete GaN RF power transistor.

TriQuint's GaN process technology has also been certified as a US Department of Defense Category 1A 'Trusted Foundry', ensuring that it meets stringent product control and secure handling standards during all stages of circuit fabrication. Accreditation also creates an avenue for increased high-security monolithic microwave integrated circuit (MMIC) business, reckons the firm.

Also, TriQuint has released several standard products based on its GaN process, including:

- The T1G4005528-FS is a discrete RF power transistor operating from DC to 3.5GHz, suiting military and civilian radar, professional and military radio communications systems, test instrumentation, avionics, and wideband or narrowband amplifiers.
- The T1G6001528-Q3 is a packaged GaN discrete RF power transistor offering substantial wideband coverage, high power-added efficiency (PAE), gain and more than 18W of output power, and greater than 50% efficiency across a wide bandwidth (DC–6GHz). The device can be used in professional and military radio communication systems, jammers, military and civilian radar, test instrumentation, avionics and wideband or narrowband amplifiers.
- The TGA2576 is a power amplifier that delivers 30W of saturated output power in the 2.5–6GHz range

and typically offers 30% PAE and 25dBm of small-signal gain. It is well suited to counter-IED (C-IED) and other EW (electronic weapons) systems.

TriQuint is also working on several ongoing research contracts with government agencies to further its development of GaN for broad commercial use:

- Defense Production Act Title III — announced in November 2010 and granted by the US Air Force Research Laboratory (AFRL), this \$17.5m multi-year contract is designed to develop manufacturing that increases yield, lowers costs and improves time-to-market cycles for defense and commercial GaN integrated circuits;
- Unmanned Aerial Vehicle (UAV) contract — awarded by AFRL, this program will develop new GaN modules for UAVs to extend the range and capabilities of drone aircraft used for reconnaissance missions over Afghanistan, Iraq and other regions.
- DARPA 'NEXT' — announced in October 2009 and awarded by the US Defense Advanced Research Projects Agency (DARPA), this \$16.2m multi-year contract funds the development of complex, high-dynamic-range circuits for future defense and aerospace applications.

www.triquint.com

Integra launches GaN-on-SiC HEMTs for C-band radar and high-voltage S-band radar

At the IEEE MTT-S International Microwave Symposium (IMS 2011) in Baltimore, MD (5–10 June), Integra Technologies Inc (ITI) of El Segundo, CA, USA, which supplies high-power pulsed RF transistors for the aviation industry, launched GaN-on-SiC HEMTs targeted at commercial C-band radar applications (including weather radar).

“GaN technology is ideally suited for high performance at frequencies above where silicon technology is competitive,” comments founder & VP Jeff Burger.

The IGN4450M50 and IGN4450M90 operate over the instantaneous bandwidth covering 4.4–5.0GHz in the lower C-band frequency range. Under 300µs pulse width and 10% duty-cycle pulsing conditions, the minimum peak output supplied is typically 60W for the IGN4450M50 and 100W for the IGN4450M90.

The IGN5459M40 and IGN5459M80 operate over the instantaneous bandwidth covering 5.4–5.9GHz in the upper C-band frequency range. Under 300µs pulse width and 10% duty-cycle pulsing conditions, the minimum peak output supplied is typically 40W for the IGN5459M40 and 80W for the IGN5459M80. Effi-

ciency is 50% for both.

The devices are housed in a ceramic flanged package, providing thermal advantages over plastic-packaged devices.

Integra also announced the development of high-voltage GaN-on-SiC technology by launching two wide-band products (IGN2735M30 and IGN2735M250) and two narrow-band products (IGN2729M400 and IGN2325CW110) for S-band radar.

“GaN technology’s inherent low capacitances enable broadband designs that cover both commercial and military air-traffic control (ATC) radar bands simultaneously,” says founder & president John Titizian. “We have years of RF expertise manufacturing high-power semiconductors, and with our low overhead cost structure we will continue to dominate in both price and performance,” he reckons.

The IGN2735M30 and IGN2735M250 operate over the instantaneous bandwidth covering 2.7–3.5GHz in the S-band frequency range. Under 300µs pulse width and 10% duty-cycle pulsing conditions, the minimum peak output power is typically 35W for the IGN2735M30 and 250W for the

IGN2735M250. With breakdown voltages approaching 80V, characterized at an operating voltage of 32V the IGN2735M30 provides more than 12dB of gain and 55% efficiency and the IGN2735M250 provides more than 11dB of gain and 55% efficiency.

Intended for commercial S-band ATC radars, the IGN2729M400 operates over the instantaneous bandwidth covering 2.7–2.9GHz in the S-band frequency range. Under 300µs pulse width and 10% duty-cycle pulsing conditions, it typically supplies a minimum of 400W of peak output power, while providing more than 12dB of gain and 55% efficiency.

The IGN2325CW110 operates over the instantaneous bandwidth covering 2.3–2.5GHz in the S-band frequency range. Operating under continuous-wave (CW) conditions, the device supplies more than 125W of output power while providing 12dB of gain and 60% efficiency.

The single-ended devices are housed in a ceramic flanged package providing excellent thermal advantages over plastic packaged devices, it is claimed. ➤

Integra debuts broadband RF devices for military communications

At IMS 2011, Integra launched several GaN-on-SiC devices characterized for broadband applications ranging from 30–512MHz to 100–1000MHz for the military communications market.

The technology allows Integra to penetrate new markets involving continuous-wave (CW) applications such as electronic warfare (EW) for the defense industry, says founder & president John Titizian. “GaN technology inherently is broadbandable with the inherent low parasitic capacitance,” he adds. “The GaN technology development effort is a direct result of customer

requests for smaller, more efficient power devices with broadband performance.”

For commercial C-band radar applications including weather radar, the IGN12UM21A1, IGN25UM21A1 and IGN50UM21A1 devices provide a range of output power from 12W, 25W and 50W. The unmatched devices provide more than 15dB of gain and 55% efficiency. The devices are housed in a small single-ended ceramic flanged package providing excellent thermal advantages.

For commercial broadband communications applications

including EW jammers, the unmatched IGN24UM22D1, IGN50UM22D1, IGN100UM22D1 and IGN200UM22D1 devices provide a range of output power from 25W to over 200W in a dual-lead push-pull configuration ceramic package. In addition, the unmatched IGN25UM72A1, IGN50UM72A1, IGN100UM72A1 and IGN200UM72A1 devices provide a range of output power from 25W to over 200W in a low-parasitic wide-lead ceramic package.

All the new devices are available for sampling now.

www.integrattech.com

► Integra launches GaN-on-SiC devices for L-band avionics

At IMS 2011, Integra launched two GaN-on-SiC devices for L-band radar.

Intended for commercial avionics applications (including IFF, TACAN and DME), the IGN0912L500 operates over the instantaneous bandwidth covering 950–1250GHz in the L-band frequency range. Characterized with a pulse train of 444 x (7µs ON, 6µs OFF) with 22.7% LTDC, the IGN0912L500 typically

supplies a minimum of 500W of peak output power. The device provides more than 12dB of gain and 62% efficiency.

The IGN1214L500 operates over the instantaneous bandwidth covering 1.2–1.4GHz. Intended for L-band radar applications, the device is characterized under 1ms and 10% duty-cycle conditions and supplies more than 500W of output

power while providing 13dB of gain and 60% efficiency.

The single-ended devices are housed in a ceramic flanged package providing excellent thermal advantages over plastic packaged devices, it is claimed.

The IGN0912L500 and IGN1214L500 are available for sampling in third-quarter 2011. www.integratech.com

Microsemi adds S-band GaN-on-SiC RF power transistors

Microsemi Corp of Irvine, CA, USA (which designs and makes high-reliability analog and RF devices, mixed-signal integrated circuits, FPGAs and customizable SoCs, and complete subsystems, based on silicon, gallium arsenide and silicon carbide) has expanded its family of S-band RF power transistors to include devices that use gallium nitride (GaN) process technology on a silicon carbide (SiC) substrate. The firm's GaN-on-SiC high-pulsed power transistors deliver what is claimed to be industry-leading peak power and power gain for radar systems operating in the 2.7–3.5GHz frequency band.

"This is a significant step in Microsemi's ongoing strategy to extend its product development and marketing initiatives to support the increasingly challenging requirements of next-generation air-traffic control and other radar systems," says Charlie Leader, VP & general manager. "By expanding our power transistor offering beyond traditional silicon material to use the latest compound semiconductor technologies, we take performance to the next level, create new markets for our products, and demonstrate our continuing commitment to customers in the radar systems development business," he adds.

Microsemi has leveraged its expertise in S-band RF power transistors to create a family of GaN-on-SiC solutions that are tai-

lored to support the requirements of next-generation systems requiring higher power, better efficiency, and wider bandwidth than is possible using conventional silicon or SiC process technologies. For applications operating in frequency bands up to 20GHz, the wide-bandgap material properties of GaN-on-SiC technology enable smaller systems with improved voltage, gain, broadband performance, drain efficiency, and long-term reliability.

The new GaN-on-SiC power transistors complement Microsemi's family of silicon BJT, RF MOSFET (VDMOS) and RF NPN power transistors, including SiC SIT devices that provide superior performance in high-power UHF-band pulsed radar applications operating at frequencies up to 450MHz. The firm also uses GaN technology for a family of enhancement-mode GaN field-effect transistors (FETs) used in satellites and other military power conversion, point-of-load, and high-speed switching applications.

Microsemi's GaN-on-SiC devices feature drain breakdown voltage well above 350V, enabling them to operate with a drain bias of 60V while delivering much higher reliability than devices manufactured using laterally diffused metal oxide semiconductor (LDMOS) technology. The higher drain bias improves peak power output while yielding more user-friendly impedance levels

and simplified circuit-matching requirements across the full system bandwidth. The GaN-on-SiC devices also deliver more than 13dB of power gain and cover 400MHz of bandwidth.

The new power transistors also reduce system size, e.g. the 2729GN-270 transistor replaces a conventional three-stage Si BJT transistor amplifier consisting of a driver transistor plus one output pallet with two 150W transistors. This substantially reduces system size and complexity while improving system power and efficiency, says the firm.

Microsemi has launched two products each for three frequency bands:

- 2.7–2.9GHz band for air-traffic control (pulse format: 100µs, 10%; power gain: 13–14dB typical; efficiency of 55–60%): 2729GN-270 (280W power, typical) and 2729GN-150 (160W power, typical);
- 2.7–3.1GHz band for air-traffic control (pulse format: 200µs, 10%; power gain: 12–13dB typical; efficiency of 50–55%): 2731GN-200 (220W power, typical) and 2731GN-110 (120W power, typical);
- 3.1–3.5GHz band for airborne tracking applications (pulse format: 300µs, 10%; power gain: 11–12dB typical; efficiency of 45–50%): 3135GN-170 (180W power, typical) and 3135GN-100 (115W power, typical).

Sample units are available for evaluation.

www.microsemi.com

Toshiba expands GaN HEMT range with 25W PA for extended Ku-band satcom

At the IEEE MTT-S International Microwave Symposium (IMS 2011) in Baltimore, MD, USA (7–9 June), Toshiba America Electronic Components Inc (TAEC) and its parent company Toshiba Corp of Japan added to its power amplifier product family by launching the TGI1314-25L, a GaN HEMT targeted at Ku-band satellite communication applications including very small aperture terminals (VSAT).

Operating in the Extended Ku-band 13.75–14.5GHz frequency range with output power of 25W, the TGI1314-25L has output power of 44.0dBm (typical) with 39dBm input power, linear gain of 8.0dB and drain current of 2.5A.

The latest product follows Toshiba in 2009 launching the TGI1314-50L (now in mass production), operating in the extended Ku-band (13.75–14.5GHz) for satcoms to support solid-state power amplifiers (SSPA) applications.

“The expansion of Toshiba’s GaN power amplifier family brings higher gain and very efficient features to microwave designers, which reduce heat-sink requirements and enable smaller terminals and converters with a full GaN HEMT line-up that includes drivers,” says Homayoun Ghani, business development manager, Microwave, Logic, and Small Signal Devices, in TAEC’s Discrete business unit. “Since Toshiba released its 50W Ku-band product a few years ago, many customers have requested a full line-up of GaN HEMTs, which will simplify the power supply design of SSPAs and block up-converters (BUC),” he adds. “In addition, small output power applications, such as VSAT, can benefit from GaN HEMTs, making fan-less or very small equipment possible.”

Samples of the TGI1314-25L will be available in Q3/2011, with mass production scheduled for Q4/2011.

www.toshiba.com/taec

Renesas announces high-output, low-distortion GaN power amplifier module for 1GHz CATV

Renesas Electronics Corp of Tokyo, Japan, which supplies semiconductors including microcontrollers, system-on-chip (SoC) solutions, and analog and power devices, has launched the MC-7802 GaN power amplifier module for applications such as trunk amplifiers in 1GHz cable television (CATV) systems.

CATV power amplifier modules are used mainly in the trunk amplifiers of CATV systems, the optical node units (ONUs) of hybrid fiber coaxial (HFC) systems, and the final stages of booster power amplifiers for common receiver units installed in multi-unit dwellings such as apartment buildings. The power amplifier modules amplify multiple channel signals to make up for transmission loss over the network. Since they amplify multiple channel signals, such as terrestrial digital TV, CATV, and Internet signals, better linearity (distortion performance) allows more stable data transfer, and better signal quality can be achieved. High output power provides greater flexibility in system design and makes it easier to keep costs down, allowing the network to be expanded by extending transmission distances and increasing the number of branches.

With the coming of digitization in recent years, CATV systems have gone beyond distribution of video content to offer hybrid services including Internet access and telephony (VoIP), and the number of channels handled has proliferated, notes Renesas. In response, the use of systems employing the 1GHz band is expected to grow. However, although systems employing the 1GHz band can transmit more channels than existing systems (which use the 770–870MHz band, depending on the region), the increased number of channels brings issues such as increased output power and distortion. In addition, demand is rising for high-

frequency semiconductor devices with high output power, low distortion, and energy efficiency for use in amplifiers in order to maximize the transmission distance and number of branches in order to reduce the transmission cost.

Renesas says that its new MC-7802 addresses this market demand by providing low power consumption with improved output linearity and distortion characteristics.

The MC-7802 incorporates newly developed GaN FETs that can be operated at higher frequencies and deliver higher output power than existing Renesas power amplifier modules that use GaAs. About double the output performance is achieved while maintaining current consumption and distortion performance at the same levels as existing products by optimizing the matching circuits of the GaN FETs and other components for CATV. This enables transmission equipment makers to roughly double output power without increasing current consumption, so the coverage area of the CATV network overall can be expanded with no rise in power consumption.

The new GaN FETs are fabricated not on the usual silicon carbide but on a less costly silicon substrate, simplifying production in future by using large-diameter wafers.

Renesas says it regards the GaN FET as a strategic product and will expand its power amplifier module product line-ups for CATV to form a family of products with a variety of gain performances. To aid growth of its share of the CATV power amplifier market, it plans aggressive sales promotion for Japan, North America, Europe and China.

Renesas also plans to continue development of products incorporating GaN FETs for high-frequency applications and to steadily expand its lineup of such products.

www.renesas.com

Siltronic joins Imec's GaN-on-Si research program

Silicon wafer manufacturer Siltronic AG of Munich, Germany has agreed to collaborate with nano-electronics research institute Imec of Leuven, Belgium on the development of silicon wafers with a gallium nitride (GaN) layer as a partner of Imec's GaN-on-Si industrial affiliation program (IIAP). The aim is to enable the production of solid-state lighting (e.g. LEDs) and power semiconductors for the next generation on 200mm silicon wafers.

Imec says that, combining superior electron mobility, high breakdown voltage and good thermal conductivity, GaN is particularly suitable for optoelectronics and advanced power semiconductors used for example in wind power turbines, solar power systems, electric vehicles and energy-saving kitchen appliances. Compared with conventional silicon-based applications, structures with GaN/(Al)GaN layers exhibit very efficient switching behavior. However, GaN technology

still needs further refinement to also be economically competitive. To achieve this, inexpensive and efficient production methods for epitaxial deposition of GaN/(Al)GaN structures on larger-diameter silicon wafers are very promising, says Imec.

Siltronic can draw on decades of experience in epitaxial deposition of materials on silicon substrates, while Imec is a pioneer in GaN deposition on silicon substrates with diameters of 2–6". Economies of scale in the production of 200mm wafers could significantly reduce the manufacturing costs for GaN-based LEDs and power semiconductors, reckons Imec.

In addition to Siltronic, other participants involved in the multinational research platform include other substrate manufacturers, silicon compound producers, foundries and integrated device manufacturers (IDMs). Siltronic will actively use Imec's facilities and

technical resources. This coordinated on-site approach aims to enable inter-company collaboration between all involved partners, while providing very early access to process and equipment technology for the next generation of LEDs and power semiconductors.

"Siltronic has an enormous amount of experience in epitaxial deposition on silicon wafers that will increase the momentum of our GaN program to deliver a manufacturable GaN technology on 200mm silicon wafers," comments Rudi Cartuyvels, VP R&D Business Lines at Imec. "Siltronic is already the world market leader for silicon wafers used to manufacture discrete and integrated power devices," claims Dr Rüdiger Schmolke, senior VP technology at Siltronic. "This research project will help us to further consolidate our leadership position in this market," he adds.

www.siltronic.com
www.imec.be

M/A-COM Tech launches GaN RF power transistors for L- and S-band pulsed radar

At the IEEE International Microwave Symposium (IMS 2011) in Baltimore, MD, USA (7–9 June), M/A-COM Technology Solutions Inc of Lowell, MA, USA (which makes semiconductors, components, and subassemblies for RF, microwave and millimeter-wave applications) is introducing a new family of gallium nitride (GaN) RF power transistors, targeting L- and S-band pulsed radar applications.

M/A-COM Tech's GaN on silicon carbide (SiC) products — offered as transistors and pallets — use a 0.5µm high-electron-mobility (HEMT) process and exhibit what are described as attractive RF performance parameters with respect to power, gain, gain flatness, efficiency and ruggedness over wide-operating bandwidths. Benefits of the GaN products

include high breakdown voltage, superior power density, and higher and broader frequency operation than silicon, M/A-COM Tech adds.

"Our highly versatile family of GaN products offers customers a single solution combining both the high power handling and high-voltage operation typically found in silicon LDMOS devices, but with higher-frequency performance more often associated with GaAs devices," says CEO Chuck Bland.

The latest market information from the firm ABI Research shows increasing demand for high-power, pulsed RF devices in S- and L-band air-traffic control, marine, and military radar applications.

"M/A-COM Technology Solutions' silicon-based products have been a major force for high-power, pulsed RF applications in the S- and L-

band radar market, and the extension into GaN technology positions their product line for continued market leadership," comments Lance Wilson, ABI's research director, RF Components & Systems.

Engineering samples for GaN transistors and pallets are available for qualified customers from stock (the products are subject to the jurisdiction of the Export Administration Regulations, so shipments to certain destinations may require an export license).

M/A-COM Tech plans to release later this year additional products that target applications such as L-band radar, avionics, electronic warfare (EW), and military communications (MilCom), as well as general-purpose devices.

www.macomtech.com

Smallest broadband 5W PA from Nitronex

Nitronex Corp of Durham, NC, USA, which designs and makes GaN-on-Si RF power transistors, has developed the industry's smallest broadband 5W power amplifier (PA), it claims.

The NPA1003 has a 4mm x 4mm thermally enhanced QFN package with RF input and output matched to 50Ω. The highly integrated GaN MMIC needs just an external resistor and inductor to provide bias. With output of more than 5W from 20MHz to 1500MHz and typical efficiency of over 50%, the overall size is under 0.25 square inches (less than any competing solution, it is claimed).

"We have already achieved several design-ins at top-tier accounts," says VP of sales & marketing Gary Blackington.

"Nitronex's MMIC process was established under a joint development agreement with a large military contractor, resulting in a fully qualified, production-ready process in July 2009," says VP of engineering Ray Crampton. "We have worked with multiple strategically selected customers since 2009 to develop and productize custom MMICs, and have shipped more than 50,000 production devices," he adds.

"Nitronex's proprietary GaN-on-Si process has a significant advantage over our competitors using SiC substrates," Crampton claims. "Our superior starting substrate quality and cost structure allow us to develop high-performance, large-area MMICs at competitive prices."

Nitronex's qualified MMIC process is based on a 28V, 0.5μm gate-length GaN HEMT and features high-voltage capacitors, air bridges, through-wafer vias, nichrome and epi resistors, and two levels of metal interconnect. Further, a 3.5μm plated gold top metallization results in low-loss inductors, and a high-resistivity silicon substrate is used which supports low-loss transmission lines to over 20GHz. Nitronex also works closely with strategic customers in both foundry and custom MMIC development activities.

www.nitronex.com

Transphorm's \$25m Series D round raises funding to \$63m

Transphorm Inc of Goleta, CA, USA has raised its total capital funding to \$63m after completing a \$25m Series D financing round with Quantum Strategic Partners Ltd (a private investment fund managed by Soros Fund Management LLC) and its existing venture capital investors.

Transphorm emerged from stealth mode in February. Backed by \$38m in funding from Google Ventures, Kleiner Perkins Caufield & Byers, Foundation Capital and Lux Capital, Transphorm was co-founded in 2007 by CEO Umesh Mishra, a professor of electrical & computer engineering at the University of California, Santa Barbara (UCSB), together with Primit Parikh as president.

Transphorm aims to solve the problem of power waste when electricity from the grid is converted into usable electric power. Existing silicon-based power converters are only 85–90% efficient, so 10% of energy is lost (e.g. as waste heat). Transphorm says that the hundreds of terawatts of lost energy across the US electrical grid is equivalent to over 300 coal-fired power plants and costs the US economy \$40bn annually. Power infrastructure must become radically more efficient to meet future energy and environmental challenges, the firm says.

In February, Transphorm released "the first complete solution to eliminate such power waste", based on replacing legacy silicon-based power conversion technology with high-voltage normally-off GaN-based power conversion modules. The Advanced Research Projects Agency-Energy (ARPA-E) had awarded the firm \$2.95m to invent normally-off switches while moving their GaN platform to low-cost silicon wafers. "Through ARPA-E funding, innovation in next-generation power electronics has put the US in a leadership position with GaN-on-Si and motor control," says Rajeev Ram, program director at ARPA-E.

"Efficient electronically controlled motors can save over \$13bn annually in the US with enough energy savings to power 13 million homes," he adds.

Transphorm says that its Total GaN solution can reduce the 10% power wastage by up to 90% (boosting efficiency into the upper 90% range), as well as simplifying the design and manufacturing of a wide variety of electrical systems and devices (including motor drives, power supplies and inverters for solar panels and electric vehicles).

At March's Applied Power Electronics Conference (APEC) in Fort Worth, TX, Transphorm launched its first product: a power diode based on its patented EZ GaN technology. To demonstrate the performance of its patented GaN-based technology, Transphorm showcased a Total GaN based DC-to-DC Boost Converter running at more than 99% efficiency. At May's PCIM Europe conference in Nuremberg, Germany, Transphorm unveiled its 600V EZ-GaN transistor, which is intended to displace legacy silicon-based power conversion technology and reduces switching losses by up to 95%. The firm also demonstrated a 100kHz 3-phase 2kW inverter, showing what is said to be the highest efficiency in its class. Transphorm claims to be the only firm currently offering a Total GaN solution for highly compact and efficient electric power conversion.

"Transphorm will use the new funding to continue our expansion and scale up to meet growing customer demand," says Parikh. In recent months Transphorm has increased its customer set by 50%, and expanded operations by 30%. "The Series D financing enables us to grow our facilities, accelerate product development, and deepen engagement with customers," he adds. "It allows us to execute rapidly on our customers' roadmaps."

www.transphormusa.com

Cascade curve tracers for wafer-level probing of power devices

Cascade Microtech Inc of Beaverton, OR, USA, which provides production test products including probe cards and test sockets for wafers, ICs, IC packages, circuit boards and modules as well as MEMS, 3D TSV and LED devices, says that its CT-3100/3200 curve tracers will be manufactured for it exclusively by Iwatsu Test Instruments Corp of Tokyo, Japan (a manufacturer of test equipment including oscilloscopes).

Providing versatile wafer-level measurement for the growing power device market, the curve tracer units complement the high-voltage and high-current capabilities of Cascade's Tesla probe systems to speed up the device characterization process and hence time-to-market for power device makers, it is claimed.

The market for power transistors will continue to post healthy gains through 2014, forecasts market research firm IC Insights. Steady growth, combined with emerging energy standards and increasing power consumption and conservation efforts, demand additional performance capabilities, says Cascade. Pressure has hence been placed on device makers to rapidly design and characterize new power devices to provide more efficiency. Power device characterization requires measuring performance across an entire operating region, often at hundreds of amperes and thousands of volts. Such high-performance requirements have created the need for innovations in curve tracer technology — tools that have long been an industry standard for power device characterization but no longer meet stringent and higher-power characterization requirements, says Cascade.

The CT-3100/3200 curve tracers are designed specifically for measuring different types of high-power semiconductor devices such as silicon carbide and gallium nitride and/or insulated-gate bipolar tran-

sistors (IGBTs), super-junction MOSFETs, diodes and thyristors. Measurement productivity is enhanced by the built-in USB port and a LAN interface for remote control of the CT-3100/3200. Complementary to existing SMU-based instruments, the CT-3100/3200 curve tracers provide fast, accurate characterization up to 3000V, 400A, 4000W peak power and support a leakage mode with cursor resolution of 1pA.

When used in combination with Cascade's Tesla probe system, design cycles can be significantly reduced from traditional package-level device characterization methods that require high-power devices be cut from wafers, packaged and returned for test in custom fixtures, says the firm. On-wafer characterization methods reduce these lengthy measurement cycle times by eliminating the need for dicing and packaging steps. As a result, device developers can do more complete characterizations to improve quality and reduce time-to-yield, Cascade adds.

"Integrated on-wafer measurement solutions for high-power device characterization will greatly help customers to speed up their design cycle," says Iwatsu Test Instruments' president Misao Saito. "No longer do they need to send the wafer for dicing and bonding in the package before devices can be tested accurately. Measurements can now be made at the wafer level," he adds.

"We are pleased to now offer Iwatsu curve tracers which, when paired with our Tesla system, will deliver an-integrated measurement solution for power device characterization not previously offered in the market," says Cascade's president & CEO Michael Burger. "Efficient on-wafer characterization shortens the design cycle, improves product quality and provides our customers with faster time-to-market."

www.cascademicrotech.com

IN BRIEF

Notre Dame THz collaboration wins \$6.3m DoD grant

Researchers involved in two of the University of Notre Dame's strategic research investments — the Center for Nano Science and Technology and the Advanced Diagnostics and Therapeutics initiative — have been awarded a \$6.3m grant from the US Department of Defense's Multi-disciplinary Research Initiative (MURI) to develop new electronic devices that operate in the terahertz range of the electromagnetic spectrum.

Patrick Fay (principal investigator), Debdeep Jena, and Huili (Grace) Xing lead a team that includes researchers at The Ohio State University, Johns Hopkins University, and Wright State University — in a program to develop GaN devices.

While terahertz phenomena have been studied in the lab for years, the ability to generate high-quality coherent sources has been limited to very low power levels. Also, the current sources are difficult to adapt for sensing systems operating outside the lab, limiting the ability to take full advantage of the unique properties of THz frequency signals.

"GaN may form the basis of "the third electronic revolution, after vacuum tubes and silicon," says Xing. "We want to develop novel ways to design GaN-based devices for ultra-high performance applications," she adds. "The goal is then to incorporate the material into electronics that enable a wide range of new terahertz applications."

Last year, Jena and Xing received separate DoD funding—through the Defense Advanced Research Projects Agency — for a project to create GaN ultraviolet light sources for use by soldiers (and eventually civilians) to purify water.

<http://nano.nd.edu>

MBE expert made RAE Fellow

Mohamed Missous, professor of Semiconductor Materials and Devices in the University of Manchester's School of Electrical and Electronic Engineering, is among 50 new UK Fellows elected by the Royal Academy of Engineering (RAE).

Having gained M.Sc. and Ph.D. degrees from UMIST (now part of the University of Manchester), Missous joined the university in 1989. His activities are centred on the growth of multi-layer semiconductor films by molecular beam epitaxy (MBE).

Over the years he has concentrated on establishing practical approaches and techniques required to meet stringent doping and thickness control, to sub-monolayer accuracy, for a variety of quantum devices. Further work has involved working on amplifiers and analog-to-digital converters for a range of applications, including the Square Kilometre Array project (SKA). Key to his work is close industrial involvement with leading players in optoelectronics and microwaves, including the design of Intelligent Cruise Control systems in cars.

Missous has given many keynote presentations concerning his disciplines, including Terahertz technology, infrared sensing, MBE and ultra-high-speed devices and has over 190 publications in the field.

He also co-founded spin-off firms Integrated Compound Semiconductors Ltd and Advanced Hall Sensors Ltd to exploit advanced semiconductor devices in ultra-high-sensitivity position sensing, Terahertz imaging, mid-infrared detection, automotive car radars and radio astronomy.

"This is very much a team effort, and I would like to pay tribute to my past and present PhDs and postdoctoral research associates and my wonderful technical support staff, without whom none of these achievements would have been possible," comments Missous.

www.raeng.org.uk

www.manchester.ac.uk/research/M.missous

EpiGaN raises €4m 1st-round funds to launch GaN-on-Si production

EpiGaN nv of Hasselt, Belgium has closed its first capital round of €4m, which will allow it to start volume production of gallium nitride on silicon (GaN-on-Si) epitaxial material for next-generation efficient power electronics. Investors include Capricorn Cleantech Fund, Robert Bosch Venture Capital, and LRM.

Incorporated in 2010, EpiGaN was founded by chief executive officer Dr Marianne Germain, chief technology officer Dr Joff Derluyn, and chief operating officer Dr Stefan Degroote, as a spin-off of nano-electronics research center imec in Leuven, Belgium. For more than 10 years, the founders jointly developed GaN-on-Si technology on 4" and 6" wafers at imec, part of which has been licensed to EpiGaN. They are now joined by a consortium of investors who, EpiGaN says, share its vision on GaN-on-Si as a key technology for enhancing power management efficiency, implementing renewable energy sources, or enabling cleaner transportation technologies with reduced environmental impact.

"EpiGaN has demonstrated the capability of its innovative material to support record device performance either in high-voltage, high-current or high-frequency operation," claims CEO Dr Marianne Germain, who adds that the investors' support will enable the firm to commercially provide the same high-standard material quality in large volume to its industrial customers.

EpiGaN says that the participation of Robert Bosch Venture Capital lends credibility to its strategic vision. "As a leading manufacturer of power electronics modules and systems, we believe that this technology has the potential to make significant contributions to the world of power conversion," comments Gadi Toren, venture capital investment partner at Robert Bosch Venture Capital (RBVC) and future board member of EpiGaN.

"Power conversion is an essential technology for an impressive number of cleantech applications such as energy-efficient power supplies, solar inverters, wind energy, electric or hybrid vehicles and smart grids," says Marc Lambrechts, who will join the board on behalf of Capricorn Cleantech Fund. "Customers of EpiGaN will benefit from higher efficiency, improved reliability and reduced system size and weight, by using the EpiGaN state-of-the-art GaN-on-silicon technology," he adds.

EpiGaN says that the investors' support will allow it to implement its own production capacity and increase its market supply: 4" and 6" GaN-on-Si wafers for high-voltage or RF applications are readily available from the firm, while a 200mm wafer technology is under development. EpiGaN will deploy its activities at the Research Campus Hasselt in Limburg, which is geographically located within the Leuven, Eindhoven and Aachen region.

"EpiGaN has chosen Limburg as the best location to grow their business after an in depth location study. We are happy that our intertwined offer of venture capital and sector-specific infrastructure played a key role in the decision process," notes Stijn Bijnens, CEO of Hasselt-based LRM. "EpiGaN will contribute to the development of high-tech solutions for the renewable energy domain, an area where Limburg is willing to play an important role," he adds.

"imec has pioneered the use of Si substrates for GaN technology, for its cost efficiency and its bright perspective of leveraging on the silicon-based semiconductor industry," comments imec's president & CEO Luc Van den hove. "We are proud to see that a highly innovative, long-term research project leads to the creation of a high-potential spin-off, bringing imec technology to the market."

www.epigan.com

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IQE to report first-half 2011 growth of 20% year-on-year Continued growth expected in second-half 2011

In an interim trading update for first-half 2011, epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK expects to report revenue of at least £38m. Compared with first-half 2010, this represents underlying growth in US dollar revenue of more than 20%, including about £1m from the Galaxy business acquired in September 2010.

Despite the adverse impact of foreign currency exchange, earnings before interest, tax, depreciation and amortization (EBITDA) should be at least £6m, down on second-half 2010's £13.1m but up from £5.4m in first-half 2010.

IQE says that the strong organic revenue growth has been driven by both the wireless and optoelectronics markets.

Wireless has been driven by sales of gallium arsenide (GaAs) products into wireless devices,

supplemented strongly by the rapid growth of gallium nitride (GaN) sales into the radar and wireless infrastructure markets.

Organic revenue growth in the optoelectronics market has been driven across a range of end markets, including IQE's vertical-cavity surface-emitting laser (VCSEL) technology for consumer and industrial applications, optical communications, and solar power.

IQE says that it continues to make good progress with its electronics division, which is focussed on combining compound semiconductors with silicon to create next-generation semiconductor materials for a broad range of ultra-high-speed and high-performance applications.

The outlook for second-half 2011 remains upbeat, says IQE. The board expects continuing robust growth in the group's core wireless

and optoelectronics businesses, as demand for both industrial and consumer end-user devices containing IQE products remains strong. This confidence is strengthened by the continued progress being made in new product developments and qualifications.

"The continued growth in demand for our wireless products and accelerated growth for our optoelectronic wafers has enabled us to maintain our rapid growth," comments chief executive Dr Drew Nelson. "The prospects for the group are very exciting and, with our highly geared business model, provide the board with considerable confidence in a continued improvement in financial performance for the second half," he adds.

IQE expects to report its full interim results on 7 September.

www.iqep.com

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AkzoNobel building two new LED precursor plants

Capacity to grow 300% for TMG and 400% for TMI

Responding to continued strong global demand for its High Purity MetalOrganics (HPMO) product range, AkzoNobel of Amersfoort, The Netherlands is to significantly expand production capacity for two of its key products: trimethyl gallium (TMG) and trimethyl indium (TMI).

The HPMO business (part of AkzoNobel's Functional Chemicals business unit) is a producer of semiconductor-grade indium-, gallium-, aluminum-, zinc- and magnesium-based metalorganics used as key precursor materials in the production of LEDs, solar cells and other semiconductor devices.

In June 2010 AkzoNobel doubled TMG production capacity at its plant in LaPorte, TX, USA. The capacity of this unit was quickly doubled again this January, and the new capacity has been ramped up during the past four months, making AkzoNobel the largest global producer of this specialty chemical, the firm says.

"Our customers' response to these expansions has been very positive, and their continued strong demand keeps absorbing our recently enlarged capacities," says Michiel Floor, global business manager of the HPMO product group. "We firmly believe in significant long-term growth of the LED and III-V solar cell industries, so we have decided to advance our plans for further major capacity additions with two new world-scale production units."

The firm plans to build a TMG plant that will be three times the size of the existing unit. With this expansion, AkzoNobel's total capacity for gallium-based metalorganics will exceed 100 tons per year, from two independent production lines. Construction of the plant will start this year, with completion in 2012.

A large second production unit for the LED precursor TMI will also be built, giving a 400% increase in capacity. Construction of this unit is

already in progress and will be completed by this December.

Both units will be built at AkzoNobel's LaPorte site, which serves the global plastics, pharmaceutical and electronic industries with large-scale, fully integrated bulk metalorganics production plants. The firm will also enhance its global distribution network by establishing regional transfilling capabilities in Asia.

"These continued investments in the HPMO business show AkzoNobel's commitment to support the LED industry in the coming years," says Jan Svärd, managing director of Functional Chemicals. "Capacity additions will enable our customers to maintain their growth pace, which will be increasingly driven by general lighting," he adds. "This business also supports our efforts in sustainability, by focusing on applications that drive energy efficiency and lower energy usage."

www.akzonobel.com/hpmo

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Gas abatement & vacuum firms Steed and Highvac merge

Steed Technology Inc of Scotts Valley, CA, which provides thermal processing equipment and point-of-use (PoU) process gas abatement systems, has merged with Highvac Corp of Colorado Springs, CO, a supplier of vacuum pumps, accessories and related equipment and services. Both firms primarily serve the semiconductor, LED and solar industries. The merged firm will operate as Steed Technologies, with headquarters at Highvac's 45,000ft² manufacturing and distribution facility in Colorado Springs.

A main focus of the merger involves ramping up sales channels, as well as expanding existing channels both domestically and internationally while putting an increased focus on new customers in regions with new, stricter air-quality restrictions. With the combination of Steed's EcoGuard PoU abatement systems and Highvac's established vacuum pump sales and service centers, customers will have access to a wider variety of vacuum/abatement solutions to better serve their specific application requirements, say the firms. Highvac has service centers throughout the USA and around the world. These locations will serve as the foundation for growth into different global regions, providing faster, more convenient access to service and support for vacuum and gas abatement products.

Highvac's long-term, core competency of process vacuum pumps and support lends itself to Steed's new EcoGuard PoU technology, the firms reckon. Through the strategic alliance, they have developed a total 'Sub-Fab' solution to be offered to end-user customers and OEMs alike. The Sub-Fab solution is a totally integrated system that includes vacuum and abatement technologies, and an onboard environmental control panel feature developed by Steed. By combining these technologies into a packaged, turnkey product, users will no longer have to piece together vac-

uum and abatement systems from separate technology providers, and will be able to purchase process vacuum pumps and exhaust abatement equipment as a totally integrated system through a single vendor.

Continuing the Highvac model of local support centers is a key ingredient for providing customers the services required to maintain mission-critical manufacturing lines in a highly responsive manner, the firms say. Support centers will be expanded throughout the USA and globally, including Taiwan, Korea, China, Singapore and Europe, as efforts are aggressively ramped up to support customer demand for process vacuum and abatement technologies.

An additional aspect of the merger is the creation of Steed's Green Consulting Service. The merger adds value to this service with the addition of the Highvac 'Vacuum Pumping Solutions' team, which has a combined 50 years of gas abatement and vacuum equipment experience. With new, increasingly strict, environmental regulations such as the 'Greenhouse' law (AB32), many firms in the semiconductor, LED, solar and other industries are closely examining ways to increase the effectiveness and efficiency of their current abatement systems, the firm says. Environmental control will play a major role in these industries in the years ahead and, to assist companies in making the transition to cleaner, more efficient manufacturing technologies, Steed will offer 'green' consulting and solutions services to help them to reduce emissions of gases such as perfluorocarbons (PFCs), oxides of nitrogen (NO_x), and carbon dioxide (CO₂). Steed's Green Consulting provides a fast-track to compliance for companies struggling to comply with local and federal laws, while offering savings through the reduction of consumed utilities such as fuel and water, the firm says.

"The companies we serve face steep and complex challenges when forced to work with separate vendors to piece together environmentally responsible solutions to the toxic and harmful exhaust created in their manufacturing process, while at the same time trying to increase machine up-time," says Steed's president & CEO Gerry Catalano. "High-tech companies

The companies we serve face steep and complex challenges when forced to work with separate vendors to piece together environmentally responsible solutions to the toxic and harmful exhaust created in their manufacturing process, while at the same time trying to increase machine up-time

will face tougher standards in the future and will need advanced vacuum and abatement equipment to be in compliance with regulations and provide the maximum up-time," he adds.

"We look forward to the new capabilities

we can bring to our customers through expanding our scope of supply with the EcoGuard Abatement system," comments Highvac Corp's president & CEO John Catalano. "Vacuum pumps and PoU abatement are a perfect product mix, and Steed's products are a direct extension that adds considerable value to the core products and services that we have offered to our customers for the past 18 years," he adds. "Additionally, the added scope enables us to expand into geographical regions and bring Highvac's proven model of being a 'local vendor' to our new customers."

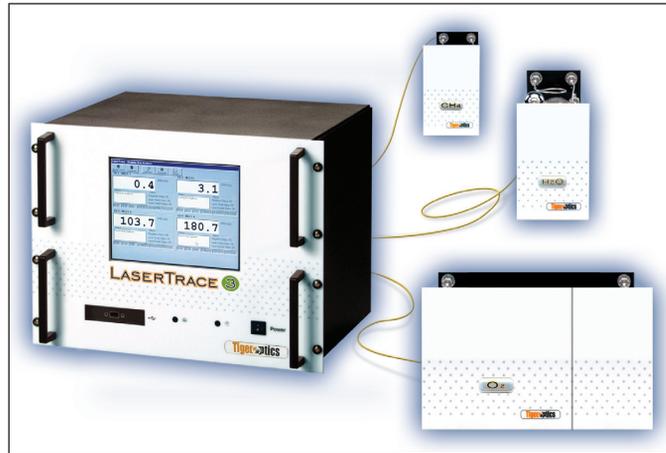
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Tiger Optics launches LaserTrace 3 trace gas analyzer

Continuing to expand the capabilities of its patented CW-CRDS technology, at the Semicon West 2011 trade show in San Francisco (12–14 July) Tiger Optics LLC of Warrington, PA, USA introduced the LaserTrace 3 trace gas analyzer, which can detect moisture, oxygen, methane, and other analyte contaminants at limits that are more than two times (2x) lower than previous generations of the product line.

Tiger sells laser-based trace gas analyzers to semiconductor manufacturers, tool manufacturers, purifier manufacturers and the gas companies that supply bulk and specialty gases to the industry. In semiconductor manufacturing, contamination in process gases has a destabilizing effect and negatively impacts deposition processes. As a result of as little as single-digit parts-per-billion impurities in process gases, product yields are reduced. To remedy this problem, the LaserTrace 3 allows users to monitor for intrusions at levels that were never previously available, it is claimed.

"Semiconductor manufacturers have adopted our patented CW-CRDS (continuous-wave cavity



Tiger Optics' new LaserTrace 3 trace gas analyzer.

ring-down spectroscopy) technology due to the superior detection range, ease of use, the lowest total cost of ownership in the industry, and the fact that this is an absolute technology — no calibration gases are required," claims founder & chief executive Lisa Bergson. "In order for our customers to meet targets for the 15-year International Technology Roadmap for Semiconductors (ITRS), they need to monitor their process gases at ever increasing levels of purity," she adds. "The technological advancements of the LaserTrace 3 are a result of Tiger Optics' on-going

investment in R&D... our customers will now be able to realize a two-fold improvement in their detection limits."

Tiger says that, since its debut in 2003, the LaserTrace platform has been widely accepted for semiconductor applications. The multi-species, multi-point, multi-gas product line accom-

modates up to four sensor modules in a standard 19-inch rack, or permits placement of individual sensor models as far as 200 feet from the computerized control unit. In 2005, the firm launched its LaserTrace O2 as the world's first laser-based, trace oxygen analyzer to detect parts-per-trillion levels in ultra-high-purity gases. In 2008, the LaserTrace+ made possible the lower detection limit (LDL) of 200 parts-per-trillion, affording the widest dynamic range of any dedicated analyzer currently in the market, it is claimed.

www.tigeroptics.com

PFT awarded \$1.5m to expand thin-film PV and LED equipment manufacturing capacity

The New York State Energy Research and Development Authority (NYSERDA) has awarded \$1.5m to Precision Flow Technologies (PFT) of Saugerties, NY, USA, which provides outsource manufacturing, ultra-high-purity specialty gas and chemical handling equipment (as well as measurement and metrology systems in support of process-critical applications), to help expand its capacity to manufacture solar thin-film and LED production equipment at its site in TechCity Kingston, NY.

Since 2007, NYSERDA has provided funding to help New York

State companies develop or expand facilities to manufacture innovative renewable, clean energy or energy-efficient products. Including this award, NYSERDA has competitively awarded \$13m to help nine New York State companies expand their operations and create jobs. These awards are projected to leverage more than \$150m in private sector investment. "NYSERDA's partnerships with companies that are manufacturing innovative products is helping support the growth of the clean energy economy in New York State," says NYSERDA's president & CEO Francis J. Murray Jr. "These

cutting-edge companies are creating the products that will help New Yorkers save energy, create jobs, and improve our environment for the future," he adds.

"This support from NYSERDA will enable Precision Flow to accelerate our growth," says the firm's president Kevin Brady. "The markets for our products are growing at breakneck speed, and New York State's investment in our growth will help ensure that we can grow fast enough to meet the demand," he adds.

www.precisionflow.com
www.nyserda.org

IN BRIEF

Tsinghua Tongfang adds MaxBright MOCVD system to new NanTong fab

Veeco Instruments says that Tsinghua Tongfang Company Ltd of Beijing, China, a publicly listed division of Tsinghua Holdings Company Ltd, has ordered a new TurboDisc MaxBright multi-reactor GaN MOCVD system for the production of high-brightness light-emitting diodes (HB-LEDs).

"Last year we selected Veeco as our primary supplier for our new production facility in NanTong, China that was completed at the end of 2010," says Nantong Tongfang general manager professor Liu Gang, adding that the firm is very pleased with the performance of Veeco's single-chamber K465i systems and is now adding the multi-chamber MaxBright system to help further improve its fab's productivity.

Tsinghua Tongfang was established and listed on the Shanghai Stock Exchange in 1997, and is engaged in information technology, energy and environment industries. "Tsinghua Tongfang has done a great job building their LED business, and we are extremely pleased to continue to support their further capacity expansion with our latest-generation product," comments William J. Miller, Ph.D., executive VP, Veeco LED & Solar.

The MaxBright system is reckoned to be the industry's most productive, lowest-cost-of-ownership MOCVD system available for manufacturing HB-LEDs. Available in a 2- or 4-reactor cluster architecture, the system delivers a productivity gain of up to 500% and a 2.5x increase in footprint efficiency over the K465i system, Veeco adds.

<http://en.thtf.com.cn>

DOE awards Veeco \$4m in R&D matching funds for LED manufacturing equipment development

Veeco Instruments Inc has been awarded \$4m in R&D matching funds by the US Department of Energy to support a high-efficiency solid-state lighting project targeted at lowering the manufacturing costs and improving the brightness and efficiency of LEDs by using novel materials, substrates, and deposition technologies. Kyma Technologies Inc of Raleigh, NC, USA, which provides crystalline gallium nitride (GaN) and aluminum nitride (AlN) materials, will supply material and services to Veeco as part of the project.

"This new project has been launched in our Plainview, NY R&D site, where we are specialists in depositing novel materials and designing equipment that provides our customers with tools that enable the lowest cost-of-ownership," says Veeco's executive VP

Robert Oates. "Veeco's R&D efforts are focused on dramatically reducing the cost of LEDs and accelerating their adoption into the general lighting market," he adds. Veeco employs about 300 staff in Plainview.

"Kyma is focused on creating and supplying high-performance crystalline materials that enable energy-efficient lighting and electric power management," says Kyma's CEO Dr Keith Evans.

This is the seventh round of DOE funding for solid-state lighting core technology research and product development, and the second time that the DOE has funded solid-state lighting manufacturing projects. Veeco also received funding in the first manufacturing solicitation in 2010.

www.kymatech.com

www.veeco.com

FOREPI orders multiple Veeco MaxBright MOCVD systems

Epitaxial deposition, process, and metrology equipment maker Veeco Instruments Inc of Plainview NY, USA says that Taiwan-based Formosa Epitaxy Inc (FOREPI) and its affiliate Jiangsu Canyang Corp of Jiangsu province, China have placed a multi-unit order for TurboDisc MaxBright multi-reactor gallium nitride (GaN) MOCVD systems (launched in February) for the production of high-brightness light-emitting diodes (HB LEDs).

"We are impressed with MaxBright's high-productivity, flexible process capabilities, and compact architecture, and think it will be a great choice for our high-production fabs," says Jiangsu Canyang president Frank Chien Ph.D. "We have selected the four-chamber configuration as we

believe it will provide the best cost of ownership and value for our investment," he adds.

"It is exciting to have our new tool selected by one of Taiwan's top LED manufacturers as part of their expansion in both Taiwan and China," says William J. Miller Ph.D., executive VP, Veeco LED & Solar.

The MaxBright system is reckoned to be the industry's most productive, lowest-cost-of-ownership MOCVD system available for manufacturing HB-LEDs. Available in a 2- or 4-reactor cluster architecture, the system delivers a productivity gain of up to 500% and a 2.5x increase in footprint efficiency over the K465i system, Veeco adds.

www.veeco.com/maxbright

www.forepi.com.tw

Aixtron launches largest MOCVD reactor for GaN LEDs

CRIUS II-L houses 16x4" or 69x2" wafers

Deposition equipment maker Aixtron SE of Herzogenrath, Germany claims to have set a new benchmark for MOCVD reactor capacity, throughput and LED production cost with the launch of the CRIUS II-L, making what is reckoned to be the largest-capacity MOCVD reactor available (16x4" or 69x2" wafers). The new reactor evolution is based on the market-proven CRIUS II platform that was launched in 2010, allowing seamless transfer of qualified GaN LED processes, says Aixtron.

"Reduction of manufacturing cost is a key issue in the LED industry, in particular when looking at the required cost reduction for solid-state lighting products," says Dr Rainer Beccard, VP marketing. "After having analyzed MOCVD-related manufacturing cost, it was obvious that the reactor capacity remains the key parameter with the strongest influence on operating cost," he adds.

"This new CRIUS II-L is the

largest-capacity manufacturing-proven MOCVD reactor available in the world today, allowing a fast reduction in LED chip cost," Beccard continues. "It offers unsurpassed capacity and throughput, combined with an outstanding yield due to its excellent uniformity and reproducibility," he claims. "The CRIUS II-L reactor is design optimized for wafer sizes of 2-8" and offers the potential for even further productivity enhancements."

As with previous generations, the CRIUS II-L reactor is based on the Close Coupled Showerhead (CCS) concept which, as a key-enabling technology, has a proven track record in being easily scalable with a seamless and short process transfer, Aixtron says. The firm adds that CCS technology is established in many markets, and is known to enable straightforward process tuning, and stable and robust processes.

www.aixtron.com

SDK to boost ammonia production

Tokyo-based chemical manufacturer Showa Denko K.K. (SDK) is to raise its production capacity for high-purity ammonia to meet growing demand from the electronics industry.

High-purity ammonia is used as a material gas in the production of liquid-crystal display (LCD) panels, gallium nitride LEDs, solar cells based on polycrystalline silicon, and semiconductors. Anticipating further growth in the electronics market in East Asian countries and to ensure stable supply of high-purity ammonia, SDK has decided to increase production.

Specifically, capacities at three sites—Kawasaki Plant in Japan; Taiwan Showa Chemicals Manufacturing Co Ltd (owned 90% by SDK); and Zhejiang Quzhou Juhua Showa Electronic Chemical Materials Co Ltd in China (owned 51% by SDK) —

will be increased from the current levels of 1000t/y, 1500t/y and 500t/y, respectively, to 1500t/y, 2500t/y and 1000t/y, by the end of 2011.

The capacity increase will be carried out via expansions of filling/storage facilities and improvement in production efficiency. As a result, the Showa Denko Group's total high-purity ammonia production capacity will rise from 3000t/y at present to 5000t/y.

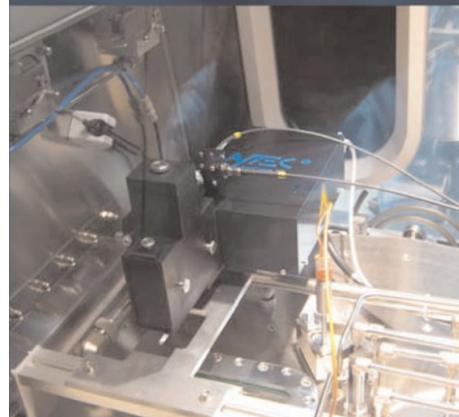
Under its medium-term consolidated business plan PEGASUS, SDK classifies its business in high-purity ammonia and other high-purity gases (for semiconductor/display production) as growth businesses. SDK aims to continue to encourage growth of this business by increasing the competitiveness of existing products and developing new products.

www.sdk.co.jp

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Aixtron – SINANO MOCVD Training Center established

MOCVD systems for Suzhou Institute of Nano-tech & Nano-bionics

On 22 June, Aixtron signed an agreement with long-term customer Suzhou Institute of Nano-tech & Nano-bionics, Chinese Academy of Sciences (SINANO) to co-establish the Aixtron – SINANO MOCVD Training Center, located in the Suzhou Industrial Park (SIP). The signing ceremony in Suzhou was attended by SINANO's director professor Yang Hui and Aixtron's chief financial officer Wolfgang Breme.

SINANO was founded in 2006 jointly by the Chinese Academy of Sciences (CAS), Jiangsu Provincial Government and the Suzhou Municipal People's Government. The 100-acre institute is located in the Suzhou Dushu Lake Science and Education Innovation District and is being built with a phased construction cost of ¥428m. The next construction phase will be complete by the end of 2012 with a construction cost totaling ¥680m.

SINANO already has several Aixtron R&D systems in its facility, but for the new center Aixtron will provide one CRIUS II MOCVD system and one AIX G5 HT MOCVD system to train its customers and potential customers' engineers on the usage of MOCVD systems. The center will be staffed by Aixtron process and maintenance engineers as well as



Signing ceremony for Aixtron – SINANO MOCVD Training Center.

other training professionals, so SINANO's process and maintenance engineers will also be trained by Aixtron in system operation. The center will start up later this year.

SINANO comments that MOCVD is the most critical epitaxial growth equipment in the upstream chain of the semiconductor lighting industry and requires high-level operation staff. By building the Aixtron – SINANO MOCVD Training Center, SINANO and Aixtron aim to take advantage of each party's strengths, in order to train high-end industry professionals and to provide the talent to support both the Yangtze River Delta region and national optoelectronics and photovoltaic industry development.

Moreover, based on this cooperation, the two sides are preparing to establish an MOCVD R&D center, with a view to fundamentally improving China's MOCVD epitaxy technology and MOCVD equipment manufacturing capacity.

"With the new training center Aixtron will provide the necessary support for this very important part of China's industrial future," said Breme. "Supported by the national government's latest 5-year plan, China plans to become a leading global manufacturer of LED devices. This center will provide the prerequisites for the education of highly skilled MOCVD operators," he adds.

<http://english.sinano.cas.cn>
www.aixtron.com

Taiyuan University of Technology selects CCS system for blue LEDs

Aixtron has received an order from new customer Taiyuan University of Technology of China for a Close Coupled Showerhead (CCS) MOCVD system in 3x2"-wafer configuration, to be used for research into gallium nitride-based materials for blue high-brightness (HB) LEDs.

The new reactor will be delivered in second-quarter 2011, and commissioned in a new facility at the university by one of Aixtron's local support teams in China.

"This will be our first Aixtron epitaxial growth system, although we

are already very familiar with this technology and know well of the reputation of this company's equipment and service," says Dr Jian Liang, professor of Taiyuan University of Technology's Material College State Laboratory. "The Close Coupled Showerhead system is an ideal choice for us because it satisfies so many criteria," he adds. "We are particularly interested in its versatility as well as stand-out factors such as low material consumption. These will ensure that this system is so much

superior for our University research project."

Celebrating its 100th anniversary in 2002, Taiyuan University of Technology comes under the authority of the provincial government of Shanxi, China. Historically, although it was originally part of Shanxi University, it did not become an independent university until much later. Today it is listed officially as one of the 'Top 100 Universities in China', according to the Chinese government.

www.tyut.edu.cn

Aixtron opens Chinese subsidiary for faster, more efficient support

Deposition equipment maker Aixtron SE of Herzogenrath, Germany has announced the opening of its Chinese subsidiary Aixtron China Ltd as the next step in its plans for further expansion in the country. The new entity replaces the representative office and operates out of expanded facilities in Shanghai. The move is intended to support Aixtron's growing base of Chinese customers, and should make it easier to grow by opening other facilities throughout China in the near future, says the firm.

"This is the next logical step in terms of our increasing commitment to support China's aggressive plans to become one of the world's leading countries in LED production," says Dr Christian Geng, Aixtron VP Greater China. "This also reflects the strong growth in Aixtron's MOCVD installed base and our increasingly competitive edge in this exciting market," he adds. "It allows us to further enhance our customer support, which will result in reducing operating costs for our customers through streamlined processes and a broader range of services."

The significant investment will make it possible to supply customers with spare parts and service support more quickly and more efficiently on a local basis, reckons the firm. Aixtron intends to continue expanding with further investments in China later this year.

"We are deeply impressed by China's commitment to introduce efficient lighting with LEDs and taking a leading role," says executive VP & chief operating officer Dr Bernd Schulte. "We are fully supportive of our increasing customer base and the government agencies involved."

Aixtron's recent growth in China has meant that the number of staff in its Chinese operation has tripled in the last two years to the current level of over 40 and will continue to grow throughout the year.

Aixtron notes it has proven MOCVD expertise in relation to carbon nanotubes, silicon, silicon carbide and organic semiconductors. Its new R&D center, which opened last summer on the site of its headquarters in Germany, is driving the development of next-generation deposition systems for future materials.

China's Guodian orders AIX 2600G3 IC reactor for CPV solar cell research

Aixtron says that in fourth-quarter 2010 it received an order from new customer Guodian International Economics & Trade Co Ltd, China for an AIX 2600G3 IC reactor in 12x4"-wafer configuration.

The system was due to be delivered in second-quarter 2011 and installed and commissioned by the local Aixtron support team in a new cleanroom at the GD Solar (JiangSu) Co Ltd, Research Group. The reactor will be dedicated to materials research for concentrator photovoltaic (CPV) solar cells.

"We look forward to the arrival of this powerful new addition to our capabilities in our research for

high-efficiency CPV solar cells," says Dr Hong Song, director of Solar Research Institute at Guodian. "Already we have been shown how straightforward it is to achieve the requisite uniformity and run-to-run productivity characteristics with the AIX 2600G3 IC reactor," he adds. "Our technical team already has considerable experience with the Aixtron Planetary Reactor technology. They will work well together with the specialist company support staff so I am sure the system will not be long in making a strong contribution to our efforts."

www.gdsolar.net

IN BRIEF

AquaLite adds CRIUS II reactor for power LED chips

In first-quarter 2011 Aixtron won an order from existing customer and power LED chip maker AquaLite Co Ltd of China for a CRIUS II MOCVD reactor (in 55x2"-wafer configuration), which will be dedicated to growing materials for high-brightness LEDs and high-voltage (HV) LED production.

The local Aixtron support team will install and commission the new reactor in second-quarter 2011 at the dedicated AquaLite power chip LED facility within its mainland China production plant.

"As the main supplier of power chip devices in China, we have an unequalled understanding of the challenges of volume production of HB LED structures and HV LEDs," claims AquaLite's CEO James Dong. "We therefore require the reactor with the best process economics, user control and uptime, which are all strong features of the CRIUS II reactor," he adds. "Our thorough familiarity with the CRIUS systems and the easy process transfer to the CRIUS II mean there will be few if any problems ahead, so the new system will quickly become a major asset."

AquaLite is seeing stronger demand for power LED chips, and is looking to the CRIUS II's higher throughput to boost capacity, Dong continues. "Last November, we acquired six CRIUS 31x2" configuration systems for high-power LED production, so I am confident that the new reactor will also be a very worthwhile new addition."

AquaLite's LED chips have reached luminous efficiency of more than 100lm/W, and are widely used in street lighting, lighting bars, light bulbs, and LED back-lighting units (BLUs).

www.aqualite-led.com

IN BRIEF

OIPT presents ALD white paper & poster

At June's AVS Topical Conference on Atomic Layer Deposition (ALD 2011) in Cambridge, MA, USA, ALD process applications specialist Dr Qi Fang of UK-based etch, deposition and growth system maker Oxford Instruments Plasma Technology (OIPT) presented a poster 'Conformal ALD layers grown with AAO templates and Carbon Nanotubes by remote plasma and thermal ALD'.

OIPT has also made available the white paper 'Growth of platinum films by atomic layer deposition' by Fang, which details both the remote-plasma and thermal-ALD processing used in the deposition of platinum films.

Platinum films were grown on silicon wafers, SiO₂, Al₂O₃ and high-k dielectric HfO₂ ALD films on silicon substrates at 300°C, using methylcyclopentadienyl-trimethyl platinum (MeCpPtMe₃) and O₂ as precursors.

The ALD Pt-films that were deposited were homogeneous and resulted in a low resistivity of 4.6μΩ-cm. Auger electron spectroscopy (AES) studies revealed high-quality Pt films deposited by both thermal and plasma ALD with carbon impurity of less than 1.5% and oxygen found only in the interface. Scanning electron microscopy (SEM) and energy-dispersive X-ray spectroscopy (EDX) were used to investigate Pt nucleation and growth in ALD processes.

OIPT says it is remarkable that the nucleation delay was different between thermal and plasma ALD Pt, although they have a similar growth rate of 0.45Å/cycle. In the white paper, the Pt ALD nucleation and growth behaviours with (i) precursor dose times, (ii) O₂ or O₂ plasma exposures and (iii) substrates are also described.

www.oxford-instruments.com

SPTS management buy-out from SPP gets backing from Bridgepoint

SPP Process Technology Systems Ltd (SPTS) of Newport, Wales, UK, the plasma etch, deposition and thermal processing equipment subsidiary of Sumitomo Precision Products Co Ltd (SPP), says that a management acquisition of SPTS from SPP is being backed by European private equity firm Bridgepoint.

Bridgepoint focusses on the acquisition of companies valued up to €1bn. It is currently investing a €4.8bn fund, Bridgepoint Europe IV, which had its final closing in November 2008, and has made nine investments to date.

SPTS was formed by SPP in October 2009 to merge predecessor firm Surface Technology Systems plc (STS) together with assets acquired from Aviza Technology Inc, including Newport-based single-wafer process equipment subsidiary Aviza Technology Ltd (ATL) and Aviza's Scotts Valley-based Thermal Products business (which provides spare parts, upgrades, and new or remanufactured systems to existing customers of Watkins Johnson, SVG and Aviza furnaces and APCVD systems). Also, last December saw completion of the transfer of ownership from SPP to SPTS of Primaxx Inc of Allentown, PA, USA, which provides residue-free micro-electromechanical systems (MEMS) dry etch release equipment.

SPTS therefore designs and manufactures equipment for producing devices in sectors including MEMS, power management, advanced packaging, high-speed RF components, and LEDs on compound semiconductor substrates. With more than 500 staff in manufacturing, sales and service operations across 19 countries, SPTS serves micro-device manufacturers through its main operations in Newport and in San Jose, CA, USA. In 2010 it generated sales of \$217m and earnings before interest, taxes, depreciation and amortization (EBITDA) of \$58m.

"The investment by Bridgepoint in SPTS signifies the next stage in our evolution as a market leader in the MEMS, compound semiconductor, advanced packaging and power markets," says president & CEO William Johnson. "We are constantly looking to develop our capabilities to meet future customer needs and, with Bridgepoint as a new investment partner, their financial and commercial expertise will be a key pillar to our expansion," he reckons.

"I have been closely involved in the development of SPTS following the time with STS since its acquisition made by SPP in 1995," says SPP's president Susumu Kaminaga. "For SPP, this transaction allows us to focus on other areas of our business which offer attractive investment opportunities," he adds.

"However, we will continue to cooperate with SPTS, retaining a [minority] stake and working together with them through a joint venture for the Japanese market." The firm's name will remain SPTS.

Bridgepoint believes SPTS represents an attractive opportunity to acquire a market leader in the wafer fabrication equipment sector. "SPTS has strong positions in every sector in which it operates, and a global customer base in end-markets poised for long-term growth," comments Bridgepoint director Chris Bell. "In addition, we have identified with management a number of initiatives to optimize its operational performance, including acquisitions in attractive niche markets and joint ventures, such as the BluGlass agreement." Last August, SPTS took a 19.9% stake in BluGlass Ltd of Silverwater, Australia, which has developed a patented low-temperature process using remote-plasma chemical vapor deposition (RPCVD) to grow materials including GaN and InGaN on glass substrates for the production of LEDs.

www.spp-pts.com

Glasgow University expands fabrication capabilities

The James Watt Nanofabrication Centre in Glasgow, UK has added a PlasmaPro System100 ICP plasma etch system to its installed base of etch and deposition tools from the UK's Oxford Instruments Plasma Technology (OIPT). The system will be used on compound semiconductor materials in applications such as optoelectronics, millimeter-wave & terahertz, bioengineering, bio-technology, lab-on-a-chip, energy harvesting and photovoltaics.

"We have been working closely with Oxford Instruments for many years, utilizing their etch and deposition systems," comments Douglas Paul, professor of Semiconductor Devices and director of the James Watt Nanofabrication Centre. "We placed this recent order for an additional Oxford Instruments system as we continue to be impressed by the tools' flexibility and performance," he adds. "We have used their tools for many years, and continue to use them to develop new etch and

deposition processes for nanofabrication as we push technology below 5nm feature sizes. In addition, maintaining our equipment is vital in order to maximize our usage and investment, and we are extremely satisfied with the consistent high levels of support."

Built in 2005, the Glasgow James Watt Nanofabrication Centre brings together all the nanofabrication tools in the University of Glasgow and focuses on nanofabrication and nanoscale systems. It houses more than £20m of nanofabrication and nano-characterization equipment, which is run and maintained in a pseudo-industrial operation by 18 technicians and 5 PhD-level research technologists. The university says it has 30 years of experience of nanofabrication and this now allows patterns, devices and systems all to be fabricated or built with length scales from a few atoms across (about a nanometer) up to many 10s of centimeters.

The University of Glasgow holds the record for the smallest metal pattern produced by electron-beam lithography (3nm), the record for the best layer-to-layer alignment accuracy (0.46nm, i.e. two silicon atoms and over 15 times better than anyone else internationally, it is claimed), the fastest mode-locked laser (2.1THz), the lowest-loss silicon waveguides at telecoms wavelengths, and (up until 2 years ago) the record for the fastest transistor. Present research aims to produce 10nm gate-length HEMTs to recover the record. The center has £53m of active research grants and industrial contracts. It collaborates with over 50 Scottish, UK and international firms, and uses University of Glasgow spin-off Kelvin Nanotechnology Ltd to provide industrial access to the facilities at commercial rates. Kelvin also provides industrial access for a further 200 firms, ranging from local SMEs up to large multi-nationals.

www.jwnc.gla.ac.uk

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Novellus PECVD system for China SemiLEDs' metal alloy LED chip manufacturing

Novellus Systems Inc of San Jose, CA, USA, which makes process equipment for semiconductor and LED manufacturing, says that it has shipped a VECTOR plasma-enhanced chemical vapor deposition (PECVD) system to Xurui Guangdian Co Ltd (China SemiLEDs), a joint venture in China in which high-brightness (HB) light-emitting diode chip and component maker SemiLEDs Corp of Boise, ID, USA is a partner.

The new VECTOR will be installed at the China SemiLEDs' plant in Foshan, and will be used for manufacturing SemiLEDs' MvpLED LED products, which are used primarily for general lighting applications, including street lights and commercial, industrial and residential lighting.

SemiLEDs' proprietary blue (white), green and ultraviolet (UV) 'metal vertical photon' (Mvp) LED chip design features a vertical LED structure on a patented copper alloy base that provides what is claimed to be the best thermal resistance on the market (0.4°C/W) as well as electrical and optical advantages such as greater luminous efficacy and longer lumen maintenance.

"In our continual effort to increase productivity and energy efficiencies, we will be placing the VECTOR LED system at China SemiLEDs' Foshan plant," says Marco Mora, general manager of China SemiLEDs. "Novellus' infrastructure and service capabilities in China made the selection of this vendor a very logical choice," he comments.

Cost-per-die and cost-per-lumen are critical factors in driving the adoption of LED technology into the mainstream lighting market, says Novellus. Current LED manufacturing technology is predominantly based on sapphire substrates with diameters of 2", 3" and 4". The inherently low-productivity manufacturing process used in making LEDs consumes a considerable amount of energy — on average, more than 200kWh of electricity is spent in making a 2" sapphire wafer, says the firm.

Novellus says that the multi-station sequential processing (MSSP) architecture of its VECTOR PECVD system provides high productivity coupled with superior uniformity and repeatability. More than 1000 VECTOR systems have been installed at customer facilities worldwide.

Novellus claims that the VECTOR system's process performance, wide process window and high productivity combines to provide a lower manufacturing cost-per-die compared with traditional LED manufacturing solutions. In particular, with a multi-wafer carrier configuration, the VECTOR LED system can handle all wafer sizes: 2", 3", 4", 6", 8" and 12". Also, in contrast to a traditional PECVD reactor used in LED manufacturing, the VECTOR LED also deposits films at lower temperatures, provides better manufacturing process control, and is more energy efficient, it is claimed.

"The new VECTOR LED system is the LED manufacturing industry's most productive PECVD solution," claims Sessa Varadarajan, senior VP & general manager of Novellus' Electrofill and PECVD business units. "We are pleased to add VECTOR LED to the company's existing suite of products for LED manufacturing, including our process solutions for photoresist strip, descum, PVD, electroplating, and wafer polishing and thinning," he adds.

www.novellustechnews.com
www.semileds.com

ASM International ships its 500th ALD reactor

Equipment and materials maker ASM International N.V. of Almere, The Netherlands says that it has shipped more than 500 atomic layer deposition (ALD) reactors for use in semiconductor manufacturing to date. The firm now has ALD reactors in high-volume manufacturing at a majority of advanced logic and memory fabs worldwide. This includes plasma-enhanced ALD which provides advantages for certain applications, such as very low temperature processing.

ASM claims to deliver the industry's broadest portfolio of ALD configurations and applications and to be

the only supplier in the market shipping both single-wafer and batch ALD tools. The firm's plasma and thermal ALD systems are used in high-volume manufacturing for a wide range of applications, including high-k

and metals for advanced transistor gates, capacitor dielectrics and electrodes, and spacers for double patterning.

ASM has established ALD centers of excellence in Europe, USA and Asia for material and precursor research

Recognizing the value and importance of ALD to the future of semiconductor manufacturing, ASM has established ALD centers of excellence in Europe, USA and Asia for material and precursor research, product development and process integration. The firm reckons that these in-house R&D program investments have uniquely positioned it to bring ALD (thermal and plasma) to high-volume manufacturing and to enable customers to achieve the performance required for the most advanced semiconductor devices.

www.asm.com

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IN BRIEF

JPSA launches IX-6168 micro-machining system

Co-exhibiting with solid-state laser supplier Lumera of Kaiserlautern, Germany at the LASER World of PHOTONICS 2011 trade show in Munich (22–26 May), JP Sercel Associates Inc (JPSA) of Manchester, NH, USA, which makes laser-based materials processing workstations for wafer processing and micro-machining, launched the IX-6168 Micromachining system.

"The flexibility of the system allows us to integrate different laser modules, such as Lumera's Super Rapid, to adapt to our customers' changing application needs," says chairman & chief technology officer Jeffrey Sercel. "The IX-6168 is another example of JPSA's commitment for providing laser system tools for next-generation micromachining processes," he adds.

The IX-6168 is a versatile laser micromachining system that can be configured with either UV excimer, DPSS (diode-pumped solid-state) or ultra-fast picosecond lasers for large-area patterning or direct-write processing. Also, JPSA's IAP (Integrated Automation Platform) wafer load and unload automation module provides LED makers fully automated production, and can be installed on any IX-6000 series of laser workstations, says the firm.

www.jpsalaser.com



JPSA's new IX-6168 laser micromachining system.

MHI's μ V1 machines SiC and sapphire wafer materials

Tokyo-based machinery manufacturer Mitsubishi Heavy Industries Ltd (MHI) says that it has used its μ V1 micro-milling system to machine four types of extremely hard, difficult-to-cut wafer materials: silicon carbide (SiC), sapphire, glassy carbon and silica glass.

On the revised Mohs hardness scale, which rates the hardness of a diamond at 15, SiC is the third hardest wafer material (13), and sapphire is fourth hardest (12). Glassy carbon is rated between 10 and 11 and silica glass is a 7.

The μ V1 is able to create grooves and grids to micron-level accuracy on wafers using a cutting process only (i.e. without additional processes that are necessary when creating grooves and grids by photolithography or etching) enabling significant reductions in production time and cost, it is claimed. MHI aims to expand sales of the μ V1 for trial machining of semiconductor materials and sample production.

For machining wafer materials, the μ V1 uses a cutting tool made of diamond. To remove hard fine swarf mixed with coolant oil, the machine is equipped with a special fine swarf collection filter. MHI says that its proprietary Optical Image-type Tool Measurement System can accurately measure the position of the rotating tool end using a CCD (charge-coupled device) camera, enabling precise real-time monitoring of tool tip position. This feature allows the machine to obtain tool rotation dynamic accuracy data and to offset thermal displacement caused by the heat generated by the machine itself, ensuring precise cutting of grooves with micron-level accuracy.

The μ V1 was released in 2006 as a three-axis milling machine for the machining of precise die and mold, electrodes as well as precision parts. In 2008, a five-axis model (which has table tilting function with rotary axes) was added to the series. To



The μ V1 micro-milling machine.

date, applications of the μ V1 have been expanded to include machining of non-ferrous materials and the production of small-sized jigs.

When photolithography or etching is used for semiconductor shaping in trial or sample production (applications in which production quantities are inherently limited and production is subject to frequent changes) these methods tend to inflate costs, as they require the production of multiple masks for each modification in semiconductor shape, says MHI. These methods also require a long time for processing patterns in the case of deep shapes, and they impose limitations on 3D free-curve shape processing.

MHI views machining by the μ V1 as a new technology that addresses these shortcomings, and the firm is also targeting additional applications such as micro-flow channels required for bio-chips. To promote use of the machine in these new fields, MHI says that it will leverage its machining expertise to support potential users in all phases, from initial consideration of the μ V1 through to its actual operation.

The machined samples of the four difficult-to-cut wafer materials and a video of the μ V1 in action was presented at the event 'Exhibition Micromachine/MEMS 2011' at Tokyo Big Sight (13–15 July).

www.mhi.co.jp/en

Ushio debuts first 200mm full-field projection litho tool for LEDs, plus 150mm laser lift-off system

Tokyo-based Ushio Inc has started shipping what it claims is the first 200mm-wafer full-field projection lithography tool (UX4-LEDs FFPL 200) for manufacturing high-brightness (HB) LED chips. The firm has also completed development of the UX4-LEDs LLO 150 laser lift-off system for high-volume manufacturing of vertical-structure LED chips on 150mm wafers.

The latest models in the UX4-LED range are based on the same platform as Ushio's field-proven UX series, which has an installed base of more than 1100 systems. Both new models were exhibited at Semicon West 2011 in San Francisco, CA, USA (12–14 July).

The UX4-LEDs 150mm-wafer full-field projection lithography tool (launched last November) has already been used for high-volume manufacturing at LED chip makers in Japan, Korea, Taiwan and China, notes Ushio. The new UX4-LEDs FFPL 200 has a 200mm-diameter full-field projection lens mounted on the common UX4-LEDs platform to enable full-field projection exposure of a 200mm wafer, with a high throughput of 120 wafers per hour. Unlike stepper systems, for which productivity reduces as wafer size increases, the UX4-LEDs FFPL 200 uses the full-field projection method to enhance its productivity by increasing the wafer size. It hence allows further enhancement in productivity and a reduction of the cost-of-ownership (CoO) in the LED lithography process, claims Ushio.

The system is designed to automatically handle wafer-size conversions up to 200mm wafers, and has a modular platform for future



Ushio's UX4-LEDs platform.

upgrades. It is also completely non-contact to cause no mask damage, and has a large depth of focus and special wafer chucking to cope with warped wafers. Also, special alignment technology accommodates low-visibility alignment marks. An optional backside alignment function supports wafer-level packaging LED applications.

Laser lift-off (LLO) technology — for stripping a gallium nitride (GaN) film from a sapphire substrate — is indispensable for increasing LED brightness, says Ushio. Leveraging a field-proven KrF 248nm-wavelength excimer laser (well known for high repetition frequency and high stability as well as proven deep-UV optical technology), the firm has developed the UX4-LEDs LLO 150 laser lift-off system, which can achieve both high yield and high throughput. The system can also contribute significantly to reducing LED manufacturing costs, claims Ushio, because it allows reuse of sapphire substrate up to 150mm in diameter by stripping the GaN film from the entire sapphire substrate surface.

www.ushio.co.jp/en

IN BRIEF

ARC delivers 100th furnace for sapphire crystal growth

Advanced RenewableEnergy Company LLC (ARC Energy) of Nashua, NH, USA, which was founded in 2007 to provide c-axis sapphire crystal growth technologies and turnkey processing solutions for the LED solid-state lighting and clean-energy markets, has shipped its 100th CHES Furnace. ARC says it is seeing demand worldwide for its highly automated c-axis sapphire growth technology, which is being used by LED makers throughout Asia.

ARC says that, by significantly increasing material utilization and efficiency for sapphire manufacturers, its products enable semiconductor-scale production and commercialization of cost-effective, large-diameter sapphire wafers for LED applications.

ARC's technology significantly drives down the cost of producing LEDs, claims co-founder & CEO Dr Kedar Gupta. "The delivery of our 100th furnace shows that our products have wide market acceptance and that our mission is being realized," he adds.

Designed for LED applications, ARC's CHES Furnaces are highly automated c-axis growth furnaces used to produce sapphire boules. Cores from the crystals are turned into LED wafers, and finally into the high-brightness (HB) and ultra-high-brightness (UHB) LED chips used in LED backlighting, general lighting, and automotive and signage applications.

ARC Energy also offers turnkey solutions to quickly and efficiently ramp-up production to generate revenue from sapphire products. The end-to-end turnkey solutions and services include setup and installation, training, material handling, inspection, core fabrication and material recycling.

www.arc-energy.com

IN BRIEF

GT Solar raises full-year order backlog forecast from \$1bn to \$1.6bn

GT Solar International Inc of Merrimack, NH, USA (a provider of polysilicon production technology as well as sapphire and silicon crystalline growth systems and materials for the solar, LED and other specialty markets) has raised its financial outlook for its fiscal first-quarter 2012 (ending 2 July 2011), reiterated its full-year 2012 guidance, and raised its outlook for order backlog for fiscal 2012.

GT Solar indicated on 24 May that for fiscal first-quarter 2012 the firm expected revenue of \$140–150m, fully diluted earnings per share (EPS) of \$0.08–0.11, and gross margin of about 37%.

However, based on sooner-than-expected completion of DSS650 upgrades in Q1/2012 — and allowing for Q1 revenue recognition for certain PV orders that had been previously expected in Q2 — GT Solar now expects revenue of about \$225m, fully diluted EPS of about \$0.30, and gross margin of 43–44%.

GT Solar also reiterated its full-year fiscal 2012 guidance (given on 24 May), which includes: revenue of \$1–1.1bn; EPS of \$1.55–1.85; gross margin of 42–44%; operating expenses of \$115–125m; capital expenditure of \$25–30m; and an effective tax rate of about 33%.

In addition, given the significant number of orders that the firm has received so far in fiscal Q1/2012, GT Solar has also raised its forecast for order backlog at the end of fiscal 2012 from “above \$1bn” to “at least \$1.6bn”.

www.gtsolar.com

GT Solar completes expansion of sapphire manufacturing facility Plant ramps to production in under 8 months

GT Solar International Inc of Merrimack, NH, USA has celebrated the grand opening of its new sapphire production facility in Salem, MA, the site of the former Crystal Systems Inc (a crystalline growth technology firm manufacturing large-area sapphire substrates, acquired in July 2010).



The opening of the newly expanded plant concludes **GT Solar's expanded sapphire production facility in Salem, opened in June for production.**

a project that began construction in October 2010 which triples the sapphire production capacity in Salem. GT invested \$27m to create a high-volume production facility to provide sapphire material for the fast-growing LED market and other industrial material sectors.

“The investment in this new plant is a testament to our belief in the growth of the sapphire market and our ability to capture a leadership position in this industry,” said president & CEO Tom Gutierrez. “We’ve leveraged 40 years of crystal growth expertise from Crystal Systems and combined it with GT’s successful track record of rapid scale-up of commercial crystalline growth technology to create a new state-of-the-art sapphire manufacturing facility capable of producing predictable and repeatable high-quality sapphire crystal run after run,” he added.

“We are also proud to be able to generate high-quality employment opportunities to the people of Salem and throughout the North Shore area,” said Cheryl Diuguid, VP & general manager of GT’s sapphire equipment and materials business unit. “Since the completion of the acquisition of Crystal Systems last summer, we have doubled our employment within our business unit. Our sapphire business is growing and, at a time

of high unemployment for so many Americans, we are pleased that we are in a position to offer high-quality manufacturing employment opportunities,” she added.

“Governor Patrick has focused on stimulating economic activity in our Gateway Cities and creating jobs in innovation sectors like clean energy and advanced manufacturing. This expansion project combines all three of those important elements,” noted Secretary of Housing & Economic Development Greg Bialecki.

The new 20,000ft² manufacturing facility should ramp to full volume production over the next several months. GT Solar says that the highly efficient manufacturing environment uses the latest production control technology to produce high-yielding boules of consistent size and quality. The boules produce cores with diameters of 2”, 4”, 6” or 8” and beyond for downstream processing into wafers for the LED market and other material such as large-diameter A- and C-axis windows for other industrial markets. The firm also uses the manufacturing facility as an R&D center — testing advances in process technology and commercializing process knowledge and expertise for the firm’s growing list of customers for its advanced sapphire furnace (ASF) equipment.

www.gtsolar.com

Rubicon's Malaysian polishing plant starts volume production of large-diameter sapphire

Rubicon Technology has announced two critical milestones that enable its new facility in Penang, Malaysia to move into volume production of 6" and 8" polished sapphire wafers.

The facility recently completed qualification of its 6" wafers by a key customer, as well as an ISO certification audit. Both milestones enable the facility to enter volume production of 6" polished wafers, which are in great demand as LED chip makers continue to migrate to larger-diameter substrates for greater efficiencies. The facility can also process and polish 8" wafers, which Rubicon provides to customers in R&D volumes.

Rubicon says that its customers demand consistent quality and often require vendors to achieve and maintain globally recognized quality standards, such as those set by the International Organization for Standardization (ISO). The Malaysia plant recently passed the rigorous audit by ISO inspectors with zero findings and has been recommended for ISO 9001:2008 certification, which is expected to be formally issued upon final review by the registrar.

Most semiconductor makers also require suppliers to re-qualify products when a new manufacturing facility is opened. Rubicon has been in the re-qualification process with a number of existing customers that have previously purchased 6" wafers produced in its US facility. The Malaysian facility has now been qualified with a major customer. The qualification process involves the production of LED chips on Rubicon's 6" sapphire wafers and rigorous testing of those chips in various applications.

Rubicon's Malaysia plant, combined with its new crystal growth facility in Batavia, IL (both leveraging large-diameter sapphire) were established to deliver the capacity to support the growing demand for

LEDs in the consumer electronics and general lighting industries. "Our facility in Malaysia further increases our ability to deliver large-diameter sapphire wafers in large volumes to customers worldwide," says president & CEO Raja Parvez.

Market research firm iSuppli expects the LED market to nearly double to almost \$14.3bn by 2013, driven by the penetration of LEDs into the general illumination market (including light bulbs). LEDs are a popular option for backlighting screens from HDTVs, traffic lights and large displays as well as in a broad range of consumer devices including tablets, notebooks, laptops, mobile phones, navigation devices, digital music players, digital photo frames, digital cameras and keypads. LED use in general lighting is also increasing significantly, particularly in street lighting, industrial lighting and architectural lighting.

"The ability of our new Malaysia operation to fabricate larger-diameter high-quality polished wafers perfectly complements our existing large-diameter crystal growth capability and makes Rubicon the world's leading vertically integrated provider of large-diameter sapphire substrates," reckons Parvez. "The location and capabilities of our manufacturing facilities around the globe minimizes the risk of business interruption while lowering cost and providing proximity to our valued Asian customers," he adds.

Rubicon says its expansion into Asia demonstrates what it claims is its leadership role in the production of large-diameter sapphire wafers. The firm can now produce polished sapphire wafers up to 12" in size. The transition to large-diameter wafers in LED production has begun with several tier-one LED makers announcing a move to producing chips on 6" polished wafers.

www.rubicon-es2.com

IN BRIEF

Rubicon forecasts Q2 at high end of \$40-43m guidance

Rubicon Technology Inc of Bensenville, IL, USA, which makes monocrystalline sapphire substrates and products for the LED, RFIC, semiconductor and optical industries, has reaffirmed its second-quarter 2011 revenue and earnings guidance (given on 5 May) and clarified its projected tax rate for Q2/2011 and remainder of the year.

The firm estimates that revenue should be at the high end of the \$40-43m range of its guidance, up 13% on Q1's \$38m.

Also, pre-tax earnings should be at the high end of previous estimates. Its Q2 earnings per share (EPS) guidance of \$0.82-0.86 assumed a diluted share count of 24 million shares and a tax rate of 7%, which represents accrual for state income taxes only.

When providing this guidance, management indicated that a determination might be made to begin accruing for federal income tax as soon as Q2 due to factors including the dramatic increase in earnings. Chief financial officer William Weissman confirmed that the firm will begin accruing for federal income tax starting from Q2, which will bring the firm's effective tax rate up to about 40% for Q2 and the remainder of 2011. He also confirmed that the projected effective tax rate for 2012 remains at 30-35%. Factoring in the higher tax rate adjusts the previously issued EPS guidance to \$0.53-0.55.

"We indicated in our last earnings call that we might begin accruing for federal income tax in the second quarter and, based on our continued strong earnings, it has been determined that accruing for federal tax in the second quarter is appropriate," says Weissman.

www.rubicon-es2.com

Nitride Solutions' Series A funding reaches \$1.8m

Nitride Solutions Inc of Wichita, KS, USA, which develops substrates for LEDs, lasers and power electronics, has secured major financing commitments from Nebraska Angels and Aurora UV Inc of Santa Barbara, CA (which makes ultraviolet LEDs for applications including air and water purification). Founded in 2009, Nitride Solutions has so far raised \$1.8m in a Series A preferred round. Nebraska and Aurora join lead investor Midwest Venture Alliance, in addition to Mid-America Angels and Manhattan Holdings, in the round.

"Our investment group, the Midwest Venture Alliance, is looking to invest in solid management teams that are solving real market problems," says Wichita Technology Corp's president & CEO Trish Brasted.

"They [Nitride Solutions] have put together an experienced business and technical management team that is developing an industry-changing advanced material."

Nitride Solutions is developing a manufacturing technology that aims to deliver high-volume, low-cost aluminum nitride (AlN) substrates. With projected defect rates 10 times lower than substrates currently on the market, the substrates will improve the quality of existing LED, laser and electronic products, while also enabling whole new categories of UV devices, the firm reckons. The result should be improved white lighting for consumer and industrial uses, more efficient power systems in hybrid vehicles, sharper color on flat-screen TVs, and better air and water purifiers. Nitride will use the funding to perfect the technology, and to begin manufacturing and sales in late 2011.

"The number of biomedical and industrial applications of LED technology is rapidly growing," says Karen Linder, co-deal lead for Nebraska Angels. "Nitride Solutions' novel method of creating substrates

on which these crystals can be grown will change the market."

Nitride Solutions' leadership has more than 30 years of experience in materials businesses — both in start-ups and Fortune 500 firms — and 14 years in crystal development. President & CEO Jeremy Jones was Kansas PIPELINE 2010 Innovator of the Year for his work at the firm, which maintains ties to Kansas State University in Manhattan, KS (via key staff and advisors).

"We expect to benefit with both high financial rewards and the satisfaction that we will have been part of the effort of applying hard science to alleviating some of the world's most vexing problems, including cheap access to pure water," says Aurora UV's president & CEO Muriel Taylor.

Nitride is still seeking a small group of financial and strategic investors to finalize the round, which will stay open until September.

www.nitridesolutions.com

AZZURRO completes team for GaN-on-Si epi roll-out

AZZURRO Semiconductors AG of Magdeburg, Germany has completed its management team with the recruitment of three industry veterans, who will play a crucial role in driving the firm into its next growth stage: the global roll-out of its gallium nitride on silicon (GaN-on-Si) epitaxial wafers for high-brightness LED and power semiconductor electronics applications. The firm reckons that the use of its large-diameter (150mm) GaN-on-Si epi-wafers will allow the industry to use standard production facilities and hence to realize huge cost savings.

VP finance Andrew Bowd is a chemical and semiconductor industry professional with 25 years of experience, having held senior leadership roles in manufacturing, R&D and sales & marketing in the UK, Germany and the USA with ICI, AstraZeneca and Advanced Micro Devices. AZZURRO says that he also has a strong understanding of



Bowd, Ysewijn and Lutgen.

technology due to being a physicist and chartered electrical engineer.

VP sales & marketing Erwin Ysewijn started his marketing & sales career in 1989 at Hitachi Semiconductors, gaining familiarity with Japanese and international business culture. He has since spent most of his time in Asia (covering countries including Korea, India, Taiwan and China), working on marketing, sales and strategic merger & acquisition projects. In his most recent position, he headed global marketing activities at Lantiq.

VP technology Dr Stephan Lutgen studied physics and gained a PhD at University Marburg/Berlin, and is

an entrepreneurial executive with 13 years of optoelectronic product experience in international production, engineering and customer-driven business at Siemens/Osram Opto Semiconductors. He has developed commercial optoelectronic products ranging from LEDs, V(E)CSELs and edge-emitting infrared and visible lasers for communications, illumination, sensing, material processing and visible-laser projection applications. Lutgen also has experience in personal management, coaching and project leadership of strategic development and funding of international projects. He has a technical background in III-V semiconductors as well as experience in MOCVD.

"It is now essential to capitalize on experienced people to propel AZZURRO on the global stage and deliver world-class technology," comments CEO Erwin Wolf.

www.azzurro-semiconductors.com

Kyma updates progress in crystalline AlGaN and AlN materials

Kyma Technologies Inc of Raleigh, NC, USA, which provides crystalline gallium nitride (GaN) and aluminum nitride (AlN) materials and related products and services, has provided an update on its progress in crystalline AlGaN and AlN materials development and its desire to collaborate with bulk AlN developers interested in improving the optical transparency of their materials.

Kyma says that it has more than a decade of experience in the fabrication of AlN templates (thin films of crystalline AlN deposited on sapphire, silicon, or silicon carbide substrates) using its patented and proprietary III-N Plasma Vapor Deposition of NanoColumns (PVDNC) technology. These products are gaining acceptance with customers engaged in blue and green light-emitting diode (LED) manufacturing, the firm adds. The nanocolumnar nature of PVDNC AlN templates presents what is claimed to be an excellent surface for nucleating GaN buffer layers, which can then be followed by a high-quality GaN LED device structure.

Kyma recently began extending its process capabilities to develop materials that are designed to support high-Al-content device layer structures, which are of interest for ultraviolet (UV) and high-temperature and high-power electronics applications.

"While our PVDNC AlN templates are excellent substrates for manufacturing GaN-rich devices such as blue and green LEDs and AlGaN/GaN field-effect transistors (FETs), we are also employing other processes to develop materials that are specifically tailored to support the manufacturing of AlN-rich devices such as mid-UV LEDs for germicidal irradiation and AlN/AlGaN FETs for temperature-insensitive high-power electronics applications," says president & CEO Dr Keith Evans.

Towards these goals, Kyma is exploring and has made significant progress in the growth of crystalline AlN and AlGaN materials using high-growth-rate hydride vapor phase epitaxy (HVPE).

By adding a novel Al source to its HVPE tools, Kyma is now able to grow crystalline AlN and a broad range of AlGaN compositions. Also, just like GaN HVPE, the structural quality of the HVPE-grown AlN and AlGaN crystals are influenced by the seed crystal on which they are grown.

Kyma has already demonstrated the ability to deposit crystalline AlN by HVPE on a range of starting seed materials, including on AlN structures that were produced by other techniques.

"Our AlN HVPE process appears to have many of the traits of our GaN HVPE process," says Ed Preble, chief technology officer & VP business development.

By adding a novel Al source to its HVPE tools, Kyma is now able to grow crystalline AlN and a broad range of AlGaN compositions

"We are able to rapidly replicate the quality of the underlying seed and, in certain cases, then improve its quality as we continue to grow the crystal," he adds.

"Additionally, optical transmission measurements show that our HVPE-grown AlN materials have high transparency in the 200–400nm spectral region, an important feature for UV LED applications, and a noted advantage over some competing AlN crystal growth approaches," Preble claims.

Kyma is currently seeking partnerships with bulk AlN materials developers who are interested in the possibility of improving the optical properties of their materials.

www.kymatech.com

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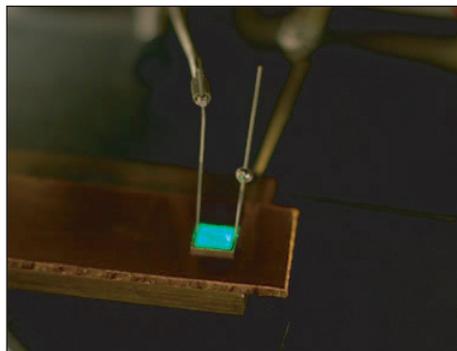
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RoseStreet Labs demonstrates first long-wavelength LED based on InGaN-on-silicon

Commercialization targeted in 2–3 years

RoseStreet Labs (RSL) of Phoenix, AZ, USA, a privately held supplier of products and services for the renewable energy and semiconductor markets, has announced what it claims is the first demonstration of a long-wavelength LED device using silicon wafers, which have a substantial cost advantage over the more traditional sapphire or silicon carbide (SiC) substrates typically used in LED fabrication. The device complements the firm's proprietary thin-film indium gallium nitride (InGaN) on silicon technology for high-efficiency photovoltaic applications and power devices.

RSL notes that green and longer-wavelength LEDs have been sought by both science and industry for an extensive period of time because they would fill a high-value gap in the rapidly growing LED market for lighting and illumination where energy efficiency, low cost and miniaturization are critical product characteristics. "Green LEDs have been elusive due to material challenges of producing a high-efficiency device in the green



RoseStreet Labs' InGaN-on-silicon long-wavelength LED.

region and the longer wavelengths of the spectrum," says chief technology officer Wladek Walukiewicz. Efficient long-wavelength LEDs are essential milestones in the roadmap for solid-state lighting (SSL), LED backlighting and next-generation display technology.

Also, green or longer-wavelength nitride-based LEDs are very challenging to fabricate compared with UV and blue LEDs due to decreasing quantum efficiencies, and have remained a tough milestone for the LED industry. However, RSL's longer-wavelength

devices are fabricated using commercial-scale deposition tools at its Nitride Research Center in Phoenix.

RSL plans to eventually package the green and longer-wavelength LEDs through sister company FlipChip International LLC (FCI), a supplier of wafer bumping, wafer-scale packaging and flip-chip products and services. FCI has extensive experience in packaging semiconductor power devices at its manufacturing locations globally, and plans to provide a proprietary packaging solution for the LED devices.

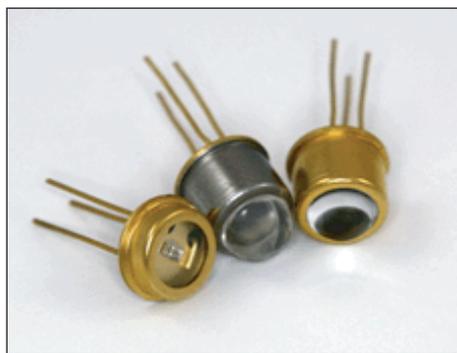
RSL has also demonstrated initial tunability of the technology to multi-color and white-light spectrums. The firm says that the device shows great promise due to its potential for high intensity, low energy consumption, and a roadmap to very low commercial cost. RSL believes that the technology could be commercialized in 2–3 years, with migration to 200mm silicon substrates.

www.rosestreetlabs.com

SETi achieves 10,000 hours lifetime on UVTOP LEDs

Under its continuous improvement program, Deep ultraviolet (UV) LED maker Sensor Electronic Technology Inc (SETi) of Columbia, SC, USA has demonstrated lifetime of over 10,000 hours on its UVTOP275 LEDs. The demonstration was performed on a statistically valid group of LEDs from several batches that are representative of UVTOP275 products; the LEDs were packaged in TO-39 metal-glass packages with flat windows and emit at a wavelength of 280nm \pm 5nm at an average output power of 0.8mW after burn-in.

Lifetime analysis was performed to SETi standard procedure; driven with a current of 20mA DC at room temperature (about 23°C ambient)



SETi's UVTOP LEDs.

with no heatsink or thermal management. The LEDs were physically life tested to about 2000 hours and L50 levels (50% of the LED's original power) modeled from these tests. SETi says that the

demonstration represents a massive leap in operational performance for the firm and far exceeds lifetime for other conventional UV light sources.

SETi manufactures LEDs from 240nm through 360nm to ISO9001 certification and claims to be currently the leading commercial manufacturer of UV LEDs shorter than 365nm. While this lifetime has not been released in the UVTOP product specifications, SETi expects its UVTOP275 LEDs to exhibit L50 lifetimes approaching 5000 hours and the firm is developing future products to meet extended lifetime specifications.

www.s-et.com

Crystal IS' board gains entrepreneur to aid UVC LED commercialization

Crystal IS Inc of Green Island, NY, USA, which makes ultraviolet light-emitting diodes (UVC LEDs) on aluminum nitride (AlN) substrates, has appointed Dr Kevin J. Knopp to its board of directors. Most recently Knopp served as vice president for Thermo Fisher Scientific Inc of Waltham, MA, USA in its Portable Optical Analysis business unit.

"With Kevin Knopp's success in commercializing innovative technology, particularly in the compound semiconductor industry, we are fortunate to have his counsel and recommendations as we begin delivering UVC LEDs to market on a global basis," says chairman Nicholas Wood. "We expect our products to significantly impact the landscape of water, air, and surface disinfection technology, bringing about much-needed change for the world," he adds. "Today we are

working with large global customers to integrate our technology into their designs."

Knopp has held many roles from R&D to sales and operations leadership. Most recently, he co-founded Ahura Scientific in 2002 and was responsible for engineering, government research, operations, and the safety & security business vertical. He then transitioned to business leader for one of Thermo Fisher's global business units after Ahura was acquired by them. Previously, he was the manager of vertical-cavity

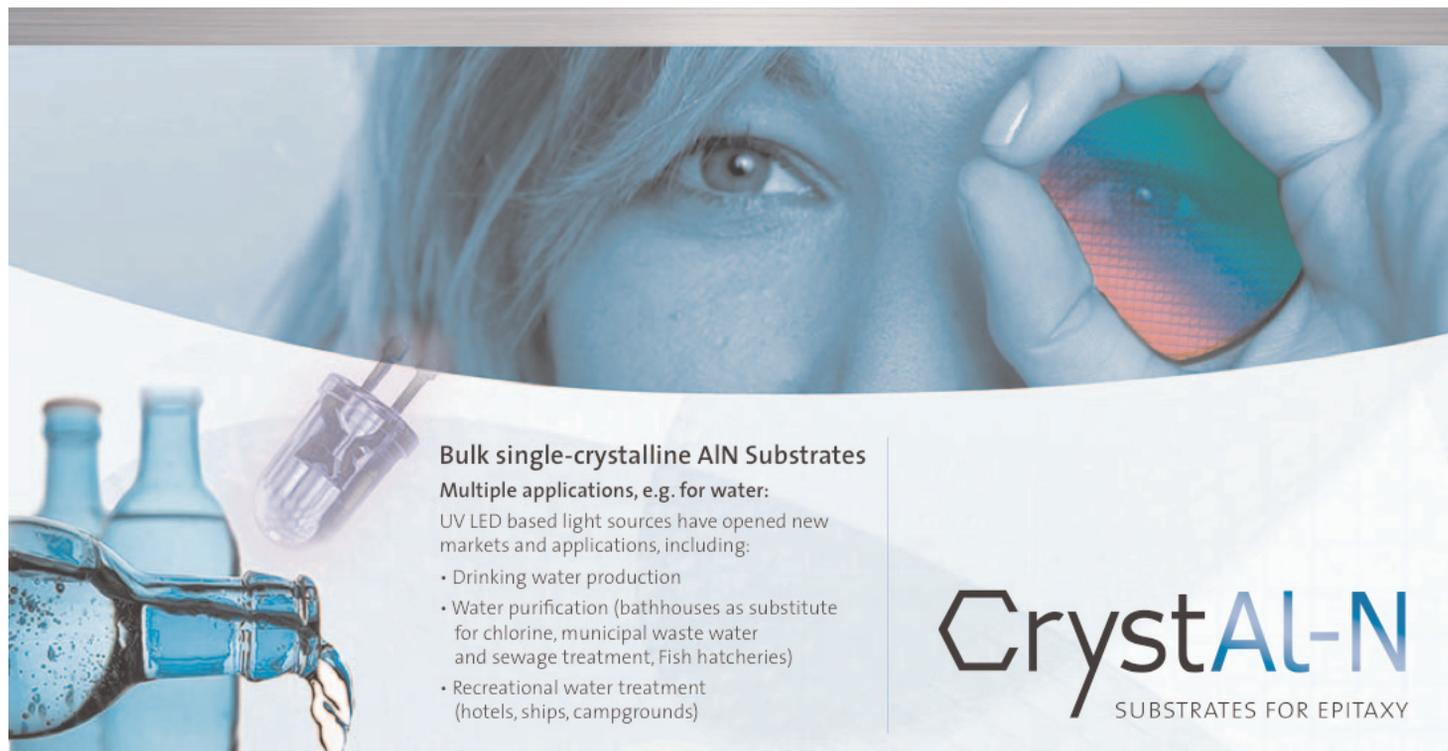
We expect our products to significantly impact the landscape of water, air, and surface disinfection

laser development at CoreTek Inc, which was acquired by Nortel Networks for \$1.4bn in 2000.

Knopp has more than 15 US patents, and his products have received R&D 100, Business Week IDEA, GSN, CPhI Gold, Cygnus, and Frost & Sullivan awards. He also has a B.S.E.E. from Boston University, and M.S.E.E. and Ph.D degrees in Optics from the University of Colorado.

"The team at Crystal IS are in a unique position just now," comments Knopp. "They have proven to be the technology benchmark in the emerging space of UVC LEDs. Now they need to bring the business into full realization with clear and focused customer strategies and selective partnerships," he adds. "I look forward to being an integral part of that."

www.crystal-is.com



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IN BRIEF

Seoul Semiconductor wins Assodel Award in LED category

South Korean LED maker Seoul Semiconductor (SSC) is the winner of the Assodel Awards 2011 in the LED category.

"We are very proud of this official recognition from our Italian partners; this confirms our business strategy to focus on customers and customer satisfaction," says managing director Manuel Zarauza, who accepted the award on 17 June at the Gala Assodel in San Siro, Italy of the Italian Association for Electronics Suppliers (Associazione Nazionale Fornitori di Elettronica). "A fair cooperation with manufacturers, distributors and partners is and remains the basis of our everyday work," he adds. "That's why we focus on our core business, in particular the development and manufacturing of high-performance and innovative LEDs."

Since 2003 the Assodel award has been given annually to manufacturers in the electronics industry who are honored for their excellent quality in collaboration and distribution. The award is presented in nine regular categories: active components, passive components, connectors, electromechanics, LED, visualization, RF & wireless, power and instrumentation. There is also an award for lifetime achievement. This year, the winners are based on reviews of the electronics industry (mainly distributors), but companies from the field of design or construction were also taken into account. Seven criteria had to be met, including technical, commercial and logistics support, but also communication, quality of products and business relationship, as well as distribution policy.

www.seoulsemicon.com

SemiLEDs' quarterly revenue drops a further 43% Transition to 4" accelerated as pricing pressure increases losses

For its fiscal third-quarter 2011 (to end May), LED chip and component maker SemiLEDs Corp of Boise, ID, USA (which has chip fabrication facilities in Hsinchu Science Park, Taiwan) has reported revenue of \$5.6m, down 43% on \$9.96m last quarter and \$9.9m a year ago, and below the expected \$6–7m.

"Pricing pressure and end-demand weakness continued from the fiscal second quarter [when revenue dropped 23% sequentially from fiscal Q1's \$13m]," says chairman & CEO Trung Doan. "However, we are seeing pricing stabilize," he adds.

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

Gross margin has fallen further, from 51% a year ago and 23% last quarter to just 9% (in contrast to the expected rebound to 25–30%). Operating margin was –70%, compared with –6% last quarter and +36% a year ago. However, margins were negatively impacted by a charge of \$1.1m for the write-downs of inventory.

On a non-GAAP basis, net loss was \$4.3m, up from \$0.74m last quarter and compared with net income of \$3.3m a year ago. Cash used in operations was \$3.3m. During the quarter, cash and cash equivalents fell from \$102.6m to \$94.4m.

On 9 December SemiLEDs completed its initial public offering, generating net proceeds of \$95.5m

for expanding production capacity in Taiwan, R&D expenses related to LED chip production based on 6" wafers, and general corporate purposes (including working capital and capital expenditure). The firm has built additional capacity through an LED chip-making joint-venture China SemiLEDs (Xurui Guangdian Co Ltd) formed in January 2010 in Foshan, Guangdong Province. However, after opening trading on NASDAQ at \$24.01 (41% above the \$17 IPO price), the firm's share price has slumped to \$6–7m in recent weeks.

"We remain focused on improving our cost structure by accelerating our efforts to transition to 4" wafer production at our Taiwan facility, continuing to ramp 4" production volume at China SemiLEDs, as well as supporting our customers to maximize the benefits of our metal vertical chip structures to reduce the total cost of ownership," says Doan. The firm's metal vertical photon

We remain focused on improving our cost structure by accelerating our efforts to transition to 4" wafer production

(MvpLED) chip design features a vertical LED structure on a patented copper alloy base (after removal of the sapphire substrate) that provides what is claimed to be the best thermal resistance on the market — allowing better heat removal than for LEDs that retain the sapphire substrate — as well as electrical and optical advantages such as greater luminous efficacy and longer lumen maintenance.

For its fiscal fourth-quarter 2011 (to end-August), SemiLEDs expects revenue of \$5.5–6.5m. Gross margin is expected to be negative.

www.semileds.com

US researchers create LEDs for flexible arrays

Novel etching, layout and thermal management allow smaller, lower-temperature InGaN-on-Si LEDs

University of Miami professor Jizhou Song together with researchers at Northwestern University have helped a team at University of Illinois at Urbana-Champaign (UIUC) led by professors Ralph Nuzzo and John Rogers to design an LED light that uses an array of LEDs 100 times smaller than conventional LEDs. The new device has flexibility, maintains lower temperature and has an increased life-span over existing LEDs (Kim et al, 'Unusual Strategies for Using InGaN Grown on Silicon (111) for Solid State Lighting', Proceedings of the National Academy of Sciences, published online 10 June 2011, doi: 10.1073/pnas.1102650108).

Properties that can now be achieved with blue indium gallium nitride (InGaN) LEDs lead to their potential as replacements for existing infrastructure in general illumination, with important implications for the efficient use of energy. Further advances will benefit from the re-examination of the modes for incorporating this materials technology into lighting modules that manage light conversion, extraction, and distribution, in ways that minimize adverse thermal effects associated with operation, with packages that exploit the unique aspects of the light sources.

In the published work, the researchers focused on improving certain features of LED lights, such as size, flexibility and temperature. Song's role in the project was to analyze the thermal management and establish an analytical model that reduces the temperature of the device.

The researchers have presented ideas in anisotropic etching, microscale device assembly/integration, and module configuration that address these challenges in

unconventional ways. "The new model uses a silicon substrate, novel etching strategies, a unique layout and innovative thermal management method," says Song. "The combination of these manufacturing techniques allows the new design to be much smaller and keep lower temperatures than current LEDs using the same electrical power."

Various device demonstrations provide examples of the capabilities, including thin, flexible lighting 'tapes' based on patterned phosphors and large collections of small light emitters on plastic substrates.

Quantitative modeling and experimental evaluation of heat flow in

Small, distributed LEDs can be passively cooled simply by direct thermal transport through thin-film metallization used for electrical interconnect

such structures illustrates one particularly important aspect of their operation: small, distributed LEDs can be passively cooled simply by direct thermal transport through thin-film metallization used for electrical interconnect, providing an enhanced and scalable means to integrate these devices in modules for white light generation.

In future, the researchers would also like to make the devices stretchable, so that they can be used on any surface, such as deformable display monitors and biomedical devices that adapt to the curvilinear surfaces of the human body.

www.miami.edu

<http://engineering.illinois.edu>

www.pnas.org/content/early/2011/06/06/1102650108.abstract

IN BRIEF

Samsung LED and KOPTI collaborate on LED lighting

Samsung LED-KOPTI LED lighting technology collaboration center established

On 30 June, Samsung LED Co Ltd (the LED-making venture of Korea's Samsung Electronics) and the Korea Photonics Technology Institute (KOPTI) signed a technology collaboration agreement with the aim of accelerating the development of LED lighting-related technology and cultivating highly skilled R&D manpower.

Samsung LED Co Ltd says that, with manufacturing expertise gained from the years of experience in the LED business, it is now seeking to achieve maximum synergy by using the assets that KOPTI has accumulated over many years, including technical skills, highly skilled researchers, and equipment.

Over the next three years, research will be undertaken at the 'Samsung LED-KOPTI LED lighting technology collaboration center', established within KOPTI. The main fields on which the two organizations will focus are the development of technologies for LED lighting, and core technologies for next-generation lighting and LED packages.

Through early development of supplementary (yet essential) technologies within the center, both organizations are aiming not only to achieve global competitiveness but also to expand cooperation on global standards.

www.kopti.re.kr/english

<http://samsungled.com/eng>

DOE offering \$14.8m funding for eight solid-state lighting projects

Lumileds, Cree, Sora and Veeco among recipients

The National Energy Technology Laboratory, on behalf of the US Department of Energy (DOE), has announced the competitive selection of eight projects in response to solid-state lighting (SSL) Funding Opportunity Announcements (FOAs) for Core Technology Research (DE-FOA-0000329), Product Development (DE-FOA-0000330), and US Manufacturing (DE-FOA-0000334). Total DOE funding is about \$14.8m. Industry cost share is more than \$4m, bringing the total project value to nearly \$19m.

This is the seventh round of DOE SSL funding for Core Technology Research and Product Development, and the second for US Manufacturing.

The selected projects are part of the DOE initiative to accelerate the adoption of SSL technology including light-emitting diodes (LEDs) and organic light-emitting diodes (OLEDs) through improvements that reduce costs and enhance product quality and performance. The projects are expected to contribute significantly to the goal of the SSL program, which is, by 2025, to "develop advanced solid-state lighting technologies that, compared to conventional lighting technologies, are much more energy efficient, longer lasting, and cost competitive by targeting a product system efficiency of 50% with lighting that accurately reproduces sunlight spectrum". The projects are also intended to play a key role in encouraging US-based manufacturing of SSL technologies, creating jobs, and promoting America's role as a global leader in energy efficiency.

The two US Manufacturing projects are focused on achieving significant cost reductions and enhanced quality through improve-

ments in manufacturing equipment, processes, or monitoring techniques, addressing the technical challenges that must be overcome to make LEDs and OLEDs cost-competitive with other lighting options. Total US Manufacturing project funding is \$8.9m (\$6.9m from the DOE and \$1m each from the two participants providing 22% as cost-share). The DOE funding, participants and projects are:

- \$4m to Veeco Process Equipment Inc of Goleta, CA (a subsidiary of Veeco Instruments Inc of Plainview, NY) for 'Development of Production PVD-AIN Buffer Layer System and Processes to Reduce Epitaxy Costs and Increase LED Efficiency', which aims to enable a 60% reduction in epitaxy manufacturing costs by introducing a high-productivity reactive sputtering system and an effective sputtered aluminium nitride (AIN) buffer/nucleation layer process.

- \$2.9m to Moser Baer Technologies Inc of Canandaigua, NY (the US-based subsidiary of Moser Baer India, Ltd) 'Process and Product Yield Improvements for Low-Cost Manufacturing of OLEDs', which seeks to reduce the cost of manufacturing OLED lighting panels at the firm's 150mm x 150mm pilot manufacturing by providing a path to improved yield and widened manufacturing process windows at all stages of the OLED device fabrication (demonstrating these yield improvement technologies in a manufacturing environment).

The two Product Development projects are focused on the development or improvement of

commercially viable SSL materials, devices, or systems with the cost and performance parameters necessary for successful market introduction. Total Product Development project funding is \$4.6m (\$3.6m from the DOE and \$1m from participants providing 22% as cost-share). The DOE funding, participants and projects are:

- \$1.6m to Cree Inc in Goleta, CA for 'High Efficiency Integrated Package', which aims to investigate various optical, thermal, and phosphor integration trade-offs in their high-brightness package design and fabrication, enabling high-efficacy warm-white LED packages with efficacies of 128lm/W at a correlated color temperature (CCT) of 3000K and a color rendering index value (CRI) >85.

- \$2m to Philips Lumileds Lighting Co LLC of San Jose, CA for 'High Power Warm White Hybrid LED Package for Illumination', which seeks to make use of multi-junction high-voltage low-current (HVLC) LED designs. The drive voltage of the HVLC LED array will be 100–200V, which will simplify driver requirements, improve driver efficiency by up to 5%, and reduce system cost. The proposed warm-white LED package will deliver illumination-grade light, have a CCT range of 2700–3500K, CRI of 80, 650lm output, and an efficacy of 130lm/W for hot operation (a junction temperature of 85°C).

The four Core Technology Research projects are expected to fill key technology gaps in LED and OLED development, improve scientific knowledge, and provide performance data (all critical to the widespread deployment of solid-state lighting for general lighting purposes). Total Core Technology Research project funding is \$5.5m (\$4.3m from the DOE and

The selected projects are part of the DOE initiative to accelerate the adoption of solid-state lighting

- ▶ \$1.2m from participants providing 21% as cost-share). The DOE funding, participants and projects are:
 - \$0.68m to Soraa Inc of Goleta, CA for 'Light Emitting Diodes on Semipolar Bulk GaN Substrate with IQE >80% at 150A/cm² and 100C', which seeks to develop high-efficiency semi-polar GaN-based LEDs for high-current-density, high-temperature operation (improvements at the device level should enable cost-effective solid-state white-light sources with 150lm/W efficacy).
 - \$1.25m to University of Rochester for 'Light Extraction from OLEDs Using Plasmonic Nanoparticle Layers to Suppress Total Internal Reflection', which aims to increase the efficiency of OLEDs by improving light extraction efficiency to 70% via use of a silver nanoparticle scattering layer.
 - \$0.66m to Arizona State University (ASU) for 'High Efficiency and Stable White OLED Using a Single Emitter', which seeks to demonstrate an efficient and stable white OLED using a single emitter

on a planar glass substrate with a luminous efficacy of 50lm/W, and operational lifetime of 10,000 hours at a brightness of 1000 candelas per meter.

- \$1.7m to Research Triangle Institute for 'Solid-State Lighting Luminaire Reliability Model', which seeks to develop and validate a reliability model and accelerated life testing (ALT) methodologies for predicting the lifetime of integrated SSL luminaires (the ultimate outcome will be a reliability prediction tool for SSL luminaires and new ALT methodologies for evaluating the system performance of luminaires in less than 3000 hours of testing).

The six projects that fall under Core Technology Research and Product Development are covered under the SSL Exceptional Circumstances Determination issued by DOE in June 2004.

All projects are award selections, and final details are subject to negotiations.

www.ssl.energy.gov

IN BRIEF

Senior VP worldwide operations for Soraa

Soraa Inc of Fremont, CA, USA, which is commercializing green and blue LEDs and lasers for general illumination and projection display, has hired Neal Woods as senior VP of worldwide operations.

Woods will be responsible for all aspects of manufacturing, supply chain operations, quality functions and worldwide operations planning.

"Neal brings a breadth and depth of operations management experience that is necessary to guide our organization as we commercialize and begin volume production," says CEO Eric Kim.

Woods has been senior VP of operations for Hewlett-Packard's Imaging & Printing Group (IPG) since 2008. He was previously VP of global manufacturing operations for Cisco.

www.soraa.com

US President Obama tours Cree's Durham plant

On 13 June, US President Barack Obama visited LED maker Cree Inc of Durham, NC, USA, touring its manufacturing facilities and speaking with staff and other guests. During his visit, Obama met with his Jobs and Competitiveness Council (in which Cree's CEO Chuck Swoboda participated) to discuss initiatives and policies to spur economic growth, promote job creation and accelerate hiring across the USA. Obama was joined on the plant tour by Jeff Immelt, chairman & CEO of General Electric and head of the White House's Jobs Council.

Obama made remarks to a crowd that included Senator Kay Hagan, Representatives David Price, Brad Miller, G.K. Butterfield and other local and state leaders as well as hundreds of Cree employees. "Today the small business that a group of N.C. State engineering students founded almost 25 years



President Obama tours Cree with Matthew K. Rose (chairman & CEO of Burlington Northern Santa Fe Corp, left); Jeff Immelt (chairman & CEO of GE and chairman of the President's Council on Jobs and Competitiveness, third from left); and Cree's CEO Chuck Swoboda.

ago is a global company," commented Obama. "Next month, your new production line will begin running 24/7. So you're helping to lead

a clean energy revolution," he added. "You're helping lead the comeback of American manufacturing."

Cree currently has more than 5000 staff globally. Most recently, it has added LED fixture manufacturing lines in Durham. Obama joined Swoboda on a tour of the new production lines, which manufacture what are claimed to be the world's most efficient troffers (the CR series). These new lights are designed to replace fluorescent troffer lighting commonly seen in office and other commercial buildings, delivering higher-quality light and increased efficiency at prices comparable to their fluorescent counterparts.

President Obama's visit highlighted topics critical to the success of the LED lighting revolution, including workforce training and education, commented Swoboda.

www.cree.com

ITC probes Osram's allegation of LED patent infringement LG joins Samsung in countersuing Osram in Korea

The US International Trade Commission (ITC) has voted to institute an investigation based on two complaints filed on 3 June by Siemens affiliate Osram GmbH of Germany (the second largest lighting firm) alleging that the importation into the USA and sale of certain LEDs and products containing them (such as liquid-crystal displays in TV sets and computer monitors) infringing its US patents on white and surface-mountable LEDs. Osram requested that the ITC issues an exclusion order and cease and desist orders.

The respondents in the investigation are: Korea's Samsung Electronics Co Ltd (and Samsung Electronics America Inc of Ridgefield Park, NJ), Samsung LED Co Ltd (and Samsung LED America Inc of Atlanta, GA); as well as LG Electronics Inc (and LG Electronics USA Inc of Englewood Cliffs, NJ) and LG

Innotek Co Ltd (and LG Innotek USA Inc of San Diego, CA).

ITC administrative law judges (ALJs) will schedule and hold an evidentiary hearing, and make an initial determination as to whether there is a violation. Within 45 days after institution of the investigation, the ITC will set a target date for completing the investigation. Remedial orders 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).

Osram has also filed lawsuits against Samsung and LG in Germany and Japan, as well as another against LG in China.

In response to Osram's ITC lawsuit, on 10 June Samsung LED countersued, filing a patent infringement lawsuit against Osram Korea Co Ltd and two Korean sales agents

(Barun Electronics and Dabo Industrial System) at the Seoul Central District Court requesting an injunction from unauthorized use of Samsung LED's intellectual property as well as monetary damages.

Now, Samsung LED has been joined by LG Electronics Inc (the world's second-biggest TV maker) and its LED chip-making affiliate LG Innotek, who have filed a complaint with the Korea Trade Commission (KTC) claiming that Osram is infringing seven LG patents on LED chip and packaging technologies, and seeking to ban import of Osram LED products into South Korea. LG plans to take similar actions in other major markets, including China and the USA.

www.usitc.gov

www.osram.com

www.lg.com

<http://samsungled.com>

Blue, green & orange added to red and yellow TOPLED Black Series

Osram Opto Semiconductors GmbH of Regensburg, Germany has supplemented its TOPLED Black Series 60° beam-angle portfolio of red and yellow LEDs (which feature integrated lenses in black packages) by adding the three new colors blue, green and orange. In addition, the firm now offers all five colors with a new 30° beam-angle version. "This means that we have the broadest portfolio of 'black' LEDs on the market and can cover a wide range of applications," claims product manager Sven Weber.

The compact, powerful LEDs are particularly suitable for monochromatic and multicolor displays, such as those in electronic road signs, travel information displays, parking control systems, and price information pillars at gas stations. The most suitable beam angle for each application depends on the distance from the viewer and on local conditions. On straight roads



The TOPLED Black Series in five colors are used to display information - bright, high contrast and legible in all lighting conditions.

the 30° beam-angle LEDs are best suited, whereas the 60° beam-angle versions are better for the curves on entrances to and exits from highways, for gas stations, and for bus destination displays. The orange LED versions are intended for pedestrian lights in America and Japan.

The completely black package of the TOPLED Black Series reduces

reflections, says Osram Opto. The LEDs also offer high contrast, so the displays have good legibility in all lighting conditions. The firm also claims that the 30° version of the green LED offers the highest luminance available at present: 7cd at an operating current of 20mA.

As surface-mount technology (SMT) components, the LEDs are suitable for automatic handling, so displays can be manufactured at lower cost than with radial LED versions. The solder legs compatible with TOPLED and PowerTOPLED provide flexibility, says Osram Opto, because changes in design can be easily made if required. This means that displays with different luminances and beam angles can be made using the same circuit board.

www.osram-os.com



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Luminus launches Compact SBT-16 and SBT-39 RGB LED chipsets for ultra-mobile LED projectors

At the InfoComm 2011 event in Orlando, FL (15–17 June), Luminus Devices Inc of Billerica, MA, USA, which manufactures PhlatLight (photonic lattice) LEDs for illumination applications, has announced the availability of the Compact SBT-16 and SBT-39 chipsets, its newest red–green–blue (RGB) LED chipsets targeted primarily at consumer projectors.

Both chipsets come in a surface-mount package (SMT) and were designed to address the market demand for increasingly compact form factors while retaining very high-brightness output.

Personal and ultra-mobile LED projectors are an emerging class of miniature projection devices with sizes of typically 150–400cm³. These projectors may include built-in digital media players and can connect to portable devices such as PDAs and notebook computers to

provide a large-display experience.

The new chipsets consist of red, green and blue LEDs that are individually assembled in a small-footprint, performance surface-mount package. Each Compact SBT-16 comes with a 1.6mm² LED emitter and has a 18.5mm² footprint (a 70% reduction over the previous-generation device). They are engineered for the most compact palm-size or embedded projectors with performance ranging from 30 to 150 lumens, depending on the available power budget. The SBT-39 include a 3.9mm² LED emitter with a package footprint of only 33mm².

It is designed for mid-range projectors with performance ranging from 150 to 300 lumens.

Continued innovation in light source technology enables new applications

“The Compact SBT-16 and SBT-39 chipsets integrate the latest advances in LED technology and allow our customers to create thinner, more compact projectors while retaining the high brightness that consumers expect from LED projectors,” says Stephane Bellosguardo, Luminus’ director of global product marketing, Display Business Group. “Continued innovation in light source technology enables new applications and product differentiation, fueling an increasingly segmented market that research firms predict will be a multi-million unit market by 2013.”

Luminus says that the Compact SBT-16 and SBT-39 integrate seamlessly with standard SMT manufacturing processes and equipment. Samples of both chipsets are now available to lead customers.

www.luminus.com

Luminus powers first Smart TV portable LED projector from LG

At InfoComm 2011 in Orlando, FL Luminus Devices announced that the latest generation of its PT-54 LED chipset is powering the LG HW300T, which is the newest addition to LG’s line of high-brightness portable LED projectors.

The HW300T is the first LED projector to integrate a series of Smart TV features that were until recently only available in consumer flat-panel TVs. These features include built-in access to pre-paid high-definition movies from Vudu as well as social networking services such as Facebook or Twitter. The HW300T’s wireless connection is compatible with the Digital Living Network Alliance (DLNA) protocol and allows direct access to content located on networked devices, including personal computers. In addition, the HW300T retains key features available in other LG LED portable projectors

such as a built-in file viewer compatible with Microsoft Office’s format, making it equally suitable for business applications.

“As our fifth-generation portable LED projector, the HW300T adds exclusive features intended to facilitate access to digital media as well as online content and is positioned to accelerate the adoption of our products as a large-screen high-definition display for the home,” says Brian Park, marketing team leader for LG Electronics. “Continued advances from Luminus’ ‘big chip’ LEDs have allowed us to increase the brightness of our Smart TV LED projectors while at the same time reducing its total power consumption to less than 100W, resulting in an extremely energy-efficient and very compact product,” he adds.

“With the HW300T, LG continues

to define and grow the market for ultra-portable LED projectors,” says Stephane Bellosguardo, Luminus’ director of global product marketing, Display Business Group. “With built-in adaptive speakers, movie streaming and internet capability through a DLNA-compatible wireless interface, this Smart TV LED projector eliminates the setup complexity of traditional projectors that require a physical connection and external source for their content, a common complaint of end users,” he adds. “This product integrates all the functionality that consumers have come to expect from their home high-definition display. In addition, the HW300T can scale to over 100 inches in size, be moved from room to room in minutes, and deliver superior color through the use of native red, green and blue ‘big chip’ LEDs.”

Smart Lighting ERC at RPI enlists 21 industrial partners Osram & Epistar to help to commercialize LED research

Now in its third year, the Smart Lighting Engineering Research Center (ERC) has enlisted 21 key industrial partners to help guide its research programs and speed the transition of innovations from the lab to the marketplace.

The center is dedicated to developing LED technologies and applications for smarter, better-performing lighting devices and systems. Launched in 2008 and funded primarily by the US National Science Foundation, the ERC is led by Rensselaer Polytechnic Institute (RPI) of Troy, NY.

"Rapidly growing industry membership in the Smart Lighting ERC is a testimony to the quality of the transformative research being conducted on future lighting systems by the ERC faculty and students," says ERC director Robert Karlicek. "It is also firm support for the ERC's vision of smart lighting systems, which are poised to revolutionize lighting by creating immersive lighting systems that can sense their environment to provide new levels of energy efficiency, health and safety benefits, and enhanced workplace productivity."

The ERC's industrial partners include German lighting firm Osram Sylvania and Taiwan-based LED epiwafer and chip maker Epistar Corp. "The Smart Lighting ERC is providing a state-of-the-art center in which we from industry engage academia to prove concepts at platform levels, ahead of industry acceptance and uptake," comments Matthew Stough, Osram Sylvania's director of engineering, materials and processes, and research coordinator. "Their work on transformative LED and lighting technology is of critical importance to the development of advanced solid-state lighting systems," says Steve Hong, Epistar's director of R&D.

The true promise of LED and solid-state lighting technology transcends illumination, says the ERC. LEDs offer the potential to control, manipulate, and use light in entirely new ways for a diverse range of areas.

To realize the potential of solid-state lighting technology, the ERC team is working to create better LEDs, as well as new sensors and systems required to effectively monitor and control them. More than 30 ERC faculty researchers at RPI and partner universities are working toward this goal, along with dozens of student researchers, postdoctoral researchers, and visiting industry engineers.

ERC university partners are Boston University and the University of New Mexico. Outreach partners are Howard University in Washington, Morgan State University in Baltimore, and Rose-Hulman Institute of Technology in Terre Haute, Indiana. Industry partners help to guide strategic planning, spur innovation, and provide university students with first-hand experience in entrepreneurship as well as corporate R&D. This summer, four ERC graduate students have taken internships with industrial partners, and two have formed a firm based on ERC technology and will be supported by a Boston-based venture capital firm.

<http://smartlighting.rpi.edu>



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Osram completes acquisition of Siteco Lighting

Munich-based Osram GmbH has acquired Siteco Lighting GmbH of Traunreut, Germany.

"With this acquisition Osram is strengthening its position in the solution business. This applies to both classic energy-saving and LED-based lighting technology," says Osram's CEO Wolfgang Dehen. More than two thirds of the global lighting market is already covered by luminaires and lighting systems.

Osram says that, with the acquisition of Siteco, it gains broad market access for lighting solutions and a modern range of products in the field of interior and exterior lighting. The acquisition also supports its Professional Lighting business unit, which offers components such as lamps, LEDs and control gear.

Siteco provides complete luminaires, light management systems and lighting solutions. In addition, it supplements the competences of the Osram joint venture Traxon, which is active in retail, architectural, entertainment and hospitality lighting.

Siteco offers professional lighting applications for commercial and public areas, including municipal infrastructure such as buildings, streets, tunnels, airports or sport stadiums. For example, it is responsible for providing lighting at the Munich Allianz Arena, Barajas Airport in Madrid, and the Taipeh Tower in Taiwan. Moreover, in the development of new products Osram can benefit from Siteco's experience in collaborating with customers, architects, light designers, and fitters.

Klaus-Günter Vennemann has been made CEO of Osram's Professional Lighting business unit, replacing Claus Regitz. Vennemann came to Siteco in July 2009 as CEO. Previously, for 16 years he was a member of the management board of LUK, a supplier to the automotive industry and part of the Schaeffler group.

www.osram.de
www.siteco.com

DOE visits Optogan in St Petersburg to discuss US–Russian SSL projects

A US delegation headed by Department of Energy Secretary Steven Chu visited the LED production plant in St Petersburg, Russia of European LED chip and luminaire maker Optogan in June.

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

Optogan says that Steven Chu, who won the Nobel Prize in Physics in 1997, is a recognized expert in the development of energy-efficient technologies, having dedicated his scientific career to solving energy problems, global warming and developing alternative and renewable energy. After graduating from the University of California Berkeley with a PhD. in Physics, he directed the National Laboratory in Berkeley in developing alternative and renewable energy sources. As well as receiving honorary degrees from 10 universities, Chu is also member of the US National Academy of Sciences.

The aim of the official visit of the US delegation to Russia was to become acquainted with Russian industry innovation and to search for possible ways to implement joint projects in energy and energy efficiency. Mutual projects were



US Energy Secretary Steven Chu visiting Optogan's LED plant in St Petersburg.

discussed within the Working Group on Energy and Environment — a bilateral US–Russian presidential commission of Chu and Russia's Energy Minister Sergei Shmatko. The Working Group engaged in developing and strengthening bilateral relations between the countries and increasing their cooperation on energy efficiency.

At the Optogan plant the US delegation was shown LED production, as well as precision equipment for creating energy-efficient solid-state lighting solutions. Further plans to launch the second and third stages of production, as well as the launch of Optogan into international markets, were also presented.

"The reformation of the energy system of a country cannot happen without the alignment of international experts, the exchange of information on the leading technologies and global cooperation," commented Maxim Odnoblyudov, president of Optogan Group.

"The fact that we have the opportunity to work hand in hand with the leading scientists of energy-efficient technologies is a success for Russia and for our company," he adds.

"Solid-state lighting is the energy-efficient solution of the future, with a convincing global potential," commented Chu. "Optogan has a great opportunity for joint projects and cooperation with American business partners."

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EpiCrystals' green laser light source for pico projectors

At the Projection Summit 2011 trade fair in Orlando, FL, USA (13–14 June), laser light source specialist EpiCrystals Inc of Helsinki, Finland introduced what it claims is the smallest and most efficient green light source available for pico projectors.

Founded in 2003 and funded by VNT Management Ltd, Finnish Industry Investment Ltd, the Finnish Funding Agency for Technology and Innovation (TEKES), and Finnvera, EpiCrystals focuses exclusively on developing laser light sources, and has patented a new way to produce them more efficiently and cost effectively than other industry players, it is claimed.

The firm's technology is based on its patented DeCIBEL laser platform. The DeCIBEL laser has a two-component design. Specifically, the green DeCIBEL laser is a 1064nm GaAs-based infrared laser diode (LD) that emits very narrow pulses. These highly energetic picosecond-class pulses undergo frequency conversion to a visible wavelength

when guided through a PPLN (periodically poled lithium niobate) nonlinear crystal. Using a single integrated lens in the laser diode, coupling can be performed very rapidly, enabling low manufacturing costs and high yield.

The spectrum width of the laser is widened so that speckle contrast is minimized. With a bright true-green color (532nm), DeCIBEL lasers exhibit optical output power of more than 60mW, modulation speed of over 100MHz, and speckle reduced by more than 70%.

DeCIBEL lasers are designed especially for pico-projector applications and, when combined with an imaging device like a MEMS scanner, enable what are claimed to be the most compact and cost-efficient projector engines.

EpiCrystals' development strategy is based on miniaturization, image quality and the lowest overall cost. Integration of the device into smart-phones and other handheld devices can allow manufacturers to quickly bring the technology to the

consumer market, the firm reckons.

While the main applications are in pico projectors and digital cameras, new RGB (red, green, blue) laser technology is expected to revolutionize smart-phones in the near future, enabling the projection of photos, video presentations and movies on almost any surface with high-definition (HD)-level quality and resolution.

"We see the largest volume opportunity for our RGB laser module in the smart-phone market, where the desired viewing experience and consumer expectations are very high," says VP of business development Tomi Jouhti. "Our RGB laser modules' bright colors and exceptional contrast are the reason for our ability to meet the individual and specific needs of the consumer," he adds.

EpiCrystal's green laser module will be available in first-quarter 2012 for \$45 in 10,000-unit volumes.

www.epicrystals.com

www.projectionsummit.com

CSTG wins supply deal from Chinese comms developer Scottish opto foundry to double revenue to £5m in next 3 years

Optoelectronics device foundry Compound Semiconductor Technologies Global Ltd (CSTG) of Hamilton Technology Park, High Blantyre (near Glasgow), Scotland, UK says that it has secured a six-figure supply agreement with one of China's emerging telecom and datacom developers.

CSTG was formed in 1999 by the universities of Strathclyde and Glasgow (together with Scottish Enterprise) as a 'pure play' foundry supplier in West of Scotland Science Park, specializing in the design, development and manufacture of discrete and integrated III-V optoelectronic wafers and chips with clients in the communications, defense, medical, energy and instrumentation markets.

The latest news comes as the firm

has reached a production milestone, having manufactured 2 million laser chips since acquiring the manufacturing facility in Hamilton in January 2010 from Intense Photonics Ltd (a manufacturer of makes single- and multi-mode monolithic laser array products and high-power laser diodes). CSTG is now set to double its annual revenue to £5m within the next three years.

"We have been making considerable headway in the Chinese market for some time and have now reached a key milestone, which underscores the significant investment we've made in developing our own proprietary modular process technology platforms," says CEO Neil Martin. "This commitment now sees CST firmly at the forefront of this global market," he reckons.

"Chinese companies are increasingly looking to develop their own operations beyond pure manufacturing," continues Martin. "Even though these markets have been traditionally high-volume low-cost, we have achieved considerable success in working with such companies to incorporate custom-built CST laser technologies into their products," he adds.

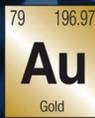
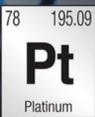
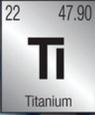
"The development of modular technology platforms has allowed us to remain both competitive and agile: CST doesn't need to go back to the R&D team every time a new requirement comes along," notes Martin. "This accelerates time to market for our customers."

The opto sector is undergoing rapid growth, with significant demand from the datacom and telecoms sectors.

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Daylight's \$15m funding round led by Northrop Grumman Firm to expand core QCL technology & manufacturing infrastructure

Daylight Solutions Inc of San Diego, CA, USA, which makes molecular detection and imaging systems based on its quantum cascade laser (QCL) technology, has closed a \$15m Series C equity financing round with US defense contractor Northrop Grumman Corp as lead investor, together with several of the company's existing investors.

The firm says the financing will enable it to continue its high rate of growth, while further maturing and advancing its technology and expanding its product offering and manufacturing infrastructure. Manufacturing capacity, quality processes, reliability, and field support will be enhanced.

Daylight has developed a wide range of QCL-based products for scientific research, defence, and commercial markets, suited for addressing molecular detection and imaging applications that benefit from mid-wave infrared (MWIR) and long-wave infrared (LWIR)

illumination. An example is the JammIR family of laser products for infrared countermeasures (IRCM).

Multiple configurations and capabilities of the JammIR product line have been tested under environmentally demanding conditions for military rotary and fixed-wing applications, and have undergone multiple flight tests, being verified as a highly effective infrared countermeasure against a variety of missile threats. The firm says that several hundred QCL-based commercial laser systems have already been manufactured and delivered for a wide range of markets.

Daylight Solutions and its subsidiary Daylight Defense LLC have leveraged their core technology in QCL modules to create multiple versions of its JammIR line of products. The firm claims that its modular approach allows great flexibility, reducing the cycle-time from design to deployment, while improving reliability and lifetime

over existing technologies.

"The Series C financing will allow us to serve all of our customers with a family of QCL-based products based on a modular, open-source, core technology platform meeting the requirements of the most demanding environments in defense as well as commercial markets," says chairman & CEO Dr Timothy Day. "Our manufacturing infrastructure, capacity and reliability programs will be expanded as a result of the financing transaction," he adds.

"Our investment in Daylight Solutions serves as an acknowledgement of their leadership position in QCL-based products, and reflects our commitment to deliver best-in-class solutions to our customers in support of our warfighters," comments Jeff Palombo, sector VP & general manager of Northrop Grumman's Land and Self Protection System Division.

www.daylightsolutions.com

Daylight expands Aries line of high-power, multi-wavelength mid-IR

After earlier this year launching its first Aries Series high-power, multi-wavelength mid-infrared laser (the Aries-100 air-cooled 2W laser), Daylight Solutions Inc of San Diego, CA, USA, which makes molecular detection, spectroscopic imaging and high-power illumination systems based on quantum cascade lasers (QCLs), has expanded the Aries commercial product line with the Aries-200, -400, and -700 products.

The modularity of the Aries family of products can now provide customizable performance in wavelength and power. Users can now choose to populate one, two, four, or seven laser 'sockets' with any wavelength and power that Daylight offers. Populating all seven sockets in the Aries-700 can provide more than 10W of continu-

ous-wave (cw), air-cooled mid-IR laser power.

"The flexibility and performance of the Aries product family is beyond anything available on the market to date," claims Michael Radunsky, product marketing manager for Daylight's scientific products.

"These turn-key systems can be configured for high power at a single wavelength or to deliver up to seven different wavelengths simultaneously and collinearly." Wavelengths of 2–13µm are available.

The Aries-100 is CDRH (Center for Devices and Radiological Health) approved and is ready for lab use. The higher models in the series are OEM laser systems that are ready for integration. They are also highly ruggedized. Standard performance includes operation within an ambient temperature

range of 15–40°C. However, they can also be specified to operate over a much wider range of operating temperatures, from –40°C to +70°C. Aries has also been tested for shake and vibration resistance. Optical fiber delivery is also available as an option.

"The flexibility of these models enable applications in multiple markets," says president Paul Larson. "These lasers are already finding applications in stand-off detection, free-space communication, infrared counter-measures, thermal imaging, and scene generation," adds Radunsky.

Daylight Solutions exhibited all four of the Aries series lasers at SPIE Defense, Security and Sensing in Orlando, FL (26–28 April) and at CLEO 2011 in Baltimore, MD (3–5 May).

University of Warsaw installs focused ion beam milling system to create micropillars

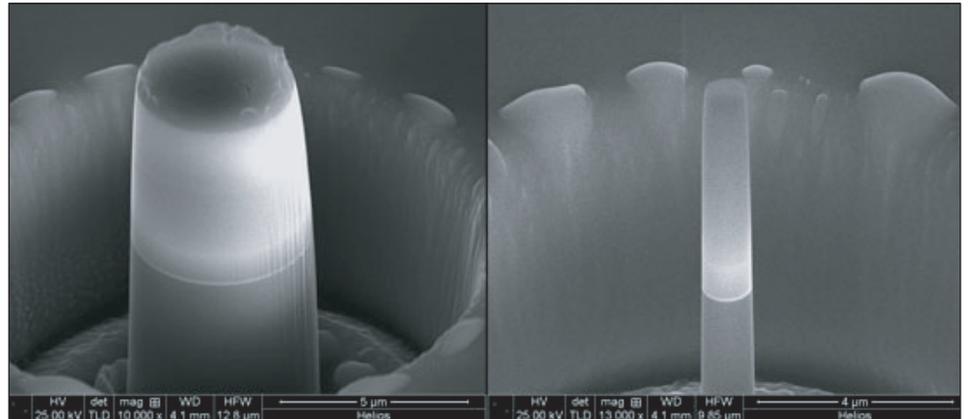
MBE reactor being added for II-VI-based yellow lasers

Focused ion beam (FIB) milling equipment from FEI Company installed at the Faculty of Physics, University of Warsaw (FUW) has enabled the production of micropillar semiconductor structures that can be used as efficient light sources.

"Being able to generate micropillars directly in the university laboratories is of key importance to our research, especially as regards works on really efficient yellow laser light sources," says Wojciech Pacuski PhD. The equipment purchased by the Institute of Experimental Physics FUW is one of only a handful of such devices in Poland.

Micropillars are a type of optical microcavity structure in which photons are confined for a relatively long time in a small volume. Micropillars are obtained by milling a surface constructed previously from many nanoscale-thick layers of semiconducting materials with carefully selected characteristics. "The surfaces out of which we are currently fabricating micropillars were made at the University in Bremen. Soon, we will be able to make them here as well with the aid of another acquisition of the Faculty, currently being installed — molecular beam epitaxy equipment," says Tomasz Jakubczyk, a PhD student at the Solid State Physics Division of the Institute of Experimental Physics FUW.

To fabricate a micropillar, material needs to be removed from the surface with precision, so as to create a pillar with micron-scale diameter and height. The Helios NanoLab system, which allows milling of a surface with a beam of gallium ions, is hence used. After acceleration to high energy, ions are focused to an accuracy of several nanometers and directed towards selected points on the surface. Given their considerable size and mass, the gallium ions do not penetrate inside the material, but rather sputter atoms from its surface. The sput-



Electron microscope image of the first micropillars fabricated at FUW.

tered atoms disperse in the vacuum chamber. The effects can be assessed immediately by a scanning electron microscope (SEM), which is an integral part of the system. Apart from micropillars, it is also possible to generate other dimensional semiconductor structures using this method.

The focused ion beam milling equipment (worth 5 million zlotys) was purchased as part of the Centre for Preclinical Research and Technology project, co-financed under the European Regional Development Fund as part of the Operational Programme Innovative Economy 2007–2013. "The equipment will be available not only to researchers, but also to students from the Faculty of Physics UW specializing in condensed-matter physics, including those who pursue the recently introduced nanostructure engineering interdisciplinary studies," stresses Pacuski.

The University of Warsaw says that micropillars have many applications, especially in constructing single-photon sources and generating entangled photon pairs. Sources of this type are used in work on optical and quantum computers and in quantum cryptography.

Researchers in the Faculty of Physics are particularly interested in micropillars containing quantum dots. "Quantum dots themselves

are good sources of single, and even entangled photons, but the desired characteristics are additionally enhanced when they are placed inside micropillars," says Jakubczyk. "A micropillar with quantum dots can, for example, emit single photons more frequently," he adds.

Physicists at the University of Warsaw aim to use the new equipment to construct micropillars that are sources of yellow laser radiation. "With a method devised by Pacuski PhD, in collaboration with colleagues from Bremen and patented in 2009, we can create mirrors, which are a crucial element of a laser, on both ends of micropillars," says Jakubczyk. "The fact that we are one of a handful of laboratories in the world specializing in materials from the II and VI group of the periodic table is an additional asset in works on a yellow laser. These compounds emit light precisely in the wavelength range corresponding to yellow light," he adds.

Micro lasers emitting yellow light will be fabricated as part of the 'Lider' project. The devices could be useful in telecom applications that use plastic optical fiber (POF), which attenuate yellow light the least. In addition, increasingly popular displays offering an additional range of colours (other than the standard RGB) also rely on yellow lasers.

www.fuw.edu.pl

VCSEL achieves 92W output record

Highest value reported for a single device, Chinese researchers believe

Researchers in China have produced vertical-cavity surface-emitting lasers (VCSEL) with maximum peak output power of 92W obtained in pulsed operation at 110A, giving a power density of 15kW/cm² [Lisen Zhang et al, Appl. Phys. Express, vol4, p052102, 2011].

"To the best of our knowledge, this is the highest value reported for a single device," say the researchers, from Key Laboratory of Excited State Processes at Changchun's Institute of Optics and Graduate School of the Chinese Academy of Science in Beijing. The room-temperature power output was limited by the capabilities of the power supply used.

VCSELs have many attractions such as low threshold currents, circular beams, high packing density in two-dimensional arrays, and single-mode emission. Solid-state laser devices tend to achieve higher output power in pulsed operation. Such high output power can be applied to cutting, drilling and welding for medical and industrial applications. VCSELs have another advantage here, since they do not suffer from the catastrophic optical damage (COD) that afflicts the end facets of edge-emitting lasers at high field intensity.

The main epitaxial structures of the Chinese device (Figure 1) were n- and p-type distributed Bragg reflectors (DBRs) sandwiching the active layer. These layers were grown using MOCVD on GaAs substrates.

The active region consisted of three quantum wells consisting of In_{0.2}Ga_{0.8}As in GaAs barriers. The wells had an emission wavelength around 980nm.

The n- and p-type DBRs were silicon and carbon doped, respectively. The DBRs were constructed from Al_{0.9}Ga_{0.1}As/GaAs pairs. The p-DBR consisted of 30 periods of quarter-wavelength thick layers giving 99.9% reflectivity. The n-DBR had 20 pairs of quarter-wavelength layers with 99.3% reflectivity. The inter-

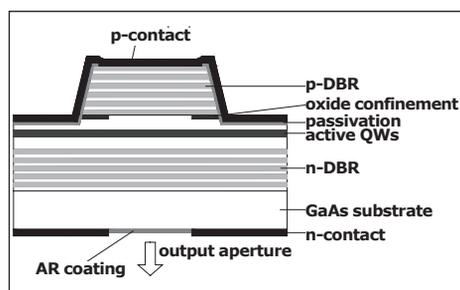


Figure 1. Schematic diagram of device structure.

faces between the layers were graded to reduce the series resistance of the DBRs.

The DBRs' reflectivity values were optimized, "balancing the threshold current and the output power to realize high differential quantum efficiency under pulsed operation."

The device mesa was formed using a wet chemical etch. The selective oxide confinement was created by heating to 420°C in a humid atmosphere. The p-contact consisted of titanium-platinum-gold.

The laser beam was designed to emerge from the n-contact side — i.e. through the GaAs substrate. To enable this, hafnium dioxide (HfO₂) was deposited on the substrate surface as an anti-reflective coat. The n-contact consisted of gold-germanium-nickel, which was evaporated around the HfO₂ window. The device's aperture was 500µm.

The device wafer was finally heated again in a rapid thermal anneal and then singulated. The singulated devices were soldered with indium junction-down on copper heatsinks.

The resulting laser diode suffered from self-heating effects. For example, in continuous-wave (CW) operation the slope efficiency was around 0.4W/A in the range 1–4A, and declined beyond that. Quasi-

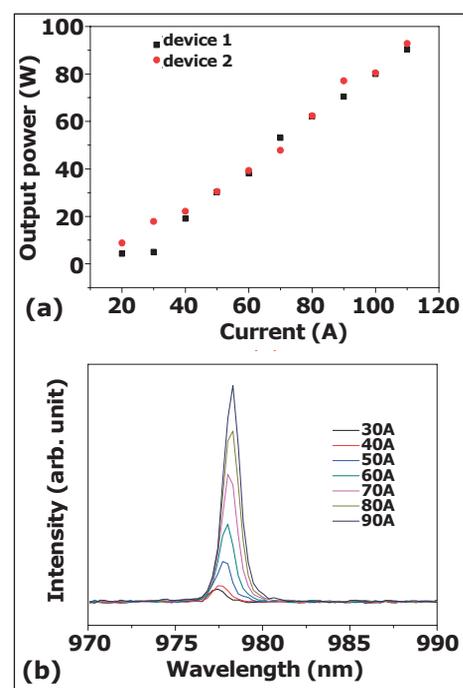


Figure 2. (a) Dependence of output power on injection current and (b) wavelength spectra versus injection currents under pulsed operation.

continuous operation (QCW, 50µs pulse, 100Hz repetition) — to reduce thermal effects — increased this efficiency to about 0.6W/A over the range 1–6A. With pulsed operation (60ns pulse, 100Hz repetition), the efficiency increased up to 0.8–0.9W/A at 70A.

Another thermal effect is a red-shift in the emission wavelength (Table). From the observed red-shifts, the junction temperature rise in CW and QCW operation were estimated at 90°C and 20°C, respectively.

Some of the researchers produced a device with CW output power of 1.95W (0.93kW/cm²) in 2007. Princeton Optics reported a record 3W CW from a 350µm VCSEL in 2005. <http://apex.jsap.jp/link?APEX/4/052102>
Author: Mike Cooke

Operation mode	Threshold (A)	Differential resistance (Ω)	Maximum output (W)	Density (W/cm ²)	Red-shift (nm/A)
CW	0.8	0.8	1.62 @ 4.5A		1.4
QCW	0.8	0.12	2.89 @ 6A		0.3
pulsed			92 @ 110A	15	0.0145

GaAsP barrier used to boost VCSEL array power by 13% Chinese researchers see device as 'better candidate' for data transmission and pumping source applications

Chinese Academy of Science (CAS) researchers have produced an array of vertical-cavity surface-emitting lasers (VCSELs) with 123W output power at 110A current in pulsed operation [Di Liu et al, Appl. Phys. Express, vol4, p052104, 2011]. The main difference with traditional VCSELs was the use of GaAsP instead of GaAs for the barriers between the InGaAs quantum wells that produced the light emission.

The researchers from Key Laboratory of Excited State Processes at Changchun's Institute of Optics Fine Mechanics and Physics and Graduate School in Beijing add: "The array device has not been measured to a very high pulsed current because of the voltage limitations of the power supply we used. So far, however, the power density and slope efficiency we obtained from a 4x4 VCSEL array are to our knowledge the highest results reported for a 2D VCSEL array".

Potential VCSEL applications include high-speed data transmission, high-resolution printing, and pumping of solid-state and fiber lasers due to low threshold current, low divergence angles of the output beam and low cost, compared with edge-emitting semiconductor lasers.

The laser mirrors of the CAS vertical cavity structure consisted of distributed Bragg reflectors (DBR). The top mirror had 28 periods of $\text{Al}_{0.9}\text{Ga}_{0.1}\text{As}/\text{Al}_{0.12}\text{Ga}_{0.88}\text{As}$, and the bottom mirror 30 periods. Graded interfaces were used in the DBRs to reduce series resistance. Current and optical confinement was achieved through oxidation.

The multi-quantum well (MQW) active region consisted of three strained 8nm wells of $\text{In}_{0.2}\text{Ga}_{0.8}\text{As}$, separated by 10nm barriers of $\text{GaAs}_{0.92}\text{P}_{0.08}$. Devices with traditional GaAs barriers were also produced. The effect of using GaAsP is to widen the energy barrier at room temperature from 1.42eV to 1.51eV.

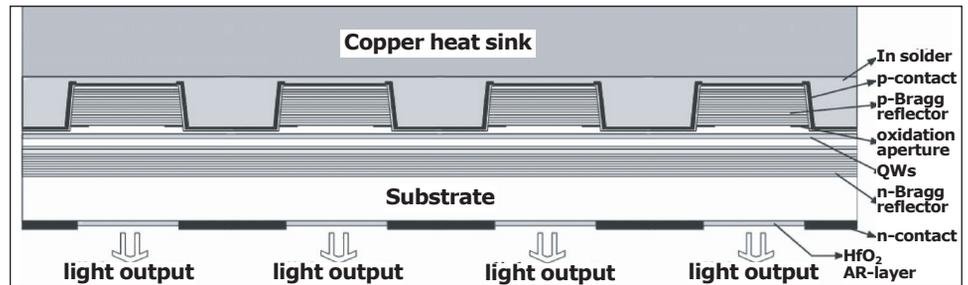


Figure 1. Schematic cross section of 4x4 VCSEL array.

This increases the conduction band offset by 23% and more than doubles the valence band offset.

The researchers comment: "The remarkable increases in both the conduction and valence band offset not only confine electrons well, but have the ability to prevent hole leakage during laser operation. Thus, compared with GaAs, large-bandgap GaAsP barriers can provide better confinement of carriers in the quantum wells, which is good for improving the output power".

The devices with 200 μm active diameter were arranged in a 4x4 array to give a total emitting area of 0.005 cm^2 . The spacing between devices was 250 μm .

The GaAsP-barrier array produced 123W of output power at 110A current in pulsed operation (60ns, 0.06% duty cycle), compared with 109W for the array with traditional

GaAs barriers (Figure 2). The power density and slope efficiency of the GaAsP array were 24.6 kW/cm^2 and 1.11W/A, respectively.

At 4A, the GaAsP-barrier array produced 1.51W light output in continuous wave (CW) operation, almost double that of a previous GaAs-barrier arrangement with devices of the same active diameter and pumping level. The wavelength of the light from the GaAsP-barrier array was 977.13nm with a full-width half-maximum (FWHM) of 1.0nm.

The threshold current of the GaAsP-barrier array was 0.98A for CW and 0.8A for pulsed operation. However, the CW condition also gives slightly higher slope efficiency, meaning that it gives more power above $\sim 2\text{V}$, before thermal roll-over (i.e. when sub-linear response to increased current sets in). The researchers attribute the improved slope efficiency (and increased threshold) in CW mode to a number of self-heating effects (thermally induced gain offset, gain suppression, and thermal lensing) that are absent when the current is pulsed.

The researchers also use the 'p-parameter' ($p = \text{turn-on voltage} / (\text{threshold current} \times \text{differential resistance})$) to evaluate their array, finding a value of 15 for CW and 13 for pulsed operation. A high value of p is desired, with values less than 10 considered 'poor' and values greater than 50 'exceptional'. The researchers describe 15 as being 'relatively good performance'.

<http://apex.jsap.jp/link?APEX/4/052104>

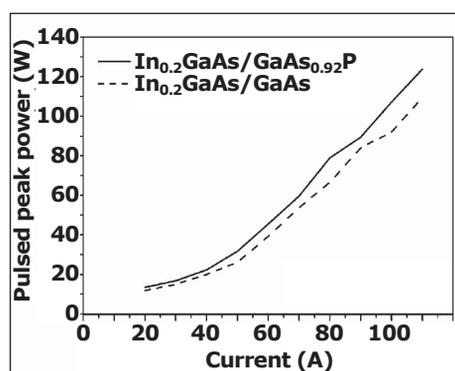


Figure 2. Peak output power for $\text{In}_{0.2}\text{Ga}_{0.8}\text{As}/\text{GaAs}_{0.92}\text{P}_{0.08}$ (solid line) and $\text{In}_{0.2}\text{Ga}_{0.8}\text{As}/\text{GaAs}$ (dashed line) QW structures under pulsed operation at room temperature, with 60ns pulses and 0.06% duty cycle.

IN BRIEF

Production order for HXT/R4 chip-set

A Taiwanese optical engine maker has entered production with GigOptix's HXT/R4 chip-set for use in a 40G quad small-form-factor pluggable (QSFP) active optical cable (AOC) application.

GigOptix's HXT/R4 chip-set has been designed to support multiple applications ranging from 5Gb/s to 10Gb/s per channel. The firm says that the feature set of its HXT/R4 family enables users to optimize the trade-off between power dissipation and performance of the optical link. This has been demonstrated by transmitting data over a 100m link with less than 100mW of total power dissipation. Moreover, GigOptix says that its unique architecture enables customers to examine the detailed status of their product after the fiber has been attached. This functionality allows them to more easily test and monitor the operation of the vertical-cavity surface-emitting laser (VCSEL) and photo-diode (PD) devices within the optical engine, leading to significant cost savings it is claimed.

"Our HXT/R4 chip-set will be key to enabling 40G optical engines for the high-volume supercomputing and consumer markets," believes VP of global sales Jay de la Barre, adding that GigOptix's is working with pioneering companies using innovative silicon bench technology, along with its VCSEL driver and receiver array chip-set, to take their solutions to production.

The HXT/R4 chip-set is designed for use in Infiniband AOC, SNAP12 and QSFP optical modules while serving the fast-growing markets of high-performance computing optical interconnects, switch and router optical backplanes and the emerging 40G and 100G Ethernet standards.

GigOptix completes Endwave takeover

At a special meeting of stockholders of Endwave Corp of San Jose, a vote approved its acquisition by GigOptix Inc of Palo Alto, CA. Holders of over 55% of the outstanding Endwave shares (over 98% of the shares represented at the meeting) voted in favor. Endwave shares will be converted into GigOptix shares at a conversion ratio of about 0.908.

"The Endwave acquisition is an exciting step towards fulfilling our long-term vision of building the industry's premier one-stop-shop supplier of analog and optical components that enable high-speed information streaming," says CEO & chairman Dr Avi Katz. "We look forward to continuing on our mission to address customers' expanding needs for innovative high-speed data communications solutions as well as simplifying our customers' supply chains," he adds.

"The combination of GigOptix and Endwave is an ideal blend of technology, opportunity and vision that will benefit our customers, employees and stockholders," believes

John Mikulsky, Endwave's former CEO and new GigOptix board member.

GigOptix is making changes to its leadership structure that include a horizontal class of functional organizations led by three executives, supported by three general managers each leading vertical product lines. The structure is intended to streamline collaboration within GigOptix, while enabling an expansion of GigOptix's business and product portfolio in order to better position it for future growth.

"We have already initiated many preliminary in-house activities in preparation for the physical and operational integration process," says Katz. "We expect the majority of the integration process to be completed early in the third quarter of this year, including the relocation of our corporate headquarters to the current Endwave site," he adds. "We continue to actively pursue the listing of GigOptix's shares on the NYSE Amex, with the closing of this acquisition bringing us one step closer."

www.endwave.com/mmics.mvc

14G parallel VCSEL drivers and receiver amplifier arrays sampled for Infiniband AOCs

GigOptix is sampling two new chip-sets for short-reach 14Gb/s serial optical interconnects.

GigOptix offers 4- and 12-channel 14Gb/s link chip-sets for Infiniband Fast Data Rate (FDR) active optical cables (AOC) operating up to 168Gb/s as well as 40G and 100G Ethernet transceivers. The compact designs address the datacom, avionics and consumer markets.

The 4-channel HXT5104 VCSEL driver & HXR5104 receiver amplifier and 12-channel HXT5112 VCSEL driver & HXR5112 receiver amplifier chip-sets are designed to enable ultra-low-power consumption of <450mW for a 40G link over 100m and to minimize the number of components required to implement a transceiver. The HXT/R5 family incorporates programmable

equalization and pre-emphasis circuitry to facilitate various trace lengths and provide full programmable control via fully integrated analog-to-digital convertors (ADC) and digital-to-analog convertors (DAC) via an industry-standard 2-wire interface.

"We have developed the HXT/R5 series to meet the requirements for reliable, high-performance, low-power and cost-effective solutions," says Martin Bossard, director of engineering and general manager for GigOptix-Helix AG. "The new devices integrate more functionality than our previous generation, while dissipating less power with improved performance in terms of eye quality, or optical output, and receiver sensitivity."

www.gigoptix.com

Advanced Photonix's quarterly revenue up 52% year-on-year, exceeding targeted 15–25% Investment in high-growth platforms leads to dip in quarterly profit

For fiscal 2011 (to end March), Advanced Photonix Inc of Ann Arbor, MI, USA (which designs and makes silicon, InP- and GaAs-based photo-detectors, high-speed optical receivers and terahertz instrumentation) has reported net sales of \$28.8m, up 37% on fiscal 2010's \$21.1m.

Growth was broad based across markets, led by telecom, industrial, homeland security and medical.

Fiscal fourth-quarter revenue was \$7.8m, up 1.2% on \$7.7m last quarter and up 52% on \$5.1m a year ago. "We exceeded our original growth targets of 15–25% by a wide margin," says chairman & CEO Richard Kurtz. "We made the correct decision by continuing to invest in our high-growth platforms. This was particularly evidenced with our High Speed Optical Receiver product line, which grew at 182% on a comparative quarterly basis," he notes. "We positioned the company for growth during the downturn and

are pleased with the success we have had in capturing market share and participating in the explosive growth of the 40G and 100G line-side market roll out."

Operating expenses were \$3.7m, up on \$3.3m both last quarter and a year ago. Full-year operating expenses have risen from \$12.7m in fiscal 2010 to \$13.2m.

Due mainly to increased expenses associated with new products, gross margin for Q4 was 44%, down from 46% a year ago although up on Q3's 40%. Full-year gross margin was 43%, flat on fiscal 2010.

Correspondingly, on a non-GAAP basis, net income has dropped slightly from \$259,000 in Q3 to \$221,000 in Q4. However, this compares with a net loss of \$324,000 a year ago. Full-year net income was \$785,000, compared with a net loss of \$1.4m for fiscal 2010. Cash reserves rose during the year from \$2.3m to \$5.2m.

"The capital raised earlier this year helped to de-leverage our balance sheet and provided funding to fuel our growth," says Kurtz. "The success of our various Terahertz application developments for industrial use is also a strong indication of our technology being embraced by various markets," he adds. "We are looking forward to continuing our growth this coming year."

● Advanced Photonix joined the Russell Microcap Index on 24 June on Russell Investments' annual reconstitution of its family of US indexes. Russell determines membership of its equity indexes primarily by objective, market-capitalization rankings and style attributes.

"This is the first step in getting greater exposure and opening the investment community to our technology and market growth opportunities," says Kurtz.

www.russell.com/Indexes

www.advancedphotonix.com

Silicon photonics firm Kotura opens China office

Kotura Inc of Monterey Park, CA, USA, which has been designing and manufacturing application-specific silicon photonics components for the communications, computing, sensing and detection markets for over five years, has opened an office in Shenzhen, China and appointed Yicheng Lu as vice president.

Kotura says that its presence in China provides greater access and support for its installed customer base, which consists of many of the largest telecom companies in the region. China is recognized as a significant market for optical components, and the new office will provide sales & marketing, manufacturing and R&D support.

Led by Lu, this local presence should enable Kotura to build strategic relationships for manufacturing, product packaging and

other key resources required to support new product development. Lu will spearhead China activities and establish a foothold for Kotura in this key region. In addition to driving business development activities to increase long-term opportunities in China, Lu joins Kotura's executive team in setting the firm's strategic direction and is chartered with expanding customer relationships.

"China is the world's largest telecom market by population and is on its way to becoming the world's largest by revenue as well," says president & CEO Jean-Louis Malinge. "Shenzhen in particular is home to some of the world's leading telecommunication equipment manufacturers, and as such has developed a very strong optical communications infrastructure," he adds. "Yicheng,

with his extensive background in the optical components industry, will be invaluable as we expand our presence in the region."

Lu has more than 17 years of experience in optical components and fiber-optic sensors. Most recently, he was sales director and country manager of Great China for optoelectronic chip and module maker JDSU. Previously, he was a sales director at optical component, module and subsystem maker Bookham (now Oclaro), in which he achieved a compounded annual revenue growth rate (CAGR) of more than 45%. Lu holds bachelors and masters degrees in materials from Northwestern Polytechnical University (NPU) in China and a Ph.D. in engineering from Brunel University in the UK.

www.kotura.com

NeoPhotonics quadruples capacity for PIC-based Integrated Coherent Receivers

Volume shipments start for 40–100Gbps systems

NeoPhotonics Corp of San Jose, CA, USA, a vertically integrated designer and manufacturer of photonic integrated circuit (PIC)-based modules and subsystems for bandwidth-intensive, high-speed communications networks, has quadrupled capacity for PIC-based Integrated Coherent Receivers (ICR) for 40 and 100Gbps coherent fiber-optic transport systems.

The firm believes that the industry is coalescing behind the 'coherent technology' approach for high-speed 'backbone' networks. By combining its PIC-based ICR (which has what's claimed to be one of the industry's highest signal detection responses) with advanced digital signal processing on each channel, the coherent approach is designed to provide service providers with a solution for leveraging their existing fiber-optic cable investments longer, more efficiently and in an 'on demand' manner.

"The rapid increase in the use of coherent transmission technology

for 40Gbps on the line side, coupled with an initial ramp of 100Gbps coherent systems, necessitates a significant increase in volume shipments of ICRs while maintaining stringent optical performance requirements," says chairman & CEO Tim Jenks. "Our photonic integration technology utilizes our semiconductor-based wafer manufacturing capabilities and is inherently high-quality, scalable and cost-effective, which positions us ahead of the demand curve for this important technology," he reckons.

NeoPhotonics' ICR is designed to convert the phase-encoded optical signals into electrical signals of varying intensity, which can then be analyzed using digital signal processing. As carriers upgrade from 10Gbps network connections, the coherent solution using the ICR provides not only more throughput capacity but also more intelligence, says the firm. NeoPhotonics has earned multiple design wins for the ICR with its tier-1 customer base and

is now shipping ICR products (with or without an internal polarizing beam splitter) to multiple customers.

The ICR is designed to support the OIF Implementation Agreement for Integrated Dual Polarization Intra-dyne Coherent Receivers. The PIC-based ICR is designed to provide advanced demodulation to analyze the state-of-polarization and optical phase of a phase-modulated signal relative to an externally supplied optical reference signal, enabling recovery of the phase-polarization constellation of 40 or 100Gbps format signals.

As well as the ICR, NeoPhotonics offers a range of PIC-based components for high-capacity data transport networks, including 90° Hybrid Coherent Mixers for both 40Gbps and 100Gbps coherent transmission systems, and both small and standard form-factor DQPSK (differential quaternary phase-shift key) demodulators for 40Gbps transmission.

www.neophotonics.com

Infinera restores 400Gb/s of Pacnet's Japan capacity

Infinera Corp of Sunnyvale, CA, USA, a vertically integrated manufacturer of digital optical network systems incorporating its own InP-based photonic integrated circuits (PICs), says that, following the earthquakes and tsunami that devastated northeast Japan earlier this year, it delivered technology to support restoration of the damaged terrestrial and subsea optical networks of independent Asian telecoms service provider Pacnet.

Headquartered in Hong Kong and Singapore (with offices in all key markets in Asia and North America), Pacnet operates a regional network providing connectivity between Japan, Hong Kong, China, the USA and other countries throughout the Pacific Rim.

Just days after the disaster, Infinera was tasked with delivering 400Gb/s of capacity over Pacnet's Japanese subsea and terrestrial networks as quickly as possible. Infinera hence assembled a virtual task force in Tokyo, Singapore and Sunnyvale to establish a recovery plan. Four days later, all the equipment needed to restore the 400Gb/s of capacity was shipped to Tokyo.

Infinera says that, in total, it took its Japanese support team less than 4 weeks to install, commission and test the new 400Gb/s of capacity.

"When the disaster hit, we immediately took action to restore the fault," says Pacnet's chief technology officer Wilfred Kwan. "Throughout the whole process, the Infinera team displayed solid commitment,

determination and professionalism in supporting the restoration of our network and service to our customers in record time," he adds.

"Both the Pacnet and the Infinera teams worked tirelessly to restore service on the network, enabling them to roll out services quickly and efficiently," says Lonny Orona, Infinera's VP for customer support.

Infinera says that its DTN-based Submarine Solution delivers the benefits of its Digital Optical Networks architecture, enabling ease of scalability and operation, as well as seamless interoperability with a terrestrial Infinera network. The firm has deployed more than 85,000km of subsea networks across five continents.

www.infinera.com

Finisar reports annual revenue up 50.6% to record \$948.8m for fiscal 2011

...but March-quarter hit by China telecoms slowdown

For its fiscal 2011 (to end April), fiber-optic communications component and subsystem maker Finisar Corp of Sunnyvale, CA, USA reported record annual revenue of \$948.8m, up 50.6% on fiscal 2010's \$629.9m.

Of the \$318.9m rise in revenue, sales of products for applications less than 10Gbps rose by 22.2% (\$64.3m), sales of products for equal to or greater than 10Gbps rose by 72.4% (\$180.1m), and sales of wavelength selective switch (WSS) and reconfigurable optical add-drop multiplexer (ROADM) line-card products rose by 108.4% (\$78.5m), while sales of products for analog and cable TV (CATV) applications fell by 20.6% (\$3.9m).

On a non-GAAP basis, Finisar also reported record operating income (\$147.7m, up from \$44.7m, as operating margin more than doubled from 7.1% to 15.6% of revenue); net income (\$138.7m, up from \$37.5m); and diluted earnings per share (\$1.55, up from \$0.56).

However, for its fiscal fourth quarter, revenue was \$236.9m, up 25.7% on \$188.5m a year ago but down 9.9% on \$263m last quarter due mainly to soft demand from telecom customers, particularly Chinese OEMs. The firm had warned in March that the quarter would be impacted by: the full three months of the annual price negotiations with telecom customers that typically take effect on 1 January; the 10-day-long shutdown at certain customers for Chinese New Year in February; the adjustment of inventory levels at some telecom customers (particularly for products that had previously been on allocation and long lead times, including WSS and ROADM line-cards); and a slowdown in business in China overall.

Of the \$26.1m drop in revenue from last quarter, sales of less than 10Gbps products fell by 3.9% (\$3.6m), sales of 10Gbps or faster products fell by 7% (\$8.2m), sales

of WSS/ROADM line-card products fell by 28.7% (\$13.7m), and sales of products for analog and CATV applications fell by 13.6% (\$0.5m).

On a non-GAAP basis, operating expenses have risen from \$43.2m a year ago and \$46.4m last quarter to \$48m, driven by higher R&D expenses associated with the development and qualification of new products, including the firm's tunable XFP transceiver. Consequently, operating income has fallen from \$44.7m (an operating margin of 17% of revenue) last quarter to \$33.1m (14% of revenue).

Likewise, despite rising 32.6% on a year ago, non-GAAP gross margin has fallen from 34.7% last quarter to 34.2% (although this exceeds guidance of 32–33%). Net income was \$32.1m (\$0.33 per diluted share), almost double the \$16.7m a year ago (\$0.22 per diluted share) but down from \$42.5m last quarter (\$0.47 per diluted share). During the quarter, cash and cash equivalents rose from \$310.2m to \$314.8m.

On 18 May, Finisar closed its cash tender offer (announced in March) for the shares of Ignis ASA of Oslo, Norway, which provides optical components and network solutions for fiber-optic communications. The firm's stake in Ignis rose from 32% to a controlling interest of about 81% of the outstanding shares. "Ignis' whole-owned subsidiary Syntune will provide us a secure supply of superior tunable lasers used in producing our tunable XFP transceiver," says CEO Eitan Gertel.

"During the quarter we continued to invest in our new product development programs, including tunable XFP, to generate a significant pipeline of new products," says executive chairman Jerry Rawls.

"We expect this pipeline will enable us to win new opportunities with both LAN/SAN and telecom customers and expand our market share," he adds. "We are currently

in qualification with 15 customers for our tunable XFP transceiver and expect production of this product to start to ramp during the first fiscal quarter of 2012."

For fiscal first-quarter 2012 (to end-July 2011), Finisar expects declines in revenue to \$215–230m, non-GAAP operating margin to 8–10%, and earnings per diluted share to \$0.17–0.21.

However, during fiscal Q1/2012, Finisar will apply consolidation accounting for its ownership stake in Ignis from 18 May through 30 June 2011 (the end of Ignis' fiscal quarter, or about 50% of Finisar's fiscal Q1). Including the elimination of any inter-company revenue and other items, Finisar expects the impact to be (i) extra revenue of \$6.5m, with a non-GAAP gross margin of 23–24%, (ii) extra non-GAAP net operating loss of \$1m and (iii) a negative impact to earnings per diluted share of about \$0.01. Nevertheless, Finisar expects the Ignis acquisition to be accretive to non-GAAP earnings per diluted share within one year of closing the tender offer (subject to the achievement of anticipated synergies).

Taking into account the impact of consolidating Ignis, for fiscal Q1 Finisar hence expects revenue of \$221–236m; non-GAAP operating margin of 7.3–9.3%; and earnings per diluted share of \$0.16–0.20.

● On 5 July, Finisar completed its acquisition of the entire equity interest in Ignis. As a result of its recommended voluntary public offer (announced in late March) and subsequent mandatory public offer to acquire all outstanding Ignis shares at a cash NOK8 per share, Finisar acquired 97.25% of the outstanding shares and subsequently acquired the remaining shares via the compulsory transfer provisions of Norwegian law. Consequently, Ignis' shares were delisted from Oslo Børs on 11 July.

www.finisar.com

IN BRIEF

Emcore announces TXFP's Telcordia qualification and production release

Emcore Corp of Albuquerque, NM, USA, which makes components, subsystems and systems for the fiber-optic and solar power markets, has announced the Telcordia qualification and production release of its tunable XFP (TXFP) transceiver.

"We have demonstrated that our technology exceeds the mandated industry robustness and reliability standards," says Rob Stone, director of Emcore's Telecom business unit. "We have been successful in our goal of enabling customers to replace their legacy 10Gb/s long-haul tunable interfaces with a more power- and size-efficient module, which improves both their operational and capital expenses," he adds.

The tunable XFP incorporates the latest 'ClearLight' generation of Emcore's patented external cavity laser (ECL) technology, which has been deployed in worldwide fiber networks by multiple carriers since 2004. All active optical subcomponents are manufactured in-house, leveraging Emcore's core capability in wafer growth and fabrication. In addition to its current volume manufacturing location, Emcore will be adding additional capacity at its contract manufacturer over second-half 2011.

www.emcore.com/fiber_optics



Emcore's tunable XFP transceiver.

Emcore's new CPV module receives certification to IEC-62108 and listing to UL-SUB-8703

Emcore Corp of Albuquerque, NM, USA, which makes compound semiconductor-based components and subsystems for the broadband, fiber-optic and solar power markets, has announced the completion of third-party testing, certification and listing to IEC-62108 and UL-SUB-8703 for its G3-1090X concentrated photovoltaic (CPV) module.

Emcore says that the test results confirm that the G3-1090X fully satisfies the product safety, performance and reliability criteria for entry into the US and European markets. The firm worked with Intertek Testing Services to obtain the US Department of Labor's Occupational Safety & Health Administration (OSHA) NRTL (Nationally Recognized Test Laboratory) and CEC (California Energy Commission) listings for the G3-1090X module.

The G3-1090X module, which operates with a geometric optical concentration ratio of 1090x, was found to meet or exceed the safety and performance requirements of the internationally accepted IEC-62108 standard, and the US product safety requirement UL-SUB-8703. Demonstrating compliance with these standards through testing and evaluations by Intertek make the module eligible to bear the ETLUS mark (recognized in the USA) and the ETLEU mark (recognized in the European Union). CEC listing of the module qualifies it for performance-based incentives in the California Solar Initiative rebate program. In addition, the module will bear the CE Mark to indicate compliance with all applicable EU directives, regulations and standards.

Emcore says that the G3-1090X CPV module is among the first to fully comply with all sections of both IEC-62108 and UL-SUB-8703.



Emcore's 1090X CPV module.

"The successful certification and listing of our latest CPV module demonstrates our product will meet the rigors and performance requirements of utility-scale solar deployments," says chief operating officer Christopher Larocca.

"This achievement, combined with the establishment of our low-cost manufacturing joint venture, Suncore, positions Emcore to supply the most competitive high-performance, CPV systems in the industry," he claims.

The IEC-62108 standard specifies safety and performance requirements for CPV modules and assemblies suitable for long-term operation in outdoor environments. The objective of this test standard is to determine the electrical, mechanical and thermal characteristics of CPV modules and assemblies with regard to the product's ability to withstand prolonged exposure in climates where the product is expected to be deployed. UL-SUB-8703 incorporates all of the tests in the IEC-62108 standard, plus evaluations of grounding schemes, fire resistance, robustness to corrosion, electrical ratings of select parts and materials, and other safety-related aspects of product design and construction not covered by IEC-62108.

www.intertek.com/solar
www.emcore.com/solar_photovoltaics

JDSU acquires assets from QuantaSol

Multi-quantum well technology to accelerate CPV product roadmap

Optoelectronic chip and module maker JDSU of Milpitas, CA, USA has acquired critical product design, patented intellectual property and other assets from UK-based QuantaSol Ltd, a designer and manufacturer of concentrated photovoltaic (CPV) solar cells that was spun off from Imperial College, London in 2007 and funded by the Low Carbon Accelerator and Imperial Innovations.

JDSU aims to boost its CPV cell product platform by leveraging QuantaSol's multiple quantum well (MQW) technology, which raises the solar energy conversion efficiency of CPV cells. The firm plans to transfer key assets from QuantaSol to Milpitas over the next 6 months.

"The CPV market is gaining momentum with major installations happening worldwide," says Alan Lowe, president of JDSU's Communication & Commercial Optical Products (CCOP) division. "Incorporating key QuantaSol technology will allow us to further differentiate our products and expand our position in the CPV solar market as popularity for CPV continues to grow," he adds. CPV installations are expected to grow 100-fold from 10MW in 2010 to more than 1GW by 2015, according to GreenTech Media.

JDSU says that its CPV cells are optimized to capture different parts of the sun's spectrum using multiple junctions, resulting in conversion efficiencies that are expected to exceed 40% in the next few years

(a range suiting solar system integrators). The CPV cells are designed specifically to capture concentrated sunlight at 500–1000 times its original power. JDSU says that additional benefits include a small footprint, improved temperature performance, less use of semiconductor materials, and lower cost per kilowatt compared with other photovoltaic technologies.

In addition to its new CPV technology for land installations, JDSU has been providing solar power products to the satellite industry for several decades. The firm also provides photovoltaic solutions for the digital monitoring of smart grid power plants.

www.quantasol.com

www.jdsu.com

Illinois' John A Rogers wins Lemelson-MIT Prize

John A Rogers, the Lee J. Flory-Founder Chair in Engineering Innovation at the University of Illinois at Urbana-Champaign (UIUC), has won the 2011 Lemelson-MIT Prize. Rogers holds joint appointments in UIUC's Departments of Materials Science and Engineering, Chemistry, Mechanical Science and Engineering, and Electrical and Computer Engineering), and he is also director of the National Science Foundation (NSF) Nanoscale Science and Engineering Center.

Rogers accepted the \$500,000 prize — one of the world's largest single cash prizes for invention — and presented his accomplishments to the public at a ceremony during the Lemelson-MIT Program's 5th annual EurekaFest at the Massachusetts Institute of Technology in Cambridge, MA (15–18 June).

Now in its 17th year, the annual Lemelson-MIT Prize recognizes outstanding innovation and creativity, and is awarded to outstanding mid-career inventors, who have developed a patented product or process

of significant value to society, which has been adopted for practical use, or has a high probability of being adopted. By recognizing and funding younger, mid-career inventors, the prize is designed to spur inventive careers and provide role models for future generations of inventors.

Known for his recent pioneering work with semiconductor materials and flexible, stretchable electronics, Rogers applies his expertise to devise technology solutions across fields such as solar power, biointegrated electronics, sensing, thin-film metrology and fiber optics.

Rogers combines soft, stretchable materials with micro- and nanoscale electronic components to create classes of devices with a wide range of practical applications. His recent work has produced devices from tiny eye-like cameras to less-invasive surgical tools to biocompatible sensor arrays.

Ilesanmi Adesida, the dean of the College of Engineering at Illinois, cited Rogers' ability to span incongruent fields of work as a reason for

his success, moving from science to technology and to practical applications with a vision for the translation of science to products. "His work exemplifies how to effectively bolster sciences and technology so the US can successfully compete and prosper in the global community of the 21st century," says Adesida.

Rogers is also co-founder and director of the device companies Semprius Inc — which focuses on massively parallel, microcell-based concentrating photovoltaic (CPV) receivers — and MC10 Inc, both of which work to apply and commercialize technology he has invented. Previously, he co-founded the firm Active Impulse Systems Inc, which commercialized his picosecond laser techniques for the analysis of thin films used in the semiconductor industry and was later acquired by a large company.

Applications for the 2012 \$500,000 Lemelson-MIT Prize are now available at:

<http://web.mit.edu/invent/a-prize.html>

Industrifonden invests in nanowire PV firm Sol Voltaics

Venture capital firm Industrifonden of Stockholm, Sweden is investing SEK18.5m (\$2.93m) in Sol Voltaics AB of Ideon Science Park, Lund, Sweden, which is developing a new type of material that can reduce the cost of producing electricity from solar cells, it is claimed. The new share issue totals SEK40m, and the funds will be used to further develop Sol Voltaics' products.

"They [Industrifonden] are Sweden's leading cleantech investor and have extensive experience in our area," says Sol Voltaic's CEO Bo Pedersen. "With Industrifonden we now have a financially strong, knowledgeable investor that can help us to shift our expansion into higher gear," he adds.

Founded in 2008, Sol Voltaics originated from nanotechnology research at Lund University. The firm is developing a new material and production method to manufacture solar cells, involving quickly fabricating nanowire from gallium arsenide, where every wire functions as a solar cell. The material has long been considered the best for producing solar cells, but to date has been too expensive to use, it is claimed. Sol Voltaics has developed a method that radically reduces the cost. The firm is still in the development stage, but now aims to intensify its development work and win its first customers.

"Sol Voltaics has an opportunity to offer the market the world's most inexpensive solar cells, providing solar cell manufacturers and users with greater value, higher efficiency and increased production at a lower cost," reckons Industrifonden investment manager Stefan Jakélius. "The market for solar cells is large and global and is practically bursting at the seams, especially in Germany, where the decision to phase out nuclear power could give solar cells an additional boost," he adds.

www.solvoltaics.com

Alta raises single-junction solar cell efficiency record again to 28.2% Extraction of light generated inside cell critical to maximizing voltage

At June's 37th IEEE Photovoltaic Specialist Conference (PVSC37) in Seattle, Dr Brendan Kayes described how Alta Devices in Santa Clara, CA, USA raised the record for single-junction solar cell efficiency (under non-concentrated 1-sun illumination) from 26.4% to 27.6% late last year, and most recently to 28.2% — as verified by the US National Renewable Energy Laboratory (NREL). The theoretical Shockley–Queisser limit for efficiency has been shown to be 33.5%, but efforts to attain this have been slow in coming.

"Up until now it was understood that to increase the current from our best solar materials, we had to find ways to get the material to absorb more light," says co-founder Eli Yablonovitch, director of the US National Science Foundation (NSF) Center for Energy Efficient Electronics Science and professor at the University of California at Berkeley. "But the voltage is a different story. It was not recognized that to maximize the voltage, we needed the material to generate more photons inside the solar cell. Counter-intuitively, efficient light emission is the key for these high efficiencies," Yablonovitch reports in the paper 'The Physics Required to Approach the Shockley–Queisser Limit'.

Founded in 2007, Alta is a development-stage company focused on improving the production economics of high-efficiency solar photovoltaic 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).

Alta fabricates single-junction GaAs photovoltaic cells in a micron-thick thin-film that it then lifts off the growth GaAs substrate (which can then be reused multiple times to amortize its high cost). The thin-film cell can then be placed on a flexible substrate.

"In 2009, our team came to me with an aggressive timeline for solar cell efficiency advances, but with a few caveats: they were butting up against what appeared to be entrenched, practical limits," says president & CEO Christopher Norris. "Over the past two years, the team has succeeded in meeting each of its milestones." Alta has achieved new cell efficiency improvements about once every two months, he adds.

"We are committed to using new scientific understanding, such as internal light generation and extraction, to push the limits of solar cell and module efficiencies while simultaneously driving production costs down through other important developments," Norris says. "The goal of achieving the \$1 per installed watt target set by the Department of Energy has energized our entire company."

Also at PVSC37, a plenary talk 'Paths to High Efficiency Low Cost Photovoltaics' was given by co-founder professor Harry Atwater, director of the Energy Frontier Research Center on Light-Matter Interactions and director of the Resnick Institute for Science, Energy and Sustainability at California Institute of Technology (CalTech).

"The energy conversion efficiency results being achieved by Alta, in combination with other manufacturing and form-factor advances, will enable new ways to deploy solar without the economic compromises of other technologies," reckons Atwater.

www.altadevices.com

NREL's Olson wins Cherry Award

At the 37th IEEE Photovoltaic Specialist Conference (PVSC37) in Seattle (19–24 June), Jerry Olson, a principal scientist in the III-V Materials and Devices Group at the US Department of Energy's National Renewable Energy Laboratory (NREL) has received the Cherry Award from the Institute of Electrical and Electronics Engineers.

The award is named in honor of William R. Cherry, a founder of the photovoltaic community. In the 1950s, he was instrumental in establishing solar cells as the ideal power source for space satellites and for recognizing, advocating and nurturing the use of photovoltaic systems for terrestrial applications. The award was instituted in 1980, shortly after his death. Its purpose is to recognize individual engineers or scientists who devoted a part of their professional life to the advancement of the science and technology of photovoltaic energy conversion. It is only awarded to scientists who are still actively contributing to the field.

IEEE says that Olson opened the door for multi-junction solar cells by showing that a top cell of gallium indium phosphide (GaInP) and a bottom cell of gallium arsenide (GaAs) can capture and convert photons more efficiently into electricity than previous attempts at using other materials.

He and his co-workers showed that the multi-junction concentrator cells not only use a fraction of the electronic materials used by the thicker flat-plate cells, but they can capture more light through the course of a day.

Olson's 1984 breakthrough was embraced by NASA, which uses multi-junction solar cells based on his invention to power most space satellites, as well as the Mars rovers Spirit and Opportunity.

Most groups working in multi-junction solar cells at the time were looking for a combination of



Olson holds one of the first multi-junction cells that were developed in the 1980s from his technology. Credit: Dennis Schroeder.

bandgap energies that would yield maximum theoretical efficiency, with less emphasis on the chemical and structural compatibility of the different semiconductor layers. In essence they were "trying too hard to hit the bull's eye," says Olson.

The key was to find materials that were compatible (and more likely to be manufactured) but that still had a bandgap combination that would deliver high theoretical efficiency. That combination was a top cell of GaInP with a bandgap of 1.9eV and a bottom cell of GaAs with a bandgap of 1.4eV. These two compound semiconductors are chemically compatible and have the same lattice constant.

Today's PV concentrators, which can extract 30–40W from a small 1cm² solar cell by using lenses to focus the power of 1000 suns on the cell, are a direct descendant of Olson's multi-junction breakthrough, says NREL.

Sarah Kurtz, acting director of the National Center for Photovoltaics at NREL, joined the lab a couple years after Olson's invention. The pair has been instrumental in clearing hurdles to ensure that the GaInP/GaAs solar cell remains the top cell for efficiency.

"Jerry wasn't dissuaded by things in the literature that might give erroneous directions," says Kurtz. "He was willing to set that aside even in the face of people telling him that his approach would never work."

www.nrel.gov

IN BRIEF

Amonix new CPV factory visited by US Energy Secretary Chu

On 23 June, US Energy Secretary Dr Steven Chu visited the new 214,000ft² manufacturing facility in North Las Vegas of Amonix Inc of Seal Beach, CA, USA, which makes concentrated photovoltaic (CPV) systems using III-V multi-junction cells.

Chu toured the facility (opened on 17 May) where Amonix makes CPV systems for utility-scale power plants, such as the 2MW plant in Tucson, AZ that showcases the technology. Chu then led a round-table discussion with solar industry business leaders at the facility.

Chu was a co-winner of the Nobel Prize for Physics in 1997 and former director of the Department of Energy's Lawrence Berkeley National Lab, which he led in its pursuit of alternative and renewable energy technologies.

"Chu has a long-standing interest in renewable energy sources," says Amonix CEO Brian Robertson. "His visit emphasizes the reality that utility-scale solar energy is an economically viable reality."

Renewable energy development is a cornerstone of President Obama's long-term economic strategy. The DOE also recently announced the SunShot Initiative to cut the cost of solar energy by 75% by 2020. The 2009 American Recovery and Reinvestment Act included \$70bn in renewable and energy-efficiency measures. The Amonix facility was financed with a \$5.9m investment tax credit from the Recovery Act awarded in 2010 plus \$12m in private capital. It should bring \$560m of overall economic impact (including more than 300 private-sector jobs) to Southern Nevada in the next five years, according to the Nevada Development Authority.

www.amonix.com

IN BRIEF

AZUR launches INDEPENDA independent power system

At the Intersolar 2011 trade show in Munich (8–10 June), AZUR Solar GmbH, Leutkirch im Allgäu, Germany has launched the new AZUR INDEPENDA independent power system, following what it claims was huge demand for the system (which allows solar energy captured on the roof to be used by the household).

The new independent power system stores and distributes solar energy intelligently throughout the house, completely automatically and in accordance with consumption habits.

"Despite, or perhaps even because of, the prevailing uncertainty in the solar industry due to the constantly changing perspectives and statements of German policymakers, we really did well at Intersolar in Munich," reckons managing director & founder Bernd Sauter. "Using electricity from your own roof, which our system controls fully automatically, is the future," he adds.

Homeowners are becoming sick of hearing about rises in electricity prices and feed-in tariffs, says AZUR. "With our innovative and intelligent INDEPENDA system, homeowners in Germany can now make themselves independent and generate and use up to 80% of their solar energy themselves," says Sauter. "There is a huge market for this in Germany, and also internationally," he reckons. "That's because our independent power system shifts the focus away from the German renewable energies act and feed-in tariffs, even though INDEPENDA owners in Germany will receive a state subsidy. Independence is the big keyword."

www.azur-solar.com

Siemens takes 16% stake in CPV module firm Semprius

Siemens AG recently acquired a minority stake of about 16% in Semprius Inc of Durham, NC, USA, which develops high-concentration photovoltaic (HCPV) modules.

The investment gives Siemens early access to what it describes as a highly promising solar power technology. Compared to conventional photovoltaics, HCPV systems are especially suitable for regions with high direct irradiation, for example along the Earth's sunbelt, it adds.

"Participating in Semprius provides us access to trailblazing technology for clean power generation," says Martin Schulz, VP of Photovoltaics in the Renewable Energy Division of Siemens Energy in Erlangen, Germany. "Siemens will act as a strategic investor to help Semprius scale up its innovative technology to market maturity," he adds. Construction of Semprius' first production facility is due to begin in July.

Semprius' HCPV modules use high-performance glass lenses to focus sunlight onto very small, highly efficient triple-junction gallium arsenide-based microcells (600µm by 600µm in area and less than 10µm thick). The firm's triple-junction cells have reached a conversion efficiency of 41.7%, as tested by the US National Renewable Energy Laboratory (NREL), according to Semprius' staff development engineer Kanchan Ghosal. Optics concentrates the sunlight 1000 times so that just 0.1% of the module area is covered with the microcells. The microcell's very small size enables use of low-cost optics and electrical interconnects, which remove the heat, eliminating the need for costly thermal management solutions.

In addition, Semprius grows its cell structures on top of a release layer so that they can be epitaxially lifted-off as part of its patented micro-transfer printing process, allowing it to reuse the GaAs substrate and hence cut costs.

"Prospects are bright for HCPV systems that enable significantly higher efficiencies than conventional PV modules, and at the same time offer enormous potential to achieve competitive levelized costs of electricity," Schulz says.

Other features such as high reliability, modular configuration and flexible plant design make the technology particularly appealing, says Siemens. Modules built with Semprius' patented production process have been on sun for several years and the first full field-test installation (a 1kW system, consisting of a 48-module array on a dual-axis tracker using two-junction microcells) has been operational at UniSource Energy Corp subsidiary Tucson Electric Power (TEP) in Arizona since August 2010, operating at an average capacity factor of 29%.

The TEP project is part of a joint development agreement signed in January 2010 by Semprius and Atlanta-based Siemens Industry Inc (the US affiliate of Siemens' global Industry Sector business) to deploy HCPV systems at test sites worldwide. Other installations are due to follow by the end of this year. The HCPV installation market is still in its early stages but is expected to grow to as much as 6GW by 2020.

"Their far-reaching presence and strength in the renewable market offer us an immediate global footprint," says Semprius' president & CEO Joe Carr about Siemens. Components for photovoltaic installations are part of Siemens' Environmental Portfolio with which it earned revenues of nearly €28bn in fiscal 2010, making it the world's largest provider of environmentally compatible technology. In the same period, its products and solutions enabled customers to reduce their CO₂ emissions by 270 million tons (equal to the total annual emissions of Hong Kong, London, New York, Tokyo, Delhi and Singapore).

www.semprius.com

Soitec, Schneider Electric and Masen form first partnership under Mediterranean Solar Plan

Concentrix CPV technology for two Moroccan 5MW pilot projects

Soitec of Bernin, France, which makes engineered substrates including silicon-on-insulator (SOI) wafers (as well as III-V epiwafers through its Picogiga International division), and global energy management specialist Schneider Electric have signed a memorandum of understanding with Masen (Moroccan Agency for Solar Energy) — the lead player in the Moroccan Solar Plan — on an integrated partnership in Morocco regarding Soitec's Concentrix concentrating photovoltaic (CPV) technology.

Soitec says that completion of the project will create a CPV segment serving domestic needs and generating exports of electricity and power plants, contributing to a strategy of controlled energy costs over the long term for Morocco and to the achievement of a plan to build a manufacturing facility in the country. The Franco-Moroccan initiative marks the first utility-scale project under the Mediterranean Solar Plan in one of the 43 member countries of the Union for the Mediterranean (UfM), a partnership uniting Europe with countries in the Mediterranean Basin.

The memorandum of understanding (MoU) between Soitec, Schneider Electric and Masen is part of the Moroccan Solar Plan (MSP), which is supported jointly by the Moroccan and French governments. It has four key components:

- R&D, involving joint work on CPV R&D subjects for technology sharing, based in part on the provision of a demonstrator by Soitec.
- Industrial integration, through the development of a local supply chain for CPV system components (including trackers) and an opportunity analysis on setting up a CPV modules assembling factory in Morocco.
- Training, involving the transfer of Soitec's CPV expertise to Masen, and joint analysis by all stakehold-

ers of the feasibility of setting up a Master's syllabus on the management of renewable energies in partnership with Moroccan universities.

● Pilot projects, involving two Moroccan CPV pilot projects of 5MW each, with two different generation systems. All or part of the electricity generated will be exported under the MSP.

The two pilot projects (totaling 10MW) will proceed as follows. The first project, scheduled for completion in early 2012, involves the development (on the technology platform at Masen's Ouarzazate site) of a 5MW demonstration unit twinned with Soitec and Schneider Electric facilities in France. A joint basis for R&D will thus be established, facilitating a strategy of knowledge sharing between the partners. The second project involves the construction of another 5MW section using next-generation modules at a site to be approved by the partners.

"This multi-dimensional pilot partnership on CPV, a promising solar power technology, fits in perfectly with Masen's vision on integrated development of the Moroccan Solar Plan," says Masen chairman Mustapha Bakkoury. "This kind of project will undoubtedly be having a positive impact on the sector, and on regional integration, which we're eager to participate in, alongside organisations like Soitec and Schneider Electric, which share our aims," he adds. Masen is in charge of carrying out the integrated Moroccan Solar Plan for the development of a minimum capacity of 2000MW by 2020, and for the promotion of all aspects of solar power resources.

"Our technology is in the process of being adopted on a large scale in the San Diego region of the USA, where climate conditions are similar and where our technology has

proven to be the best suited to regions with abundant sunshine," says Soitec's chairman & CEO André-Jacques Auberton-Hervé. "We are working very closely alongside Masen on roll-out of solar power plants in Morocco and to promote the economic development of the region," he adds.

"Schneider Electric has a 60-year history of working in Morocco," notes Schneider Electric's renewable energies director Laurent Bataille. "We'll be working jointly with Soitec to address the needs expressed by Masen," he adds. "Schneider Electric will be harnessing its international expertise in intelligent energy management systems for solar power plants, and its unique know-how in access to renewable energies."

Soitec says that Concentrix technology has been optimized for high-capacity industrial-scale solar power plants. The technology suits use in areas with high direct normal irradiance (DNI), such as Saharan Africa, southern Africa, the Middle East, Australia, and the Southern and Southwestern USA. Soitec solar plants have already been built in more than ten countries, including the US Sun Belt, where its two-axis sun-tracking system has been delivering record yields.

Schneider Electric's renewable energies access offering covers needs ranging from electricity generation through to network connection. It includes feasibility studies, power distribution architecture design, the supply of all types of equipment including junction boxes, inverters, prefabricated transformer substations, MV transformer substations, the supervision system and video surveillance, as well as operation and maintenance of the system.

www.soitec.com

www.masen.ma

www.schneider-electric.com

3Sun inaugurates Italy's largest solar panel plant

Initial annual module capacity of 160MW could rise to 480MW

Early July saw the inauguration in Catania, Italy of a factory run by 3Sun S.r.l. that will manufacture integrated multi-junction, thin-film photovoltaic cells and modules. 3Sun is a joint venture formed last August by Rome-based Enel Green Power (EGP, a company of Italy's largest power firm Enel Group), Japan's Sharp Corp and Europe-based semiconductor manufacturer STMicroelectronics (ST).

In attendance were government representatives Raffaele Lombardo (President of the Sicily Region), Giuseppe Castiglione (President of the Catania Province) and Raffaele Stancanelli (Mayor of Catania), as well as Enel's chairman Paolo Andrea Colombo and CEO Fulvio Conti, Sharp Corp's president Katsuhiko Machida, STMicroelectronics' supervisory board vice chairman Bruno Steve and president & CEO Carlo Bozotti, Enel Green Power's CEO Francesco Starace, Sharp's representative director & executive VP Toshishige Hamano, and 3Sun's president Andrea Cuomo and CEO Mauro Curiale.

Initially with 280 qualified staff and annual panel production capacity of 160MW (which could be increased to 480MW over the next years), the plant is already the largest solar panel factory in Italy and one of the largest in Europe. The development was financed through a mixture of capital from the JV partners, funding from the Italian government's



Inauguration ceremony for 3Sun's factory.

CIPE (Comitato interministeriale per la programmazione economica/Inter-ministerial Committee for Economic Planning) — which earmarked €49m for the project — and project financing with three major lending institutions (Banca IMI, Centrobanca and Unicredit).

Following the JV agreement last August, each of the three partners subscribed to a third of the capital, committing €70m each in cash or in tangible and intangible assets. The partners have also contributed their specific expertise: Enel Green Power, with the development and operation of plants generating power from renewable resources at the international level and the retail marketing of solar panels on a national scale through its subsidiary Enel.si; Sharp, with its unique multi-junction thin-film technology (already manufactured at its factory in Sakai, Japan) and the marketing of solar panels

through Sharp's subsidiaries in Europe; and STMicroelectronics, with its manufacturing capabilities, a staff highly trained in advanced technology sectors such as micro-electronics as well as its competence in energy-saving power-management systems.

The factory's output is intended to meet the demand of solar power markets in Europe, the Middle East and Africa (EMEA), using both projects under development and the sales networks of Enel Green Power and Sharp. Also last August, Enel Green Power and Sharp formed a second joint venture, Rome-based ESSE (Enel Green Power & Sharp Solar Energy S.r.l.), to develop, build and operate photovoltaic systems in the EMEA area, with an output target of over 500MW by 2016, using panels manufactured by the factory. The panels will also be used on the 1MW solar power installation that ESSE will build on the rooftop of the new factory.

Enel.si (the Enel Green Power subsidiary that specializes in installing photovoltaic systems for the retail market) will also participate in the marketing effort, offering panels through its franchise network of more than 570 qualified installers throughout Italy.

www.3sun.com



Profile of 3Sun's new integrated multi-junction, thin-film photovoltaic cell and module manufacturing plant.

DOE offers \$4.5bn in conditional loan guarantees to support three Californian CdTe PV plants

US Energy Secretary Steven Chu has announced offers of conditional commitments for loan guarantees of about \$4.5bn to support three alternating-current cadmium telluride (CdTe) thin-film photovoltaic (PV) solar generation facilities.

The Department of Energy (DOE) is offering conditional commitments for a \$680m loan guarantee to AV Solar Ranch 1 LLC for the 230MW Antelope Valley Solar Ranch 1 project, for partial loan guarantees of \$1.88bn to Desert Sunlight 250 LLC and Desert Sunlight 300 LLC for the 550MW Desert Sunlight project, and for partial loan guarantees of \$1.93bn to Topaz Solar Farms LLC for the 550MW Topaz Solar project.

First Solar Inc of Tempe, AZ, USA, which makes thin-film photovoltaic (PV) modules based on cadmium telluride (CdTe) as well as providing engineering, procurement and construction (EPC) services, is sponsoring all three projects and will provide modules from a new manufacturing plant that has begun construction in Mesa, AZ, as well as from its recently expanded manufacturing plant in Perrysburg, OH, which serves as its primary hub for engineering, research and development. The firm expects that the projects will create a total of 1400 jobs in California during peak construction.

"These projects will bring immediate jobs to California in addition to hundreds more across the supply chain," says Chu. "Together, the projects will power hundreds of thousands of homes with clean, renewable power and increase our global competitiveness in the clean energy economy."

The 230MW Antelope Valley Solar Ranch 1 project will be located in the Antelope Valley area of the Western Mojave Desert (about 80 miles north of Los Angeles) and is expected to generate 350 construction jobs. It will feature utility-scale deployment of inverters with volt-

age regulation and monitoring technologies that are new to the US market. The inverters enable the project to provide more stable and continuous power, increasing the efficiency and reliability of large-scale solar power plants greater than 100MW. The facility is expected to generate more than 622,000MW-hrs of electricity per year (equivalent to powering over 54,000 homes) and will avoid over 350,000 metric tons of carbon dioxide emissions annually. Power output will be sold to Pacific Gas & Electric Company.

The 550MW Desert Sunlight project will be located on land managed by the Bureau of Land Management in eastern Riverside County, CA, and is expected to generate 550 jobs during construction. It is expected to use 8.8 million CdTe PV modules, generating enough electricity to power more than 110,000 homes and avoiding over 735,000 metric tons of carbon dioxide annually. Construction will take place in two phases: Phase I will generate 300MW (to be sold to Pacific Gas & Electric Company); Phase II will generate 250MW (to be sold to Southern California Edison). The \$1.88bn in loans will be funded by a syndicate of institutional investors and commercial banks led by lead lender and lender-applicant Goldman Sachs Lending Partners LLC, which submitted the project under the Financial Institution Partnership Program (FIPP), and co-lead arranger Citibank N.A.

The 550MW Topaz Solar project will be located in eastern San Luis Obispo County, CA, and is expected to generate 500 jobs during construction. It will use more than

First Solar to supply 1330MW of CdTe PV modules... Projects will create a total of 1400 jobs in California during peak construction

8.5 million CdTe PV modules, generating enough electricity to power about 110,000 homes and avoiding nearly 725,000 metric tons of carbon dioxide emissions annually. Power output will be sold to Pacific Gas & Electric Company. The \$1.93bn in loans will be funded by a syndicate of institutional investors and commercial banks led by lead lender and lender-applicant The Royal Bank of Scotland plc, which submitted the project under the Financial Institution Partnership Program (FIPP).

The DOE's Loan Programs Office administers three separate programs: the Title XVII Section 1703 and Section 1705 loan guarantee programs, and the Advanced Technology Vehicle Manufacturing (ATVM) loan program. The loan guarantee programs support the deployment of commercial technologies along with innovative technologies that avoid, reduce, or sequester greenhouse gas emissions, while the ATVM supports the development of advanced vehicle technologies. Under all three programs, DOE has issued loans, loan guarantees or offered conditional commitments for loan guarantees totaling over \$38bn to support 40 clean energy projects across the US. The program's 23 generation projects will produce more than 32 million megawatt-hours annually (enough to power over 2.5 million homes).

To date, the program has conditionally committed more than \$16bn in loan guarantees to support 15 solar generation projects. DOE has also conditionally committed financing to support many other projects, such as four of the world's largest solar projects, two geothermal projects, the world's largest wind farm, and the USA's first new nuclear power plant in three decades.

<http://lpo.energy.gov>
www.firstsolar.com

NREL and Helmholtz Association collaborating on next-generation photovoltaics

The US Department of Energy's National Renewable Energy Laboratory (NREL) and Germany's Helmholtz Association have signed a memo of understanding (MOU) to work together more closely in order to close gaps in solar energy research and accelerate the development of new technologies.

The MOU was signed in Berlin by NREL director Dan Arvizu, and leaders of three research institutes within the German Helmholtz Association: the Research Center Jülich (Forschungszentrum Jülich, FZ Jülich), the Helmholtz Center Berlin (Helmholtz-Zentrum Berlin für Material und Energie, HZB), and the German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt, DLR). Also present for the signing were Greg Delawie (Deputy Chief of Mission, US Embassy) and Thomas Rachel (Parliamentary State Secretary of the Federal Ministry of Education and Research).

The MOU identifies several key solar energy topics to explore for joint research cooperation.

Scientists from the two countries, among other endeavors, will cooperate to synthesize and characterize novel materials that are candidates for more efficient solar cells and solar fuels.

The will also develop and use fast imaging techniques to help characterize thin-film materials on the micron to nanometer scale, and to characterize in-situ growth processes.

The researchers will seek a fundamental understanding of grain boundary/interface passivation in thin-film silicon and search for the potential and limits of wide-bandgap thin-film solar cells. Thin films, made of copper, indium, gallium, selenium (CIGS) and other emerging materials could replace silicon as the most efficient materials in next-generation thin-film solar arrays, it is reckoned.



Contract signing in Berlin. Photo: Helmholtz/Ausserhofer.

To measure the performance and reliability of solar cells and modules, the scientists will use electroluminescence, photoluminescence and thermography. They will also investigate the stability of solar cells by subjecting them to high temperatures and light exposures.

New device structures and lower-cost catalysts will also be investigated for the generation of hydrogen in photocatalytic solar fuel generation.

"This agreement promises to advance the state of knowl-

edge and the development of new materials and technologies that will form the basis of next-generation solar cells and solar fuels," says Arvizu.

In one area, the work builds on an MOU that NREL signed two years ago with DLR that involved developing standard test methods to quantitatively assess the reflectance and durability of solar mirrors for concentrating solar power (CSP) systems. The MOU also called for round-robin testing of commercial reflector samples and commercial parabolic trough receivers. In the new MOU, this work will be extended to understanding fundamental mechanisms for soiling rates on CSP mirrors.

Overall, the new MOU sets the basis for collaboration on basic and applied research issues to advance the next generation of solar cells for electricity and solar fuel production, as well as addressing improvement in the performance of concentrating solar thermal power systems.

www.nrel.gov
www.helmholtz.de/en

The researchers will seek a fundamental understanding of grain boundary/interface passivation in thin-film silicon and search for the potential and limits of wide-bandgap thin-film solar cells. Thin films, made of copper, indium, gallium, selenium and other emerging materials could replace silicon

SoloPower raises a further \$15m Volume manufacturing plant construction to begin in Portland in July

According to a filing with the US Securities and Exchange Commission (SEC) on 27 June, SoloPower of San Jose, CA, USA has raised \$15m (of a targeted \$43.75m) from Greentech Capital Advisors Securities of New York and Thomas Weisel Partners of San Francisco as part of its fifth round of equity funding. Previously, in March, it had raised \$13.5m (out of fifth-round funding then targeted at just \$20m) from the same Investors.

SoloPower makes flexible, light-weight copper indium gallium diselenide (CIGS) thin-film photovoltaic (PV) cells and modules on stainless-steel materials using a proprietary roll-to-roll electro-deposition process. In January, the firm said that it had agreed to construct its first commercial-scale manufacturing plant in Oregon, as the Small Scale Energy Loan Program (SELP) Advisory Committee recommended approval to the Oregon Department of Energy for a \$20m loan to the firm. SoloPower has also been awarded a Business Energy Tax Credit (BETC) of an estimated \$14m from the State of Oregon.

The State funding supplemented \$51.575m in fourth-round equity and warrant/option financing raised last December from existing investors Crosslink Capital (of San Francisco), Convexa A/S (of Oslo, Norway) and Hudson Clean Energy Partners LP (of Teaneck, NJ) in order to expand SoloPower's existing 109,000ft² small-scale production plant in San Jose and to finance construction of the new plant. Previously, SoloPower (which was founded in 2005) raised \$230m in 2008 alone, followed in February 2010 by \$44.9m in debt financing via Thomas Weisel Partners.

When completed and at full capacity, the new plant should produce about 400MW of modules annually and provide direct employment to about 500 full-time staff. About 270

construction jobs will be created to build it, and additional jobs are also likely to be generated in the local supply chain.

This February, SoloPower received a conditional commitment from the US Department of Energy (DOE) Loan Programs Office for a \$197m loan guarantee to help it secure about 54% of the \$364m project cost of constructing its high-volume manufacturing plant in Oregon. SoloPower has until 30 September to finalize the loan guarantee and start construction.

The firm originally planned to site the plant in Wilsonville, OR by retrofitting a former Nike Inc distribution center, around which the Wilsonville City Council in April voted to create a new urban renewal district involving about \$11m in cash and tax abatements for SoloPower, supplementing a \$10m loan guarantee through a federal Department of Agriculture program (available only in rural areas). However, some of Wilsonville's 19,000 residents launched a petition to put the issue to a municipal ballot, delaying construction and jeopardizing the federal loan guarantee.

In mid-April, SoloPower hence began seeking other locations, leading on 13 May to an agreement to site the plant 20 miles north in North Portland's Rivergate Industrial District, an existing city-designated enterprise zone (partially owned by the Port of Portland) in which SoloPower will be eligible for \$15.2m in tax abatements on \$271m worth of capital expenditure, plus an extra \$5m loan guarantee from the Oregon Department of Energy's State Energy Loan Program (backed by revenue from Portland city's on-street parking meters).

SoloPower now aims to begin preparing the new plant in July, with production beginning early next year.

www.solopower.com

NREL confirms 16.3% efficiency for XsunX

The US National Renewable Energy Laboratory (NREL) has certified the peak conversion efficiency of 16.36% achieved by XsunX Inc of Aliso Viejo, CA, USA for its hybrid copper indium gallium (di)selenide (CIGS) thin-film photovoltaic (TFPV) cell devices.

Overall efficiency of tested samples ranged from 15.3% to 16.36%, producing an average efficiency of 15.91%. The sample given to NREL was part of a 125mm substrate which, after deposition, was subdivided into quadrants to produce NREL device test structures and analytical equipment test structures. The purpose was to provide a statistically significant body of data in support of XsunX's continuous process improvement efforts.

"NREL's official measurement of 16.36% supports our manufacturing approach and the viability of single-cell processing," says chief technology officer Robert Wendt. "We believe the efficiency levels that we achieved will provide an economically viable process that we can offer the market," he adds. "Our approach lends itself to direct translation to production," he believes.

XsunX's technology uses co-evaporation for the rapid deposition of final-sized cells to better control the complex management of the CIGS layer deposition process. The firm's method, unlike other CIGS manufacturing technology, begins and ends using individual substrates sized to match silicon cells. As well as providing a smaller and more precise deposition environment, this also helps to avoid performance losses experienced when cells are either cut from rolls of CIGS material or mismatched electrically in monolithic assemblies, the firm claims.

"The official measurements conducted by NREL help to show that small-area co-evaporation offers the necessary conversion efficiencies to compete with silicon," says CEO Tom Djokovich.

www.xsunx.com

juwi chooses Japan's Solar Frontier for 3.8MW CIS project in north-east US

Tokyo-based Solar Frontier, a subsidiary of Japanese energy business Showa Shell Sekiyu K.K., has been selected by juwi solar Inc (JSI) of Boulder, CO, USA (which is majority-owned by juwi Holding AG of Germany) to supply 3.8MW of its proprietary CIS (copper, indium, selenium) thin-film photovoltaic (PV) modules for a project to be operated by a regulated utility in the Northeast USA.

When completed by the end of 2011, it will be the largest Solar Frontier installation to date in North America, and one of the largest solar projects in the Northeast USA. Solar Frontier says that it is the latest competitive win in its global strategy to work with nationally and globally leading companies.

The solar panels will be produced at Solar Frontier's new gigawatt-scale Kunitomi plant in Miyazaki, Japan, which is claimed to be unparalleled for its combination of advanced automation, scale, and low-energy, end-to-end processing.

"Achieving this milestone project immediately after opening our gigawatt-scale factory in Japan [in April] highlights the commercial attraction of our CIS modules," reckons Greg Ashley, chief operating officer of Solar Frontier Americas Inc of Santa Clara, CA, USA. "Our work with JSI is a strong indicator of the growing confidence that global markets have in Solar Frontier's economical and ecological solar panels," he adds.

"JSI provides the most competitive utility-scale solar developments for our clients, and Solar Frontier's CIS technology will allow us to deliver a low cost of energy and long-term, reliable energy production for this project and its long-term owner," claims JSI's managing director Michael Martin.

www.solar-frontier.com

www.juwisolar.com

Q-Cells launches Q.SMART CIGS PV modules on North American market

Q-Cells SE of Bitterfeld-Wolfen, Germany, which manufactures both silicon and thin-film copper indium gallium diselenide (CIGS) solar photovoltaic (PV) modules, has introduced its Q.SMART CIGS PV modules in the North American market. Q.SMART is a high-yield and high-efficiency thin-film module designed to maximize power output and return-on-investment in distributed solar generation.

With aperture efficiencies of up to 14.7%, Q.SMART has held the record for thin-film modules in serial production since 2009. Its CIGS technology is claimed to be the only thin-film solar technology that does not initially degrade in the first years of operation.

Q.SMART harnesses a 'light-soaking' effect to generate an average of 2.5% power boost above Nominal Power at Standard Test Conditions when deployed in the field.

Q-Cells claims that Q.SMART also outperforms competitors in diverse environmental conditions, including low-light periods of the day and high-heat climates, suiting both commercial and residential settings. The modules are also claimed to be the highest-yield panels in the world, with high production efficiency rates.

Q.SMART comes with a unique Power Appreciation Warranty of 25 years — a 100% performance guaranty for the first three years, and linear degradation of not more than 0.7% per year thereafter, still achieving 85% of rated output power after 25 years. The warranty program reassures customers that their Q.SMART modules will continue at peak performance throughout their operational lifetimes.

The modules also come with the Q-CELLS YIELD SECURITY seal of quality. This includes an Additional Power Boost (APB), an increase in output by up to 15% through positive sorting and the light-soaking effect; plus 360° efficiency (TDE)

through flexible installation in diffused light conditions, in shade and at unfavorable angles.

"The release of our innovative Q.SMART technology in North America aligns with Q-Cells' corporate vision to bring best-of-world solar technology and partnerships to local markets," says Marc van Gerven, managing director of Q-Cells North America of San Francisco, CA, USA. "Since entering North America one year ago, Q-Cells introduced first its utility-scale solar business, then rolled out its PV systems business, and began module sales with the availability of Q.SMART," he adds.

The technology behind Q.SMART was developed in 1983 by the Ångström Solar Center at Uppsala University, Sweden, commercialized by the spin-off company Solibro in 2006, and acquired by Q-Cells in 2009. This March, Q-Cells said it had achieved the milestone of 14.7% production efficiency on the aperture area, a record for monolithically integrated CIGS thin-film modules. At the end of 2010, total production capacity in Thalheim, Germany had reached 135MWp.

Outside of North America, Q-Cells has already deployed Q.SMART modules in both commercial and residential installations. Projects in 2010 include a 3.4MWp commercial rooftop Tontarelli, Italy; a 610kWp commercial rooftop at Venice Airport, Italy; and an 880kWp carport at Frankfurt Trade Fair, Germany. Most recently in 2011, iGen Energy of Manchester, UK completed work on the first phase of a 96kWp installation in Buxton, Derbyshire for professional cleaning solutions manufacturer Selden Research. The commercial roof-top project is the first in the UK to use Q.SMART modules. When it is completed, the new system covering 1500m² will be one of the largest in England.

www.q-cells.com

Global Solar's PowerFLEX CIGS module awarded IEC and UL certifications

Global Solar Energy Inc of Tucson, AZ, USA, which makes copper indium gallium diselenide (CIGS) thin-film photovoltaic cells and modules, says that its flexible module PowerFLEX BIPV has been awarded IEC 61730 and 61646 as well as UL 1703 certifications, fulfilling the strict requirements of safety, reliability and durability set by the two independent test laboratories (the International Electrotechnical Commission and Underwriters Laboratories).

Founded in 1996, Global Solar Energy's solar modules are lightweight and flexible, suiting building-integrated photovoltaic (BIPV) applications and solar power stations or foldable solar chargers. Production facilities in Tucson have a capacity of 40MW, while the firm's subsidiary in Berlin-Adlershof, Germany has a production capacity of 35MW (with 250 staff currently employed at the two sites).

The firm says that the low weight of just 3.5kg/m² of module area makes the PowerFLEX BIPV particularly suited to industrial flat roofs, which are often not strong enough to bear the weight of thick-film photovoltaic installations. Despite having a large format (5.75m x 0.5m) and a high power density (300W), the PowerFLEX module is rolled onto and adhered to the roof membrane, requiring no mounting hardware. The roof membrane is not perforated, and no additional wind load is created. The look of the building is not altered.

Also, with a conversion efficiency of 12.6% in relation to the aperture area, the module is the most efficient flexible module in the market to date (and about 50% more efficient than flexible silicon solar cells), the firm claims.

Global Solar says that certification confirms that the flexible thin-film modules are able to guarantee safe

electrical and mechanical operation for the duration of their expected lifetime, and that they are suitable for permanent open-air use. They also meet the requirements of the Prototype Building Regulation (MBO) laid down by the Conference of Ministers of Construction, a working group for urban development, construction and housing of the responsible Ministers and Senators from the 16 German Federal States.

"The UL and IEC certifications represent another milestone in the rapid development of Global Solar Energy. We are already planning several installations in the US and Europe," says president & CEO Dr Jeff Britt. "Due to its high efficiency and low volume of materials, the new module can be offered at an extremely competitive price, which will help property owners to reach a quick return on their investment and achieve profitability," he reckons.

www.globalsolar.com

Non-penetrating mounting system for metal roof market

Solyndra LLC of Fremont, CA, USA, which makes cylindrical copper indium gallium diselenide (CIGS) photovoltaic (PV) systems consisting of panels and mounting hardware for large commercial rooftops, has launched the Solyndra 200 Series Metal Roof Solution.

What is claimed to be a unique non-penetrating adjustable mounting system is designed to meet the additional solar installation challenges posed by metal roofs, which make up a significant and growing portion of the large, low-sloped, commercial, industrial and agricultural rooftop markets.

"Customers with metal roofs have been excited about the benefits of using our lightweight, non-ballasted and non-penetrating design on metal roofs, but have been in need of a flexible mounting solution to address the wide variety of roof

types in the market," says president & CEO Brian Harrison. "Adapted from our proven 200 Series mounting system, the new metal roof mounts require no tools in the assembly process and are adjustable to meet the majority of low-slope metal roof configurations supplied by the industry's leading metal roof manufacturers," he adds.

The adjustable mount design has no attachments and uses no tools, allowing Solyndra 200 Series panels to be installed faster than any other standing seam solution on the market, it is claimed. The mounts are currently available and to date have been installed and tested on metal roofs by ASC Building Products, Bemo USA, Kalzip, Kingston and Gibraltar.

Solyndra says that its 200 Series products are suited to metal roofs.

The low, 2.8lbs per square foot distributed load allows simple installation without ballast or penetrations in winds up to 130mph when installed in accordance with Solyndra's installation guidelines. Attaching conventional racking to metal roofs often damages the metal roof and could compromise its integrity. Although not required, in order to maximize power from the cylindrical solar modules, roof owners can choose white or reflective 'cool roofs', which conserve energy and reduce ambient heating caused by rooftops while generating more power. Metal roofs are often employed on temporary or re-locatable buildings, and Solyndra says that ease of installation and simple relocation makes the panels a good solution where there is possibility of relocation.

www.solyndra.com

Belgian rooftop becomes Solyndra's largest installation

Solyndra International AG of Baar, Switzerland, a subsidiary of Solyndra LLC of Fremont, CA, USA, which makes cylindrical copper indium gallium diselenide (CIGS) photovoltaic (PV) systems consisting of panels and mounting hardware for large commercial rooftops, has completed a 3MW system atop a distribution center in Zellik (a suburb of Brussels, Belgium) belonging to Delhaize (a supermarket chain with over 2800 stores worldwide, including 805 in Belgium and Luxemburg).

The project was completed by solar integrator U|S|E AG (a Solyndra Platinum Solution Provider based in Reutlingen, Germany), together with its Belgium subsidiary Enerdeal. The installation consists of more than 17,000 modules covering 34,000m² of roof space and generates an annual yield of about 2400MWh (enough to power more than 700 households).

"Their simple, non-penetrating, flat-mounting system allows for the maximum level of roof coverage," says U|S|E's CEO Arnold Berens. "This helps companies like ours carry out quick and simple installations, reducing costs while maximizing yields per square meter — a solution that keeps both building owners and their insurers happy," he adds.

Delhaize is a winner of the Platinum Leadership in Energy and Environmental Design certification from the US Green Building Council. The Belgian multi-national has committed to reducing its CO₂ emissions by 20% by 2020, and rooftop solar is a part of its strategy.

"Having worked with Solyndra on previous installations, the choice of supplier was an easy one," says Denis Knoops, senior VP business & concept development & new business opportunities of Delhaize Belgium. "The innovative panel design allows us to maximize the installed capacity, reducing our CO₂ emissions by 600 tons annually on these distribution center roofs alone," he adds.



The 3MW Solyndra CIGS PV system on the distribution center roof in Belgium.

Supermarkets and distribution centers are typically among the largest flat-roofed commercial buildings, suiting the installation of solar panels.

Solyndra says that its module design allows panels to be oriented in any direction with minimal effect on the levels of generated energy. The modules generate electricity from direct, diffuse and reflected sunlight. USE added a white Sure-Weld thermoplastic polyolefin (TPO) roof membrane from Carlisle SynTec to simultaneously maximize reflected light capture and further reduce costs through building cooling.

"This installation bears testimony to our desire and ability to engage with large-scale distributed energy projects at a time when more and more corporations are seeing the hidden value in their fixed rooftop assets," comments Clemens Jargon, Solyndra's president of EMEA.

This deal demonstrates Ex-Im Bank's commitment to US exporters such as Solyndra, as well as to foreign companies that wish to purchase high-quality US goods

Non-recourse financing for the project included assistance from the Export-Import Bank of the United States (Ex-Im Bank) and KBC Bank NV. KBC provided lower-cost, non-recourse project financing with the loan guaranteed by Ex-Im Bank under its Renewable Express program. Ex-Im's streamlined Renewable Express process for rooftop PV financings resulted in approval for the Delhaize project in just a few weeks.

"The Delhaize project represents a significant milestone for Ex-Im Bank and its Renewable Express Program," says Timothy Kim, in the Renewable Energy and Environmental Finance group of Ex-Im Bank. "This deal demonstrates Ex-Im Bank's commitment to US exporters such as Solyndra, as well as to foreign companies that wish to purchase high-quality US goods," he adds.

"Our KBC Renewable Energy Team will be able to leverage the additional acquired know-how and experience from this particular project in future renewable energy investment projects to the benefit of Solyndra and other US exporters," reckons says Dirk Mampaey, senior general manager, KBC Corporate Banking.

www.solyndra.com

Sports event center to install Solyndra CIGS PV array

The Seattle Seahawks, Sounders FC and First and Goal Inc (FGI) are to install the largest solar energy array to date in the state of Washington on the roof of Qwest Field Event Center.

The project consists of 3750 individual solar panels made in the USA by Solyndra. Capturing both direct and reflected sunlight across a unique 360° cylinder-type surface, the panels take advantage of the facility's new white 'cool roof' which conserves energy by reducing the amount of heat absorbed by the roof surface and lowering the need for building cooling. The system will cover over 2.5 acres, or about 80% of the Event Center roof.

The panels are projected to generate over 830,000kWh of electricity annually, the equivalent of powering 95 Seattle area homes for a year. The system is expected to be fully operational in late summer.

The team has hired Seattle-based



Seahawks president Peter McLoughlin checks solar panels on roof of the Qwest Field Event Center.

McKinstry, a full service design-build firm specializing in energy solutions, to install the solar array in addition to developing a comprehensive resource conservation project for Qwest Field and Event Center. McKinstry has identified modifications to reduce energy and water usage throughout the complex, including high-efficiency lighting.

The combined projects will result in a 21% reduction in annual utility

costs as well as a reduction in carbon emissions of 1346 metric tons per year (equivalent to removing 260 cars from the roads). The investment in energy and water reduction measures was made enabled by conservation rebates provided by Seattle's two main utilities, Seattle City Light and Seattle Public Utilities. Through partnerships made with the electrical union, these projects will also provide clean technology job training opportunities for local trades' people.

Since the opening of Qwest Field and Event Center, the Seahawks, Sounders FC and FGI have encouraged fan involvement in their sustainability goals. Now, fans will be able to track the current and total energy produced via the new solar array as well as track the progress against energy reduction goals through on-site educational kiosks.

www.mckinstry.com

www.solyndra.com

Solyndra CIGS PV installation providing 80% roof coverage on Pfizer Global Supply Belgian site

Solyndra International AG of Baar, Switzerland, a subsidiary of Solyndra LLC of Fremont, CA, USA, which makes cylindrical photovoltaic systems for large commercial rooftops, says that SunSwitch, a Certified Solyndra Solution Provider, has completed a 205kWp rooftop solar system installation on the rooftop of the Pfizer Global Supply site in the Walloon region of Belgium. Pfizer Animal Health decided to add solar panels to its Louvain-la-Neuve site to contribute to renewable electricity production and lower the site's carbon emissions. The installation is one of the largest in the Walloon region, and Pfizer Group's largest PV installation to date.

"The initial challenge we faced was that, due to the roof structure, we had to keep the roof load to a minimum," says SunSwitch's CEO Jérôme Kervyn de Meerendré.

"Solyndra's lightweight panels enabled us to install the panels easily and quickly. With no roof penetration, there is no risk of leaks into the building from the solar panels."

With a distributed load of just 13.9kg/m², Solyndra panels are lightweight and self-ballasting, with no penetration or attachments required. This means they are simple to install on existing flat roofs, and minimize the load.

"More and more large corporations are seeing the benefits of Solyndra solar systems," says Solyndra International AG's president Clemens Jargon. "This project, completed hand-in-hand with leading Belgian PV installer SunSwitch in just four weeks, provides an impressive 80% net photovoltaic roof coverage, resulting in a maximized power density and renewable energy production."

The installation required a total of nearly 15,000m of cable and included 15 Refu inverters. The roof area of Pfizer's plant is 3000m², of which 2400m² is covered by Solyndra panels. The 80% roof coverage increases energy generated by the roof, which will provide an annual yield of 171MWh, enough to power 38 households.

Pfizer estimates that it has reduced the cooling costs of its building by 5% due to the new white roofs. The Solyndra modules will generate enough electricity to reduce Pfizer's annual CO₂ emissions by 60 tons.

"We are delighted with the fast installation of the panels, and can see that they will make a significant contribution towards lowering our carbon emissions," says Christian Borgniet, Site Manager at Pfizer Animal Health.

www.sunswitch.be

Built-in charge boosts quantum dot solar cell efficiency

US researchers show how delta doping between layers can increase the performance of quantum dot solar cells by up to 50%.

Researchers at US military and academic institutions have improved quantum dot (QD) solar cell performance by as much as 50% through doping [Kimberly A. Sablon et al, *Nano Lett.*, published online 5 May 2011].

Up to now, QD solar cells have had disappointing performance, compared with predictions of efficiency increases of 64% through increasing the numbers of energy levels (Figure 1). The hope has been to increase the amount of light absorption and to extend the absorption edge into the infrared range. Instead, there tends to be a trade-off between modest increases in short-circuit current density (J_{SC}) offset against deterioration in open-circuit voltage (V_{OC}).

One potential problem from increasing the number of energy levels is increased recombination of carriers before they can be extracted from the photovoltaic structure, analogous to the Shockley-Read-Hall (SRH) recombination that occurs from deep impurity levels.

The research team from US Army Research Laboratory, University at Buffalo, and the US Air Force Office of Scientific Research Physics and Electronics directorate (AFOSR/NE) set out to investigate the possibility of using doping to improve QD solar cell performance by adding charge to the dots. Such doping has been found to avoid deterioration of V_{OC} in normal heterojunction solar cells (i.e. without dots). In addition to the voltage improvement, the researchers also expected that doping-induced light absorption processes would aid energy harvesting and the extension of infrared response (Figure 1b, c).

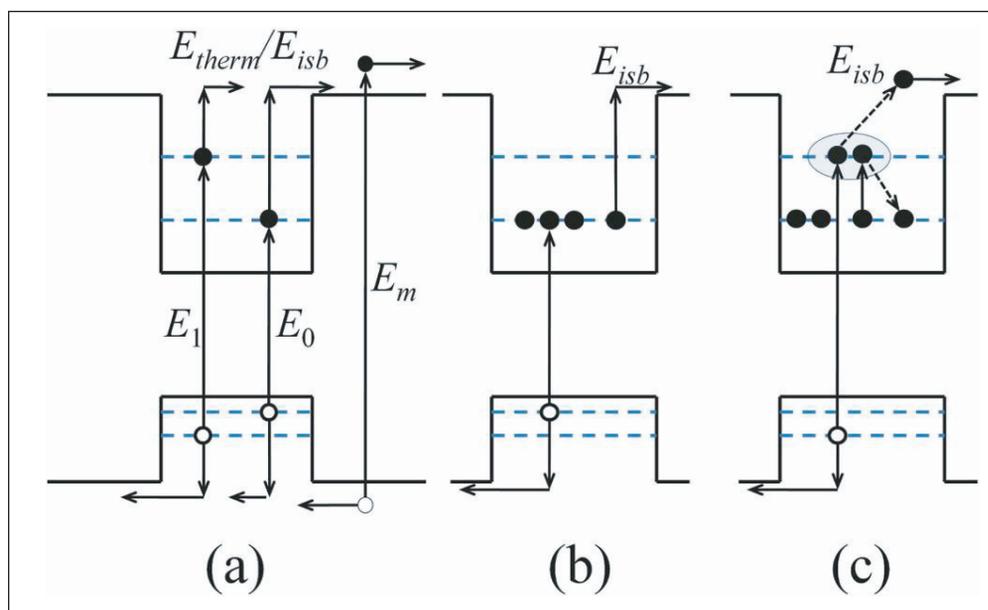


Figure 1. (a) Photogeneration of electron–hole pairs into the ground QD state (E_0) and into the excited QD state (E_1) followed by either thermionic emission (E_{therm}) or intersubband photoexcitation (E_{isb}) into the conducting channel; E_m is the direct photogeneration in the GaAs matrix. (b) Process induced by n-doping with IR transition of an electron from the localized to the conducting state. (c) Another doping-induced process, where the radiation excites two electrons to QD excited states, then — due to strong inter-electron interaction in a QD — one of these electrons transfers to the conducting state and the other transfers to a low-energy state.

In particular, the researchers expected improvements from adding electrons to the dots: “The energy-level spacing for electrons in QDs is relatively large. It substantially exceeds the spacing for holes and the thermal energy. For this reason, it is precisely the electron intradot processes that limit the electron–hole escape from QDs. Thus, it is critically important to enhance the photoexcitation of electrons rather than holes.”

The material structure of their quantum dots with built-in charge (Q-BIC) solar cell (Figure 1) was created using molecular beam epitaxy (MBE) on heavily doped n-type gallium arsenide substrates. The n-type buffer

layer was grown at 595°C, while the quantum dot layers were grown at the lower temperature of 530°C.

Quantum dots were stacked in 20 layers consisting of 2.1 monolayers of indium arsenide (InAs) separated by 50nm GaAs spacers. The effect of putting a very thin layer of InAs in GaAs is for phase separation to occur, resulting in self-assembled InAs quantum dots.

The distance between the layers was made relatively large in order to dissipate strain and hence suppress dislocations. In addition, the large spacing reduces tunneling and prevents formation of an intermediate band.

Delta doping between the layers was used to provide electrons to occupy the quantum dots with up to six electrons on average. (Delta doping with p-type material, adding holes to the quantum dots instead, was found to reduce conversion efficiency, as expected.) The structure was completed with three p-doped layers.

The epitaxial material was used to create circular solar cells of 250µm diameter. The n-type contact consisted of annealed tin-gold-tin evaporated on to the back side of the substrate. A ring p-type contact was used with 100µm opening, consisting of chromium-gold. The devices were mounted in 68-pin leaded chip carrier (LDCC) packages using indium.

The researchers report on their measurements (Table 1): "For the most heavily doped sample, the photovoltaic efficiency improves by as much as 50% compared with an undoped device. Because we have not observed any evidence of the effect saturating, we can expect an even stronger enhancement of the photovoltaic efficiency for further increase of the doping level."

However, "One of the limitations on the doping level may originate due to Auger recombination, which at the current doping levels remains substantially weaker than the Shockley-Read-Hall recombination." Auger recombination only occurs when there are large numbers of carriers present.

Spectral investigations showed that one effect of delta-doping quantum dots is to increase the response to longer-wavelength photons (880–1150nm), at the expense of short wavelengths (less than 880nm).

The researchers associated the response above 920nm with QD excited and ground states. Beyond this, one also finds a rise in the region 4.8µm (4800nm) that the team attributes to a transition from the dot ground state to the low-energy resonance conducting state (E_{isb} in Figure 1b). A broad weak peak is also seen above this up to ~8.0µm, where the experimental measurements are close to the edge

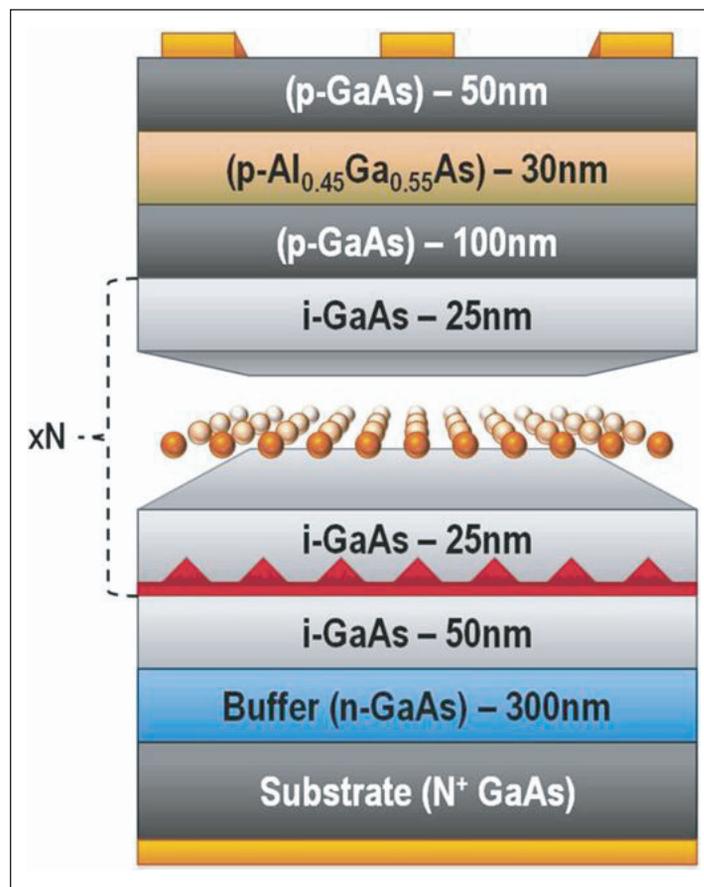


Figure 2. Growth diagram of delta-doped QD solar cell structure.

of their capability. The strength of the peak depends on the amount of delta doping and is completely absent in undoped GaAs reference samples (i.e. without QDs).

The researchers also believe that their structure could benefit from pumping effects, where the energy harvesting takes place in a number of steps: "The improvement of IR harvesting is anticipated to be even stronger at higher radiation intensities due to optical pumping effects. This makes the Q-BIC solar cells promising candidates for use with concentrators of solar radiation." ■

<http://pubs.acs.org/doi/abs/10.1021/nl200543v>

The author Mike Cooke is a freelance technology journalist who has worked in the semiconductor and advanced technology sectors since 1997.

Table 1. QD solar cell parameters under 1 sun (AM1.5 G) at 100mW/cm² illumination for QD solar cells as a function of doping designed to provide 0, 2, 3, and 6 electrons per dot on average.

Average dot electron population	J_{sc} (mA/cm ²)	V_{oc} (V)	Fill factor (%)	Efficiency (%)
0	15.1	0.77	77	9.31
2	17.3	0.74	76	9.73
3	18.5	0.79	75	12.1
6	24.3	0.78	72	14.0

Short-wavelength quantum cascade lasing without antimony

ETH-Zürich researchers achieve antimony-free Watt-level emission at room temperature at sub-3.6 μm wavelengths.

The Institute for Quantum Electronics at ETH-Zürich has achieved short-wavelength performance (near 3 μm) in quantum cascade lasers (QCLs) without using antimony (Sb) [A. Bismuto, M. Beck, and J. Faist, *Appl. Phys. Lett.*, vol98, p191104, 2011].

Up to now, QCLs have needed to contain Sb to push wavelengths below 3.6 μm . However, commercial producers would prefer not to use this material in their devices.

Professor Jerome Faist, the leader of the research team, comments: "Sb is a relatively difficult material to control and is not so commonly used in epitaxy. It also makes re-growth more difficult if one wants to make buried heterostructures." Faist was part of the Bell Labs team and lead author of the pioneering paper on QCLs published in 1994.

The ETH-Zürich team sees environmental monitoring applications for QCLs in the 3 μm region since this range contains the fundamental frequencies for the stretching modes of C-H, N-H, and O-H bonds that abound in materials of interest. "These absorption lines can be several orders of magnitude stronger than the overtone and combination bands in the near infrared (NIR), permitting the measurement of extremely low concentrations using compact and relatively simple systems," researchers comment. High-powered QCL devices could also be used for back-scattering detection and other radar-like light detection and ranging (LIDAR) imaging methods.

The active region (Figure 1) of the Sb-free QCL epitaxial structures were produced on n-type indium phosphide (InP) substrates by using solid-source molecular beam epitaxy (MBE). The device's active region consisted of strain-compensated layers of indium gallium arsenide ($\text{In}_{0.72}\text{Ga}_{0.28}\text{As}$), indium aluminum arsenide ($\text{In}_{0.52}\text{Al}_{0.48}\text{As}$), and

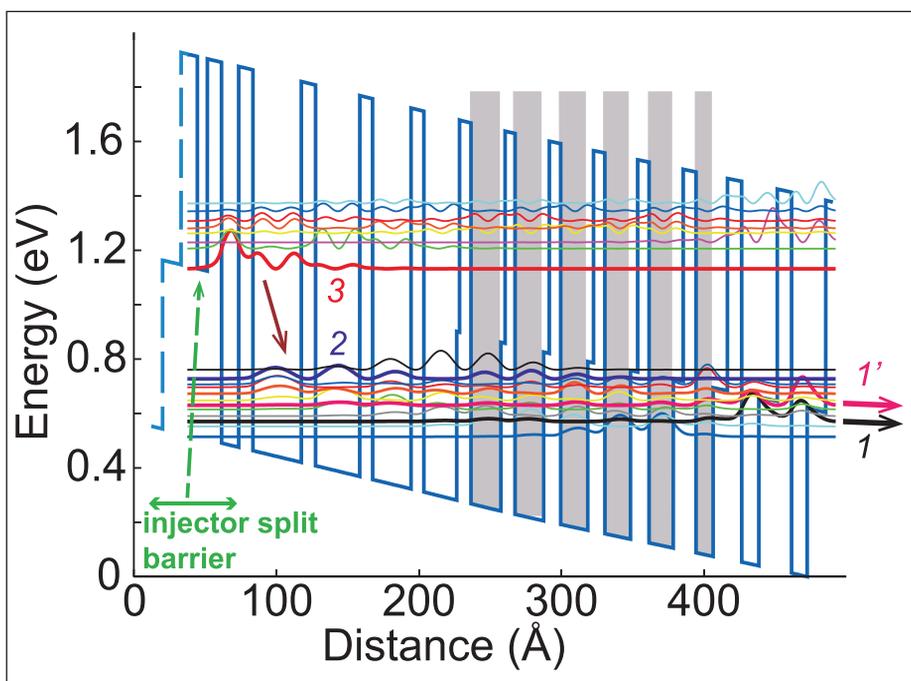


Figure 1. Conduction band diagram of a period of the active region at an average field of 120kV/cm. Moduli squared of the relevant envelop wave functions are shown. Light gray is used to show doped wells. Part of the previous active region period is shown as a dashed line.

aluminum arsenide (AlAs) arranged in 30 periods of 37 layers. One reason to use binary AlAs compound barriers is to eliminate the alloy scattering of ternary materials such as AlAsSb (or InGaAs). Two 200nm confinement layers of InGaAs sandwiched the active region.

Cladding layers (2 μm and 1 μm n-InP, followed by 100nm highly doped InGaAs) were grown using metal-organic chemical vapor deposition (MOCVD).

The cascade structure was based on traditional bound state-to-continuum transitions with an enlarged lower mini-band designed to extract carriers efficiently. The strain of the structure was analyzed using x-ray analysis. The AlAs layers had 3.5% compressive strain, with respect to InP, and the InGaAs layers were 1.3% in tension. However, the overall strain was less than 0.1%. ▶

► The epitaxial material was processed into standard 10–20 μm -long ridged laser devices. Insulation was provided by silicon dioxide; thinning to 200 μm was performed to improve thermal conductivity, along with electroplating the ridge with a 4 μm gold layer.

The cleaved devices were mounted on copper heatsinks, epi-side up. The back facet was coated with a highly reflective combination of aluminum oxide (Al_2O_3), titanium and gold. When the device was placed on a Peltier cooler, Watt-level emission (Figure 2) was observed at room temperature, performance that is “comparable to what was observed for Sb-containing QCLs”, according to the researchers. Threshold currents as low as 3.6 kA/cm^2 were also achieved at room temperature, along with a slope efficiency of more than 600 mW/A .

Temperature-dependent measurements between 250K and 350K showed a shift in wavelength from around 3.25 μm to 3.35 μm , more precisely a shift rate/tuning coefficient about 0.98 nm/K . Characteristic temperatures for threshold current (T_0) and slope efficiency (T_1) were 100K and 70K, respectively. These figures are also comparable with those of Sb-containing QCLs. ■

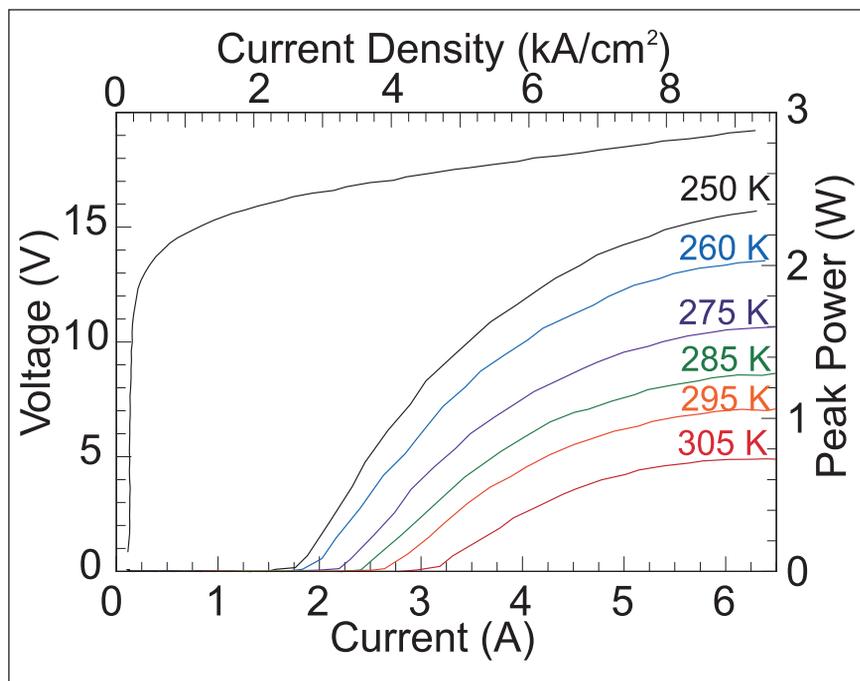


Figure 2. Pulsed power–voltage–current characteristics of a high-reflection-coated 4.75mm-long and 18 μm -wide laser for different heat-sink temperatures.

<http://link.aip.org/link/doi/10.1063/1.3589355>
Author: Mike Cooke

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ZnO particle enhancement to nitride LED light extraction

Spin-coated zinc oxide nanoparticles have been used to boost nitride LED light power output by 39% without raising the forward voltage.

Researchers at Chonbuk National University in South Korea have developed a technique to improve light extraction efficiency in nitride LEDs using zinc oxide (ZnO) nanoparticles in an indium tin oxide (ITO) film to reduce total internal reflection at the air interface [Beo Deul Ryu et al, *J. Appl. Phys.*, vol109, p093116, 2011]. The resulting device has up to 39% improved output power without impacting the electrical performance.

A good LED depends on both efficient production of photons in the active layers and extraction from the device into the outside world. Extraction is a particular problem in nitride devices since these materials have high refractive indices. For example, gallium nitride (GaN) has a refractive index of 2.5. This severely restricts the angles at which light incident on the GaN–air interface can be transmitted out rather than totally reflected back into the device.

A number of different techniques have been directed at improving light extraction efficiency of nitride LEDs, usually through some sort of patterning of the device emission surface or adding layers of different materials.

Some groups have recently used zinc oxide nano-tips or nano-rods to enhance light extraction by up to 70%. Unfortunately, these devices also have an increased forward voltage for operation, which means that energy is wasted. The increase in forward voltage is attributed to damage of the transparent p-electrode caused by the high-temperature ZnO nano-tip or nano-rod growth method.

The Chonbuk method is to use already formed ZnO nanoparticles that can be spin-coated onto the epitaxial nitride semiconductor wafer. The epitaxial structure (Figure 1) was grown on sapphire using metal-organic chemical vapor deposition. The active region consisted of a five-period multi-quantum well of InGaN/GaN pairs with a blue emission wavelength of about 460nm.

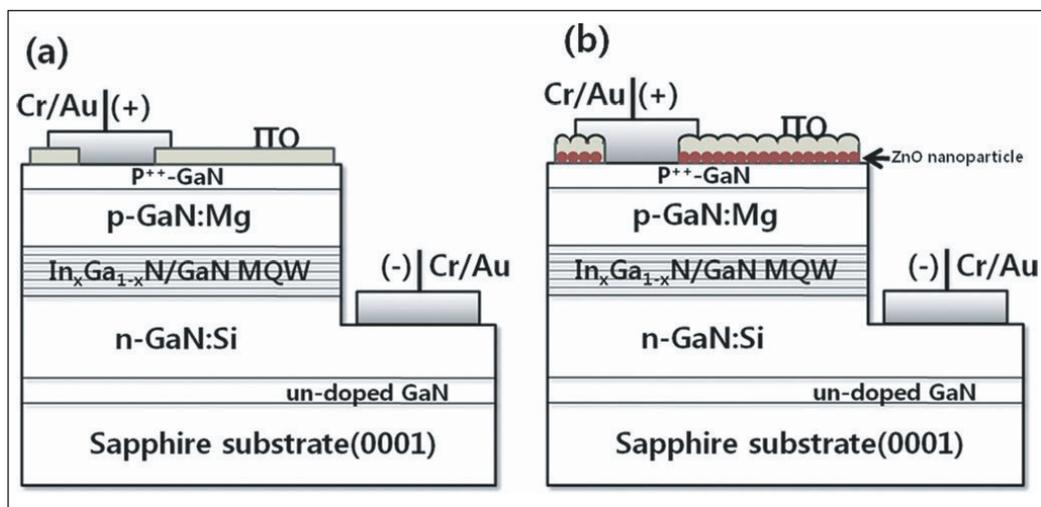


Figure 1. Schematic cross section of (a) conventional LED and (b) LEDs using ZnO nanoparticles.

Before further processing, the LED wafer was cleaned with acetone, isopropanol and deionized water. The ZnO particles (~20nm in diameter) dispersed in methanol were then spin coated onto the LED wafer surface. The spin cycle consisted of three steps: 500 rotations per minute (rpm) for 10 seconds, 1500rpm for 30 seconds, and 3000rpm for 30 seconds. Various numbers of spin cycles were used to vary the density of ZnO particles on the surface (Table 1). The particles were then covered with 200nm of indium tin oxide (ITO) annealed at 600°C for 30 seconds in air.

Dilute nitric acid was used to remove unwanted ZnO particles and ITO. Mesa structures were created using inductively coupled plasma (ICP) etching. The metal contacts consisted of chromium-gold.

The current–voltage (I–V) characteristics were unaffected by different levels of ZnO nanoparticles (Figure 2),

Table 1. ZnO particle density versus spin cycles.

Sample	Spin cycles	ZnO particle density
A	1	$4.14 \times 10^{10} / \text{cm}^2$
B	2	$5.32 \times 10^{10} / \text{cm}^2$
C	3	$8.31 \times 10^{10} / \text{cm}^2$
D	5	$1.40 \times 10^{11} / \text{cm}^2$
Reference	0	$0 / \text{cm}^2$

unlike other treatments designed to improve the extraction efficiency such as ZnO nano-tips or nano-rods. The forward voltage at 20mA was around 3.45V. At the same drive current (20mA), light output powers for samples A, B, C and D were increased over a conventional device by 9%, 27%, 39% and 19%, respectively.

The researchers ascribe the improved light extraction to light scattering by the ZnO nanoparticles and to the nano-rough morphology of the covering ITO film. However, with the highest density of nanoparticles, one sees increased scattering/reflection, reducing the amount of extracted light.

The researchers comment: "both the nano-rough ITO surface and the ZnO nanoparticles presumably improve the angular distribution of emissions in the optical phase space, leading to a larger escape cone at the nano-rough ITO film. Moreover, the reduction in the total internal reflection as a result of the difference in refractive indices at the GaN/ZnO/ITO interfaces has a significant impact on the enhancement of light output power."

The refractive indices of GaN, ZnO, and ITO are 2.5, 2 and 1.9, respectively.

Some measurements were made of transmittance of light by the nanoparticle layers before and after deposition of the ITO film. Without the film, samples A, B, C and D had transmittances of 98%, 97%, 93% and 90%, respectively. Planar ITO film (i.e. without ZnO nanoparticles) had a transmittance of 90%, and samples A, B, C and D had transmittances of 86%, 85%, 83%, and 81%, respectively.

The researchers believe that greater enhancement can be achieved through optimizing the nanoparticle dispersion technology. ■

<http://link.aip.org/link/doi/10.1063/1.3575174>

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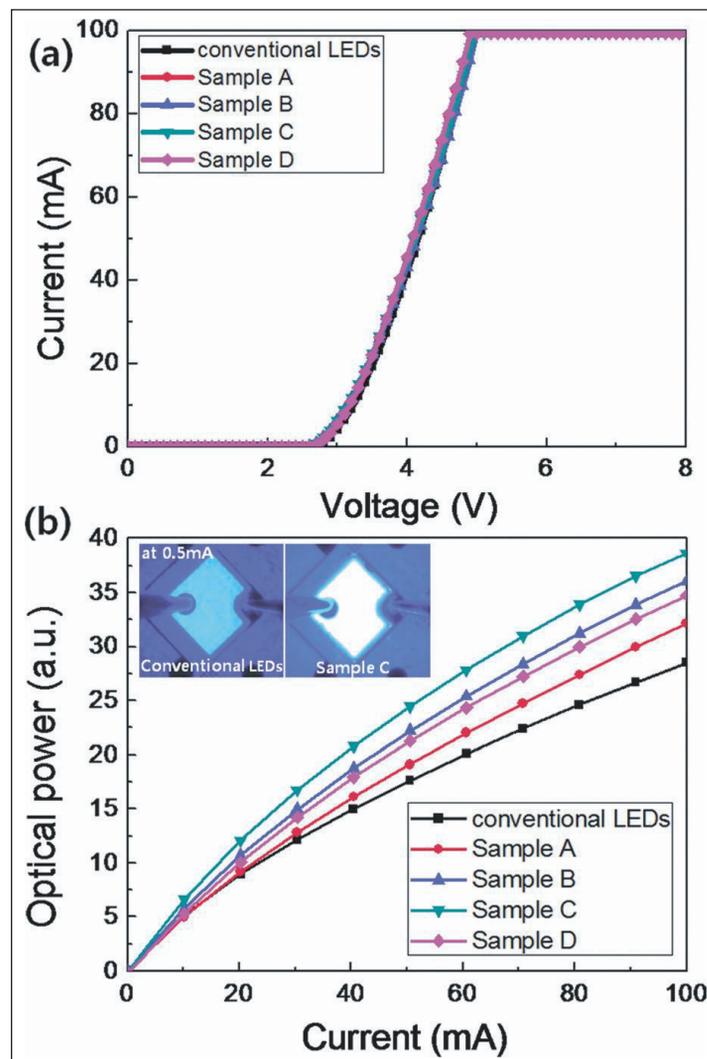


Figure 2. (a) Current–voltage and (b) light output power–current characteristics of samples A, B, C and D. Inset in (b): optical microscopic photographs of a conventional LED and sample C.

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Nitrogen-polar advantages for longer-wavelength nitride LEDs

Ohio State University uses new N-polar growth model to create 540nm green emitters.

Ohio State University (OSU) has used a new growth model for nitrogen-polar (N-polar) nitride material to create 540nm (green) LEDs at 600°C using plasma-assisted molecular beam epitaxy (PAMBE) [Fatih Akyol et al, Jpn. J. Appl. Phys., vol50, p052101, 2011]. One of the researchers is also affiliated with Turkey's Atatürk University.

N-polar growth is quite widely used in the development of nitride semiconductor electronic devices and has achieved comparable performance to gallium-polar (Ga-polar) devices. This has not been the case so far for optoelectronic devices.

In the case of long-wavelength light-emitting devices, it is hoped that, by reversing the direction of the polarization field in nitride devices, performance and growth parameters can be changed beneficially.

To raise the wavelength into the green part of the visible spectrum, one needs increasing amounts of indium in the nitride alloy. Unfortunately, indium nitride has a much lower optimal growth temperature than the gallium nitride it is being alloyed into.

Also, the two materials have a different lattice constant, so the InGaN layers are strained compared with the background GaN lattice, leading to large strain-dependent (piezoelectric) polarization fields.

These factors make it difficult to grow high-quality InGaN multi quantum well (MQW) structures.

N-polar InN can be grown at temperatures about 100°C higher than with Ga-polar growth using PAMBE. It is believed that this is because InN has higher stability on N-polar surfaces. Inspired by this, the OSU group has recently grown InGaN at 'significantly higher' temperatures than usual by growing in the N-polar direction.

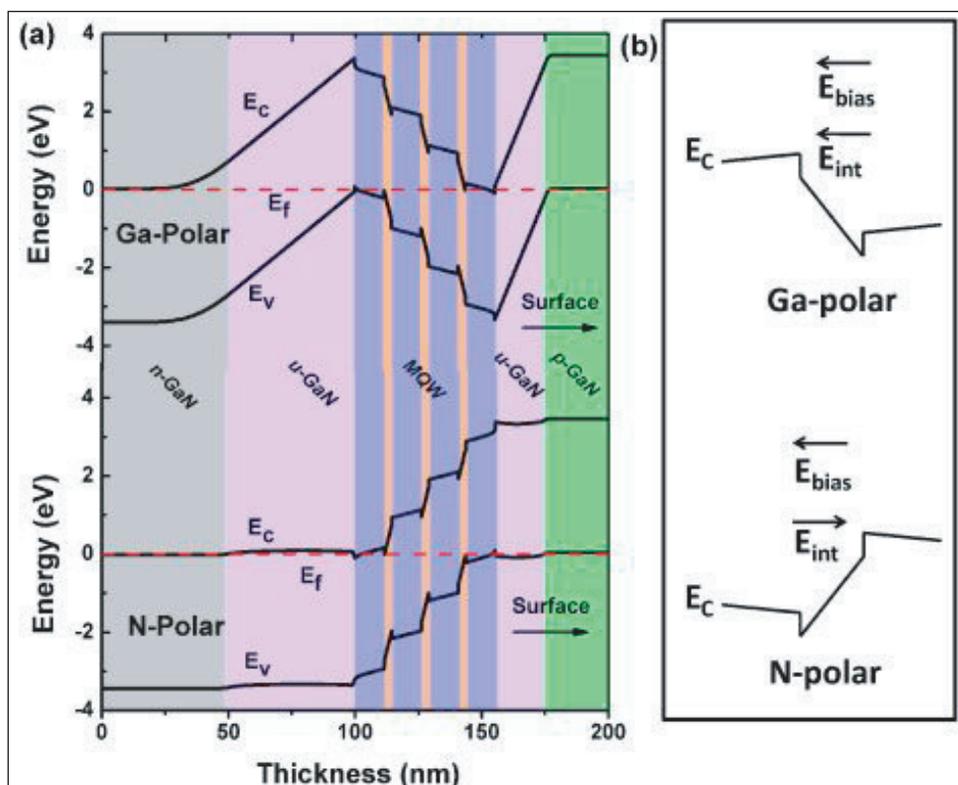


Figure 1. (a) Schrödinger-Poisson computation of energy band diagrams of typical InGaN MQW device with both polarities, including spontaneous and piezoelectric polarization. (b) State of intrinsic (including both spontaneous and piezoelectric polarization) and bias-induced electric fields in the QWs of a typical device in both polarities.

In addition, the high polarization fields can lead to poor carrier confinement in the active region of light-emitting devices. Normal growth techniques on c-plane GaN templates lead to crystal structures oriented with a Ga-face surface. Orienting in the opposite N-polar direction reverses the spontaneous and piezoelectric polarization fields, which can be advantageous in terms of carrier confinement and thus device performance.

One effect is that the polarization field then acts in the direction of the depletion of the p-n junction structure, reducing the depletion width (Figure 1). This is in contrast to Ga-polar devices, where the polarization field points in the opposite direction, increasing the depletion

width. The reduced depletion width is expected to reduce turn-on voltages for light-emitting devices.

Another effect is that, under bias, the polarization field and bias field tend to act against each other in N-polar devices. This means that there is less tendency for the electrons and holes to separate (quantum-confined stock effect, QCSE), unlike in Ga-polar devices. Electron-hole separation reduces light-emission probabilities.

OSU used an N-polar free-standing LED-quality GaN template (dislocation density $\sim 10^9/\text{cm}^2$) from Lumilog in France. The growth was carried out using RF PAMBE. During the multi quantum well (MQW) growth (Figure 2) the gallium and indium fluxes were kept constant with an In-rich environment, leading to In-coverage of the surface. The InGaN composition for wells and barriers was controlled by the nitrogen flux. The growth temperature was 600°C.

The p-contact consisted of nickel-gold-nickel. Inductively coupled plasma (ICP) etching was used to create mesas down to the n-type layer, where a titanium-gold contact was deposited. The device area was $17,000\mu\text{m}^2$. Measurements were carried out at room temperature using continuous-wave (cw) operation.

The turn-on voltage of the device was 5V with differential resistance of 72Ω ($0.012\Omega\text{-cm}^2$). Some variation in light intensity was found across the contact, which was attributed to unoptimized growth of the p-GaN layer and ohmic contacts.

Performance was tested up to 30mA, corresponding to $176\text{A}/\text{cm}^2$ density (Figure 3). The researchers describe the increase in electroluminescence as 'linear' up to $88\text{A}/\text{cm}^2$ (15mA), beginning to saturate after this, due to self-heating effects on the device operation.

The blue-shift between 2mA (563nm) and 30mA (540nm) was 23nm, attributed to screening of the piezoelectric field by electrons and holes at higher injection current density. The blue-shift between 15mA and 30mA was only 0.7nm. The much smaller blue-shift in this range is again attributed to self heating, with the higher junction temperature reducing the energy bandgap, competing with 'band-filling effects', where the energy levels fill up at higher currents, widening the energy difference between electrons and holes.

The spectral peak full-width at half maximum (FWHM) value was wider than with state-of-the-art green LEDs. "Growth conditions used for the LEDs described in this work were optimized only to achieve the required emission wavelength," the researchers say. They

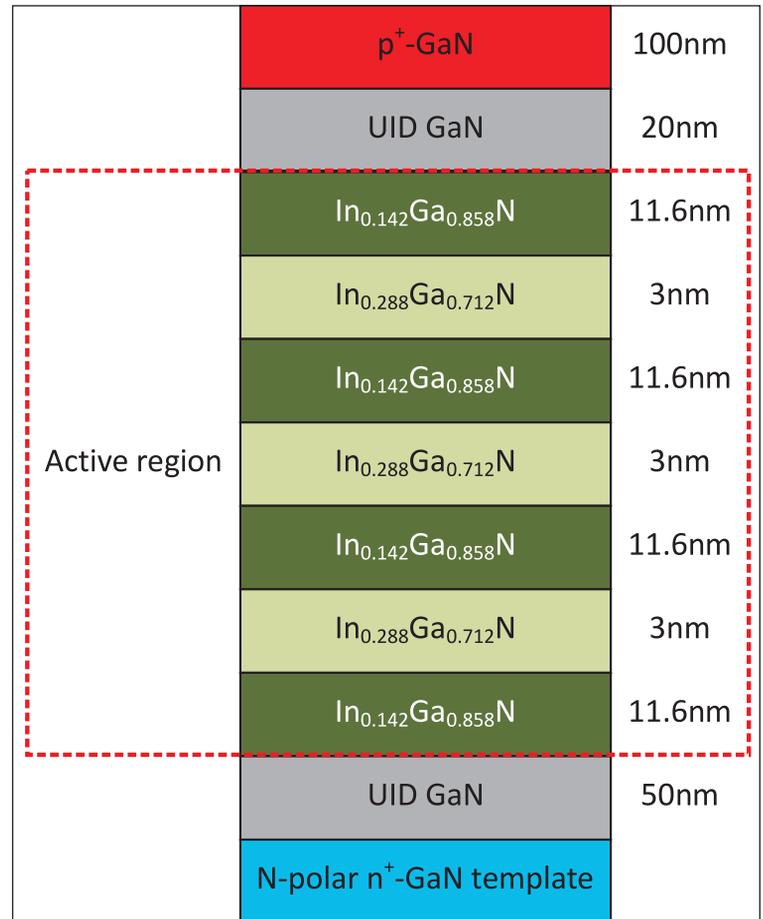


Figure 2. Epitaxial design of the green MQW LED.

believe that fluctuations in indium and quantum well thickness contribute to the FWHM results. ■

<http://jjap.jsap.jp/link?JJAP/50/052101/>

Author: Mike Cooke

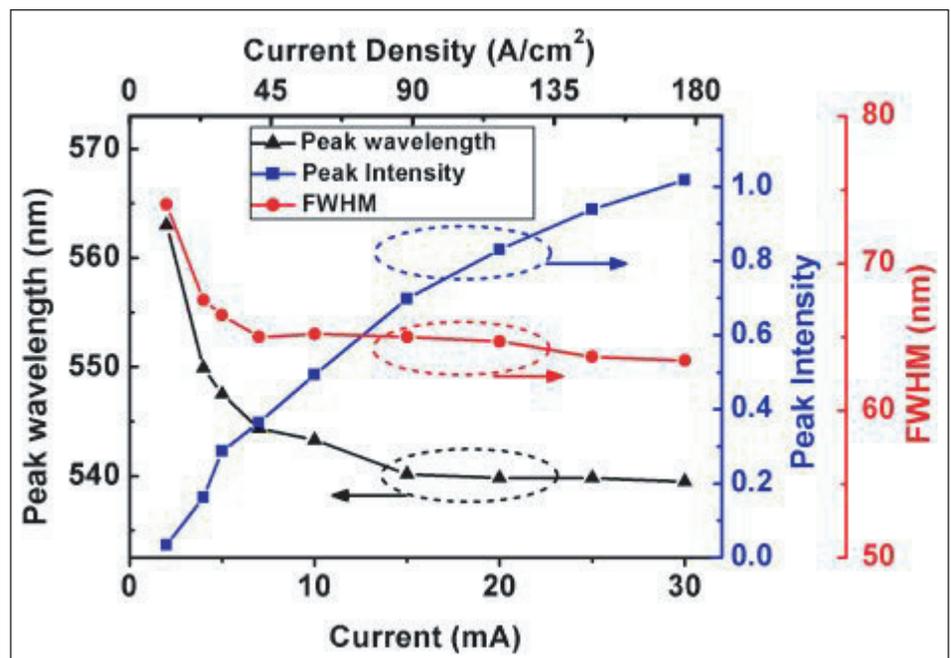


Figure 3. EL emission peak intensities (normalized to the highest value), peak wavelengths and FWHMs as a function of driving current from 2mA to 30mA ($11\text{A}/\text{cm}^2$ to $176\text{A}/\text{cm}^2$).

High-brightness nitride LEDs on silicon through wafer bonding

Korean research team uses wafer bonding to produce 9.5mW light output power from GaN-on-Si LED at an injection current of 20mA.

Researchers based in Korea have used wafer bonding to create high-brightness LEDs from nitride on silicon material with 9.5mW light output power at an injection current of 20mA [Seung-Jae Lee et al, Appl. Phys. Express, vol4, p066501, 2011]. The work involved researchers from Korea Photonics

Technology Institute as well as one researcher from Chonbuk National University.

The big attraction of silicon-based technology is the potential for lower costs, in terms of substrate prices, processing with standard tools, and the use of larger-diameter wafers (up to 300mm) for mass pro-

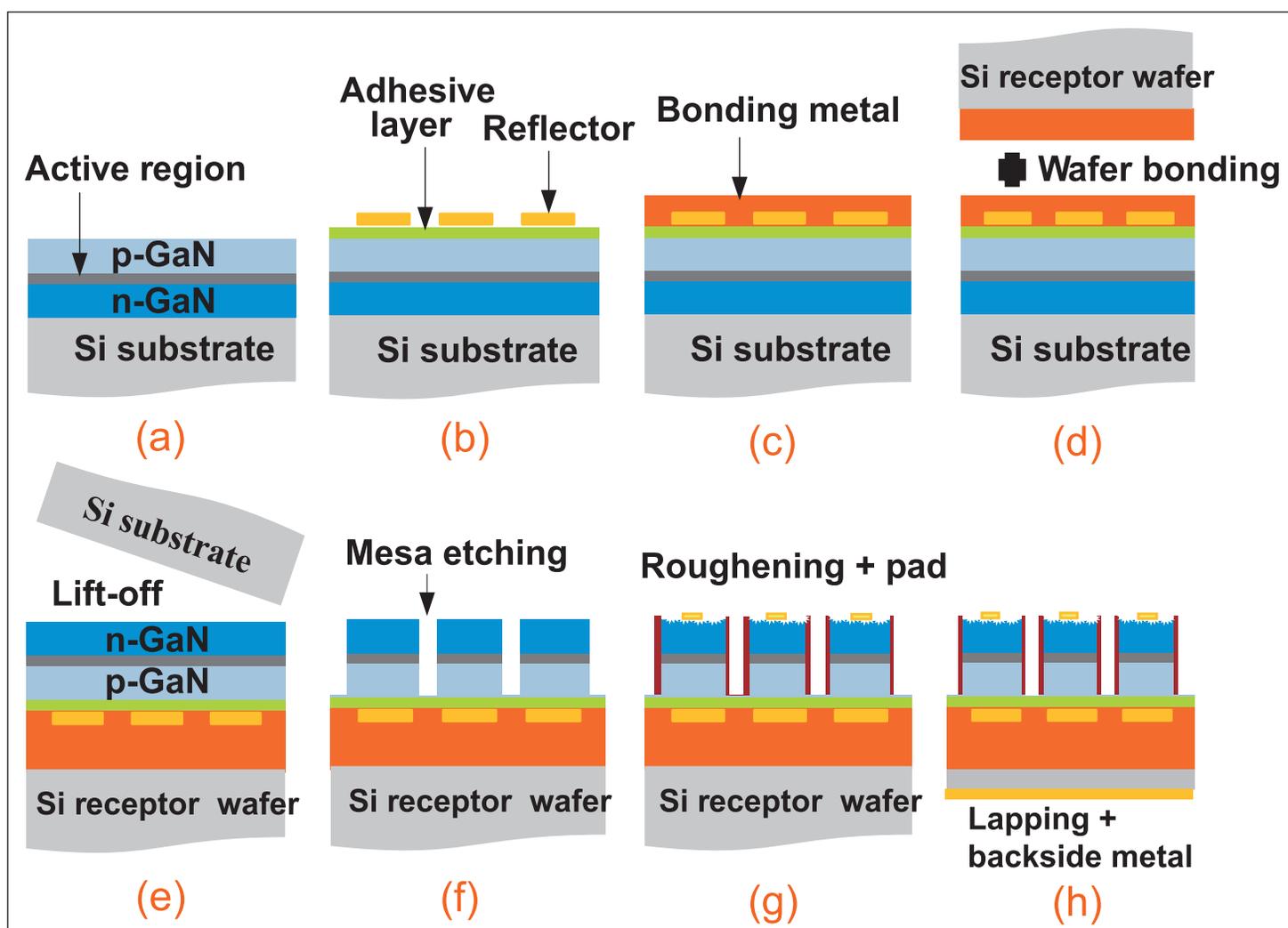


Figure 1. Fabrication process for vertical LED: (a) GaN-based LED grown on Si(111) substrate, (b) ITO and reflection metal deposition, (c) barrier/bonding metal deposition, (d) wafer bonding to Si(100) receptor substrate, (e) removing Si(111) substrate, (f) mesa etching, (g) n-GaN roughening and formation of n-electrode, and (h) p-contact metallization after thinning Si.

duction/economies of scale.

Nitride semiconductors can be grown on silicon (Si) substrates oriented in the (111) crystal direction, but there is a large lattice mismatch, and different thermal expansion properties can introduce a large tensile stress, and even cracking, in the nitride layers. Also, because the bandgap of silicon is narrower than that of light emitted from nitride devices, there is heavy absorption of radiation that travels through the substrate material.

The basic epitaxial material for the Korean device was grown using MOCVD on n-Si(111) wafers. The active region consisted of five quantum wells of InGaN separated by GaN barriers. Before the active region, an AlN complex buffer and then Si-doped n-GaN layers were grown. The device layers were completed with a magnesium-doped p-GaN layer.

To overcome the problem of light absorption by the silicon substrate, these LED layers with a reflecting layer deposited on top were transferred using wafer bonding techniques to another Si wafer (Figure 1). The ohmic p-GaN contact consisted of 200nm indium tin oxide (ITO), annealed at 650°C for one minute. The reflection metal was 200nm gold-copper alloy and the bonding metal was a series of gold-tin layers. A barrier of nickel-titanium-platinum layers was used to prevent damage of the reflecting by the bonding layers.

The p-Si(100) receptor wafer was prepared with a titanium-gold layer. The receptor and the LED wafers were bonded using a pressure of 4kg-f/cm² for 30 minutes at 300°C. The material from the original n-Si(111) wafer was removed by lapping down to less than 50µm and then etching with xenon fluoride plasma.

The LED device mesas were formed using inductively coupled plasma (ICP) etching. The sidewalls of the mesas were passivated with silicon nitride and then the n-GaN surface was roughened using a boiling potassium hydroxide solution. The p-Si(100) material was thinned to 100µm by lapping and then the backside titanium-gold metal was deposited.

The epitaxial material was used to create vertical (VLED) and lateral (LLED) LED structures (Figure 2). The LLED configuration is the one that has to be used when the epitaxial material is deposited on insulating substrates. However, where both surfaces of the LED material are conducting, the VLED structure can offer better performance through more even distribution of the current flow.

The tested chips had an area of 300µm x 300µm. One effect of the vertical structure was to slightly reduce the series resistance so that the operating voltage of 3.2V at 20mA injection current was comparable to that of sapphire-based devices. The LLED voltage at 20mA was 3.5V. At the same injection current, the VLED emitted 9.2mW of light output, more than 2.6x that of the LLED's 3.5mW performance (Figure 3).

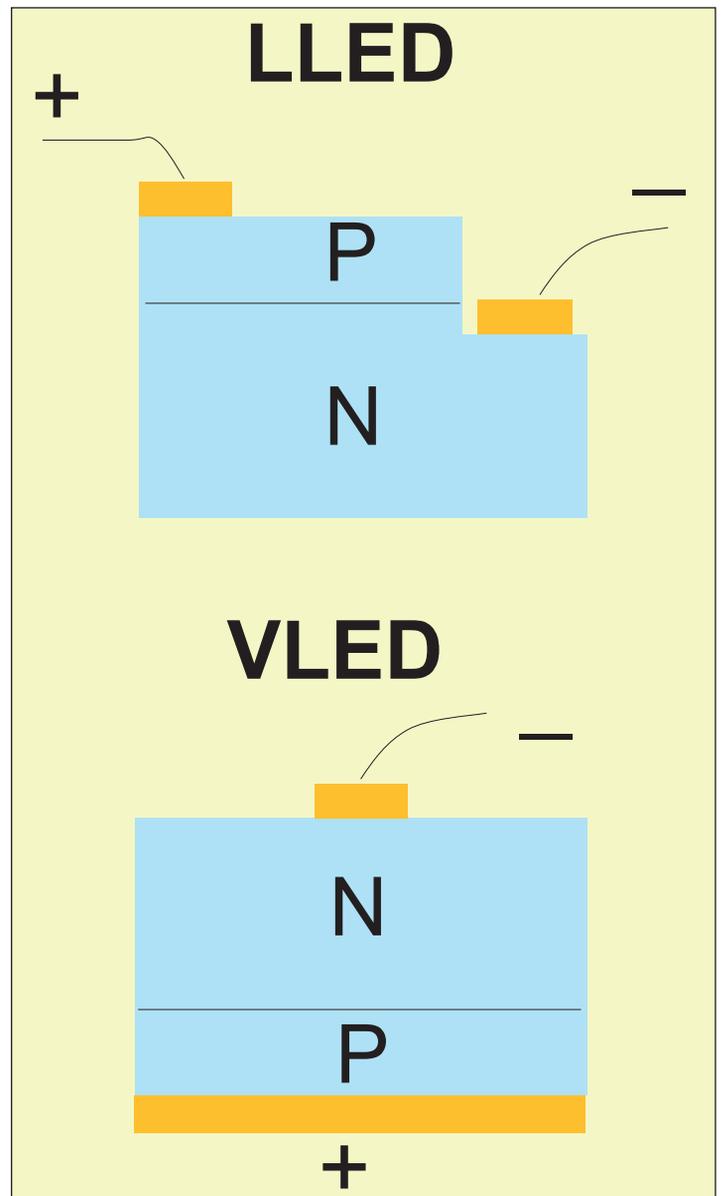


Figure 2. Lateral (LLED) and vertical (VLED) LED structures.

The researchers comment: "The superior light emission from the VLED can be attributed to the relatively larger effective light-emitting area by using only one electrode, the providing of better reflection of the downward-absorbing light by the reflection metal layer, and improvement of the light-extraction efficiency by roughening the n-GaN surface. Furthermore, the current can spread uniformly without an n-metal layer or a transparent layer (ITO), because the VLED structure was p-side down and n-side up, with an n-metal electrode. Accordingly, the VLEDs do not exhibit the current-crowding problem on the top emission area."

The researchers also tested shifts in wavelength as the injection current increased. In the low-current region there was a blue-shift, meaning that the produced photons had higher energy and shorter wavelength. Such behavior is often seen as carrier densities increase because filling with electrons and holes

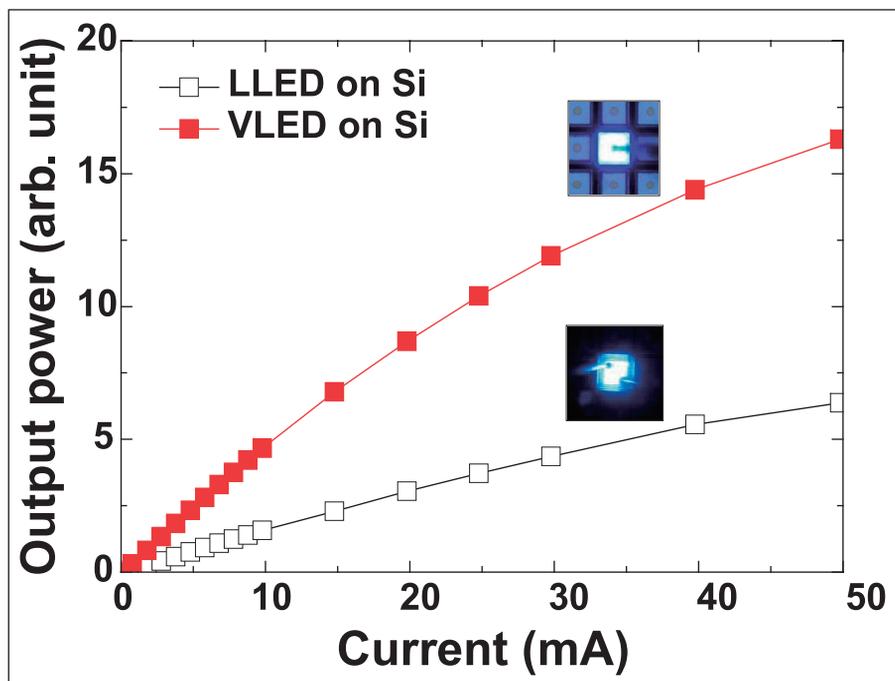


Figure 3. Comparison of the light output power vs current (L-I) characteristics of VLED and LLED.

widens the separation in the respective energy levels. At higher currents, self-heating effects begin to affect the energy-level structure itself and the bandgap becomes narrower, leading to lower-energy photons and longer-wavelength emissions (red-shift).

Both devices began emitting light with wavelengths

around 454nm. The VLED emission wavelength red-shifted down to around 452.5nm at about 41mA, and then increased to about 453.5 at 100mA. The LLED red-shifted much further to around 450.5nm at 60mA, afterwards increasing to ~451.7nm at 100mA.

The researchers believe that, by detaching the VLED from the Si(111) substrate, the tensile strain in the structure was much reduced. In the LLED, such tensile strain leads to piezoelectric polarization electric fields that affect the device performance. Such fields tend to make it harder for electrons and holes to recombine to produce photons, a behavior that is called the quantum-confined Stark effect (QCSE). The QCSE reduces recombination efficiency and also increases wavelength shifts.

The researchers conclude: "These results show the promise of Si as a large-area, inexpensive substrate for high-efficiency

GaN-based LEDs with similar performance to devices on sapphire. It is expected that GaN-on-Si-based VLED technology will be very favorable for the applications of high-power and cost-effective solid-state lighting." ■

<http://apex.jsap.jp/link?APEX/4/066501>

Author: Mike Cooke.

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Piranha gobbles up hysteresis of aluminium oxide–nitride semiconductor interface

The Naval Research Laboratory shows how nitride surface pre-treatment can cut charge traps to almost a quarter for Al₂O₃ gate insulator.

US Naval Research Laboratory researchers (with Nelson Y. Garces of Global Strategies Group) have been studying ways to improve the quality of aluminium oxide (Al₂O₃) grown on gallium nitride (GaN) by atomic layer deposition (ALD) [Neeraj Nepal et al, *Appl. Phys. Express*, vol4, p055802, 2011]

Aluminium oxide is of interest as a gate insulator for high-frequency, or high-power, nitride semiconductor transistors to reduce gate leakage currents compared with devices that use a direct Schottky metal gate contact with the semiconductor barrier. Other advantages of an insulated gate are higher breakdown voltages and higher channel current.

However, producing a high-quality insulator–semiconductor interface is tricky. In particular, one needs to avoid charge traps and fixed charges from developing that adversely affect device performance. For this, some surface preparation of the semiconductor surface before deposition is needed. For convenience, it is preferable to perform this preparation in the deposition chamber itself, rather than having to use an external process.

A popular technique for creating Al₂O₃ films is atomic layer deposition. Surface preparation in such chambers requires a relatively low-temperature process.

Three pre-treatments were studied: hydrogen peroxide–sulfuric acid (H₂O₂:H₂SO₄, 1:5), hydrofluoric acid solution (H₂O:HF, 1:1), and hydrochloric acid solution (H₂O:HCl, 1:1). Hydrochloric acid is commonly used as a native oxide etchant for GaN (e.g. for removal of oxides that form on exposure to air). The acid solution treatments were carried out for one minute at room temperature. The hydrogen peroxide–sulfuric ‘piranha’ treatment lasted for 10 minutes at 80°C. The substrate consisted of 2µm of n-GaN on sapphire.

The atomic layer depositions consisted of 250 cycles of alternating 15ms pulses of deionized water and trimethyl-aluminium (TMA), separated by 20s purges to remove unreacted precursors. The carrier gas was nitrogen. The deposition temperature was either 240°C or 260°C. The resulting film was measured to be 22nm.

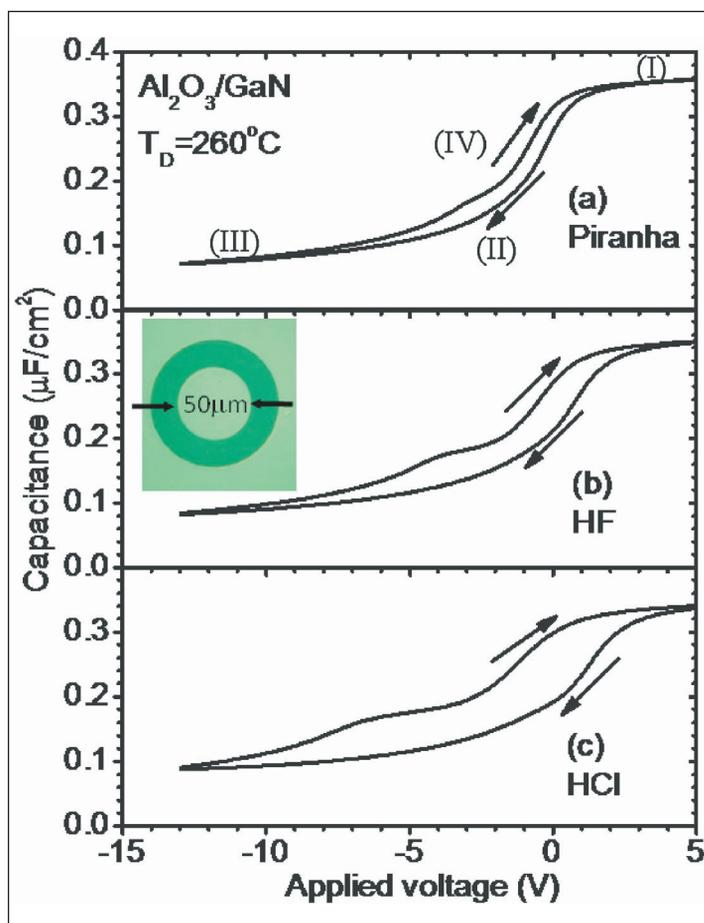


Figure 1. Capacitance–voltage curves of Al₂O₃ on n-GaN for (a) piranha, (b) HF, and (c) HCl surface treatments at deposition temperature of 260°C. Inset of (b) shows microscope image of 50µm diameter capacitor.

Circular metal-oxide-semiconductor capacitor structures were formed using photolithography and electron-beam evaporation/lift-off of a nickel-gold metal stack. The top contact had a diameter of 50µm, separated from a concentric large-area 3.4×10⁷µm² contact by a gap of 20µm.

The piranha and hydrofluoric treatments resulted in uniform and smooth layers of Al₂O₃, but the hydrochloric treatment gave non-uniform nucleation with 10–30nm diameter particles being shown in

atomic force microscopy (AFM) examinations. Such non-uniform nucleation can generate point defects (vacancies, vacancy-complexes, and interstitials) that potentially lead to higher densities of charge traps and fixed charges.

Capacitance-voltage measurements (Figure 1) showed a larger hysteresis for the sample pre-treated with hydrochloric acid, confirming that the non-uniform nucleation did indeed result in higher trap and fixed charge densities.

The researchers calculated a dielectric constant for their Al_2O_3 film of ~ 8.9 (with piranha pre-treatment). The behavior at the flat-band voltage was used to quantify the amount of hysteresis (Table 1). The measurements suggest the presence of negative trapped charge at or near the $\text{Al}_2\text{O}_3/\text{GaN}$ interface. On this measure, the piranha treatment at 260°C more than halved the trapped charge compared with hydrofluoric treatment, and almost quartered it compared with hydrochloric treatment. A similar trend was seen with 240°C treatment.

Although there are a number of possible explanations for the hysteresis, such as oxide trapped charge, interface trapped charge, and/or mobile ionized impurities, the researchers suggest that there are oxide and interface trapping states at or near the $\text{Al}_2\text{O}_3/\text{GaN}$ interface that are being charged and discharged (Figure 2). X-ray photoelectron spectroscopy did not find impurity-related peaks, leading the researchers to say that it is 'unlikely that ionized impurities contribute significantly'.

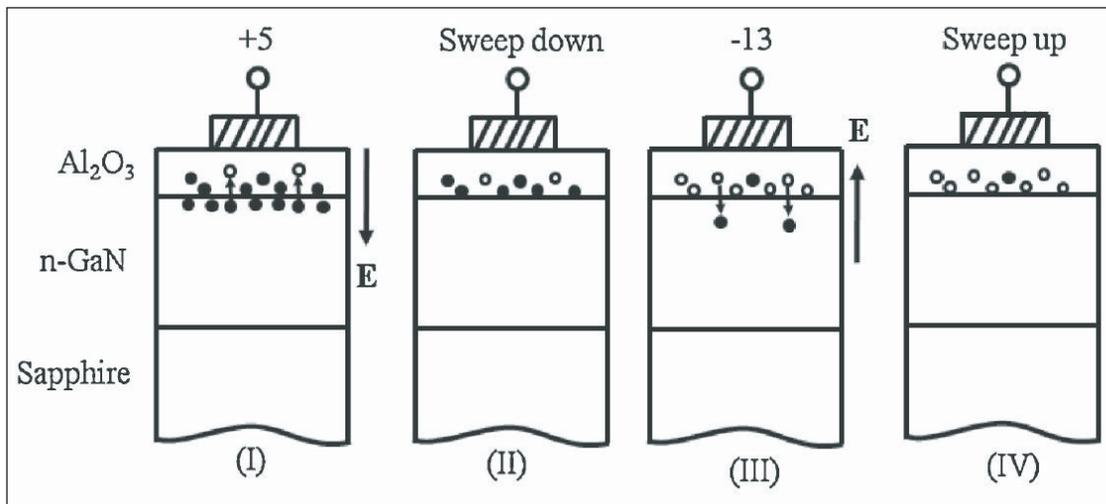


Figure 2. Schematic of electrons and their motion near the $\text{Al}_2\text{O}_3/\text{GaN}$ interface due to applied bias at the (I) accumulation, (II) positive to negative bias polarity sweep (sweep down), (III) depletion, and (IV) negative to positive bias sweep (sweep up) regions. Corresponding hysteresis curve positions are marked in Figure 1(a). Closed circles represent electrons and open circles represent neutral or positive trapping states.

The researchers comment: 'During (I) accumulation, we suspect that electrons are injected into or captured by nearby trapping states and held there during (II) the sweep from accumulation to depletion, causing a positive V_{FB} shift. In (III) deep depletion, we suspect that the large electric field causes Poole-Frenkel or direct-tunneling electron emission from oxide and interface trapping states, resulting in a net positive shift in trapped charge. Since trap states are no longer occupied during (IV) the sweep from depletion to accumulation, V_{FB} shifts negatively until electron injection/capture can take place again during (I) accumulation.'

On the basis of the present results, it is difficult to determine the relative contributions of oxide and surface state contributions to the trapping. However, a 'surface-state ledge' is seen in the hydrochloric treated sample (Figure 1(c)) that diminishes progressively with the hydrofluoric and piranha treatments. ■ <http://apex.jsap.jp/link?APEX/4/055802>
The author Mike Cooke is a freelance technology journalist who has worked in the semiconductor and advanced technology sectors since 1997.

Table 1. Summary of oxide and flat band capacitance, dielectric constant, hysteresis at V_{FB} , and total trapped charge density of ALD Al_2O_3 deposited at 260°C on n-GaN for different surface pre-treatments.

Pre-treatment	C_{OX} ($\mu\text{F}/\text{cm}^2$)	C_{FB} ($\mu\text{F}/\text{cm}^2$)	ϵ	Hysteresis at V_{FB} (V)	Total trapped charge ($\times 10^{12}/\text{cm}^2$)
Piranha	0.357	0.324	8.9	0.54	1.2
HF:H ₂ O (1:1)	0.348	0.317	8.7	1.15	2.5
HCl:H ₂ O (1:1)	0.340	0.309	8.4	2.13	4.5

Nitride HEMTs grown on CMOS-compatible silicon

Swiss/French collaboration makes devices with cut-off/maximum oscillation frequencies of 70/93GHz.

Researchers based in Switzerland and France have produced aluminum gallium nitride (AlGaN) barrier high-electron-mobility transistors (HEMTs) on high-resistivity silicon (Si) substrates oriented in a direction compatible with mainstream complementary metal-oxide-semiconductor (CMOS) integrated circuits [Diego Marti et al, Appl. Phys. Express, vol4, p064105, 2011].

The work was carried out at ETH-Zürich's Millimeter-Wave Electronics Group and Centre de Recherche sur l'Hétéro-Epitaxie et ses Applications of France's Centre National de la Recherche Scientifique (CRHEA-CNRS). The researchers comment on their achievement: "DC and RF performance of short-gate-transistor AlGaN/GaN HEMTs grown on (110) high-resistivity (HR) Si is reported for the first time."

Nitride HEMTs are being intensively developed for power amplification of radio-frequency signals and for high-power switching. The possibility of manufacture on silicon substrates promises lower production costs and hence wider application of such devices.

Previous nitride HEMTs on silicon substrates have used wafers that are oriented in the (111) crystal direction since they present a hexagonal surface that is better suited to growing wurtzite epilayers such as GaN. However, Si(111) material has poor properties in terms of CMOS circuit elements. Researchers (and manufacturers) would like to develop integrated circuits that combine the advantages of nitride HEMTs and silicon CMOS.

While the Si(001) crystal orientation is preferred at the moment in mainstream CMOS, it is difficult to grow high-quality crack-free nitride material on such wafers, limiting HEMT cut-off (f_T) and maximum oscillation (f_{MAX}) frequencies to less than 37GHz and 55GHz, so far.

Another possible silicon orientation is (110), which has even been proposed as a booster of conventional

CMOS due to improved channel transport in ultra-thin-body silicon-on-insulator CMOS devices. Nitride semiconductor devices (blue light-emitting diodes, long-gate transistors, etc) grown on Si(110) have shown similar characteristic to those grown on Si(111) substrates.

Now, having produced the first AlGaN/GaN HEMTs on Si(110), the ETH/CNRS researchers conclude: "The results indicate that it is possible to fabricate GaN HEMTs on a Si(110) substrate, suggesting that GaN epitaxy on (110) Si provides a promising avenue for the future integration of GaN and mainstream CMOS technology on a (110) Si platform."

The researchers used molecular beam epitaxy (MBE) to grow the HEMT epilayers on 2" high-resistivity Si(110) substrates. The Si wafer surface was prepared by etching away the native oxide layer with hydrofluoric acid and rinsing in deionized water before the MBE processing.

Nucleation (43nm AlN at 920°C) and stress-mitigating (250nm Al_{0.15}Ga_{0.85}N, 800°C; 250nm AlN, 920°C) layers were applied before the 1.7µm GaN buffer. The active layers consisted of 1nm AlN spacer, 18nm undoped Al_{0.29}Ga_{0.71}N barrier, and 3nm GaN cap. The purpose of the spacer was to reduce alloy scattering in the two-dimensional electron gas (2DEG) that forms at the GaN buffer-AlGaN barrier interface to provide the channel in HEMTs.

The resulting structure was subjected to a number of standard structural and electrical tests (Table 1). ➤

Table 1. Structural and electrical properties of AlGaN/GaN heterostructure grown on Si(110).

Substrate Si(110)	
GaN thickness	1.7µm
X-ray diffraction (002) peak full-width half-maximum	1044arcsec
X-ray diffraction (302) peak full-width half-maximum	1764arcsec
Substrate bow	50µm
Carrier sheet density from capacitance-voltage measurements	1x10 ¹³ /cm ²
Pinch-off voltage	5.3V
GaN background doping, n	1x10 ¹⁴ /cm ³
Carrier sheet density from Hall measurements	9.70x10 ¹² /cm ²
Mobility from Hall measurements	2047cm ² /V-s

According to the researchers, the GaN (302) x-ray diffraction peak result is directly connected to the density of threading dislocations and, on the basis of their previous research, is assigned a value of not more than $4 \times 10^9/\text{cm}^2$.

HEMTs were created with titanium-aluminum-molybdenum-gold ohmic contacts and nickel-platinum-gold Schottky metal gate electrodes. Devices with varying gate lengths of 50nm, 75nm and 100nm were produced. The head height and stem width of the gates were 120nm and 400nm, respectively. The devices were isolated on etched mesas. Silicon nitride was used as a passivation layer. The contact pads consisted of titanium-gold.

The DC performance was similar for all three gate lengths with maximum drain current of 1.2A/mm for zero gate potential. The maximum transconductance of 250mS/mm occurred at -4.5V gate potential and 6V drain bias. At -7V gate potential, the gate leakage was $7.5 \mu\text{A}/\text{mm}$.

The raw cut-off (f_T) and maximum oscillation (f_{MAX}) frequencies, without de-embedding the contacts, were 44GHz and 39GHz, respectively. On-wafer calibration structures were used to de-embed the effect of the contacts on frequency performance through appropri-

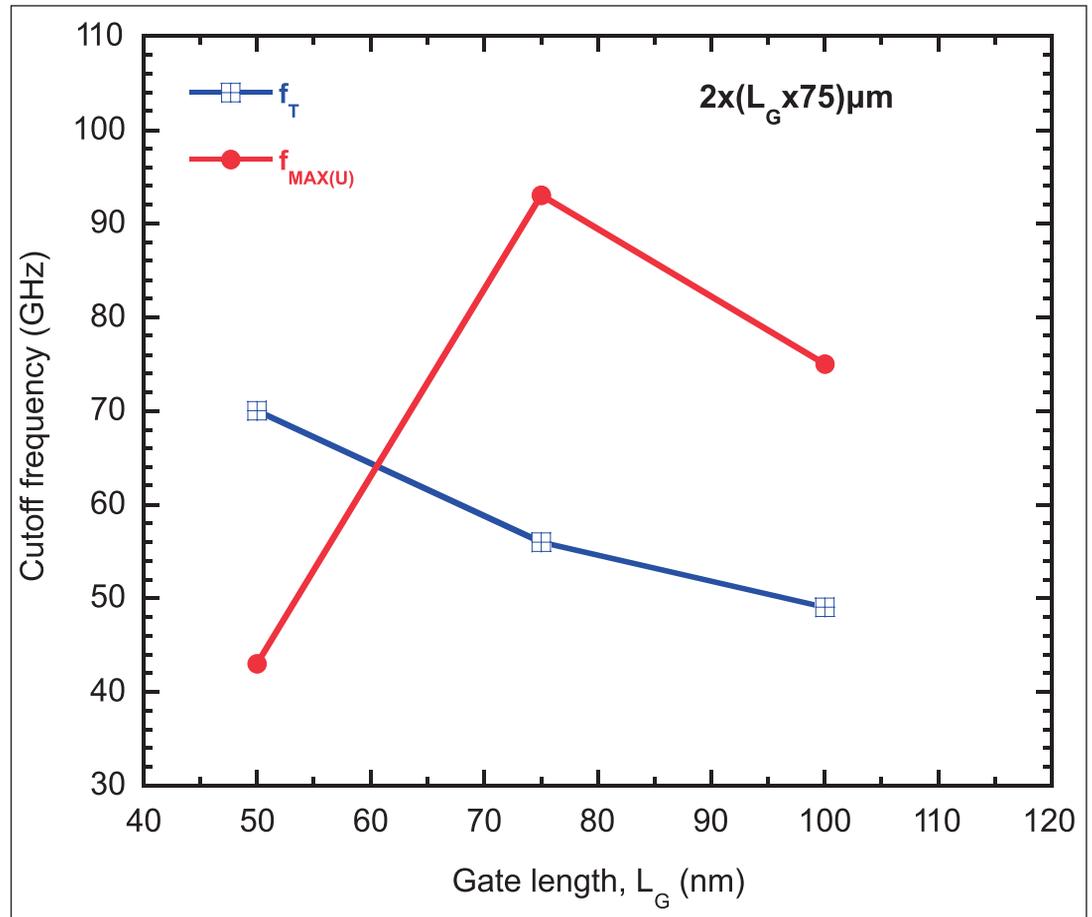


Figure 1. Dependence of f_T and f_{MAX} on gate length (L_G).

ate extrapolations. The maximum f_T of 70GHz was obtained for the 50nm short-gate device, while the best f_{MAX} was demonstrated by the intermediate 75nm gate (Figure 1). The researchers explain this as being due to a trade-off between increased gate resistance as the gate length shortens and a decrease in f_T as the gate covers more area. ■

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Author: Mike Cooke

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AlN barrier enhancements to nitride HEMTs on silicon

France's Institute of Electronic, Microelectronic and Nanotechnology (IEMN) has published three reports of record performance for nitride semiconductor high-electron-mobility transistors (HEMTs) on silicon just in the last few months. **Mike Cooke reports.**

The next generation of millimeter-wave (mmW) power amplifiers could benefit from work at IEMN, where researchers are seeking to extend the frequency performance of nitride HEMTs on low-cost silicon substrates [1–3]. Already, an extrinsic cut-off frequency (f_T) and a maximum oscillation frequency (f_{MAX}) of 85GHz and 103GHz, respectively, have been achieved for one device [3].

These latest results also give high current (more than 2A/mm) and transconductance ($\sim 600\text{mS/mm}$) figures for the structure, along with the improved frequency characteristics. The DC performance is described as being "well beyond the highest reported values of any GaN-on-Si HEMTs".

The lead investigator Dr Farid Medjdoub reports on his attendance at the Device Research Conference (DRC, Santa Barbara, CA, USA, 20–22, June 2011) where he has recently presented the group's work: "As compared to the competitors (namely US labs), it appears that a key feature of this technology (beyond the record performances) is the possibility to maintain very low leakage current while aggressively down-scaling the device. The other research groups seem to struggle with gate leakage current with their short GaN devices and use a gate insulator to overcome this problem, which in essence degrades the DC and RF performance."

The IEMN devices all used ultrathin aluminum nitride (AlN) barrier layers to maximize carrier densities in the channel, reducing on-resistance (Figure 1). The use of AlN allows the barrier layer to be much thinner than normal (less than 10nm), bringing the gate much closer to the channel region. One of the devices developed by IEMN had a barrier as thin as 3nm [2].

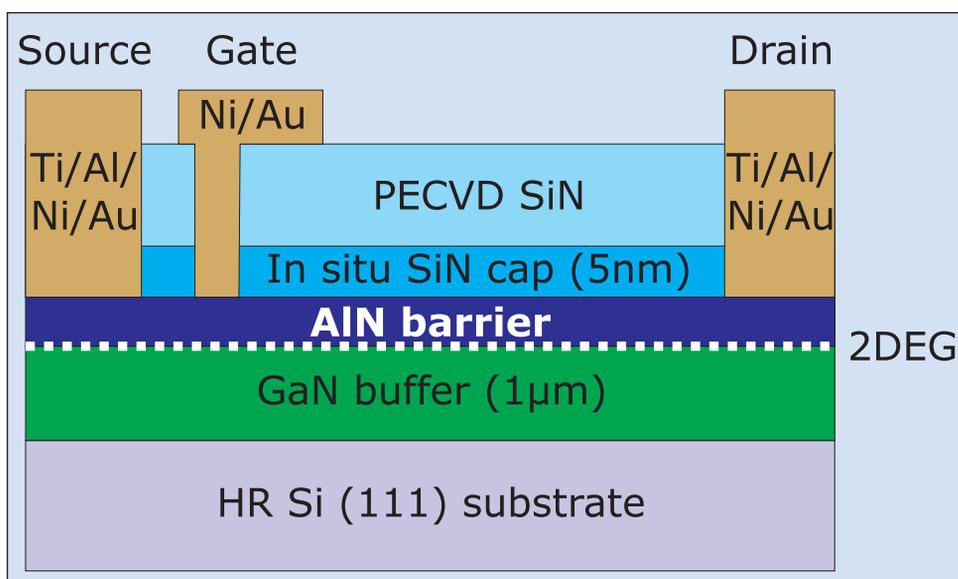


Figure 1. Schematic cross section of AlN/GaN-on-Si HEMTs fabricated by IEMN.

Nitride semiconductor material has a number of properties that makes it an attractive base for microwave power electronics applications. Among these characteristics, the large polarization charge can be used to create two-dimensional electron gases (2DEGs) with high carrier density and hence low resistance.

The wide bandgaps of nitride semiconductors also enable high power/current densities, and these materials' high thermal conductivity can be used to dissipate generated heat effectively. Improved breakdown voltages can also be expected.

In conventional nitride HEMTs, an aluminum gallium nitride (AlGaN) barrier layer is deposited on a GaN buffer, creating a 2DEG at the interface. As the barrier layer becomes thinner, the charge density decreases. Unfortunately, thinner barrier layers are needed to access high-frequency performance.

A further disadvantage is that thinner barriers make it more difficult to isolate the gate electrode from the channel, requiring the use of gate dielectric insulation,

Table 1. Physical dimensions of devices [1–3].

Ref.	AlN barrier (nm)	PECVD SiN (nm)	SiN passivation (nm)	Gate length (μm)	Gate-source (μm)	Gate-drain (μm)	Isolation implant
[1]	6	50	200	0.2	0.4	1.3	He
[2]	3	50	200	0.2	0.4	1.3	He
[3]	6	50	0	0.16	0.3	1.0	N

rather than a simpler Schottky contact, to reduce gate leakage currents. The processes used to apply dielectrics or to bring the electrode closer to the channel (e.g. recessing, where an etch process is used to make a slot in the barrier for the gate electrode) tend to degrade the reliability of devices.

High-aluminum-content barriers of indium aluminum nitride (InAlN) or even AlN, which has the highest spontaneous polarization of all the III-N materials, have lately been used to maximize 2DEG charge densities with promising results, suggesting useful performance up to W-band microwave frequencies (75–110GHz). Other groups use an AlN spacer layer, followed by AlGa_{0.3}N, to increase carrier densities in the 2DEG.

Another recent development in nitride semiconductors is their growth on large-diameter (up to 6 inch/150mm) silicon (Si) substrates, despite the challenge of a large lattice mismatch between the materials for high crystal quality. The achievement of nitride on Si suggests the possibility of low-cost — and hence large market adoption of — nitride semiconductor electronics.

EpiGa_{0.3}N (www.epigan.com) was commissioned to grow all the epitaxial material used on 4-inch (100mm) diameter (111)-oriented silicon wafers using metal-organic chemical vapor deposition (MOCVD). The substrates were highly resistive at more than 5000 Ω -cm. EpiGa_{0.3}N was spun-out of the IMEC European semiconductor research center in Belgium by Dr Stefan Degroote, Dr Joff Derluyn and Dr Marianne Germain (CEO).

Germain comments: "We are today able to provide GaN-on-Si epiwafer material for R&D or evaluation purposes, growing epilayer stacks upon specific customer request."

The epitaxial structures grown by EpiGa_{0.3}N for IEMN (Table 1) included a 5nm in-situ silicon nitride (SiN) layer that was designed to relax the high tensile stress in the AlN due to the large lattice mismatch with the underlying 1 μm GaN buffer. The stress relaxation prevents cracking of the surface, and reduces surface roughness. The in-situ SiN

also passivates surface charges that can deplete the 2DEG that forms in the barrier-buffer interface region, needed for channel conduction. The researchers further believe that the in-situ SiN layer enhances the surface robustness of the high-quality AlN barrier, avoiding gate tunneling under high electric field.

Room-temperature Hall measurements on epitaxial material with a 6nm AlN barrier on a GaN buffer gave an electron sheet density of $2.15 \times 10^{13}/\text{cm}^2$ and a mobility of $1250\text{cm}^2/\text{V-s}$ [1, 3]. By contrast, the traditional AlGa_{0.3}N barrier 2DEG carrier density becomes less than $10^{13}/\text{cm}^2$ for thicknesses less than 10nm. Although lattice-matched In_{0.17}Al_{0.83}N has much better performance in this respect than AlGa_{0.3}N, it is beaten by AlN at all barrier thicknesses less than 10nm (Figure 2). The mobilities of the AlN 2DEGs were in the range 1100 – $1550\text{cm}^2/\text{V-s}$.

An ultrathin barrier layer of 6nm is less than the critical thickness of 9nm above which the crystal quality of AlN epitaxial layers degrades, but it is still subject to a high amount of tensile stress due to the lattice mismatch between AlN and GaN. ▶

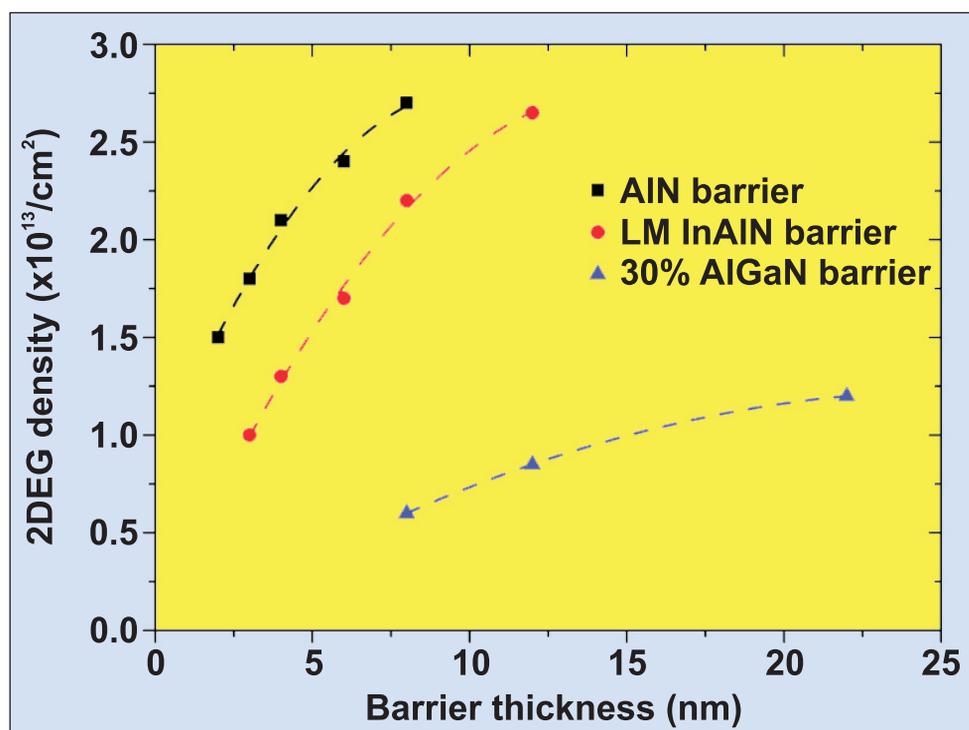


Figure 2. Room-temperature 2DEG carrier density measured by van der Pauw method of SiN/AlN/GaN, lattice matched In_{0.17}Al_{0.83}N/GaN, and Al_{0.3}Ga_{0.7}N/GaN heterostructures as a function of barrier layer thickness.

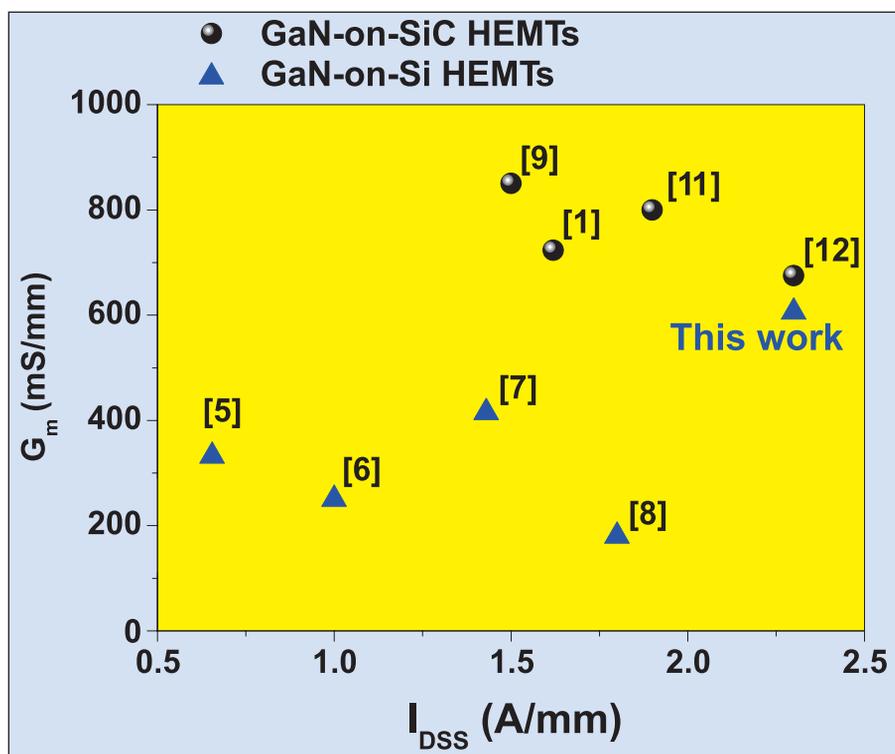


Figure 3. Benchmarking of extrinsic transconductance as a function of maximum saturated current density (I_{DSS}) of GaN-on-Si HEMTs (blue triangles) and GaN-on-SiC HEMTs (black circles).

► Medjdoub credited the better results of the latest work [3] on “process improvement” in the construction of the HEMT devices. The Ohmic source–drain contacts consisted of titanium–aluminum–nickel–gold (Ti/Al/Ni/Au), deposited on the AlN barrier material after etching through the SiN layer. The ohmic metal layers were then subjected to rapid thermal annealing (RTA) at 850°C for HEMT [3]. Nitrogen was implanted to isolate devices.

The earlier devices [1, 2] were isolated using helium implantation, and the annealing was performed at 900°C in nitrogen ambient. The ohmic contacts in [3] achieved a lower contact resistance of 0.4Ω–mm, compared with the 0.65Ω–mm of [1, 2]. Forming Ohmic contacts on AlN can be particularly tricky (see e.g. www.semiconductor-today.com/news_items/2011/JULY/MITSUBISHI_020711.html).

More silicon nitride was then deposited in devices [1, 3] using plasma enhanced chemical vapor deposition (PECVD), before gate formation. The nickel–gold (Ni/Au) gate was deposited after photolithography and etching through the SiN with sulfur hexafluoride

plasma that has a SiN/AlN selectivity factor of 90.

The gate length of the new device [3] was smaller than before [1, 2] (Table 1) at 0.16μm with gate–source and gate–drain distances of 0.3μm and 1μm, respectively. The device width was kept at 50μm. The earlier devices [1, 2] had an extra 200nm PECVD SiN layer that was added as further passivation.

The maximum DC output current density for the new device [3] was 2.3A/mm, “reflecting the high sheet carrier density provided by the AlN material that possesses the highest spontaneous polarization among all III–nitrides.”

Current densities up to 2.3A/mm were also seen in device [1] (Table 2), but only under pulsed operation (500ns, 1% duty cycle). The difference in behavior between the DC (2.03A/mm) and pulse maxima was attributed to the limited thermal dissipation of the silicon substrate when the device is subjected to direct current. The researchers also reported slight gate and drain lag effects in [1] due, it

was thought, to damage from the gate etch process that needed to be further optimized.

Leakage was also investigated using various structures. Under reverse bias of the Schottky diode gate, where the current should be small, the gate leakage was found in [3] to be less than 100μA/mm up to 80V. Buffer leakage, which was determined using a separate structure with two isolated ohmic contacts having 5μm spacing on the material, was less than 4μA/mm up to 200V bias.

The extrinsic transconductance of device [3] had a peak value of 606mS/mm at a –1.6V gate potential and a source–drain bias of 4V. The transconductance was more than 500mS/mm for V_{DS} in the 2–6V range under the same gate potential. This performance puts the device into comparison with GaN HEMTs on expensive silicon carbide that benefit from smaller lattice mismatch (and hence better nitride crystal quality, giving an improved 2DEG) and the high thermal conductivity of the substrate reducing self-heating effects (Figure 3).

Frequency performance measurements were also carried out (Figure 4), giving an extrinsic cut-off fre-

Table 2. Electrical performance summary.

Ref.	Output current density (A/mm)	Peak transconductance (mS/mm)	f_T (GHz)	f_{MAX} (GHz)	$f_T \cdot L_g$ (GHz–μm)
[1]	2.03	390	52	102	10.4
[2]	1.3	470	—	—	—
[3]	2.3	606	85	103	13.6

quency (f_T) and a maximum oscillation (f_{MAX}) frequency of 85GHz and 103GHz, respectively. These are high figures, given the “relatively high access resistances and residual losses most probably located at the buffer/Si substrate interface”. The high lattice mismatch between the buffer and silicon substrate is blamed for a 0.7dB/mm loss at 50GHz in coplanar waveguide measurements.

The cut-off-gate length product ($f_T \times L_g$) of 13.6GHz- μm suggests that downscaling the gate length to less than 100nm “will allow very high-frequency operation considering the high aspect ratio achievable with sub-100nm gate lengths.” The previous device [1] had a cut-off-gate length product of 10.4GHz- μm with an f_T of 52GHz and an f_{MAX} of 102GHz (Table 2). These cut-off-gate length products are favorably comparable to reported state-of-the-art GaN-on-Si HEMTs with 80nm gate length.

Medjdoub reports that IEMN is acquiring a 40GHz-input power amplifier to be able to fully characterize the high-power performance at higher frequency of his group’s devices.

The researchers conclude: “The high-frequency performance achieved for a gate length of 0.16 μm promises breakthrough millimeter-wave low-noise and high-power monolithically integrated amplifiers in a cost-effective way.” ■

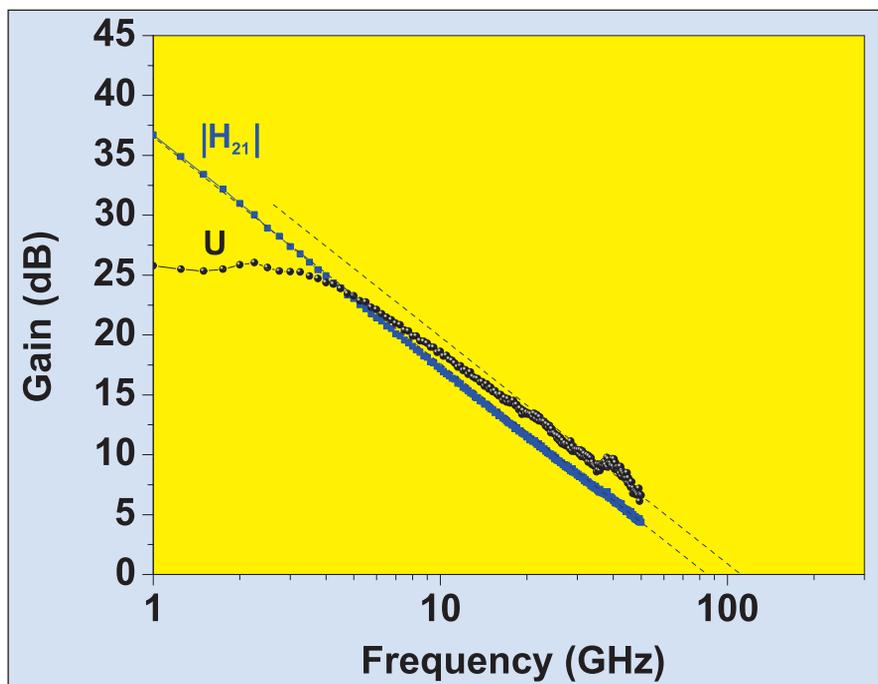


Figure 4. RF performance of 0.16 μm x 50 μm AlN/GaN HEMT on highly resistive silicon substrate. Extrapolation at -20dB/dec yields f_T of 85GHz and f_{MAX} of 103GHz at V_{DS} 4V and V_{GS} -1.6V.

Mike Cooke is a freelance technology journalist who has worked in semiconductor and advanced technology sectors since 1997.

References

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Compound semiconductor industry continues growth

This year's CS MANTECH event evidenced the continued economic recovery and technical progress in the compound semiconductor manufacturing industry.

Mark Telford reports.

This year's International Conference on Compound Semiconductor MANufacturing TECHNOlogy (CS MANTECH) in Palm Springs, CA, USA in May drew a healthy attendance, despite the aftermath of the earthquake and tsunami in Japan on 11 March preventing some delegates from that country being able to attend (with consequently a mere six papers stemming from Japan, out of the total of 85, of which 33 were non-US).

It was poignant then that this year's conference chairman was Hitachi Cable's Yohei Otoki, whose family home and company headquarters in Hitachi City are both in the disaster area. In his opening address he spoke movingly about how some family members had been flooded out of their home, but also how — by the time of the conference — most of the functionality of the Hitachi Cable factory had been recovered.

Otoki commented that one thing highlighted by the disaster was the need for information. In that context — along with the power of relatively new media like Skype and Twitter — the impact of a crowded cell-phone network, shortages of electricity, and limited battery life highlighted the need to develop the smart grid, as well as the importance of photovoltaics.

Wide-bandgap electronics

Fittingly, as has been the trend in recent years, the MANTECH program included many presentations on high-efficiency, energy-saving wide-bandgap micro-electronic technologies, as well as a session dedicated to nitride-based LEDs. In fact, over 40% of all papers presented concerned wide-bandgap materials.

In the Rump Session 'Are There Real High Volume Applications for GaN?' (moderated by Yohei Otoki), it was noted by Eric Higham of market research firm Strategy Analytics that the non-optoelectronic gallium nitride device market was just \$75m in 2010 (1.6% of the GaAs market, and just 0.8% of the \$10bn opto GaN market, which is forecast to rise to \$12bn in 2011 and \$15bn in 2012).

However, while the GaN microelectronics market is currently still dominated by military applications (driven by DARPA programs), applications such as cable TV are coming in 2012–2014 via manufacturers

Recovery continues

The recovery in the compound semiconductor industry from 2009 has continued through 2010 into 2011 (see GaAs market values in Figure 1). This was evident at MANTECH, judging from the proliferation day-by-day of job recruitment notices on the conference notice board. These were posted by the likes of TriQuint, Skyworks, Kopin, Avago, M/A-COM, Agilent, Sumika, Northrop Grumman, Cree, Nitronex, Soitec and Hexatech, with a particular emphasis on vacancies for GaAs process engineers.

like RF Micro Devices. Meanwhile, 'green' initiatives will drive applications in wireless infrastructure, especially as the increase in the number of frequency bands leads to narrower bands, and hence a market opportunity. In his presentation in the 'Business Analysis' session, Higham added that he expects a 'big bump' for LTE in the next few years (2011–2012). Consequently, the non-opto GaN market is forecast to increase rapidly at a compound annual average growth rate (CAAGR) of 57% to \$376m in 2014 (7% of the GaAs market), says Higham (see Figure 1).

In particular, according to a delegate from NXP, for silicon LDMOS technology (which is now on its 8th or 9th generation) it is increasingly difficult to improve efficiency. By comparison, with efficiency for GaN-based devices rising to about 50%, GaN will increasingly be seen in base-stations. "No firm is not looking into GaN, but it's not yet ready for production," he commented. At a frequency of 2.7GHz, there is a 'clear case' for GaN in Doherty configuration circuits, since there is 'no way' for LDMOS. In addition, since LDMOS represents just a small proportion of silicon production volume, it is very difficult to get it into fabs — "TSMC won't get involved". Consequently, 2013 will see the first significant volumes for GaN, starting on 4" substrates.

One comment from Higham is that 3–4" equipment (for the silicon industry) is currently "going away". There is hence a need to get equipment vendors onside, but this must be done as a group, not individually. As an example, he noted that sub-100nm lithography can only be done economically on electron-beam tools,

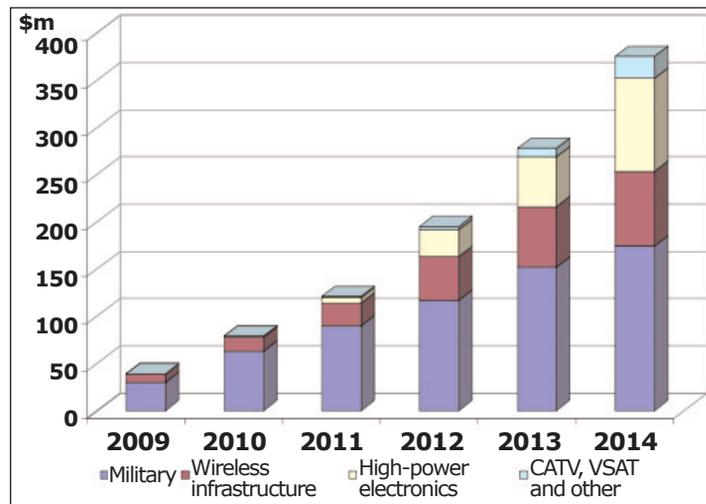
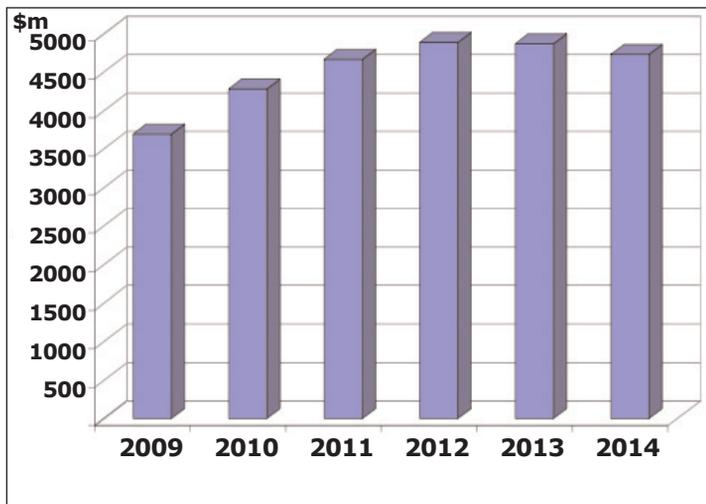


Figure 1. Value of the microelectronic markets for (left) GaAs and (right) GaN, according to Strategy Analytics.

because optical lithography exposure systems (such as from ASML) are too high-volume and too expensive.

Also, in the 'Business Analysis' session, Jeff Perkins, general manager (business development) for market research firm Yole Développement, addressed the topic 'Will GaN-on-Si displace Si and SiC in power electronics?', for which a key factor is the compatibility with silicon processing and extendibility to 6" diameter and beyond.

Yole reckons that the total addressable market for GaN power devices was \$16.6bn in 2010. However, the actual GaN power electronics market has just started in 2010, with launches by International Rectifier and EPC Corp of products with a maximum commercially available breakdown voltage of 200V (addressing the IT and consumer segments). However, these firms (and other possible entrants like MicroGaN, Furukawa, GaN Systems, Panasonic, Sanken and Toshiba) are rapidly moving to launching 600V and even 900V devices, addressing the industrial and automotive hybrid electric vehicle (HEV) segments.

Taking into account the minimum qualification period required for the implementation of new technology, Yole forecasts that the inflexion point for GaN market ramp-up will occur in early 2012, leading to a market size of \$50m+ by 2013 and about \$350m by 2015 (equally split between discretets, ICs and modules).

Yole reckons that, of the power electronics market, about 3% is for >3.3kV, 11% for 2–3.3kV, 19% for 1.2–1.7kV, and as much as 67% is in the 0–900V range (mostly cost-driven consumer and IT applications). To address the latter segment requires high-volume manufacturing capability and aggressive market price positioning, so technology involving expensive bulk GaN substrates is not compatible with market requirements, reckons Yole. GaN-on-Si appears to be the most cost-effective option for reaching at least 0–900V applications, it adds, since it has been calculated that GaN-on-Si HEMTs could be 50% cheaper than the same SiC device. However, the existing state-of-the-art

remains two or even three times more costly than the equivalent silicon device.

The choice to integrate GaN instead of silicon will be made at the system level, while calculating the overall module cost, says Yole. In particular, implementing GaN will allow a reduction in thermal management costs (fewer fans, smaller heat-sinks); RF filtering costs (higher switching frequency will need small capacitors and inductances), and overall housing costs (30–50% overall module size shrinkage is expected).

Yole adds that, based on the expected price erosion of 6" GaN-on-Si epiwafers, the GaN substrate market should exceed \$100m in 2015.

High-frequency GaN devices

In the session 'High-frequency GaN devices', Colombo Bolognesi's Millimeter-Wave Electronics Group at Switzerland's ETH-Zürich reported what it claims is the first broadband characterization of coplanar waveguides (CPWs) on GaN-on-silicon. Conventional CPWs on commercially available AlGaN/GaN on high-resistivity (HR)-Si HEMT buffer layers (fabricated by Nitronex Corp of Durham, NC, USA) have loss as low as 0.8dB/mm at 110GHz, which is further reduced to 0.47dB/mm by etching trenches between the CPW conductors. The group says this shows that CPWs on GaN-on-Si exhibit performance comparable to those on semi-insulating indium phosphide (SI InP), demonstrating the feasibility of mm-wave interconnects on GaN-on-Si epilayer stacks and hence the viability of a low-cost AlGaN/GaN HEMT MMIC technology on high-resistivity silicon substrates.

The Air Force Research Laboratory's Wright-Patterson Air Force Base and Sensor Electronic Technology Inc (SETI) of Columbia, SC reported the dc/RF characteristics of AlInN/AlN/GaN HEMTs on SiC with novel 5nm ultra-thin atomic layer deposition (ALD) Al₂O₃ dielectric passivation for high-frequency operation (thinner than in previous lattice-matched 25nm ALD Al₂O₃ in AlInN/GaN and 4nm ALD Al₂O₃ in AlGaN/GaN HEMTs) — see Figure 2. ▶

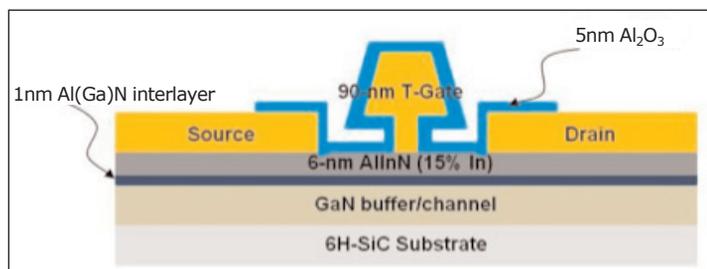


Figure 2. AFRL/SETi's strained $\text{Al}_{0.15}\text{In}_{0.85}\text{N}/\text{AlN}/\text{GaN}$ HEMTs with 90nm T-Gate and 5nm Al_2O_3 .

▶ The barrier layer contains a lower indium concentration (15%), which induces a lattice-strain-induced piezoelectric field to boost the two-dimensional electron gas (2DEG). Ideally, one wants a very thin low- k dielectric that can suppress traps and decrease parasitic gate capacitance, increasing small- and large-signal gain. HEMTs were fabricated with $2 \times 150 \mu\text{m}$ gate periphery and a T-gate length of $L_G \sim 90 \text{nm}$. Compared with devices fabricated with 100nm Si_3N_4 passivation, using ALD Al_2O_3 yields a 25%+ decrease in parasitic capacitance and a 15% increase in small-signal gain. An intrinsic cutoff frequency of up to 130GHz highlights the promise of AlInN/GaN HEMTs with ultra-thin ALD Al_2O_3 passivation, say the researchers.

Future work targets optimum material growth conditions and improved breakdown voltage for high-power, high-frequency conditions.

Device technology

In the 'Device Technology' session, Hitachi Cable reported how it has boosted the output of high-power GaAs MESFETs by 20% by not only using a high-quality channel but also optimizing the epitaxial buffer layer. Key factors were found to be a reduced impurity level in the epilayer-substrate interface, smooth electron flow near the buffer layer, and low leakage current at the buffer layer. An appropriate buffer structure had Al concentration of 0.20–0.40 (with higher Al concentration effective for improving leakage current due to raising the heterojunction barrier), while multiple heterojunctions (with a periodic stacked GaAs/AlGaAs layer) were more effective than a single AlGaAs buffer layer.

Recent progress in MOCVD epi growth and device fabrication techniques have enabled several demonstrations of GaN/InGaN npn heterojunction bipolar transistors (HBTs) that used a single-pass epi growth scheme, showing that good dc performance can be realized for III-N HBTs without additional re-growth. To further develop a viable III-N HBT technology for RF power amplification (preferred to III-N HFETs for linear power amplifiers because of the higher power density, linear current gain and uniform device turn-on characteristics), high collector current density (J_C), low collector offset voltage (V_{offset}) and low knee voltage (V_{knee}) are desired.

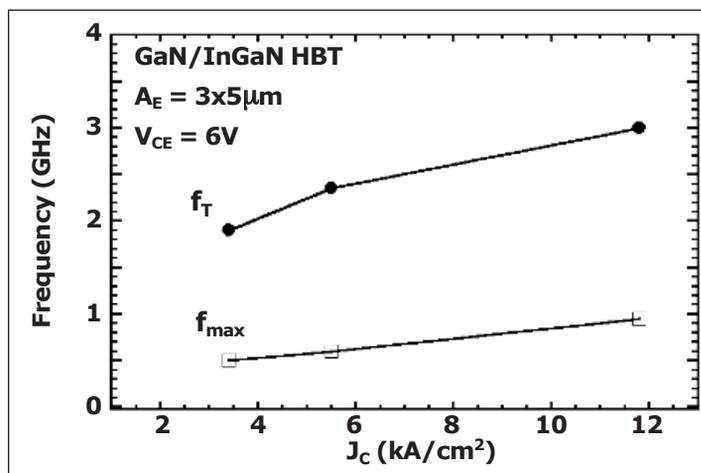


Figure 3. The f_T and f_{max} at different J_C of a $3 \times 5 \mu\text{m}^2$ GaN/InGaN HBT fabricated by GeorgiaTech.

To this end, researchers led by Russ Dupuis and Shyh-Chiang Shen at the Georgia Institute of Technology reported GaN/In_{0.03}Ga_{0.97}N npn HBTs grown by MOCVD on sapphire substrates having a $J_C > 20 \text{kA/cm}^2$ with a low V_{offset} of 0.22V and a V_{knee} of 2.1V. Also, the breakdown voltage (BV_{CEO}) was a high 110V with low off-state leakage, and the maximal small-signal differential current gain (h_{fe}) was 38. In addition, the cut-off frequency (f_T), measured at $J_C = 11.8 \text{kA/cm}^2$, is reckoned to be the first over 3.0GHz for a GaN/InGaN HBT.

However, f_{max} is a much lower 950MHz, suggesting that the large base resistance (R_B) of $22 \text{k}\Omega$ is still a challenge to achieve higher power gain.

Presenter Yun Zhang comments that better f_T and f_{max} performance can be expected for III-N HBTs grown on substrates with better thermal conductivity and lower defect density, with perhaps $f_T > 5 \text{GHz}$ achievable on semi-insulating silicon carbide or gallium nitride. Indeed, already an f_T of 5.3GHz and an f_{max} of 1.3GHz have been achieved.

Interactive Forum

In the 'Interactive Forum', researchers from University of Notre Dame, IntelliEPI of Richardson, TX and IBM T.J. Watson Research Center, Yorktown Heights, NY reported for the first time a self-aligned and potentially manufacturable vertical tunneling field-effect transistor (VTFET) process using an In_{0.53}Ga_{0.47}As/InAs/InP pocket vertical heterojunction.

Tunnel field-effect transistors (TFETs) are being investigated for low-power applications due to their potential for very low subthreshold swing and low off-state leakage. Most efforts have focused on Si- and Ge-based TFETs but — due to high tunneling barrier and effective mass — these exhibited a low on-current (I_{on}). In contrast, III-Vs — with small effective mass and broken band lineup — promise high I_{on} and $I_{\text{on}}/I_{\text{off}}$ ratios.

Pocket vertical TFETs are adopted because the gate electric field can augment the internal tunnel junction

electrical field, controlling more effectively the band overlap for minimal subthreshold swing. At 300K, the VTFETs showed an $I_{on}/I_{off} = 10^4$ and $I_{on} = 3\text{--}4.8\mu\text{A}/\mu\text{m}$ with a subthreshold swing (SS) of 220mV/dec using 8nm-thick atomic-layer-deposited Al_2O_3 gate oxide.

Previous results by other researchers have yielded $20\mu\text{A}/\mu\text{m}$ ($V_{GS} = 2\text{V}$) and an SS $>150\text{mV}/\text{dec}$ for $\text{In}_{0.53}\text{Ga}_{0.47}\text{As}$ TFETs using 10nm Al_2O_3 gate oxide, and an improved I_{on} of $50\mu\text{A}/\mu\text{m}$ ($V_{GS} = 2\text{V}$) and an SS of 86mV/dec were achieved by using 5nm ALD-deposited HfO_2 gate oxide and $\text{In}_{0.7}\text{Ga}_{0.3}\text{As}$ tunnel junctions.

The researchers note that their results are largely limited by the unoptimized ohmic contacts, interface density of states under the gate, and traps in the tunneling junction.

Fab Management & Technology Transfer

In the 'Fab Management & Technology Transfer' session, Cobham Sensor Systems described the relocation of its GaAs MMIC wafer fab in Roanoke, VA (at the former ITT site) to a more modern 50,000ft² facility in nearby Blacksburg (starting in early February 2010 and completing last October).

Another presentation described the transfer of Freescale Semiconductor's 12V GaAs pHEMT to Taiwanese 6" GaAs foundry WIN Semiconductors (in four stages: transfer mask; epitaxial substrate; front-side process; back-side process), after Freescale closed its GaAs fab at the end of 2008 and exited GaAs wafer processing.

Mobile phone markets

In the 'Business Analysis' session, Quinn Bolton of Needham and Company noted that the handset market is bifurcating into two markets: broadband-data-driven smartphones for developed markets; and low-cost multi-SIM mobiles for emerging markets. Indeed, only a third of handsets are currently 3G enabled, but by 2014 3G multi-mode, multi-band phones will represent about 59% of mobile device shipments. The firm forecasts that cellular handset unit shipments will grow at a CAGR of 11% between 2009 and 2014. Also, there will be at least 35% unit growth in data modems, although this "might be conservative", says Bolton, given recent growth in the market for tablets. So, total mobile device unit shipments are forecast to grow at a CAGR of 13% from 1.4 billion in 2009 to 2.29 billion in 2014.

China LED manufacturing

Morris Young, CEO of substrate maker AXT Inc of Fremont, CA, USA, gave an overview of China's 'Fast Growing Role in the Future of Compound Semiconductor Technology and Manufacturing'. He detailed how MOCVD reactor installations at Chinese LED chip makers grew 152% in 2010 to an estimated 327 and are forecast to grow 133% in 2011 to 764. The number of systems

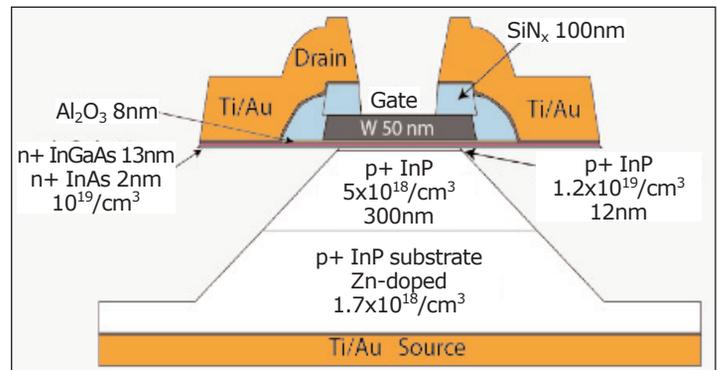


Figure 4. Cross section of vertical $\text{In}_{0.53}\text{Ga}_{0.47}\text{As}/\text{InAs}/\text{InP}$ TFET fabricated using a gate-first self-aligning process.

currently in use exceeds 250, but the number of installations over 2010–2015 is expected to exceed 2000.

Among the 41 enterprises in China that mass produce and sell LEDs, 28 have MOCVD equipment. Between January 2009 and December 2010 alone, 45 new LED chip-related projects in China attracted total investment of RMB112.9bn, Young says. In particular, more than 10 firms in China have developed and plan to offer chips for LED backlighting of TVs.

Young noted that China is the leading producer of virgin germanium and gallium, and that in recent years, due to the rapid global growth in all compound semiconductor sectors, their consumption has risen significantly, as have the prices per kg. In particular, 99.99%-pure gallium rose from under \$650 to almost \$1000 in the 6 months from December 2010 to May 2011, while 99.99%-pure germanium rose from \$880 to \$1650 over 12 months, according to Metal Pages.

Young says that the Chinese Government's incentive policy (which includes subsidies of about \$1.5m per MOCVD reactor) is playing an important role in compound semiconductor industry development, but that a strong capital market and entrepreneur spirit are also fueling the boom in LED market growth in China.

However, he cautioned that the Chinese government's MOCVD subsidies had stopped already, and expressed the belief that "a crash is going to come". ■

● Next year's CS MANTECH 2012 will take place on 23–26 April in Boston, MA, USA.

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He Bong Kim Award

Opening ceremonies saw the presentation of the 'He Bong Kim Award' (named after MANTECH's founding chairman) in recognition of the best papers from last year's conference. The winner was 'Benchmarking of Thermal Boundary Resistance of GaN-SiC: Interfaces for AlGaIn/GaN HEMTs— US, European and Japanese Suppliers' by Martin Kuball, Nicole Killat, Athikom Manoi and James W. Pomeroy of the UK's University of Bristol.

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Orangeburg,
NY 10962,
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Fax: +1 845 398 8304
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6 Deposition equipment

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7 Wafer processing materials

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MicroChem Corp

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MA 02464, USA

Tel: +1 617 965 5511

Fax: +1 617 965 5818

E-mail: sales@microchem.com

www.microchem.com

Power + Energy Inc

(see section 8 for full contact details)

Praxair Electronics

(see section 5 for full contact details)

8 Wafer processing equipment

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(see section 8 for full contact details)

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TECDIA Inc

(see section 16 for full contact details)

Veeco Instruments Inc

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9 Materials & metals

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Ermine Business Park,
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Fax: +44 (0)1954 786818

www.cambridge-fluid.com

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Fax: +1 805 541 9399

www.saesgetters.com

11 Process monitoring and control

k-Space Associates Inc

3626 W. Liberty Rd.,
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Tel: +1 734 668 4644

Fax: +1 734 668 4663

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k-Space Associates Inc specializes in
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Fax: +44 (0)1745 535 186

www.ors-ltd.com

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www.wepcontrol.com

12 Inspection equipment

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Germany

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www.bruker-axs.de

13 Characterization equipment

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www.jawoollam.com

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www.lakeshore.com

14 Chip test equipment

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Fax: +1 440.248.6168

www.keithley.com

SUSS MicroTec Test Systems

228 Suss Drive,
Waterbury Center,
VT 05677,
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Fax: +1 802 244 7853

www.suss.com

15 Assembly/packaging materials

ePAK International Inc

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Austin, TX 78759,
USA

Tel: +1 512 231 8083
Fax: +1 512 231 8183

www.epak.com

Gel-Pak

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Hayward,
CA 94544,
USA

Tel: +1 510 576 2220
Fax: +1 510 576 2282

www.gelpak.com

Wafer World Inc

(see section 3 for full contact details)

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Fax: +1 716 833 2926

www.williams-adv.com

16 Assembly/packaging equipment

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Helvetie 283,
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Switzerland

Tel: +41 329257111
Fax: +41 329257115

www.ismeca.com

Kulicke & Soffa Industries

1005 Virginia Drive,
Fort Washington,
PA 19034,
USA

Tel: +1 215 784 6000
Fax: +1 215 784 6001

www.kns.com

Palomar Technologies Inc

2728 Loker Avenue West,
Carlsbad,
CA 92010,
USA

Tel: +1 760 931 3600
Fax: +1 760 931 5191

www.PalomarTechnologies.com

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Tel: +1 858 674 4676
Fax: +1 8586 74 4681

www.quikcpak.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

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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,
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Fax: +1 412 471 9427

www.ansoft.com

Crosslight Software Inc

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Fax: +1 604 320 1734

www.crosslight.com

Semiconductor Technology Research Inc

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www.semitech.us

22 Used equipment

Class One Equipment Inc

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23 Services

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www.henrybutcher.com

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Stuttgart, Germany

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Fax: +49 711 8804 1950

www.mw-zander.com

TECDIA Inc

(see section 16 for full contact details)

24 Consulting

Fishbone Consulting SARL

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78460 Choisel, France

Tel: + 33 (0)1 30 47 29 03

E-mail: jean-luc.ledys@neuf.fr

25 Resources

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Fax: +1 408 428 9600

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E-mail: pvj@semi.org

www.pvjapan.org/en

21–25 August 2011

SPIE Optics + Photonics

San Diego, CA, USA

E-mail: CustomerService@spie.org

<http://spie.org/optics-photonics.xml>

28 August – 2 September 2011

ISES Solar World Congress (SWC 2011)

Kassel, Germany

E-mail: info@swc2011.org

www.swc2011.org

5–8 September 2011

NUSOD 2011 (11th International Conference on Numerical Simulation of Optoelectronic Devices)

Rome, Italy

www.nusod.org/2011

5–9 September 2011

26th European Photovoltaic Solar Energy Conference and Exhibition (EU PVSEC)

Hamburg, Germany

E-mail: pv.conference@wip-munich.de

www.photovoltaic-conference.com

6–9 September 2011

13th China International Optoelectronic Exposition (CIOE 2011)

Shenzhen Convention & Exhibition Center, China

E-mail: shirly@cioe.cn

www.cioe.cn/html/list_543.html

11–16 September 2011

International Conference on Silicon Carbide and Related Materials (ICSCRM 2011)

Renaissance Cleveland Hotel, Cleveland, OH, USA

E-mail: Barbara.L.Kakiris@nasa.gov

www.icscrm2011.org Neudeck@nasa.gov

12–16 September 2011

Solid-State Device Research – 41st European Conference (ESSDERC-2011) and

Solid-State Circuits Research – 37th European Conference (ESSCIRC-2011)

Helsinki, Finland

E-mail: cor.claeys@imec.be

www.esscirc.org

13–15 September 2011

LED Lighting Institute

Rensselaer Polytechnic Institute's Lighting Research Center (LRC), Troy, NY, USA

E-mail: frerid@rpi.edu

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14–16 September 2011

8th IEEE International Conference on Group IV Photonics (GFP 2011)

The Royal Society, London, UK

www.photonicsconferences.org/GFP2011

19–22 September 2011

SPIE Remote Sensing 2011 and SPIE Security & Defence Europe 2011

Clarion Congress Hotel, Prague, Czech Republic

E-mail: customerservice@spie.org

<http://spie.org/security-defence-europe.xml>

<http://spie.org/remote-sensing-europe.xml>

19–22 September 2011

SPIE Photomask Technology 2011

Monterey, CA, USA

E-mail: customerservice@spie.org

<http://spie.org/photomask.xml>

21–23 September 2011

SOLARCON Korea 2011

COEX, Seoul, Korea

E-mail: jkim@semi.org

www.solarconkorea.org/SOLARKOREA-EN

27–29 September 2011

LED professional Symposium + Expo 2011

Bregenz, Austria

E-mail: symposium@led-professional.com

www.led-professional-symposium.com

28–30 September 2011

LED Japan Conference & Expo/ Strategies in Light

Pacifico Yokohama, Japan

E-mail: Lubah@pennwell.com

www.sil-ledjapan.com

28 August – 1 September 2011

ICSI-7 (7th International Conference on Si Epitaxy and Heterostructures)

Leuven, Belgium

E-mail: annemie.kumps@imec.be

www.icsi7.com

2–7 October 2011

36th International Conference on Infrared, Millimeter, and Terahertz Waves (IRMMW-THz 2011)

Hyatt Regency Hotel, Houston, TX, USA

E-mail: daniel@rice.edu

www.irmmw-thz2011.org

4–6 October 2011

Strategies in Light Europe Conference and

Exhibition (SIL Europe 2011)

Crowne Plaza Milan Linate, Milan, Italy

E-mail: emilylp@pennwell.com

www.sileurope.com

4–6 October 2011

2011 US Workshop on the Physics and Chemistry of II-VI Materials (2011 II-VI Workshop)

Chicago, IL, USA

E-mail: jamodeo@pcm411.com

www.ii-viworkshop.org

4–8 October 2011

CEATEC JAPAN 2011

Makuhari Messe, Japan

E-mail: contact@ceatec.com

www.ceatec.com

9–14 October 2011

220th Electrochemical Society (ECS) Meeting

Boston, MA, USA

E-mail: meetings@electrochem.org

www.electrochem.org/meetings/biannual/fut_mtgs.htm

9–14 October 2011

14th European Microwave Week (EuMW2011)

Manchester, UK

E-mail: www.eumweek.com

16–19 October 2011

2011 IEEE Compound Semiconductor Integrated Circuit Symposium (CSICS 2011)

Hilton Waikoloa Village, Hawaii, USA

E-mail: customer.service@ieee.org

www.csics.org

18–20 October 2011

Solar Power International 2011

Dallas Convention Center, TX, USA

E-mail: spi@experient-inc.com

www.solarpowerinternational.com

20–21 October 2011

11th International Conference on Condensed Matter and Statistical Physics (ICCMSP-2011)

Agadir, Morocco

E-mail: iccmstp2011@gmail.com

www.univ-ibnzohr.ac.ma/iccmstp-2011

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