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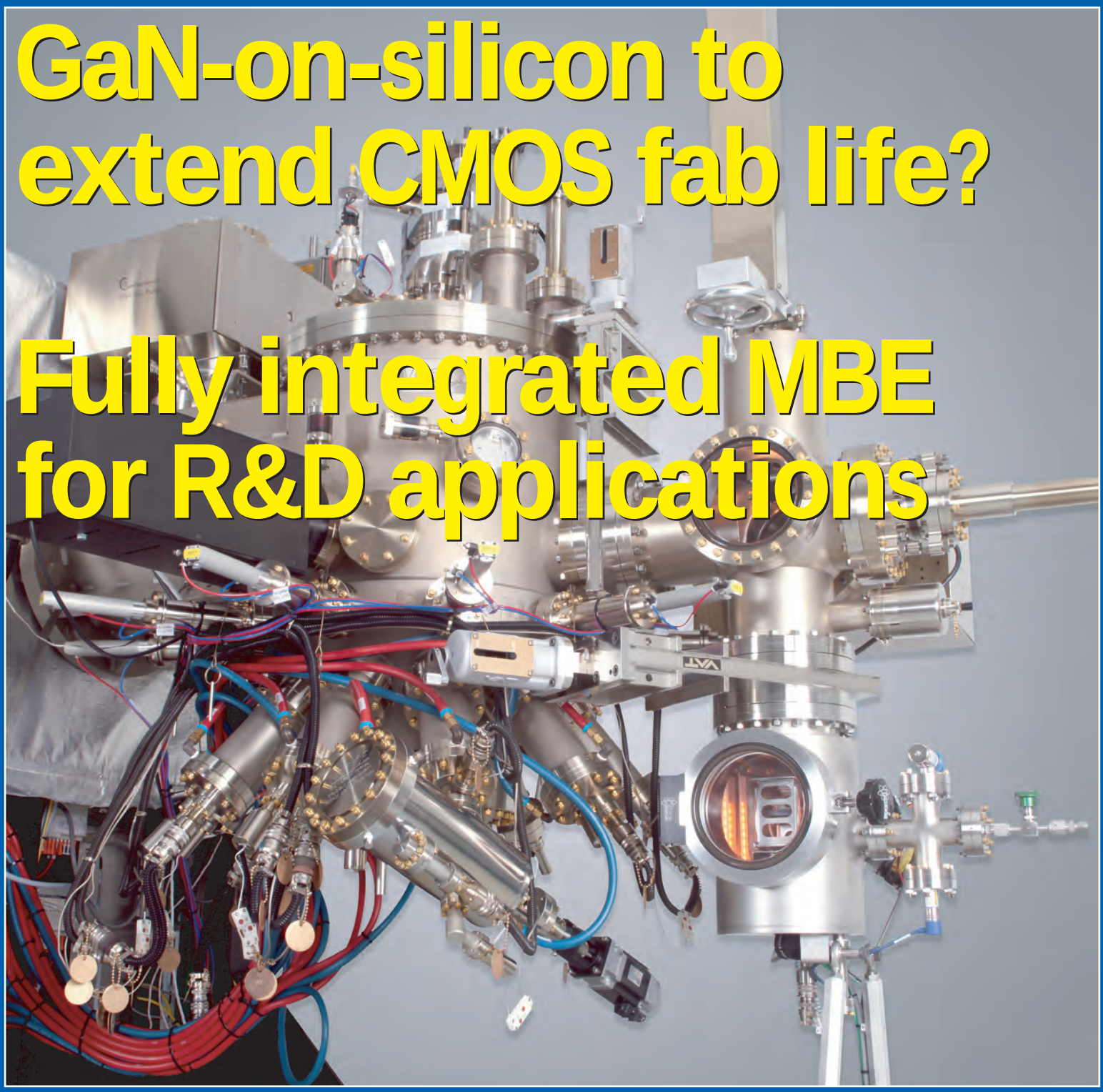


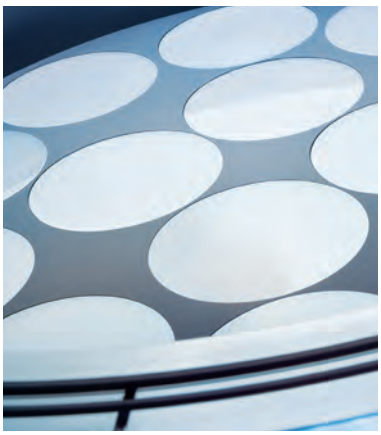
GaN-on-silicon to extend CMOS fab life?

Fully integrated MBE for R&D applications

Imec demos strained Ge FinFETs • CZTS efficiency hits 12.6%
Transphorm & Fujitsu GaN device merger • Finisar buys u2t

Light Up a Brighter World

MaxBright MHP MOCVD System



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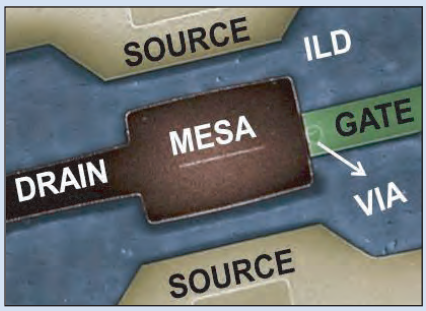
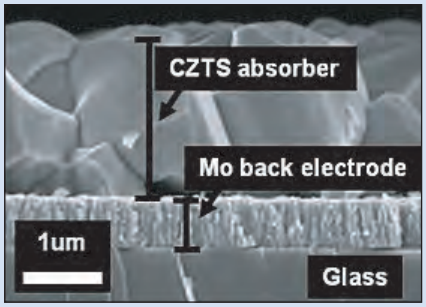
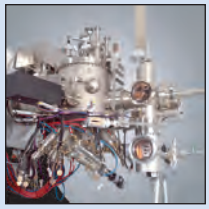


p14 SEM top-view of InGaAs/GaAsSb near-broken-gap tunnel FET made by IQE, Penn State and NIST.



p65 SEM of record 12.6%-efficient 0.42cm^2 CZTS solar cell fabricated by Solar Frontier, IBM and Tokyo Ohka Kogyo.

p80 Kaga Toshiba Electronics Corp, where Toshiba's GaN-on-Si LEDs are produced.



Cover: Close-up view of Veeco's new GENxplor fully integrated molecular beam epitaxy system for R&D applications. The first tool was installed at the University of Oklahoma, tailored for use by its III-V MBE Group. **p76**

editorial

GaN gains increasing impetus

In the editorial of the last issue (November), we previewed the late news that University of California, Santa Barbara (UCSB) spin-off Transphorm had agreed to combine with the gallium nitride power device business of Fujitsu. The latter will take a minority stake in Transphorm and form a new subsidiary of Transphorm for high-volume manufacturing of power devices on the 6" GaN-on-silicon production line at Fujitsu's existing Aizu-Wakamatsu plant. See page 23 for the detailed news story.

Also in this issue, in the feature article on pages 78–82, we give an overview of recent announcements of GaN LED samples produced on 150mm and 200mm silicon by firms including Japan's Toshiba (which last April acquired the GaN-on-Si technology of US LED lighting array maker Bridgelux) and the UK's Plessey Semiconductors (which bought University of Cambridge spin-off CamGaN in February 2012, and has just made available its second generation of GaN-on-Si mid-power LEDs — see page 44). Meanwhile, Germany's Azzurro Semiconductor has been developing 150mm GaN-on-Si epitaxial template wafers for LED production, and Korea's Samsung Electronics and Seoul National University have used hydride vapor phase epitaxy (HVPE) to produce high-quality free-standing GaN substrates on silicon templates. Such activity raises the prospect that, as older 200m CMOS silicon fabs look to fill their capacity, GaN LEDs on silicon (rather than smaller-diameter and more costly sapphire and silicon carbide substrates) could extend their profitable lifetime.

Indeed, on page 7, IHS forecasts that the penetration of GaN-on-Si wafers into the LED market will rise at a compound annual growth rate of 69% from 2013 to 2020, increasing from just 1% to 40% of all GaN LEDs made while the proportion made on sapphire and SiC falls. "Companies that previously manufactured CMOS semiconductors already own legacy 8" CMOS fabrication units that can be converted for LED production with a small modification," the firm reckons. "There is a large pre-existing industry for silicon-based manufacturing that is leveraged to create economies of scale."

Again, just as we closed for press for this issue, came news that the US Department of Energy announced the selection of a Raleigh-based public–private consortium of more than 25 companies, universities and state and federal organizations to lead a US manufacturing innovation institute for next-generation power electronics — led by North Carolina State University and including Cree, II-VI, IQE, RF Micro Devices, Toshiba, Transphorm, the University of California at Santa Barbara, and the National Renewable Energy Laboratory — to receive $70m in funding (see www.semiconductor-today.com/news_items/2014/JAN/DOE_150114.shtml). Together with a matching $70m in non-federal cost-share from consortium partners, the $140m Next Generation Power Electronics Innovation Institute aims to develop and manufacture wide-bandgap semiconductor-based power electronics that, within the next five years, are cost-competitive and 10 times more powerful than current silicon-based technology on the market.

Along with the prospect of silicon chip makers like Toshiba and Plessey repurposing silicon fabs for GaN LEDs, such investment in GaN for power electronics — especially given the declining profit in silicon equivalents — could give a kick-start to the economics of gallium nitride manufacturing, attracting more large, traditional silicon-based chip makers like Toshiba.

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***Semiconductor Today* covers the R&D and manufacturing of compound semiconductor and advanced silicon materials and devices** (e.g. GaAs, InP and SiGe wafers, chips and modules for microelectronic and optoelectronic devices such as RFICs, lasers and LEDs in wireless and optical communications, etc).

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

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ALWAYS ONE STEP AHEAD

Chinese LED packaging growth driven by lighting, but technical progress still greatest challenge

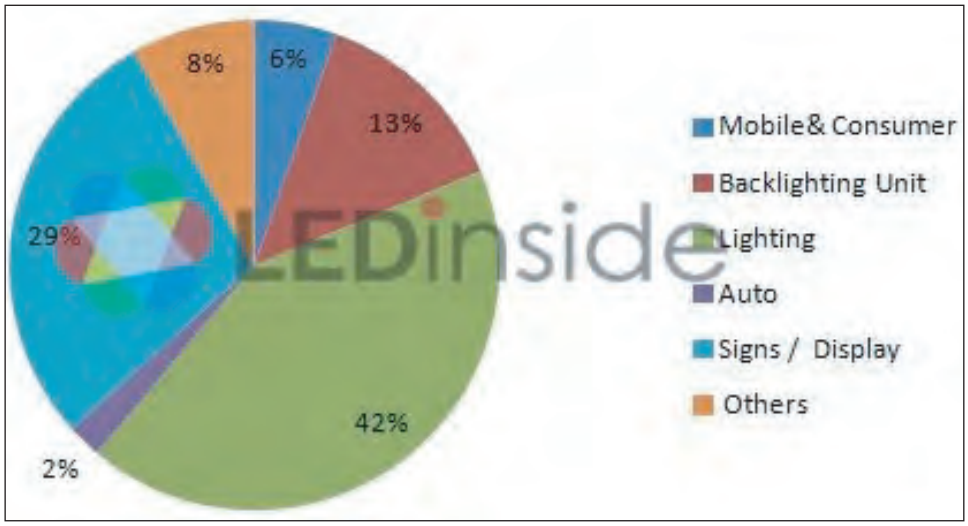
Indigenous chips to capture almost 80% of Chinese market in 2013

In 2013 the Chinese LED packaging market has grown far quicker than the global average, reckons TrendForce's Green Energy Division LEDinside.

LED lighting is still the largest application sector, accounting for 42% of the 2013 Chinese LED packaging market, says the market research firm. Due to the rapid growth in demand for LED commercial lighting in the China market, Chinese manufacturers of LEDs for lighting applications (such as MLS Lighting, Honglitronic, and CF Lighting) have achieved continually improving performance, says LEDinside. High-quality indigenous chips have greatly improved the competitive position of China's lighting-use LED packaging industry, the firm adds, with indigenous chips capturing almost 80% of the Chinese market in 2013.

For the backlighting sector, LEDinside analyst Allen Yu said that, with the support of Chinese TV and mobile phone makers, mainland LED packaging firms gradually replacing those of Taiwan, Japan and Korea has become an irreversible trend in the market. In particular, in the TV backlighting field, Refond, DSBJ, AMTC, Shineon and other manufacturers have all attained fast-growing performance, and penetrated the supply chain of China's top six TV makers. Supplying products for brand manufacturers can not only significantly improve the quality control and management capability of the Chinese LED packaging industry but also help Chinese packaging firms to build strength for participating in global competition, notes LEDinside.

For emerging fields such as automotive lighting and flash LEDs, the monopoly of international manufacturers is expected to change. Chinese packaging firms are actively penetrating these emerging markets. In the case of lighting, with the backlighting and display markets being almost fully competitive, these emerging fields are expected to become the new battleground for Chinese packaging firms to compete.



Chinese package market in 2013, by application.

In view of the global market, the main challenge for Chinese LED packaging firms to improve their market share in the future still comes from technology. In 2013, EMC (epoxy molding compound) lead-frame materials, flip-chip, chip-scale packaging (CSP) and other emerging technologies have appeared. China's Elec-Tech International (ETi) and Sanan Optoelectronics have developed flip-chip technology, and EMC lead-frame technology has also attracted much attention. Lightning Optoelectronic Technology, Smalite Optoelectronics, Honglitronic, Refond, APT and other manufacturers have adopted EMC packaging production lines. Although this is not sufficient to reshape the competitive landscape, the impact on existing industry development is still worth noting, says LEDinside. However, it will take some time to verify how the new materials and technologies will affect existing industry development over the next few years.

Allen Yu points out that the evolution of LED packaging technology always focuses on the continual decline of end-use costs. The use of new packaging materials, the formation of new packaging specifications, and the emergence of new packaging technologies should reduce the cost per lumen on the premise that quality is guaranteed. LEDinside expects that global LED lighting product shipments will grow by 68% in 2014, with the production value reaching $17.8bn. Given the situation that backlight market penetration is becoming saturated and other applications are still emerging, how the Chinese LED packaging industry seizes the opportunity of rapid development of the global lighting market will become an important factor to the outcome for manufacturers.

www.ledinside.com

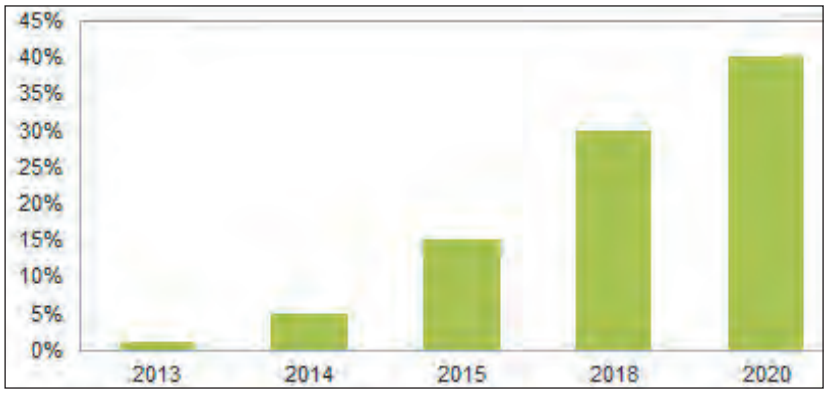
GaN-on-Si LEDs to grow at 69% CAGR from 1% market share in 2013 to 40% in 2020

Repurposing 8" silicon fabs to take share from sapphire and SiC wafers

The penetration of gallium nitride-on-silicon (GaN-on-Si) wafers into the light-emitting diode (LED) market is forecast to increase at a compound annual growth rate (CAGR) of 69% from 2013 to 2020, by which time they will account for 40% of all GaN LEDs manufactured, according to a new report from market research firm IHS Inc.

In 2013, 95% of GaN LEDs will be manufactured on sapphire wafers and only 1% on silicon wafers, the firm reckons. But growth in the manufacturing of GaN-on-Si LEDs between 2013 and 2020 will take market share from both sapphire and silicon carbide (SiC) wafers.

"Manufacturing large ingots made from sapphire is difficult, whereas silicon wafers are available from 8" up to 12" and are generally cheaper and more abundant," says Dkins Cho, senior analyst for lighting and LEDs at IHS. "There is a large pre-existing industry for silicon-based manufacturing that is leveraged to create economies of scale and reduce the cost of an LED," he adds.



GaN-on-Si market share outlook by revenue for packaged LEDs.

Repurposing manufacturing facilities to accommodate the shift toward GaN-on-Si LEDs is generally accepted to require minimal investment, notes IHS. Companies that previously manufactured CMOS semiconductors already own legacy 8" CMOS fabrication units that can be converted for LED production with a small modification, the firm notes. These companies already have in-house expertise and technology associated with silicon-based processes.

"Many of the CMOS semiconductor manufacturers already have excellent inspection tools, unlike traditional LED companies," Cho says. "This could help increase their process yield through in-situ monitoring," he adds. "However, it is unlikely the repurposing will happen overnight; instead we forecast a shift during the coming years."

www.ihs.com

China's LED lighting market to more than double from $3.1bn in 2013 to $7.4bn in 2017

LED penetration of lighting market to nearly double from 9.6% to 18%

Driven by a virtuous cycle of falling prices, policy support and energy goals, the light-emitted diode's share of the lighting market in China will nearly double from 9.6% to 18% in four years, forecasts Lux Research in its report 'Running to the Light: Sizing China's LED Lighting Market'.

Both residential and commercial segments will drive LED lighting to a compound annual growth rate (CAGR) of 24%, far outpacing the 5.6% CAGR for the broader lighting market. China's LED lighting market revenue will hence more than double from $3.1bn to $7.4bn in 2017, as ongoing urbanization, local energy savings targets, and price cuts make the technology more appealing, according to Lux.

"LED lighting has changed from expensive products outside the cost-conscious sweet-spot of Chinese buyers to value-adding solutions, gaining market share and realizing sustainable growth," says Jerrold Wang, Lux Research associate and the lead author of the report.

Lux Research studied the Chinese LED market and industry value chain to assess opportunities for global players and investors. Their findings include the following:

- In Lux's Market Adoption Grid, Guangdong, Shanghai, Zhejiang and Jiangsu provinces emerged as the upper tier of 'premium' markets for LED adoption. Guangdong offers the best overall combination, driven by the largest new and existing building floor space in 2015.
- The Chinese residential LED market will grow from $23m in 2013 to $310m in 2017, a CAGR of 92% (the highest among five market segments) as average prices fall the fastest, from $6.02 per fixture in 2013 to $3.13 in 2017.
- China's end-product market is highly disaggregated, with more than 5000 players. The top 50 suppliers account for only 33% of the market and the top 10 take merely 18%. Industry consolidation is imminent over the next five years, with suppliers of poor-quality products facing elimination, reckons Lux.

www.luxresearchinc.com

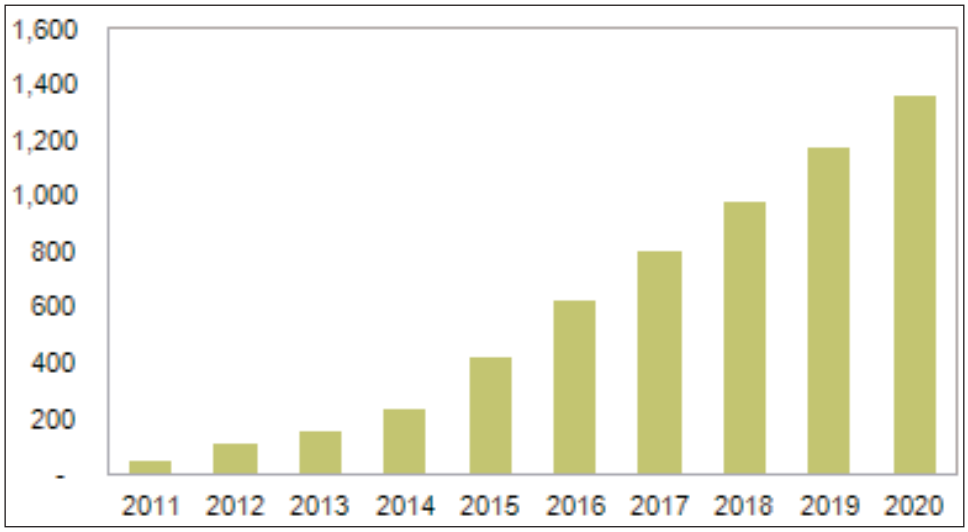
CPV installations to grow 750% from 160MW in 2013 to 1362MW in 2020

Installed pricing to fall at 15% annually from 2012 to end-2017

After years of slow progress, the global market for concentrated photovoltaic (CPV) systems is entering a phase of explosive growth, with worldwide installations set to expand at double-digit percentages every year through 2020, rising by 750% from 160MW in 2013 to 1362MW in 2020, forecasts IHS Inc in its 'Concentrated PV (CPV) Report – 2013'.

CPV technology employs lenses or mirrors to focus sunlight onto solar cells. However, while this allows more efficient PV energy generation, the use of the additional optics has also driven up the cost of CPV compared to conventional PV installations, limiting acceptance of concentrated solar solutions, notes the market research firm.

Nonetheless, the situation is changing rapidly as advancements in CPV technology reduce costs. "What is happening in today's CPV market is very similar to that of the overall PV space in 2007, beset by high costs and an uncertain outlook," says photovoltaic analyst Karl Melkonyan. "However, the CPV market in 2013 is on the verge of a breakthrough in growth," he adds. "Costs for CPV have dropped dramatically during 2013 and are expected to continue to fall in the coming years. Furthermore, when viewed from the perspective of lifetime cost, CPV becomes more competitive with conventional PV in large ground-mount systems in some regions."



Forecast of global CPV system installations (MegaWatts).

No trouble with the curve

Prices for CPV are falling as manufacturing processes progress down the learning curve. The average installed pricing for high-concentration PV (HCPV) systems is estimated to have decreased by 25.8% from $3.54 per watt in 2012 to $2.62 per watt in 2013. The decline is being driven by rising volumes and improved system efficiencies.

IHS forecasts that prices will slide further, at an annual compound rate of 15% from 2012 to $1.59 by the end of 2017.

Lifetime costs

In the conventional PV market, cost analysis predominantly focuses on the module price-per-watt and the total installed cost-per-watt. Comparing the installed cost-per-watt of conventional PV to CPV, the cost of conventional PV is significantly lower, notes IHS.

This is mainly due to the higher panel cost of CPV, given that CPV suppliers have yet to achieve the economies of scale, as well as a better balance of system and installation cost, because of the required tracker system.

Costs for CPV have dropped dramatically during 2013 and are expected to continue to fall in the coming years. When viewed from the perspective of lifetime cost, CPV becomes more competitive with conventional PV in large ground-mount systems in some regions

Conventional PV certainly has a lower upfront cost and appears to be a more attractive option based on upfront system costs. However, this does not take into account the overall cost of the system over its lifetime. Nor does it consider the energy yield of the system. Instead, it is important to compare the levelized cost of electricity (LCOE), IHS believes. The LCOE estimates the cost of generating electricity at the point of connection, dividing the total lifetime system costs by the total energy produced over the system's lifetime. Such a calculation is also necessary in order to compare the competitiveness of PV and CPV with that of conventional power generation.

Using the LCOE, IHS predicts that system costs for HCPV will remain low enough to compete with conventional PV for large commercial, ground-mount systems in target regions. These are the areas with hot, dry climates and high daily irradiation at more than 6.0 kilowatt-hours per square meter of direct normal irradiation (DNI), the firm concludes.

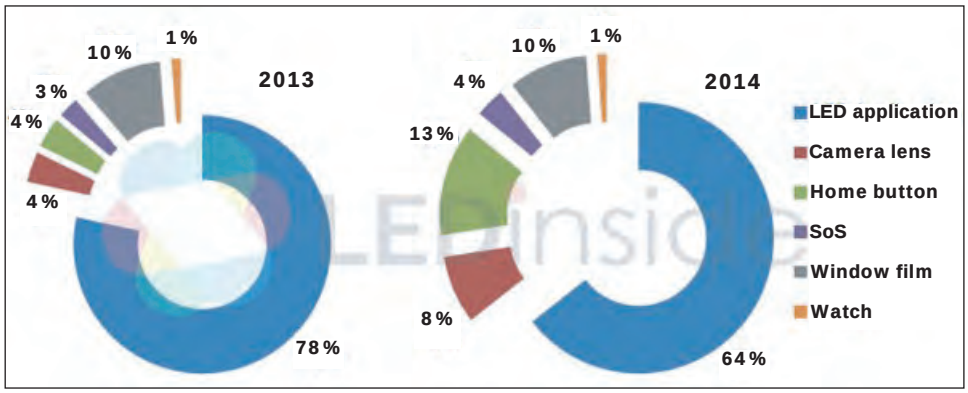
www.ihs.com

Sapphire substrate makers expanding production to meet LED lighting and smartphone demand

...but LED share of market falling from 78% in 2013 to 64% in 2014

Spurred by demand from the LED lighting and mobile device markets, sapphire substrate manufacturers have been actively expanding their production capacity, according to the report 'Global Sapphire Substrate Market 2013' from LEDinside, a subsidiary of market research firm TrendForce. For example, the top five sapphire ingot manufacturers have seen monthly production capacity for 2"-equivalent sapphire substrates grow by 75% to 7800Kmm compared to 2012.

LED industry development has been driven by high demand from the lighting market, especially for LED bulbs, tubes and MR16 lamps. To meet this demand, major LED chip makers — including Korea's Seoul Viosys, Taiwan's Epistar and China's San'an Optoelectronic and HC Semitek — still have expansion plans for 2013–2014. Major chip makers are also continually increasing their production capacities on 4" wafers, leading to 4" wafers having a 40% share of production capacity in 2013 and an expected 43% in 2014.



Share of sapphire substrate market for LED and non-LED applications.

Among non-LED applications, handheld devices represent the strongest demand. Apple has introduced sapphire material into the camera lens of the iPhone5 and 5S smartphones, and into the 5S' home buttons with the entry of fingerprint identification feature. LG is also following this latest trend and has introduced a sapphire camera lens into its newest smartphone, the LG G2. This may drive other smartphone makers to use the material, notes LEDinside. The market research firm hence estimates that the non-LED share of the sapphire substrate market will reach 36% in 2014, including handheld devices perhaps reaching as much as 31%.

www.ledinside.com

Chip-on-board LED market to grow 40% CAGR to 2018

The global chip-on-board (COB) LED market will grow at a CAGR (compound annual growth rate) of 40.71% up to 2018, forecasts a report from TechNavio (the market research platform of Infiniti Research Ltd).

One of the key factors contributing to this market growth is the declining average selling price (ASP) of LEDs. The chip-on-board LED market has also been witnessing increasing demand for COB LED in general lighting applications. However, fluctuating global economic conditions could pose a challenge to growth of this market, cautions the market research firm.

According to the report 'Global Chip on Board LED Market 2014–2018', key vendors dominating the market are Citizen Electronics Co Ltd, Cree Inc, Nichia Corp, Osram Opto Semiconductors GmbH, Philips Lumileds Lighting Co, Samsung Electronics Co Ltd, and Seoul Semiconductor Co Ltd. Other vendors mentioned in the report are Everlight Electronics Co Ltd, Lumens Co Ltd and LG Innotek Co Ltd.

"The shift from traditional lighting sources to solid-state lighting [SSL] technology has resulted in the wider adoption of COB LEDs," comments a TechNavio analyst. "COB LEDs are wide-area light emitters and thus are increasingly used in highway and street lighting, which require large amounts of light spread across a large area. COB LEDs produce better color mixing, better lighting effect, and require very low thermal resistance systems. Thus, greater power density, efficient heat dissipation, small space requirement, and high performance make COB LEDs more suitable than conventional LED packages for various general lighting applications."

The huge decline in LED ASPs is resulting in increased adoption of COB LEDs in various lighting application segments, the report adds. Also, COB LEDs offer high intensity with a homogenous luminous field suitable for high-power LED applications, which also increases the potential for savings.

The report further states that one of the major challenges in this market is the fluctuating global economic conditions. Europe's ongoing debt crisis had a spillover effect on the global economy, which is also negatively affecting demand for COB LEDs because their production involves a significant cost for manufacturers, it is noted.

www.technavio.com

RF Micro Devices adds two ISO/TS 16949-certified front-end modules for automotive Wi-Fi

RF Micro Devices Inc of Greensboro, NC, USA has expanded its portfolio of Wi-Fi products to include two new front-end modules (FEMs) for automotive Wi-Fi applications.

The RFFM8500Q is a compact, high-linearity FEM supporting 5GHz Wi-Fi and featuring a power amplifier (PA), low-noise amplifier (LNA) and single-pole double-throw (SPDT) switch. The RFFM8200Q is 2.4GHz Wi-Fi high-linearity FEM that includes a PA, LNA and single-pole triple-throw (SP3T) switch. Both are ISO/TS 16949 certified, offer what is claimed to be best-in-class performance, and are tested in accordance with the AECQ-100 automotive specification.

According to market analyst firm ABI Research, shipments of connected automotive infotainment systems will grow from 9 million in 2013 to more than 62 million in 2018, with connected navigation, multimedia streaming, social media and in-car Wi-Fi hotspots as key features. Several car makers have already announced their commitment to in-car Wi-Fi, including General Motors, Audi and Mercedes Benz. GM announced that it will add 4G/LTE connectivity and in-car Wi-Fi hotspots to several of its 2015 GMC, Chevrolet, Buick and Cadillac model cars, trucks and crossovers available in the USA and Canada later this year. Audi has a goal of 1 million connected Audi vehicles on the road worldwide by 2015 through its Audi connect service, which supports up to eight in-car Wi-Fi-enabled devices simultaneously.

"RFMD's expanding ISO/TS 16949-compliant Wi-Fi product portfolio highlights our commitment to excellence in product design and manufacturing processes for the fast-growing automotive Wi-Fi market," says Rohan Houlden, general manager of RFMD's Wireless Connectivity business unit. "We expect to significantly expand our presence in the automotive industry and are eager to support the leading chipset providers as they gear up for the rollout of new cars, trucks and SUVs that offer in-car Wi-Fi later this year," he adds.

The RFFM8500Q and RFFM8200Q FEMs are the newest addition to RFMD's growing family of ISO/TS 16949-certified products for automotive Wi-Fi, and will be available for volume production in first-quarter 2014. ISO/TS 16949 certification is the highest international quality standard for the automotive industry, and incorporates ISO technical specifications that are more stringent than ISO 9001 quality management system requirements, says the firm. RFMD achieved ISO/TS 16949 certification in 2012 and provides complete production part approval process (PPAP) packages for its automotive Wi-Fi products.

RFMD offers a complete portfolio of Wi-Fi FEMs (PA, LNA, switch, harmonic filtering) and discrete devices such as auto switches and switch LNA modules to support the latest 802.11ac reference designs from automotive Wi-Fi chipset makers. The firm is also evaluating its automotive Wi-Fi products for the emerging 802.11p standard for adding wireless access in vehicular environments (WAVE).

RFMD's envelope tracking PAs and antenna control solutions enhance power efficiency of new flagship Android smartphone

RFMD says that the newest flagship Android smartphone incorporates its envelope tracking (ET) power amplifiers, antenna switch module, diversity switches and antenna tuner. This fifth-generation smartphone from a "leading Korea-based manufacturer" is the slimmest and fastest Android phone to date and the first new smartphone to benefit from the improved power efficiency of RFMD's ET power amplifiers (PAs) and antenna control solutions.

The Android 4.4- (KitKat-) equipped smartphone integrates the RF8017 and RF8020 ET power amplifier modules; RF1492A antenna switch module; RF1119 antenna tuners; RF1136, RF1633 and RF1660 diversity switches; and RF5521 low-band Wi-Fi and RF5540 high-band Wi-Fi switch low-noise amplifiers (LNAs). RFMD's ET PAs are designed to maximize the efficiency of the phone's quad-core processor while its antenna control solutions help to optimize antenna efficiency.

"Our ET PAs and antenna tuning help maximize RF power efficiency and power transfer to the antenna, which translates to improved battery life and an enhanced user experience for this feature-packed new LTE smartphone as well as others coming to market," says Eric Creviston, president of RFMD's Cellular Products Group.

RFMD claims that its ET technology significantly enhances power efficiency in new LTE platforms, resulting in enhanced battery life across all modes and bands, increased network coverage, and higher-data-rate throughput. Unlike traditional PAs that operate with a constant supply voltage, the supply voltage applied to RFMD's ET-enabled PAs is continuously adjusted so that the amplifier operates at maximum power efficiency. The result is up to 25% less current consumption, which translates to much lower battery power consumption, particularly in LTE platforms, it is claimed.

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IN BRIEF

MACOM launches upconverter for 18 and 23GHz point-to-point wireless

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 an upconverter suited to 18 and 23GHz point-to-point radio applications.

Operating in the 17.68–23.62GHz frequency bandwidth, the MAUC-010506 has what is claimed to be industry-leading LO suppression, eliminating the customers' need for a Tx filter. The device is packaged in a lead-free 4mm x 4mm QFN that enables what is claimed to be excellent variable gain to be achieved by adjusting the bias. The upconverter delivers turn-down trajectories optimized to maintain linearity and 2xLO leakage over the gain control range, and is suited to 18–23GHz bandwidth for point-to-point radios under both LSB and USB operation.

This device is designed as part of MACOM's 18 and 23GHz chipset solutions that service the microwave point-to-point market.

"The exceptional LO leakage performance [of –30dBm] and high linearity enables the implementation of high-order modulation schemes using direct up-conversion or using an IF with minimal LO filtering, hence reducing the complexity and cost of the overall system," says David Richardson, market director, Wireless. "The QFN packaging makes these devices compatible with standard SMD assembly lines," he adds.

Production quantities and samples of the MAUC-010506 are available from stock.

www.macomtech.com

Imec demos first strained germanium FinFETs at IEDM

Compressively strained Ge p-channel on relaxed SiGe trench buffer builds on III-V FinFET integration on 300mm silicon for 7nm and 5nm CMOS

At the IEEE International Electron Devices Meeting (IEDM 2013) in Washington D.C., USA (9–11 December), nanoelectronics research institute imec of Leuven, Belgium reported the first functional strained germanium (Ge) quantum-well channel pMOS FinFET transistors, fabricated with a silicon fin replacement process on 300mm silicon wafers. The device shows a possible evolution of the FinFET/trigate architecture for 7nm and 5nm CMOS technologies.

Since the 90nm technology node, an embedded silicon germanium (SiGe) source/drain has been a popular stressor method to produce strained silicon that enhances pMOS devices. With diminishing device dimensions, the volume to implement stressors in the source and drain has also been severely scaled. In particular, with thin-body devices like FinFETs, the difficulty is even more pronounced. A possible relief would be to implement highly strained material directly into the channel itself.

Imec's solution — growing compressively strained Ge-channels on a relaxed SiGe buffer — has already proven to boost the channel mobility, and is also known for its excellent scalability potential. The use of a fin replacement process to fabricate the strained Ge channel device makes it especially attractive for co-integration with other devices on a common silicon substrate. The reported strained Ge p-channel FinFETs on SiGe trench buffer achieved peak transconductance (g_{mSAT}) values of 1.3mS/µm at V_{DS}=–0.5V with good short-channel control down to 60nm gate length. The transconductance-to-subthreshold slope ratio of the devices (g_{mSAT}/SS_{SAT})is high compared to published relaxed Ge FinFET devices.

Future developments will focus on improving the device performance through P-doping in the SiGe, optimizing silicon cap passivation thickness on the Ge, and improving the gate wrap of the channel.

"Unlike published Ge FinFETs, this work demonstrates a Ge-SiGe heterostructure-based quantum-well device in a FinFET form, which not only provides strain benefits but also enhances short-channel control," notes Nadine Collaert, program manager of the Ge/IIIV device R&D.

Developments will focus on improving the device performance through P-doping in the SiGe

"Just recently, we reported the implementation of IIIV material into the device architecture using a fin replacement process," says Aaron Thean, director of the logic R&D program at imec. "This new achievement — implementing Ge into the channel through our fin replacement process — is another key ingredient to our menu of process possibilities for monolithic heterogeneous integration to extend CMOS and SOCs [system-on-chip devices]."

Imec's research into next-generation FinFETs is part of imec's core CMOS program, in cooperation with the key partners including Intel, Samsung, TSMC, Globalfoundries, Micron, SK Hynix, Toshiba/Sandisk, Panasonic, Sony, Qualcomm, Altera, Fujitsu, nVidia and Xilinx.

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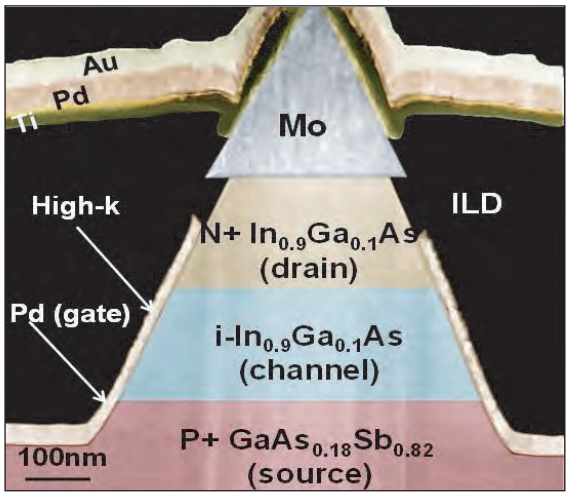
Low-power tunneling transistor for high-speed implantable devices at low voltage

IQE, Penn State and NIST report InGaAs/GaAsSb near broken-gap TFET for high-speed, low-voltage/low-power devices

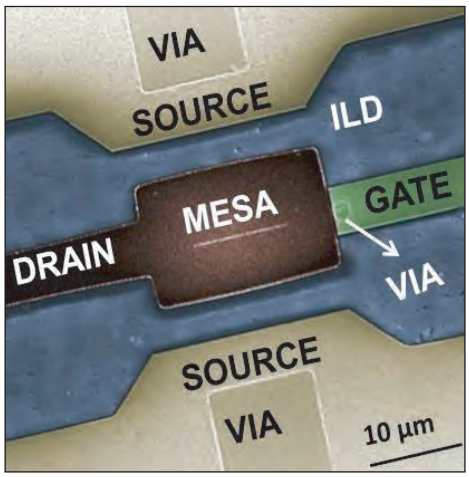
At the IEEE International Electron Devices Meeting (IEDM 2013) in Washington DC (9–11 December), epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK, Pennsylvania State University and the US Commerce Department's National Institute of Standards and Technology (NIST) presented a joint paper on a new type of transistor that aims to make possible fast and low-power computing devices for energy-constrained applications such as smart sensor networks, implantable medical electronics and ultra-mobile computing. The new near-broken-gap tunnel field-effect transistor (NBTFET) device uses the quantum mechanical tunneling of electrons through an ultrathin energy barrier to provide high current at low voltage. Specifically, NBTFETs with a 200nm channel length that exhibited record drive current (I_{ON}) of 740µA/µm, intrinsic RF transconductance (G_M) of 700µS/µm and a cut-off frequency (f_T) of 19GHz at a source–drain voltage (V_{DS}) of 0.5V.

Tunnel field-effect transistors are considered to be a potential replacement for existing CMOS transistors, as device makers search for a way to continue shrinking the size of transistors and packing more transistors into a given area. The main challenge facing current chip technology is that as size decreases, the power required to operate transistors does not decrease in step. The results can be seen in batteries that drain faster and in increasing heat dissipation that can damage delicate electronic circuits. Various new types of transistor architecture using materials other than the standard silicon are being studied to overcome the power consumption challenge.



Transmission electron microscope cross-section of the vertical TFET. Interface of the source and channel is the point where electron tunneling occurs. ILD is the interlayer dielectric separating the contacts. Top plane contacts are gold (Au), palladium (Pd) and molybdenum (Mo).

"This transistor has previously been developed in our lab to replace MOSFET transistors for logic applications and to address power issues," says lead author and Penn State graduate student Bijesh Rajamohanan. "In this work we went a step beyond and showed the capability of operating at high frequency, which is handy for applications where power concerns are critical, such as processing and transmitting information from devices implanted inside the human body."



A scanning electron microscope top view of the TFET. Image: Suman Datta/Penn State.

For implanted devices, generating too much power and heat can damage the tissue that is being monitored, while draining the battery requires frequent replacement surgery. Led by professor of electrical engineering Suman Datta, the researchers tuned the material composition of the indium gallium arsenide (InGaAs)/gallium arsenide antimony (GaAsSb) so that the energy barrier was close to zero- or near broken gap, which allowed electrons to tunnel through the barrier when desired. To improve amplification, the researchers moved all the contacts to the same plane at the top surface of the vertical transistor.

The device was developed as part of a larger program sponsored by the US National Science Foundation (NSF) through the Nanosystems Engineering Research Center for Advanced Self-Powered Systems of Integrated Sensors and Technologies (NERC-ASSIST). The broader goal of the ASSIST program is to develop battery-free, body-powered wearable health monitoring systems with Penn State, North Carolina State University (NCSU), University of Virginia, and Florida International University as participating institutions.

The paper 'Demonstration of InGaAs/GaAsSb Near Broken-gap Tunnel FET with I_{ON}=740µA/µm, G_M=700µS/µm and Gigahertz Switching Performance at V_{DS}=0.5V' will appear in the conference proceedings publication for IEDM 2013.

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IN BRIEF

Skyworks launches optical solutions for Varian Medical

Analog semiconductor maker Skyworks Solutions Inc of Woburn, MA, USA says that its subsidiary Isolink in Milpitas, CA is shipping customized optical solutions to Varian Medical Systems Inc of Palo Alto, CA for radiation oncology applications.

Varian Medical Systems is said to be the leading manufacturer of medical devices and software for treating cancer and other medical conditions with radiotherapy, radiosurgery, proton therapy and brachytherapy.

Isolink supplies optoelectronic radiation-tolerant components serving the high-reliability, military, aerospace, hybrid, industrial, medical, and telecoms markets. It specializes in manufacturing miniature hybrids and hermetically sealed devices with high isolation voltage, common mode rejection and radiation tolerances for demanding environments. For medical applications, Isolink's emitter and detector arrays help to ensure that the correct treatment doses are delivered to patients.

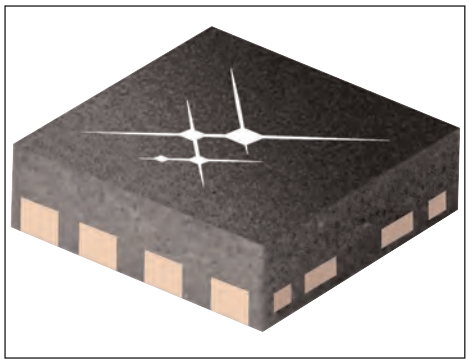
Skyworks is expanding its portfolio of analog solutions for a wide range of medical applications, including radiation oncology, hearing aids, glucose monitors, heart defibrillators and patient telemetry, says Liam K. Griffin, executive VP & corporate general manager. "Our design with Varian is just one example of how traditional analog end-markets like medical are embracing connectivity and intersecting directly with Skyworks' core competencies," he adds. "These are highly attractive markets for us, characterized by longer product life cycles, fewer competitors and higher margins."

www.isolink.com

Skyworks launches high-linearity, active bias low-noise amplifier for cellular infrastructure

Skyworks Solutions has launched a 0.7–1.2GHz, single-die cascode gallium arsenide (GaAs) pseudomorphic high-electron-mobility transistor (pHEMT) low-noise amplifier (LNA) for cellular infrastructure applications such as tower-mounted amplifiers, remote radio units, repeaters, and base stations.

The SKY67111-396LF offers very low noise figure and high linearity along with what is claimed to be excellent return loss and gain flatness in a small 2mm x 2mm, no lead plastic package. On-die active bias design of the new LNA ensures consistent performance and enables unconditional stability with a 5V supply, says the firm. The rugged cascode design achieves nearly 19dBm IIP3, 0.5dB noise figure, and >20 dB gain. The bias circuit allows the device current to be set independently from the V_{dd} supply, enabling optimal efficiency for a wide range of applications.



Skyworks' SKY67111-396LF LNA.

Skyworks says that the amplifier is suitable for wireless infrastructure OEMs having receiver applications that require highly efficient amplification with high gain and flat gain response. In addition, its linearity makes the part a suitable linear amplifier for transmitter applications.

Samples are available, and pricing depends on quantities.

Skyworks appoints industry veteran Christine King to board

Skyworks Solutions Inc of Woburn, MA, USA has appointed Christine King to its board of directors. She currently also serves on the boards of Cirrus Logic, IDACORP, Idaho Power Company and QLogic.

King was most recently CEO of Standard Microsystems (SMSC), a developer of silicon-based integrated circuits that uses analog and mixed-signal technologies, until the firm's acquisition by Microchip Technology in 2012. Prior to that, she was CEO of AMI Semiconductor before it was acquired by ON Semiconductor. King also spent more than 23 years at IBM in various management positions, including VP of Semiconductor Solutions. She was formerly a director for Analog Devices and Atheros Communications (prior to its acquisition by Qualcomm).

Semiconductor experience will be particularly relevant as Skyworks continues to grow

"She is an accomplished industry executive whose broad semiconductor experience will be particularly relevant as Skyworks continues to grow and become a diversified analog semiconductor leader," says David J. McLachlan, chairman of the board.

"This is an exciting time in wireless and I look forward to sharing my experience as Skyworks capitalizes on the explosive demand for connectivity," comments King.

www.skyworksinc.com

TriQuint launches GaN amplifiers and GaAs phase shifters and high-power limiters

In conjunction with the Defense Manufacturers Conference (DMC 2013) in Orlando, FL (2–5 December), RF front-end component maker and foundry services provider TriQuint Semiconductor Inc of Hillsboro, OR, USA is releasing new gallium arsenide (GaAs) phase shifters, high-power limiters and gallium nitride (GaN) monolithic microwave integrated circuit (MMIC) amplifiers that can improve system performance, increase efficiency and reduce part counts in wide-ranging defense and commercial applications.

TriQuint's three new high-power limiters handle up to 100W and protect sensitive circuits from electrical overload. Their low flat leakage shields low-noise amplifiers (LNAs) while low insertion loss maximizes efficiency with reduced noise. The devices are suitable for receive chain (Rx) protection in commercial and defense radars.

The firm's two new phase shifters cover 6–18GHz (including the X- and Ku-bands), delivering wider frequency coverage than competing solutions for reduced part counts, it is claimed. Their 6-bit digital logic assures smooth, continuously variable time delay functionality. They are packaged for easy assembly in radar, electronic warfare (EW) and satellite communications applications.

The new GaN amplifiers cover a wide range of applications with greater output power at superior efficiency, it is claimed, enabling smaller systems and reduced part counts. TriQuint's new die-level amplifier delivers what is claimed to be superior broadband power and efficiency; its two new packaged 50W amplifiers support key radar (9–10GHz) and satellite communications (7.9–8.4GHz) frequencies.

Spatium high-power amplifiers deliver a reliable, efficient alternative to travelling-wave tube amplifiers for commercial and defense communications, radar & electronic warfare

TriQuint says that its Spatium high-power amplifiers deliver a reliable, efficient alternative to travelling-wave tube amplifiers (TWTAs) for commercial and defense communications, radar and EW. The firm says that Spatium improves broadband RF power and efficiency through patented coaxial spatial combining techniques using GaAs or GaN MMIC amplifiers, supporting the need for RF power at high efficiency from hundreds to thousands of watts.

http://dmcmeeting.com
www.triquint.com

Peregrine opens new laboratory facilities and expanded technical resources in UK, Korea and China

Global customer support to deliver quicker response time and hands-on RF engineering

Peregrine Semiconductor Corp of San Diego, CA, USA, a fabless provider of radio-frequency integrated circuits (RFICs) based on silicon-on-sapphire (SOS) and silicon-on-insulator (SOI), has completed its 2013 initiative to deliver a higher level of customer support globally. The firm has opened new lab facilities and expanded technical resources at its sales offices in the UK, Korea and China. Peregrine says that the new facilities and resources enable it to service key global markets during local business hours.

"Field application engineering (FAE) support is the secret ingredient to sales success in this fast-paced global economy," says Carl Burrow, VP of sales. "Peregrine can now develop deeper technical relationships with customers and work together in real time as they deploy our technology."

Peregrine's 2013 facilities expansion began with Korea in April, the UK in July, and China in October. The new facilities are co-located with existing Peregrine sales offices and offer complete lab-bench capabilities supported by RF engineering technical staff.

"In today's global economy, businesses operate 24 hours a day around the world," says Diana Baxter, director of worldwide applications engineering and architect of the initiative. "To support customers locally, Peregrine has embraced this idea and expanded our presence by placing highly technical experts in the field," she adds. "This support model enables our customers to quickly move forward when using our products."

www.psemi.com

Peregrine ships 75Ω RF switch for TVs, set-top boxes and DVRs

Peregrine Semiconductor has introduced the UltraCMOS PE42721 75Ω RF switch for designers of digital TV (DTV) tuner modules, cable TV (CATV) signal switching and distribution systems, multi-tuner digital video recorders (DVRs) and set-top boxes.

The switch is suitable for geographic markets — such as China, Japan, Korea and Latin America - where broadband-TV devices must accommodate multiple RF inputs for cable, satellite and terrestrial reception while avoiding interference between these signals, says the firm. To achieve this, the PE42721 switch features isolation so high that only this one tuner chip is needed in each device, reducing the overall tuner footprint and cost of the system. The switch also delivers what is claimed to be best-in-class linearity and electrostatic-discharge (ESD) performance, because it pairs the high isolation with low insertion loss, which improves the signal fidelity by reducing the signal-to-noise ratio (SNR).

Peregrine's PE42721 75Ω RF switch.

"This latest extension of Peregrine's 75Ω switch portfolio offers broadband consumer-device and infrastructure designers a cost- and space-saving RF switch that prevents signal distortion," says Mark Schrepferman, director of the commercial and industrial product line with Peregrine's High Performance Solutions business unit.

The PE42721 is a single-pole, double-throw (SPDT) switch that balances the requirements for high isolation and low insertion loss, while also reducing noise figure in broadband TV systems that require switching between two RF sources. The new switch provides isolation of greater than 55dB across the entire, broad frequency range from 5MHz to 2.2GHz. The switch features video feedthrough of $4mV_{pp}$ for reduced distortion. In addition, it delivers low insertion loss (0.4dB @ 220MHz; 0.5dB @ 870MHz; and 0.65dB @ 2.2GHz), which enhances overall system performance by reducing the noise figure (NF) of the RF receive path and improving the SNR. Also, the high linearity (CTB/CSO of –99/–105dBc) boosts TV systems' dynamic range. The PE42721 supports 1.8V and 3.3V control logic, and high ESD performance of 3kV HBM on RF pins to GND 2kV. Its package is a 3mm x 3mm 12-lead QFN.

Samples and volume-production parts are available, priced at $0.45 each in 10,000-unit orders. Evaluation kit boards are $95.

RFaxis unveils envelope tracker to boost system efficiency of CMOS multi-mode multi-band PAs in smartphones

Fabless semiconductor firm RFaxis Inc of Irvine, CA, USA, which designs RF semiconductors and embedded antenna solutions for wireless connectivity and cellular mobility, has developed an advanced envelope tracker to enhance the system-level efficiency of converged multi-mode multi-band (MMMB) power amplifiers, which are currently finding increasing popularity in smartphone designs.

The patent-pending RFaxis envelope tracker (RFeT) is a pure CMOS-based single-die envelope tracking modulator integrated into a family of converged MMMB power amplifiers (PA). It is engineered to support the latest class of cellular transceivers with envelope tracking algorithms and power management ICs (PMICs).

"As the cellular industry rapidly migrates from 3G to 4G/LTE networks to meet end-users' insatiable demand for increased wireless data, the cost and efficiency of multi-mode multi-band PAs and associated RF front-ends are becoming major bottle necks," says chairman & CEO Mike Neshat. "CMOS PAs and related technologies such as envelope tracking and antenna tuning hold the key to ultimate success of cost-effective 4G/LTE solutions," he believes. "RFeT is a disruptive technology, as it eliminates the need for an external envelope tracking chip at the system level."

CMOS PAs and related technologies such as envelope tracking and antenna tuning hold the key to ultimate success of cost-effective 4G/LTE solutions. RFeT is a disruptive technology, as it eliminates the need for an external envelope tracking chip at the system level

The RFeT has digital control that is compatible with the MIPI (Mobile Industry Processor Interface) eTrak standard, and plays a critical role in enabling the RFaxis MMMB PA portfolio to achieve ultra-high efficiency (UHEFF) and high linearity while offering broadband, scalable support of GSM, GPRS, EDGE, WCDMA, HSPA+ and LTE, including other linear modulations such as CDMA, EVDO and TD-SCDMA, says the firm. This eliminates the need of using exotic envelope tracking power supplies (ETPS), where standard DC–DC converters or direct battery connection would suffice to achieve the targeted efficiencies.

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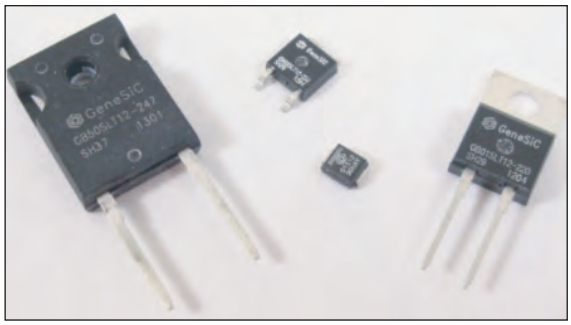
GeneSiC launches 650–3300V SiC Schottky rectifiers in small-form-factor surface-mount packages

Silicon carbide power semiconductor supplier GeneSiC Semiconductor Inc of Dulles, VA, USA has announced the immediate availability of a new family of industry-standard surface-mount SMB (JEDEC DO-214AA)-packaged SiC rectifiers operating in the 650–3300V range.

The firm says that incorporating the high-voltage, reverse-recovery-free, high-frequency and high-temperature-capable SiC diodes can increase conversion efficiency and reduce the size/weight/volume of multi-kV assemblies. The products are targeted at micro-solar inverters as well as voltage multiplier circuits used in a wide range of x-ray, laser and particle-generator power supplies.

Contemporary micro-solar inverters and voltage multiplier circuits can suffer from low circuit efficiencies and large sizes because of the reverse recovery currents from silicon rectifiers, says GeneSiC. At higher rectifier junction temperatures, this situation becomes worse because the reverse recovery current in silicon rectifiers increases with temperature.

With the thermal constraints of high-voltage assemblies, junction temperatures rise quite easily, even when modest currents are passed. GeneSiC claims that high-voltage SiC rectifiers offer unique characteristics that promise to revolutionize micro-solar inverters and high-voltage assemblies.



GeneSiC's SMB-packaged SiC rectifiers.

The GB01SLT06-214 (650V/1A), GB02SLT12-214 (1200V/2A) and GAP3SLT33-214 (3300V/0.3A) Schottky rectifiers feature zero reverse recovery current that does not change with temperature. The maximum junction temperature (T_{jmax}) is 175ºC. In particular, the 3300V-rated devices offer relatively high voltage in a single device, allowing a reduction in the number of voltage multiplication stages required in typical high-voltage generator circuits, through the use of higher AC input voltages.

The near-ideal switching characteristics allow the elimination or dramatic reduction of voltage-balancing networks and snubber circuits. The SMB (DO-214AA) over-molded package features an industry-standard form factor for surface-mount assemblies.

"The SMB form factor is a key differentiator for the micro solar inverter and voltage multiplier market," believes president Dr Ranbir Singh. "GeneSiC's low-V_F, low-capacitance SiC Schottky rectifiers and improved SMB packages enables this breakthrough product." The typical V_F and reverse recover charge are, respectively, 1.5V and 7nC for the GB01SLT06-214; 1.5V and 14nC for the GB02SLT12-214; and 1.7V and 52nC for the GAP3SLT33-214.

All devices are 100% tested to full voltage/current ratings. Technical support and SPICE circuit models are offered.

www.genesicsemi.com

Richardson RFPD announces SiC Tech Hub

Richardson RFPD Inc (an Arrow Electronics Company) of LaFox, IL, USA has launched its SiC Tech Hub, a micro-website featuring the latest news and new product releases related to silicon carbide technology.

SiC offers significant advantages in high-power, high-voltage applications where power density, higher performance and reliability are of the utmost importance. Industrial applications like solar inverters, welding, plasma cutters, fast vehicle chargers and oil exploration are a few examples that benefit from the higher breakdown field strength and improved thermal conductivity that SiC offers over silicon material.

Richardson RFPD's SiC offering includes a selection of Schottky diodes, MOSFETs and IGBTs from manufacturers Cree, Microsemi, Vincotech and Powerex. The SiC Tech Hub brings together these products with exclusive design resources focused on this emerging technology.

The wide range of design resources offered on the SiC Tech Hub includes application notes, brochures, datasheets, presentations, selector guides, supplier documentation, technical articles and videos.

"As we continue to expand our design support resources, a centralized resource for silicon carbide was the next logical step," said Dave Rossdeutcher, Director, Global Marketing - Energy, Power & Interconnect, Richardson RFPD. "With the participation of our key suppliers, the SiC Tech Hub will provide focused SiC content to support our energy and power market customers and their design activities with this rapidly-expanding technology."

The SiC Tech Hub is the latest Tech Hub from Richardson RFPD and follows the successes of the M2M Tech Hub, the Avionics & Radar Tech Hub, and the TriQuint GaN Tech Hub, which debuted in 2012.

www.richardsonrfpd.com/sicpower

Mitsubishi Electric launching 3.3kV, 1500A inverter with all-SiC power module for high-power trains

Tokyo-based Mitsubishi Electric Corp has launched a railcar traction inverter system for 1500V_{DC} catenaries that incorporates what is claimed to be the first all-silicon carbide (SiC) power modules made with SiC transistors and SiC diodes. The all-SiC inverter greatly reduces power loss, size and weight compared with conventional silicon-based insulated-gate bipolar transistor (IGBT) power modules and hybrid power modules made with silicon transistors and SiC diodes.

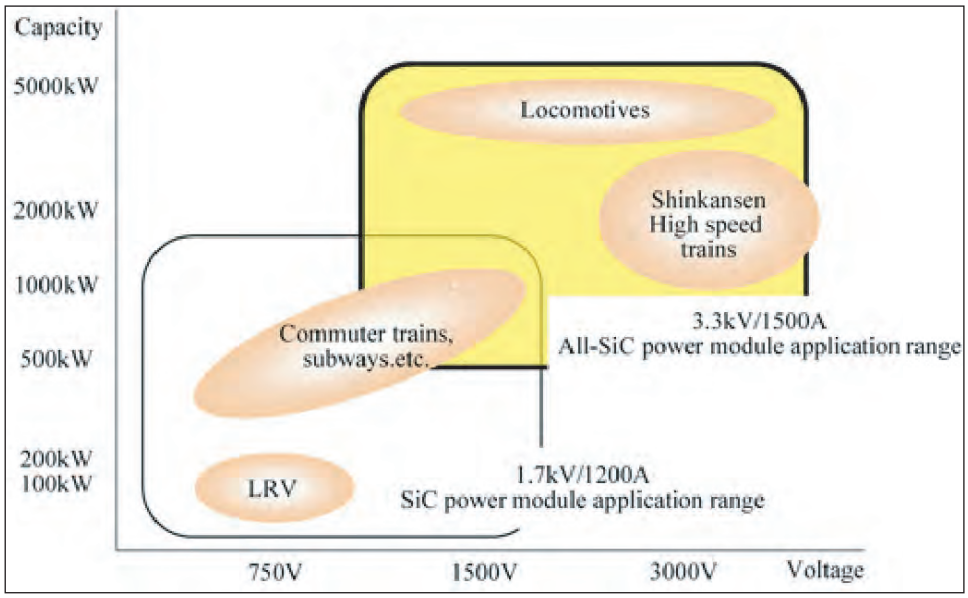
Previously, in October 2011, Mitsubishi Electric produced a railcar traction inverter for 600V_{DC}, 750V catenaries incorporating the first large-capacity hybrid SiC power modules. With help from Tokyo Metro Co Ltd, the system was field-tested in commercial railcars operating on its Ginza Line subway, demonstrating 38.6% energy reduction compared with conventional inverters in other railcars operating on the same line.

Mitsubishi Electric's new large-capacity, all-SiC power modules are expected to help save power as well as lower the size and weight of equipment used in high-power trains including Japan's Shinkansen.

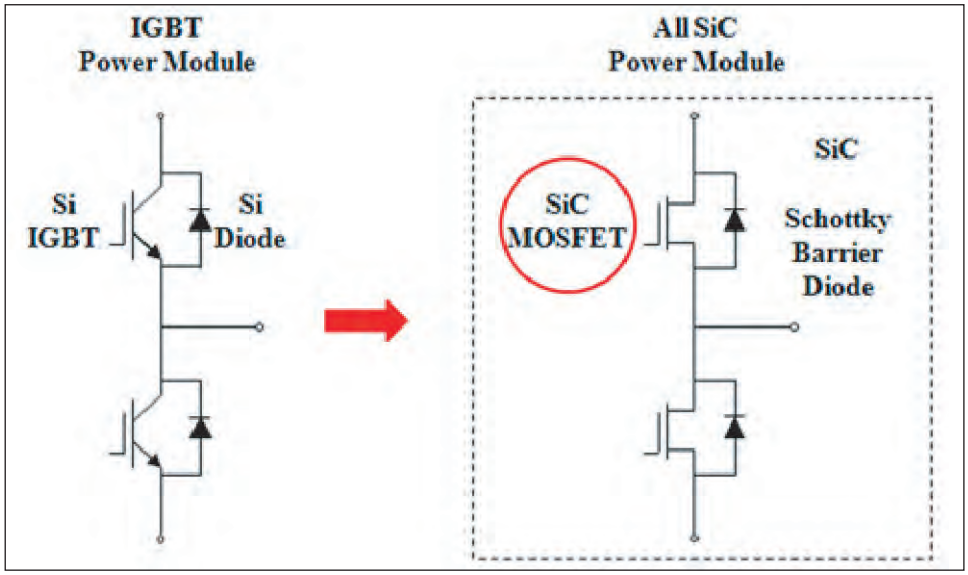
The new traction inverter system's switching loss is about 55% less than the firm's conventional inverter system incorporating IGBT power modules. The system also increases regenerated energy through the use of regenerative brakes in all speed ranges. Total energy consumption of railcar systems, including their motors, is hence cut by about 30% compared to conventional systems.

Size and weight are reduced by about 65% compared to conventional inverter systems with IGBT power modules and about 30% compared to existing hybrid inverter systems with SiC diodes.

The number of components is also reduced by integrating SiC transistors and diodes into one package per inverter circuit phase.



Application range of SiC power modules.

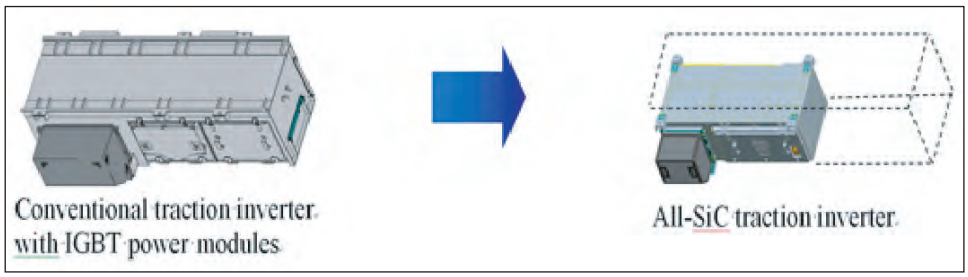


Replacement of Si-based IGBT with SiC MOSFET to create all-SiC power module.

Energy saving in total railway systems is further enhanced by effectively transferring regenerated electric power from the railcar to stations to be equipped with station energy-saving inverters (S-EIV).

Development of the SiC power modules was supported partially by Japan's New Energy and Industrial Technology Development Organization (NEDO).

www.MitsubishiElectric.com/



AFRL's Defense Production Act Title III program for X-band GaN MMICs completed

Project results in improved technologies for communication, imaging and sensor systems

A government and industry team led by engineers from the US Air Force Research Laboratory's Materials and Manufacturing Directorate (AFRL/RX) has completed a program to assess, improve, refine and validate a domestic source of supply for X-band gallium nitride (GaN) monolithic microwave integrated circuits (MMICs).

Because GaN enables devices and MMICs with improved power, efficiency and bandwidth, MMICs offer the highest level of integration and the smallest form factor and they have become the technology of choice for power amplifiers and radars. MMIC technology typically provides better high-frequency performance by reducing parasitic circuit elements and provides enhanced reproducibility as a result of uniform processing and integration of all circuit elements.

GaN products include power amplifiers (PAs) and supporting MMIC solutions, such as low-noise amplifiers (LNAs), driver amplifiers and limiters. GaN power amplifier technology significantly enhances military capabilities by increasing radar ranges, sensitivity and search capabilities compared with existing radar platforms based on other semiconductor technologies. Additional defense applications for GaN MMICs include communication systems, electronic warfare (EW) applications, imaging, and sensor systems.

The Manufacturing and Industrial Technologies Division (AFRL/RXM) Defense Production Act (DPA) Title III team is responsible for conducting this work. Title III is a US Department of Defense (DoD)-wide initiative under the Deputy Assistant Secretary of Defense, Manufacturing and Industrial Base Policy (MIBP). The Air Force serves as the Executive Agent for the Title III Program within the DoD, and the Title III Program Office is located at Wright-Patterson Air Force Base (AFB) in Ohio as a component of AFRL/RXM.

"The Title III Program is a government-funded venture that aides manufacturers who specialize in materials used for defense applications," says RXM engineer Jeffrey Smith, who serves as Air Force Executive Agent Program Manager. "Production capabilities that would otherwise be inadequate are transformed to support the material requirements of defense programs in a timely and affordable manner," he adds.

Smith notes that Title III focuses on materials and components that could be used in a broad spectrum of defense systems. "The direct and indirect benefits to defense programs resulting from Title III initiatives are substantial, and Title III projects create numerous economic and technological benefits for domestic industries and consumers."

DPA Title III engineers worked with Raytheon of Waltham, MA, to execute the program at its Compound Semiconductor Foundry, located within its Integrated Air Defense Center (IADC) in Andover, MA. Raytheon has a broad international and domestic customer base, including the US Missile Defense Agency, the US Armed Forces, and the Department of Homeland Security. In addition, its IADC facility is a DoD Category 1A Trusted Foundry (the highest category awarded), and is recognized for providing trusted, national security critical components. Its foundry employs 30 researchers and 100 device, circuit and module engineers in addition to many production staff operating a 23,000ft^2, Class-100 cleanroom facility.

The Title III project achieved the primary objective of improving and maturing the production of GaN MMICs by producing a manufacturing process capable of low-rate initial production (LRIP).

"The project achieved a Manufacturing Readiness Level of 8, meaning the fabrication processes are ready for LRIP for insertion into defense systems," says Dr Gene Himes, the AFRL/RXM program manager for the initiative. "When comparing the final results to the baseline Manufacturing Readiness Assessment, Raytheon exceeded all threshold yield key performance parameters, resulting in a three times improvement in product yield and a 76% cost reduction for its GaN MMICs," he adds.

In addition to yield improvements, the project team logged more than 1 million hours of reliability testing over the course of the project. Comprehensive reliability testing helped to eliminate the early MMIC failures and exceed the median time to failure (MTF) key performance parameters by 1000 times.

Raytheon engineers also enhanced their GaN MMIC computer design model, which resulted in first-pass design successes, robust models incorporating temperature and process variations, and comprehensive design kits for use in two separate software packages.

"This program exploited the material properties of GaN semiconductors to enable devices and MMICs with higher power, higher efficiency and bandwidth, and superior performance than existing semiconductor technologies," Himes concludes.

www.wpafb.af.mil/afrl
www.raytheon.com

Transphorm & Fujitsu merge GaN power device businesses

Fujitsu taking stake in Transphorm; to establish new firm for mass production at Aizu-Wakamatsu plant

Tokyo-based Fujitsu Ltd, its Yokohama-based subsidiary Fujitsu Semiconductor Ltd and Transphorm Inc of Goleta, near Santa Barbara, CA, USA have agreed for Fujitsu Semiconductor and Transphorm to integrate their respective businesses supplying gallium nitride (GaN) power devices for power supplies. It is reckoned that the integration will greatly improve the market competitiveness of Transphorm's GaN power device business. The three firms have also agreed that both Fujitsu and Fujitsu Semiconductor will take a minority equity position in Transphorm.

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), but only emerged from stealth mode in early 2011.

Device makers worldwide are competing to commercialize GaN power devices. While Transphorm has already released what it claims are the first qualified high-voltage commercial GaN devices, the company continues to make significant improvements in performance, quality and productivity. Given this, Fujitsu, Fujitsu Semiconductor and Transphorm will bring together their complementary strengths in technology and manufacturing to enable GaN power device solutions to be delivered quickly to the market with both scale and affordability.

"Integrating Transphorm's operations with Fujitsu will enable high-volume and high-performance GaN power device production at Aizu-Wakamatsu, and we will also benefit from Fujitsu's strong technological capabilities underpinned by Fujitsu Groups' years of developments in the field of GaN power device," says Transphorm's CEO Fumihide Esaka.

"In addition to being a future user for GaN solutions, Fujitsu has also built customer relationships with many power management companies in Japan, one of the most important markets for Transphorm," he adds.

"This business integration, together with our contribution to Transphorm's management as a minority shareholder, will enable Fujitsu to meet Transphorm's needs by offering low-cost volume production, highly reliable technologies, and quality assurance methodologies," says Fujitsu's president Masami Yamamoto. "This collaboration will greatly accelerate the introduction and market share expansion of Transphorm's GaN power devices," he adds. "While making efforts to promote the innovative value of more compact and exceptionally efficient power supply which only GaN technologies can provide, Fujitsu will aggressively work to embed GaN power devices into Fujitsu products as one component of our energy-saving solutions. Our work in the GaN RF device business continues to move forward, as does our drive to conduct advanced research on GaN devices and applied development of RF and power supply modules," Yamamoto continues.

"From 2009, Fujitsu Semiconductor has moved forward on developing the mass-production technology needed to bring GaN power devices to market, and at the end of 2011 began sample shipments of GaN power devices with 600V breakdown voltage, followed by 150V breakdown voltage GaN devices in July of this year," notes Fujitsu Semiconductor's president Haruki Okada. "We have positioned GaN power devices as one of our future core products for the Aizu-Wakamatsu plant," he adds. "The integration announced today will enable us to collaborate with Transphorm and leverage their technologies to accelerate the drive to mass production and, we anticipate, contribute to the vitality of the Aizu-Wakamatsu region. With our track record and capabilities to mass produce silicon devices that meet the stringent quality requirements of customers in automotive, industrial equipment and other industries, the Aizu-Wakamatsu plant will also be able to offer GaN power devices that customers can purchase with confidence."

Fujitsu and Fujitsu Semiconductor will establish a new company in Japan for the GaN power device business, and will transfer their combined design and development assets as well as intellectual property rights in GaN power devices. The two firms will make an in-kind investment in Transphorm in the form of the new company's shares, and will receive an equivalent value of shares in Transphorm in return. The new company will hence become a wholly owned subsidiary of Transphorm. In addition, Fujitsu and Fujitsu Semiconductor will make a cash investment in Transphorm and contribute to Transphorm's management as minority shareholders.

The staff at Fujitsu and Fujitsu Semiconductor who are directly involved in the GaN power device business will be reassigned to the new company, where they will continue development and production work with Transphorm's employees. After the integration, Transphorm will continue R&D work at both its prototyping line in the USA as well as Fujitsu Semiconductor's Aizu-Wakamatsu plant, which will be under exclusive contract with Transphorm to handle wafer processing.

Transphorm and Fujitsu Semiconductor conclude that they intend to build a global market by generating synergies from bringing together their marketing, customer support and applications development capabilities.

www.transphormusa.com
www.fujitsu.com

EPC included in National Instruments' Multisim 13.0 enhanced SPICE circuit simulation and design software

Efficient Power Conversion Corp (EPC) of El Segundo, CA, USA says that its enhancement-mode gallium nitride-on-silicon transistor (eGaN FET) SPICE models have been included in the latest version of National Instruments' Multisim circuit simulation and design software. The Multisim toolkit enables engineers to easily calculate, change and sweep critical component parameters in advanced power conversion system applications.

"The EPC component models in Multisim 13.0 are now leveraged by thousands of engineers to improve power system efficiency, reduce final product size, reduce development cost, or a combination of all three," says Mahmoud Wahby, product manager at National Instruments (NI). "Multisim is also a leading circuit design tool in both academia and with companies that

are excited about basing their power electronics designs on cutting-edge components... We are looking forward to the future releases of eGaN FETs and their continued integration within Multisim," he adds.

"To make eGaN FETs easy to use, we developed these devices to behave very much like silicon power MOSFETs, but with greatly enhanced high-frequency capability," notes EPC's co-founder & CEO Alex Lidow. "With the inclusion of our products in Multisim SPICE models, National Instruments provides user-friendly tools that make a significant impact in how easy it is to design with our eGaN devices," he adds. "These device models will enable rapid time-to-market of power conversion systems taking full advantage of our high-performance gallium nitride power transistors."

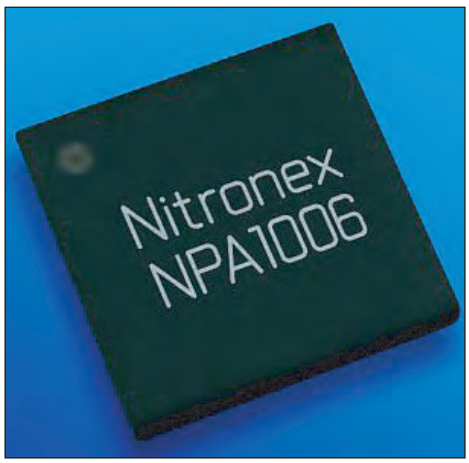
A webcast highlighting the features of EPC components in the Multisim database (as well as application examples where circuit simulation is vital in making accurate design decisions) is available for viewing at:

www.ni.com/webcast/3263/en
www.ni.com/multisim
http://epc-co.com/epc

Nitronex launches broadband GaN amplifier for military radar, radio, and SatCom applications

Nitronex LLC of Morrisville, NC, USA, which designs and makes gallium nitride on silicon (GaN-on-Si)-based RF power transistors for the defense, communications, broadband, and industrial markets, has launched the NPA1006, a 28V, 20MHz–1GHz, 15W broadband GaN amplifier with 14dB gain and 60% drain efficiency housed in an industry-standard 6mm by 5mm DFN plastic package.

The NPA1006 is the latest addition to Nitronex's integrated amplifier family that offers low-cost, high-performance GaN devices in industry-standard surface-mount plastic packages. The thermal resistance is 4.6°C/W (best in class for this power level, it is claimed). The amplifier input is internally matched to 50 Ohms for easy integration and the output needs



Nitronex's NPA1006 GaN amplifier.

just a simple two-element external match for full band coverage. The NPA1006 uses Nitronex's 28V NRF1 GaN HEMT process, which has been in production since 2006. Samples and evaluation boards are available now.

"In the coming months, Nitronex will further expand our product offering by releasing additional integrated amplifiers covering different bandwidths and power levels using our proven GaN-on-Si technology," says president & CEO Greg Baker.

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

www.nitronex.com

EPC development board receives industry awards in China

Efficient Power Conversion Corp announces that its EPC9005 development board has been recognized with two industry awards in China; namely, Optimized Development Award of the Top 10 Power Products Award 2013 presented by Electronics Product China and Leading Product Award of China Innovation Award 2013 presented by EDN China magazine.

"It is an honor to receive these recognitions as an industry leading product from Electronics Product China and EDN China magazines," noted Alex Lidow, CEO, Efficient Power Conversion Corporation. "Our EPC9005 board facilitates rapid design of high frequency switching power conversion systems based on our 40V EPC2014 eGaN FET. The EPC9005 is a ready-made and easy-to-connect development board complete with well-documented engineering support materials."

The EPC9005 measures 2" x 1.5" and contains two EPC2014 eGaN FETs in a half-bridge configuration using Texas Instruments LM5113 gate driver, supply and bypass capacitors. The board contains all critical components and layout for optimal switching performance. There are also various probe points to facilitate simple waveform measurement and efficiency calculation.

www.epc-co.com

Tektronix launches precision single-phase power analyzer to meet demands of GaN and SiC

Test, measurement and monitoring equipment supplier Tektronix Inc of Beaverton, OR, USA has expanded its family of precision power analyzers with the introduction of the PA1000 single-phase power analyzer.

Featuring a patent-pending Spiral Shunt design, the PA1000 provides engineers designing and testing power supplies, consumer electronics and other electrical products with accurate power measurements in the shortest possible time, the firm says. Features such as a color graphical display, one-button application modes and intuitive menu system enable optimum instrument set up in seconds, and the PWRVIEW PC software includes reporting features such as a full-compliance IEC62301 standby power certificate.

Engineers developing power supplies for single-phase electronics face new demands for greater energy efficiency and lower line pollution, along with a growing array of government regulations and commercial demands to reduce energy consumption, says Tektronix. As semiconductor technologies such as gallium nitride (GaN) and silicon carbide (SiC) emerge to meet these demands, new test & measurement tools such as the PA1000 are required to keep pace, the firm adds.

The PA1000 complements the PA4000 series of precision three-phase power analyzers introduced earlier in 2013, as well as Tektronix oscilloscopes and probes for circuit analysis, giving engineers end-to-end solutions for optimizing and debugging power electronics designs.

"Power is one of the most dynamic segments in electronics today, given the intense interest on the part of consumers, business and government to reduce overall energy consumption," says Curt Willener, general manager, Power Analyzer Product Line, Tektronix. "Improving battery life is another key driver," he adds. "To help our customers meets these demands, Tektronix continues to step up with the precision instruments they need such as the PA1000 and PA4000 power analyzers with a compelling combination of industry leading performance, value and usability."

The PA1000 offers 0.05% basic accuracy and 1MHz measurement bandwidth. Two internal current shunts are included on each PA1000 — one for current measurements up to 1A, for precise low-current measurements, and another for current measurements up to 20A. The 1A shunt is particularly useful for maintaining measurement resolution and accuracy on demanding low-current signals common to standby power testing.

A full-color graphics display (unusual in this instrument class, it is claimed) makes setup and other tasks easy and intuitive, with one-button access to measurement results, power waveforms, harmonic bar graphs, and menus. Application-specific test modes for standby current, lamp ballast testing and energy integration help to simplify optimization of instrument settings, saving engineers time and reducing mistakes, Tektronix says. PWRVIEW PC software further simplifies testing with one-click test automation for compliance-test applications.

The PA1000 offers standard features including LAN, USB and GPIB interfaces, harmonic analysis, and PC software that cost extra on many analyzers.

Based on recent field and metrology analysis, Tektronix has released improved accuracy specifications for the PA4000 power analyzer and extended the standard warranty to five years from the previous three years. The new accuracy specifications apply to RMS voltage, RMS current and power. For instance, RMS voltage accuracy was rated at ±0.04% and has now been improved to a rating of ±0.01%.

www.tektronix.com/pa1000

AKHAN founder named to 2014 Forbes '30 Under 30' list in Energy & Industry category

AKHAN Technologies Inc of Chicago, IL, USA, which was formed in April 2007 to commercialize Diamond Lattice Technology for diamond semiconductor devices, says that its 29-year-old founder & CEO Adam Khan has been named to the 2014 Forbes Magazine '30 Under 30' list in the Energy & Industry category.

Forbes' third annual '30 Under 30' awards 30 top mover-and-shakers under the age of 30 in 15 different fields. Khan was named among the top innovators and entrepreneurs in the Energy & Industry field.

"We are at a point in time now where diamond has the real potential to not only fuel the next generation of electronics, but substantially reduce the amount of e-waste generated by the status quo offerings," believes Khan. "We started this with the goal of trailblazing this market with much needed materials, and it is an honor to be recognized by Forbes for our work."

Recently recognized with an R&D 100 award for its Miraj Diamond platform, AKHAN Technologies is jointly developing its technology with the Center for Nanoscale Materials (CNM) at the Department of Energy's Argonne National Laboratory. In March 2013, CNM granted AKHAN exclusive diamond semiconductor application licensing rights to low-temperature diamond deposition technology.

The Argonne-developed technology allows the deposition of low-defect nanocrystalline diamond (NCD) thin films on a variety of wafer substrate materials at temperatures as low as 400°C, which is advantageous for integration with processed semiconductor electronic materials. Argonne's low-temperature diamond technology can be combined with AKHAN's Miraj Diamond process to provide diamond semiconductor thin-film technology. AKHAN debuted its Miraj Diamond platform in November 2011 in a series of patent filings and technical journal submissions.

This approach is claimed to allow for a first-time commercially feasible approach to creating cheaper, better devices relying on integrated circuits – reckoned to be transformational to telecommunications, consumer electronics, defense, and aviation electronics.

www.forbes.com/30-under-30
www.akhantech.com

P+E names Labcare and AccuDEVICE as Asia distributors for HEMS hydrogen analyzers

Hydrogen gas impurity analyzer manufacturer Power+Energy Inc (P+E) of Ivyland, PA, USA has established sales alliances with Labcare Scientific Group in mainland China, Hong Kong and Macau SAR as well as AccuDEVICE Co Ltd in Taiwan.

Both distributors will introduce the new HEMS (hydrogen elimination mass spectrometry) analyzers to fabricators of compound semiconductors for LEDs, laser diodes and other high-performance power semiconductors. The HEMS-T hydrogen analyzer is a full-spectrum analyzer capable of rapidly measuring parts-per-trillion (ppt) levels of all contaminant species that reduce product quality and yields. Integrated into the plants' hydrogen feed lines and continuously sampling the gas, the HEMS instrument automatically detects and measures impurities that reduce product quality and yield and thus can significantly increase tool up-time.

Both firms will focus HEMS hydrogen analyzer sales efforts on compound semiconductor manufacturers that use metal-organic chemical vapor deposition (MOCVD) epitaxy processes, which require ultra-pure hydrogen with sub parts-per-billion (ppb) levels of oxygen, moisture, hydrocarbons and other contaminants (which adversely affect the optoelectronic properties of the fabricated semiconductor). Knowing the specific species and their respective concentration enables fab operators to manage the problems early, before the damage is substantive and there is major productivity loss, says P+E.

Shanghai-based Labcare Scientific Group distributes mass-spectrometry-related equipment and solutions for laboratory gas and industrial gas applications in mainland China, aided by a team of in-house analysis experts and sales representatives and a lineup of complementary products such as hydrogen generators.

AccuDEVICE Co Ltd is a Taiwanese provider of ultra-high-purity gas purification equipment, gas analysis equipment, detectors and specialty gas supply systems. The firm offers solution sales and maintenance services to semiconductor manufacturers in Taiwan as well as Taiwanese companies operating in China. AccuDEVICE currently represents lines of equipment that are complementary to P+E's full-spectrum hydrogen analyzers.

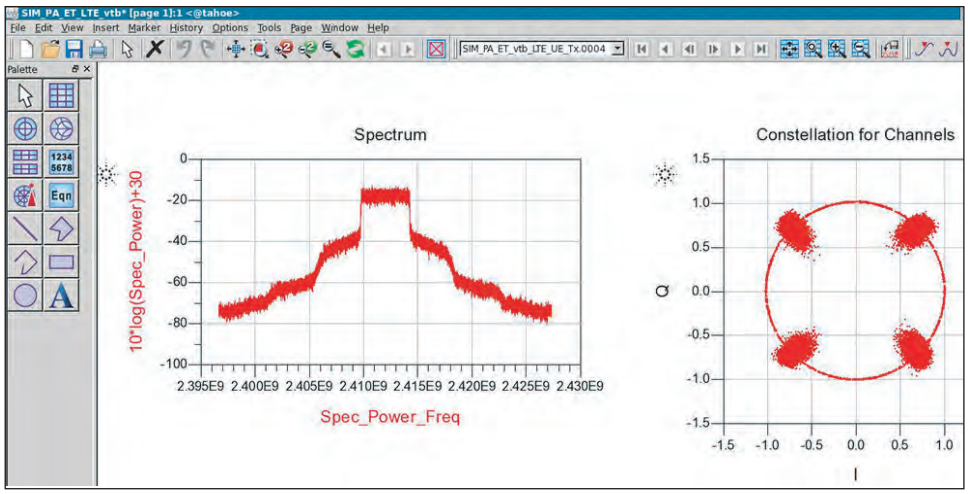
"Both Labcare Scientific Group and AccuDEVICE are strategic additions to P+E's global network of sales and service providers for our analyzer instruments," says P+E's director of sales & marketing David Kepniss. "These companies are regarded as product and market experts in their respective geographies."

www.powerandenergy.com

Agilent's newest GoldenGate software release brings wireless standard-compliant RFIC design

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

GoldenGate 2013.10 provides RFIC designers with easy-to-use EVM-, BER- and ACPR-type measurements and enables quick analysis and diagnosis of problem areas in large-signal analysis. It also offers new capabilities to reduce simulation time and increase design efficiency.



The GoldenGate 2013.10 spectral mask and constellation diagram results for a LTE testbench.

Wireless standard-compliant design

Advanced wireless standards such as LTE Advanced (4G) and 802.11ac (WLAN) put high demands on linearity, bandwidth and noise performance, which is changing the nature of transceiver IC design, says Agilent. GoldenGate 2013 introduces new verification test benches that allow RFIC designers to easily validate and optimize their designs using standard-compliant waveforms and measurements such as EVM/ACLR in transmitters, or sensitivity/desensitization in receivers.

"RF system simulations using the actual standard-compliant modulated signals in order to fully capture third-order nonlinearities, AM/AM and AM/PM distortions, spectral regrowth and memory effects are crucial to develop leading-edge RF products targeting advanced wireless standards," says Juergen Hartung, RFIC product manager at Agilent EEsof EDA. "As a result, designers are now able to identify marginal designs early, as well as overdesigns that add costly, unnecessary die area or current consumption."

Ability to identify and optimize critical components

While GoldenGate is known for its best-in-class RF circuit simulation performance and robustness, claims Agilent, it also provides technologies to explore, analyze and optimize RF circuits early in the design cycle. The latest release adds a new sensitivity analysis that can be applied when analyzing RF circuits, even when running large-signal analyses.

Additional capabilities

GoldenGate 2013 introduces several enhancements covering a broad range of applications, including:

- The fast circuit envelope (FCE) model export from GoldenGate to SystemVue, which now includes noise support that is critical for any receiver test (e.g. sensitivity/desensitization). FCE creates a model that is used in SystemVue to represent the degradation due to the RFIC in system-level simulations without facing much of a performance impact.
- Fast yield contributor support in envelope transient and S-parameter analyses, speeding up Monte Carlo simulations for process and mismatch variations. It also provides a contributor table to identify root cause devices and/or blocks.
- Core solver improvements (such as a new oscillator algorithm) that specifically target high-Q oscillators and high-level transient accuracy control.
- New automatic steady-state detection and auto-harmonic estimation within initial transient, reducing simulation time and increasing design efficiency.
- A broad range of usability enhancements within the graphical user interface, results display and post-processing functionality. Examples include new band spectrum functions for envelope transient measurements or mean value, and standard deviation for each noise source within the noise contribution table.
- Model support for UTSOI v1.14 and v2.0, and Angelov GaN, as well as model release updates for HICUM level0 1.31 and NXP's SiMKit version 4.0 and 4.01.

GoldenGate is available for integrated RF circuit design within the Cadence Virtuoso design flow. Its simulation algorithms are optimized for the demands of complex RF circuit designs, enabling full characterization of complete transceivers prior to tape-out. GoldenGate is part of Agilent Eesof's RFIC simulation, analysis and verification solution, which also includes Momentum for 3D planar electromagnetic simulation, SystemVue and Ptolemy wireless test benches for system-level verification, and the Advanced Design System data display for advanced data analysis.

www.agilent.com

Soitec and CEA renew partnership for five more years

Smart Cut engineered substrate and materials R&D targets electronics, solar energy and lighting

Soitec of Bernin, France, which makes engineered substrates including silicon-on-insulator (SOI) wafers and III-V epiwafers, and CEA (the French Atomic and Renewable Energy Commission) have renewed their long-standing partnership for the next five years. The new contract aims to support Soitec's strategy for the electronics, solar energy and lighting markets, and will focus on engineered substrates and materials offering higher performances and energy savings at a competitive cost.

As the new partnership is putting in place what is described as a powerful R&D ecosystem, time from research to product should be reduced considerably. Due to the strengths of CEA-Leti of Grenoble, France (CEA's Laboratory for Electronics & Information Technology) in electronic materials, multi-domain research and its pre-industrialization infrastructure, competitive R&D sample prototyping will be enabled through a common platform, reducing time to market and R&D costs for Soitec and its customers, it is reckoned.

The CEA-Leti and Soitec teams will focus their efforts on developing new materials generations to support Soitec roadmaps in three markets (electronics, solar energy and lighting). To do so, they will leverage the expertise of CEA-Leti and Soitec and use Smart Cut technology and extended tool box as key assets to support the next generations of mobile devices, solar cells and LEDs.

"In our industry, competitive pre-industrialization research, development of technology and product prototypes have become very important to make the difference," says Soitec's chief technology officer Dr Carlos Mazuré. "The CEA-Leti and Soitec partnership establishes a powerful alliance that is capable of answering the numerous challenges of today's industrial requirements and building on our well-established material expertise," he reckons.

"The agreement aims at accelerating exploratory research as well as technology innovation to prepare the products of tomorrow," Mazuré continues. "It complements the Soitec strategy of entering new markets with high-efficiency concentrating photovoltaic (CPV) technology, high-intensity LEDs for lighting applications, and engineered substrates for electronic applications," he adds.

"In recent years, Soitec has widely expanded its footprint and impact by addressing the electronics and energy challenges through its unique technologies which we developed together," comments CEA-Leti director Laurent Malier. "Our partnership is the most efficient framework for securing research execution to support the ambitions of Soitec."

www.soitec.com
www.leti.fr/en

Soitec and IntelliEPI collaborate to provide second source for GaAs market

Soitec grants technology license to IntelliEPI

Soitec of Bernin, France, which makes engineered substrates including silicon-on-insulator (SOI) wafers and III-V epiwafers, and Intelligent Epitaxy Technology Inc (IntelliEPI) of Richardson, TX, USA, which uses molecular beam epitaxy (MBE) to manufacture indium phosphide (InP), gallium arsenide (GaAs) and gallium antimonide (GaSb) epiwafers, have signed a collaborative agreement to serve the GaAs market.

The partnership aims to address market requirements for a reliable second source, while also extending the position of both firms in the GaAs market as well as delivering the best product at the lowest cost. The agreement includes a technology license granted by Soitec to IntelliEPI, which may be extended to address future business opportunities in the GaAs market, including equipment transfer.

The agreement includes a technology license granted by Soitec to IntelliEPI, which may be extended to address future business opportunities in the GaAs market, including equipment transfer

"We are delighted to announce the license of our technology, leading to a second source for our products for our key GaAs customers ," says Bernard Aspar, senior VP & Soitec's Communication & Power business unit general manager.

"This collaborative agreement will reinforce our GaAs technology and product know-how while, at the same time, offering Soitec's customers supply-chain security," says IntelliEPI's president & CEO Yung-Chung Kao.

www.intelliepi.com
www.soitec.com

Soitec and SunEdison enter into patent cross-license agreement for silicon-on-insulator

Research and development to target products for SiGe, Ge or III-V high-mobility channels

Soitec of Bernin, France, which makes engineered substrates — including silicon-on-insulator (SOI) wafers and III-V epiwafers — and silicon wafer manufacturer SunEdison Inc of St. Peters, MO, USA have entered into a patent cross-license agreement relating to SOI wafer products. The agreement provides each firm with access to the other's patent portfolio for SOI technologies and ends all outstanding legal disputes between the companies.

"This agreement represents a key milestone in the continuing development of a strong supply chain in the SOI ecosystem," reckons Christophe Maleville, senior VP of Digital Electronics Division of Soitec. "It also demonstrates the key role of SOI substrate technology for the current and future CMOS device roadmap," he adds.

"SunEdison has been a leading silicon substrate innovator for over 50 years with a strong patent portfolio," states Horacio Mendez, VP of Semiconductor Advanced Solutions at SunEdison. "This cooperation adds to SunEdison's current SOI product capability and enhances the ability of both companies to provide more compelling SOI solutions to our customers."

The agreement provides access to a portfolio of patents from both companies and covers the manufacturing of existing engineered unpatterned handle-substrates such as partially depleted SOI (PD-SOI), fully depleted SOI (FD-SOI) and radio-frequency SOI (RF-SOI) as well as advanced FinFETs.

In addition to the current technologies covered by the agreement (including applications beyond the 10nm node), Soitec and SunEdison have agreed to grant each other the right to use their respective patents for R&D purposes. This will allow the firms to develop products in which the device layer is made of a semiconductor material other than plain, non-strained silicon, such as a silicon-germanium compound, germanium or III-V materials, enabling the fabrication of high-mobility channels for advanced-generation digital applications.

www.sunedisonsilicon.com
www.soitec.com

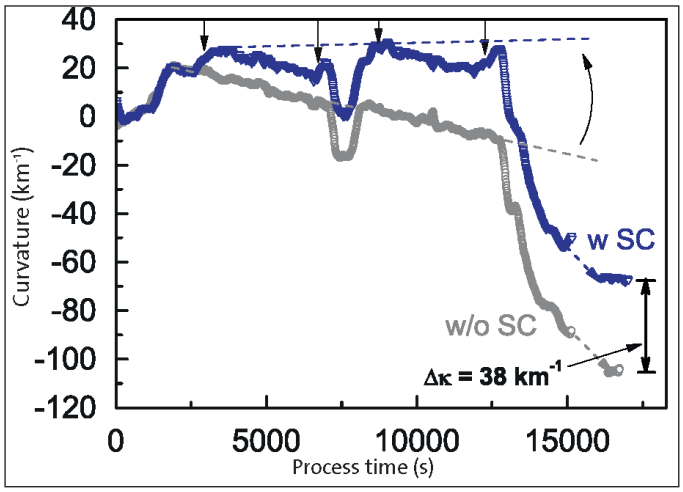
LayTec's EpiCurve TT used for strain engineering of GaAs-based laser structures

It is known that metal-organic vapor phase epitaxy (MOVPE) growth of AlGaAs on GaAs is limited by lattice mismatch at room temperature and not at growth temperature (A. Maassdorf et.al., J. Cryst. Growth 370 (2013) 150-153), notes in-situ metrology system maker LayTec AG of Berlin, Germany. The resulting wafer bow may cause problems during the subsequent processing and chip mounting of edge-emitting laser diodes.

To reduce the wafer bow at room temperature, Dr Andre Maaßdorf and his team at Ferdinand-Braun-Institut (FBH) in Berlin, Germany, have developed a special scheme for strain engineering: they add phosphorus (P) and replace $Al_{0.85}GaAs$ by $Al_{0.85}GaAs_{0.96}P$ in a distributed manner.

To control their laser growth in an Aixtron MOCVD system in real-time, the team uses LayTec's EpiCurve TT for simultaneous curvature, pyrometry and reflectance measurements to observe the curvature development, the temperature and the layer thickness.

The Figure shows two curvature transients of an edge-emitting laser structure with and without strain-compensating (SC) AlGaAsP layers (indicated by vertical arrows). These layers directly replace AlGaAs and have a thickness of 230–350nm.



In-situ curvature data of laser structure with (blue) and without (grey) SC layers (marked by arrows). Dashed lines show envelopes of the curvature in both cases (A. Maassdorf et.al., J. Cryst. Growth 370 (2013) 150–153).

The dashed lines show the curvature envelopes of both transients. The envelope for the non-compensated structure is tilted (grey dashed line), which leads to an increased convex bow throughout growth, but the envelope of the compensated structure is flat (blue dashed line).

Furthermore, it can be seen that compressive strain occurring during cool down (after ~1250s) remains the same in both cases, as it is caused by the differing thermal expansion of the layer and substrate. However, the final room-temperature curvature of the compensated structure is reduced by 38km^{-1} (see Figure).

Finally (in A. Maaßdorf et al., J. Appl. Phys. 114 (2013), 033501), Maaßdorf has also described the procedure for using EpiCurve TT to measure the thermal expansion coefficient of ternary compound materials between room temperature and growth temperature.

www.fbh-berlin.com

LayTec's EpiTriple TT with AbsoluT temperature calibration used for precise control of three heating zones

Dr Tony SpringThorpe of the National Research Council of Canada recently reported fast and easy temperature calibration of all three heating zones of his showerhead MOCVD reactor by using LayTec's AbsoluT for calibration of EpiTriple TT, which monitors the growth of As- and P-based devices via three measurement heads at three different viewports.

The precision of temperature measurements is crucial for proper in-situ monitoring of epitaxial growth, LayTec notes. It is even more important if you measure temperature at different points on the same wafer, on different wafers or in different reactors simultaneously or if you compare the temperature of different runs.

AbsoluT attached to a showerhead reactor lid for calibration.

AbsoluT sets up one exact reference point for pyrometry measurements at three viewports, where temperature variations are often caused by adjustment, window coating or manufacturing tolerances of the equipment. "AbsoluT is a quantum leap compared to the former calibration methods," comments SpringThorpe. "It takes only 5 minutes to calibrate all three heads and requires no further calculation," he adds. "Hence, I can take under real-time control all three heating zones. This helps enormously to grow uniform buffer and MQW [multiple quantum well] structures."

www.laytec.de/absolut

Riber wins order for research system in France

Riber S.A. of Bezons, France, which manufactures molecular beam epitaxy (MBE) systems as well as evaporation sources and effusion cells, has announced the sale to the IES electronics institute in Montpellier, France, of an MBE412 III-V system, and of a major upgrade for an existing Compact21 system.

The firm says that acquisitions will further strengthen and renew the fleet of equipment in place at the IES, a joint research unit involving Université Montpellier 2 and the Institute for Engineering and Systems Sciences (INSIS), which is part of the French national center for scientific research (CNRS). They are being funded by the 'equipment for excellence' (EquipEx) program in connection with France's 'Investments for the Future' initiative.

The equipment will contribute towards improving the research capabilities of IES' 'nanoMIR' research group, which works on III-V semiconductor components in the gallium antimonide (GaSb) sector. The equipment "will make it possible to further strengthen the work carried out on innovative optoelectronic components, laser diodes and photodetectors, operating in infrared, as well as the work on their integration with silicon, the core technology for electronics," says professor Eric Tournié, who heads the group. "The applications for these components include major economic sectors (photonics, defense, telecommunications, etc) and societal sectors (environment, health, etc)," he adds.

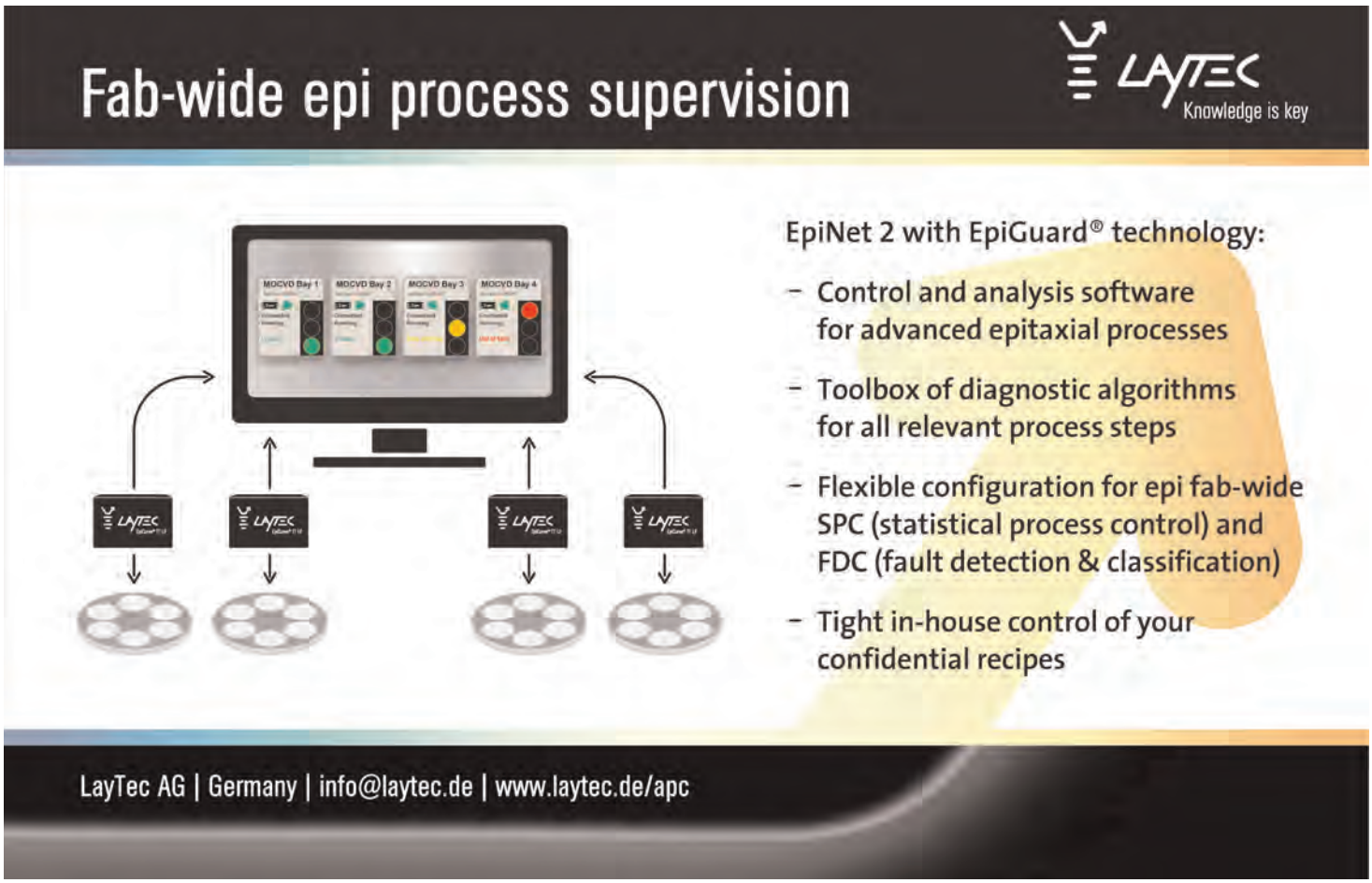
The equipment will contribute towards improving the research capabilities of IES' 'nanoMIR' research group, which works on III-V components in the GaSb sector

"The Riber MBE412 system sold to the IES offers very high modularity and a unique technique for processing large-format substrates for the controlled development of III-V semiconductor-based nanostructures," Tournié states. "The refurbishment of the IES' Compact21 reactor will transform it into a totally new, modular cluster system, with an identical configuration to that of the MBE412 system."

The system (the only one of its kind in Europe) will make it possible to structure academic and industrial research in the GaSb-based semiconductor component field, in line with the objectives of the EquipEx program, says Riber.

The order — with a leading European laboratory, within the framework of France's investments for the future program — confirms Riber's key position in the semiconductor research sector, says the firm.

www.riber.com



Aixtron celebrates its 30th anniversary

Deposition equipment maker Aixtron SE of Aachen, Germany has celebrated its 30th anniversary, after being co-founded by physicist Dr Holger Jürgensen (now honorary chairman of Aixtron's Supervisory Board), Dr Meino Heyen and Heinrich Schumann in December 1983.

What started as a spin-off of RWTH Aachen University is now a publicly listed provider of deposition systems that has played a key role in shaping manufacturing technologies for microelectronic and optoelectronic products including LEDs, lasers, transistors and solar cells.

"One major event was the delivery of the first commercial Planetary Reactor system in 1990 — a milestone in the development of reliable, scalable deposition systems for semiconductors", comments Jürgensen.

Since the first research system supplied by Aixtron to AEG in Ulm in 1984, the firm has sold about 3000 deposition systems worldwide, driven by demand for ever smaller, faster and more cost-effective components.

The development of gas-phase deposition materials coating technologies for use in chip manufacturing has made a great impact, states Aixtron. The firm's production technologies have advanced the global take-up of light-emitting diodes (facilitating efficient and environmentally friendly lighting for consumers) as well as contributing to the fields of data communication, entertainment electronics and cellphone technology.

Aixtron's headquarters building.

"None of this would have been possible without greatly committed employees, colleagues and outstanding partners in research and industry, with whom Aixtron has established longstanding close relationships," says CEO Martin Goetzeler. "Innovative materials technologies will always be the key to new applications," he adds. "We are therefore investing extensively in research and development to create promising new processes and materials. Relevant examples include silicon applications, high-performance electronics and OLED [organic light-emitting diode] technology."

The firm notes that, like the entire semiconductor industry, it witnessed a substantial dip in demand in the 2012/13 financial year. It is therefore implementing a 5-Point Program (presented by Goetzeler at the end of May) that aims to cut costs and enhance efficiency.

Nevertheless, currently about 800 staff worldwide (of which 250 scientists and engineers) are working on future technology trends at Aixtron. In particular, the firm has four R&D laboratories in Herzogenrath in Germany, Cambridge in the UK, Sunnyvale, CA in the USA, and Suzhou in China (with Aixtron generating most of its sales in Asia).

www.aixtron.com

SAMCO's stock transferred to First Section of Tokyo Stock Exchange

Japan's SAMCO Inc, a supplier of etch, chemical vapour deposition (CVD) and surface treatment systems for the semiconductor industry, says that its stock has been transferred from the Second Section to the First Section of the Tokyo Stock Exchange (TSE) market.

Founded in 1979, SAMCO specializes in manufacturing thin-film deposition (PECVD), etching (ICP, RIE, DRIE) and surface treatment (plasma and UV-ozone cleaning) systems for the R&D and production of compound semiconductor, optoelectronics, MEMS and components, including next-generation power devices and LEDs. In May 2001, the firm went public on the Japan Securities Dealers Association over-the-counter market (now TSE JASDAQ – standard). However, SAMCO determined it was best to switch to the main market of the TSE in order to improve its performance in developing new fields and expanding into global markets. Hence last July it switched to the Second Section of the TSE. SAMCO was the first transfer of a listing following consolidation of the TSE and OSE (Osaka Securities Exchange).

SAMCO says that it aims to take advantage of this opportunity to continue improving its financial performance by growing operations.

www.samcointl.com

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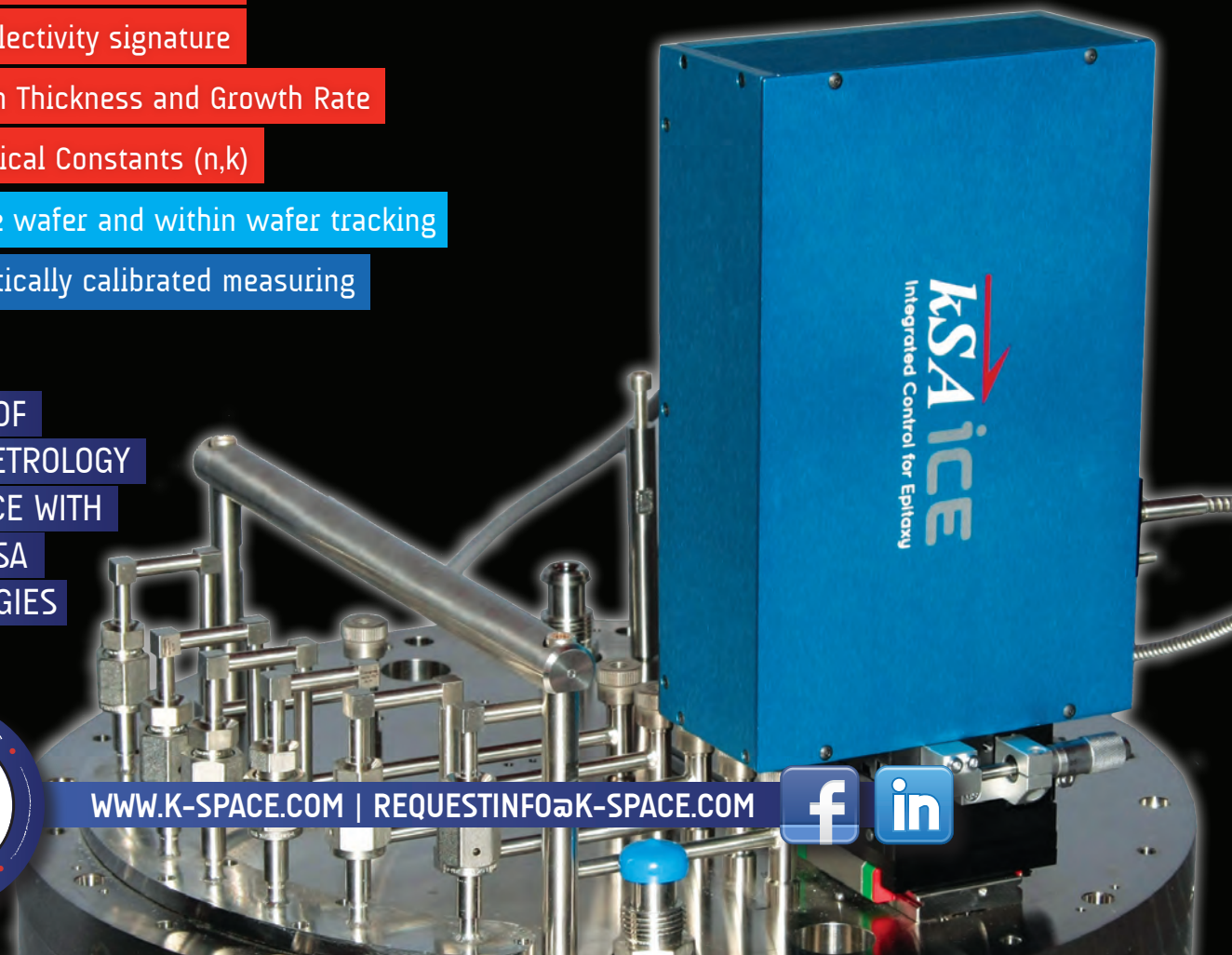

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IN BRIEF

Seminars in India

After a first series of seminars in India (in Bangalore) in 2012, Oxford Instruments has completed a second series (on 'Tooling Nano') at the Indian Institute of Science Education and Research (IISER) Mohali and at the Indian Institute of Technology (IIT) Bombay Mumbai. Over 500 registered overall.

Fabrication sessions discussed etch and deposition, including ALD, magnetron sputtering, ICP PECVD, nanoscale etch, MEMS and MBE.

Analysis sessions covered: ultra-high-vacuum SPM, cryo-free low-temperature solutions, XPS/ESCA, AFM and applications such as nanomechanics, in-situ heating and tensile characterization using EBSD, measuring layer thicknesses and compositions using EDS, nanomanipulation and fabrication within the SEM/FIB.

Oxford Instruments Plasma Technology expands in India with direct sales and service office

After several years growing its plasma and ion beam etching and deposition tools business in India, UK-based equipment maker Oxford Instruments Plasma Technology (OIPT) says that it has experienced such increased demand for its products and support services that it has opened a direct sales and service office through Oxford Instruments India Private Limited (a subsidiary of UK-based Oxford Instruments plc), catering for the firm's key market segments of industry, research and academia.

"We have worked successfully with our agent Aimil Ltd for many years to sell and support our products to our Indian customers, and would like to thank them for their long-standing commitment to our business," says OIPT's sales & marketing director Dr David Haynes.

"We are now in an excellent position to set up a direct presence in India, and are confident that customers will benefit from having local, dedicated Oxford Instruments Plasma Technology service engineers," he adds. "Our direct sales representatives and service engineers will allow an immediate line of communication with us, supporting their existing equipment and consulting on future needs," Haynes says.

Oxford Instruments India's managing director Anurag Tandon adds: "The addition of the Oxford Instruments Plasma Technology business to our Indian operation demonstrates Oxford Instruments' absolute commitment to growing a long-term sustainable business in India."

www.oxford-instruments.com

Structured Materials Industries introduces temperature profiling flange for CVD vertical reactors

Structured Materials Industries Inc (SMI) of Piscataway, NJ, USA, which provides chemical vapor deposition (CVD) systems, components, materials, and process development services, says that its temperature profiling flange is a versatile tool for in-situ optical pyrometry profiling of CVD deposition planes, adding that achieving good temperature uniformity across the deposition plane is essential to optimizing CVD growth uniformity.

The temperature profiling flange is compatible with SMI's Epic and Legend series reactors and is designed to be easily adapted to a variety of Emcore/Veeco MOCVD reactors (D180, D125, E300, E400 etc) or other custom reactors (with offset adapter plates or custom sizes). It is also compatible with a variety of optical monitoring tools including pyrometers, optical growth rate monitors, as well as k-Space and LayTec in-situ monitors. The temperature profiling flange's quartz viewport offers angled or direct perpendicular optical access to platters as large as 7" OD (outside diameter) or, with offset mounting, the same flange can service multiple reactor sizes with adapters. Alternatively, larger custom versions can be fabricated.

Water-cooling lines protect the flange's differentially pumped double O-ring seal, allowing the flange to monitor platter temperatures up to 1200°C in most operating conditions. Additional water cooling of the viewport is required to allow operation through 1600°C platter temperatures.

The flange contains two gas delivery ports, and has mounting points for a perforated gas distribution plate to disperse the gas to simulate a uniform flow. Adapter tubing is required to go between the standard gas line plumbing and the temperature profiling 'showerhead'.

Product specifications include: stainless-steel 304 flange/O-ring or metal sealed versions as standard; an O-ring sealed quartz viewport (with other materials available) that can be given 5° angle to reduce beam scatter; rated to measure platter temperatures up to 1200°C, or 1600°C with optional optical port water cooling clamp-on plates. Options include: custom flow flange adapter plumbing; in-situ/pyrometer adapters; and other angles.

www.structuredmaterials.com

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IN BRIEF

SPTS wins more regional awards in manufacturing and skills investment

Plasma etch, deposition and thermal wafer processing tool maker SPTS Technologies Ltd of Newport, Wales, UK has won two more awards in Wales and the South West UK. This completes a year in which the firm was recognized for a variety of initiatives; from manufacturing excellence to company growth over the past 3 years, culminating in the Queen's Award for Enterprise in International Trade.

At the annual Insider's Made in Wales Awards held in Cardiff, SPTS won the Manufacturer of the Year Award. "The judges recognized our focus on continuous improvement in our internal operations and in our ability to execute on customer engagements," says chief operating officer Kevin Crofton. The firm won the Technology category in 2011.

SPTS has also been honored by UK-based manufacturers' organization EEF's Future Manufacturing Awards with The South West Investing in Skills Award, which recognizes firms that invest to build skills, develop employees and harness the talent of its workforce. SPTS now automatically qualifies for the national finals, where it will compete against other regional winners from the UK. "The skills required by our workforce are highly technical and specialized, and recruitment of new staff as the company grows is an ongoing challenge," says Tony Knowles, VP for global human resources. "It is vital we invest in our people to stay ahead of the technology curve and developments in the market," he adds.

www.spts.com
www.eef.org.uk/awards
www.insidermedia.com/made-in-wales

Plasma-Therm's CEO named an 'All-Stars of the Chip-Making Industry'

Abdul Lateef, CEO of plasma process equipment maker Plasma-Therm LLC of St Petersburg, FL, USA, has been named one of nine 'All-Stars of the Chip-Making Industry' for 2013 by 'The Chip Insider', a weekly report published by semiconductor industry market research and data services company VLSIresearch.

"For some, it's taken several years of methodical execution to an overarching strategy to bring this year together," the report says. "For others it was about being fleet of feet."

Chip Insider cites Plasma-Therm's introduction this year of the first plasma-based die-singulation system as one factor in Lateef's selection. The MDS-100 MicroDieSingulator uses plasma technology to separate individual integrated-circuit chips (on wafers of either silicon or other materials). Other Plasma-Therm products, including VERSALINE and Mask Etcher systems, are used for R&D and in manufacturing of ICs, micro-mechanical devices, LEDs, and other types of electronic components.

Lateef "successfully developed the company into an incredibly innovative etch and deposition tool supplier," comments The Chip Insider report.

The report also cites Lateef's leadership role in the 2009 management buyout of Plasma-Therm from parent company Oerlikon, as well as the firm's success "against far bigger companies" in the mask-etching market. "Plasma-Therm has had continuous growth since the spin-off into an independent equipment supplier," it notes.

Others named as 2013 All-Stars include William M. Holt, executive VP & general manager, Technology and Manufacturing Group, Intel Corp; Dennis P. McGuirk, president & CEO of the SEMI industry association; and executives of Applied Materials and Tokyo Electron Ltd, who recently engineered a merger to form a $12bn combined company.

www.plasmatherm.com

Plasma-Therm holds nanotech symposium at Stanford's Nanofabrication Facility

Plasma-Therm LLC of St Petersburg, FL, USA has conducted a nanotechnology symposium at Stanford University's Nanofabrication Facility (SNF). Presentations at the technology community outreach event addressed a broad range of research topics, including: plasmonics, single-electron devices, gallium nitride (GaN) power devices, GaN-based optoelectronics, terahertz (THz) transistors, and high-resolution lithography and etching. Symposium speakers (professors and researchers from Harvard, Notre Dame, University of New Mexico, Arizona State University, Teledyne Scientific, and GlobalFoundries) provided insight into successes and challenges in their respective fields.

Attendees included graduate students and post-doctoral researchers from seven universities, along with researchers and engineers from 23 local companies, from start-ups to Fortune 500 companies.

The event was held with support from the SNF and the US National Nanofabrication Infrastructure Network (NNIN), which provides resources for academic and industrial users locally and worldwide.

"Events of this type give the technical community an opportunity to interact with researchers who are leading the way in exploring the nanoscale regime," says symposium organizer Dr David Lishan, Plasma-Therm's principal scientist.

http://snf.stanford.edu

Nanotronics Imaging to scale production after $7m Series B financing round

Founders Fund partner Peter Thiel joins board

Optical inspection tool manufacturer Nanotronics Imaging LLC of Cuyahoga Falls, OH, USA has completed a $7m Series B financing round from San Francisco-based technology investment firm Founders Fund (which has previously backed companies including Palantir, SpaceX, Facebook, ZocDoc and The Climate Corporation).

Nanotronics Imaging was founded in 2010 by CEO Matthew Putman Ph.D., former professor of materials science and engineering at Columbia University, and John Putman, former CEO of automated instrumentation firm Tech Pro, which was sold to Roper Industries in 2008.

"Our company's customer base is rapidly growing, and this investment will ensure that we will be able to continue to provide and scale best-in-class products and services to the semiconductor industry, as well as to expand our offerings into new domains such as biomedical diagnostics," says Nanotronics Imaging founder & CEO Matthew Putman, who describes Founders Fund as a "highly regarded and successful venture firm that shares our vision for transformative technology".

Nanotronics Imaging combines optical microscopy with patented image processing and machine intelligence algorithms to produce inspection tools used in a wide variety of manufacturing environments. The firm's technology allows the imaging of a very large area of a specimen with nanoscale resolution. Its nSpec tool couples a computer-controlled microscope and stage with fast image processing techniques to enable high-throughput defect classification and localization for semiconductor substrate and IC chip fabricators.

"Nanotronics' fundamental advances in optics will dramatically enhance the production lines of many of the most critical industries of the future... as more industrial processes take advantage of nanoscale structures," says Founders Fund partner Peter Thiel, who will be joining the Nanotronics' board of directors.

www.nanotronicsimaging.com

SEMI-GAS debuts mobile analytical cart for critical gas line monitoring

SEMI-GAS Systems, a division of Applied Energy Systems Inc of Malvern, PA, USA and a manufacturer of ultra-high-purity gas source and distribution systems, has introduced Mobilytix, a new mobile analytical cart for analyzing impurities within a process gas line. Created to monitor and protect critical downstream gas processes and tools, the new Xturion system features a flexible design that allows for customized instrumentation and data collection.

The standard Mobilytix is designed to monitor moisture, oxygen and particle levels as well as trace impurities of nitrogen, argon and oxygen. As with all SEMI-GAS custom Xturion systems, each unit can be engineered to meet application-specific requirements including mechanical, electrical and enclosure design upgrades. Various analyzer configurations are also available to precisely tailor the system's operational needs for each application.

SEMI-GAS Systems' Mobilytix mobile analytical cart.

The new mobile cart features a color touch-screen, with intuitive navigation, views and sample trends to control day-to-year sampling and data presentation. Overall system operation is easily performed through each individual analyzer's control panel. An integrated automatic data-logging controller collects and compiles analytical data from each analyzer.

The standard enclosure is constructed of 12-gauge black steel and is 44 inches tall, 24 inches wide and 40 inches deep with lockable, steel mesh doors. Size adjustments can be made based on physical constraints and mechanical upgrades.

Each unit features lockable heavy-duty steel casters for both stationary and mobile analytical monitoring.

www.semi-gas.com

Brewer Science ships its first Cee 1300CSX thermal slide debonder for thin-wafer handling

Brewer Science Inc of Rolla, MO, USA, which provides thin-wafer-handling materials, processes and equipment, has announced the first commercial placement of its Cee 1300CSX thermal slide debonder. The debonder was purchased by "an industry leader in the production of high-powered radio frequency (RF) components for use in wireless communications".

The Cee 1300CSX enables high-temperature slide-off debonding of thinned silicon and compound semiconductor substrates — including gallium arsenide (GaAs), gallium nitride (GaN), indium phosphide (InP) and silicon carbide (SiC) — from a rigid carrier to allow further processing of delicate thinned wafers. This debonding can be accomplished in a confidential laboratory setting without interrupting high-volume track production time and without investing large amounts of capital in additional automation.

"This commercial launch marks another strategic milestone in reducing the customer's cost of ownership for thin-wafer handling through Brewer Science's industry-leading equipment, temporary bonding materials, and process integration," says equipment technology strategist Justin Furse.

In a compact footprint, the tool has precise lower platen z-position control and programmable electronic lift pins for loading and unloading. and substrate sizes can be varied. The Cee 1300 CSX also has a constant force mode, excess force sensing and data logging.

Brewer Science claims that the Cee 1300CSX delivers exceptional accuracy, interface capabilities and process flexibility, and enables precise control of the process temperature for thermally sensitive substrate materials, allowing users to accelerate time to market of their new ultrathin wafer technologies.

Improvements engineered into the new Cee 1300CSX debonder design include: precise lower platen z-position control; programmable electronic lift pins for loading and unloading; a compact footprint; flexible substrate sizes; a constant force mode; data logging and excess force sensing.

www.brewerscience.com

SMART orders EVG automated production system

EV Group (EVG) of St Florian, Austria, a supplier of wafer bonding and lithography equipment for MEMS (microelectromechanical systems), nanotechnology and semiconductor applications, says that the Singapore-MIT Alliance for Research Technology (SMART) has ordered an EVG850LT fully automated production bonding system designed for silicon-on-insulator (SOI) and direct wafer bonding using low-temperature plasma activation processing.

SMART — a research center set up by the USA's Massachusetts Institute of Technology in partnership with the National Research Foundation of Singapore, will use the system to support its advanced substrate development efforts.

The MIT research center is located outside the USA in Singapore and has five different research groups, including the Low Energy Electronic Systems (LEES) Research Group, which focuses on integrating silicon CMOS and compound semiconductor materials to enable new integrated circuits for wireless devices, power electronics, LEDs, displays and other applications. The LEES Research Group has a fabrication facility where the EVG850LT has already been installed and is in use.

According to professor Eugene Fitzgerald of MIT's Department of Materials Science and Engineering, SMART chose the EVG850LT for the center's R&D efforts due to the system's high process flexibility and performance, EVG's experience in low-temperature bonding, and expertise and support in process development. "The charter of our LEES Research Group is to identify new IC technologies that enable devices that consume less power, enable higher performance and open up new applications for information systems," he adds. "EV Group's technology and expertise will play an important role in supporting this effort."

The EVG850 platform, upon which the EVG850LT system is built, is the only SOI and direct wafer bonding platform designed to operate in high-throughput, high-yield environments — establishing it as the industry standard in the SOI wafer bonding market, it is claimed. The EVG850LT combines all essential steps for wafer bonding — from cleaning and alignment to pre-bonding and IR inspection — in a single platform, ensuring an ultra-clean production process throughout all stages to enable high-yield, void-free wafers (as opposed to stand-alone processing units that require the wafers to be manually transported in a regular cleanroom environment). The EVG850 supports a variety of advanced substrates, including SOI and silicon on lattice engineered substrate (SOLES) technology, up to 300mm in diameter.

EVG has worked closely with leading research institutes and inventors of SOI technology for more than 20 years, says Frank Huysmans, regional sales director, Asia/Pacific. "SOI wafer producers and researchers rely on EVG's equipment to advance the production and technological capabilities of SOI wafers."

www.EVGroup.com

EVG launches full-field UV nanoimprint litho system for photonics, LED and BioMEMS production

EV Group (EVG) of St Florian, Austria, a supplier of wafer bonding and lithography equipment for MEMS (microelectromechanical systems), nanotechnology and semiconductor applications, has launched the EVG 720 automated ultraviolet nanoimprint lithography (UV-NIL) system.

Providing full-field imprint lithography with an integrated soft stamp/template fabrication capability, the EVG720 enables throughputs of more than 60 wafers per hour. Capable of printing nanostructures as small as 40nm in diameter over a large area in volume production, the system is suited to use in manufacturing optics, photonics, light-emitting diodes (LEDs), microfluidics and other bioMEMS devices, as well as advanced data storage devices. Several systems have already been installed, evaluated and accepted at customer sites.

The EVG720 (the firm's most advanced dedicated NIL system) uses a next-generation UV-NIL process designed specifically to address the needs of high-volume manufacturing (HVM). It provides a combination of high throughput, ease of use and high resolution, enabling volume manufacturing of nanoscale structures at what is claimed to be the lowest cost of ownership (CoO). EVG says that its UV-NIL solutions (including the EVG720) are designed to work with a wide variety of resist materials. This open materials platform approach provides users a high degree of flexibility and process customization, says the firm.

In addition, the EVG720 has an integrated stamp replication capability, which minimizes tool footprint and avoids increased capital equipment costs associated with stand-alone replication systems. EVG's soft working stamps have optimized releasing properties that extend the life of the stamp and enable what is claimed to be ideal imprint results on both flat and rough substrates. Traditional stamps wear down quickly or require additional surface treatment after each imprint and result in increased defectivity on the substrate, which leads to yield loss as well as increased costs from continuous replacement.

The EVG720 automated UV-NIL system.

A one-size-fits-all approach to NIL cannot address every customer's unique manufacturing requirements, which is why EV Group has created a complete NIL solutions portfolio that encompasses all widely accepted imprint techniques

The EVG720 platform is based on nearly 20 years of experience with more than 100 UV-based imprint lithography systems in the field, states business development manager Gerald Kreindl. "We recognize that a one-size-fits-all approach to NIL cannot address every customer's unique manufacturing requirements, which is why EV Group has created a complete NIL solutions portfolio that encompasses all widely accepted imprint techniques: UV-NIL, hot embossing, micro contact printing, step-and-repeat, full-field, and roll-to-roll imprint," he adds. "In addition, we are continuously working to improve the imprint lithography infrastructure by collaborating with companies and research organizations throughout the imprint lithography supply chain."

● EVG exhibited at the SEMICON Japan show in the Makuhari Messe International Convention Complex, Chiba, Japan (4–6 December). Also, during the Exhibitor Seminar the firm presented 'EVG's HVM solution updates for automotive and smart phone applications'. In addition, at the 'Proposals to the Assembly Technologies to Drive 3D-IC' session, Masaya Kawano, head of technology Japan/applications engineer for the Technology Division of EV Group Japan, presented 'Latest wafer bonders which drive 3D-IC technology'.

www.evgroup.com/en/products/lithography/nil_systems/evg720

Packaging equipment firm TOWA establishes TOWA Europe BV as Packaging Development Center

The TOWA Corporation of Japan, which supplies packaging (molding and singulation) equipment for the semiconductor, electronics and LED industries, has expanded its activities in Europe with an Innovation Center for Packaging Development via the establishment of the subsidiary TOWA Europe B.V. of Duiven,The Netherlands.

Europe has become a region where special ICs and electronic applications are being developed and produced, such as sensors, MEMS, vision applications and specific ICs, in particular for semiconductor, automotive and medical applications, says TOWA.

In 2004 TOWA Europe GmbH was established to serve European customers. Activities originally consisted of supplying TOWA encapsulation equipment, after-sales service, and spare parts. However, in addition to this, cooperation with the package/product development centers of European customers and European institutes became an important activity, and TOWA Europe started to play a leading role in the development of new products.

To further expand this, TOWA has hence decided to establish a Packaging Development Center in Duiven, The Netherlands, for which TOWA Europe B.V. has been founded.

A fully equipped laboratory with two TOWA molding systems, test & measuring equipment and an engineering department is available to give full support in all the phases of product development, from initial concept up to test, qualification and industrialization. The Dutch-, German- and English-speaking staff can assist European customers in the process of new package development. In addition, the new facility is also home to the European Marketing, Sales and Service department for TOWA systems.

www.towaeurope.com

Eulitha unveils litho system for photonic patterning

Eulitha AG (a spin-off from the Paul Scherrer Institute in Villigen, Switzerland that develops nanolithographic technologies for optoelectronics, photonics, biotechnology and data storage applications) has announced the availability of the PhableR 100 photolithography system for printing high-resolution nano-structures, especially R&D applications as well as pilot and low-volume production. The system particularly targets the production of periodic patterns such as gratings and photonic crystals required in optics and photonics.

The PhablerR 100 system is based on the proprietary PHABLE (Photonics Enabler) photolithographic technology developed by Eulitha, which enables printing of high-resolution structures in a non-contact, proximity photolithography system. The resolution obtained with the PhableR 100 is essentially the same as what is obtainable from a deep-ultraviolet (DUV) projection lithography system, claims Eulitha, but without the complex and expensive optics and mechanics of such a system. For example, linear gratings with a half-pitch of 150nm can be printed with high uniformity. Also, the "practically unlimited" depth of focus of the image formed by the PhableR 100 means that the high-resolution patterns can be printed with high uniformity even onto non-flat substrates (commonly encountered in photonics applications).

Eulitha's PhableR 100.

The system can expose substrates with diameters up to 100mm using industry-standard chrome-on-glass or phase-shifting masks. The mask and the substrate are loaded manually onto the system and the exposure process is controlled by an onboard computer. Standard i-line photoresists (both positive and negative tone), which are available from common vendors, can be used. Linear or curved gratings, 2D photonic-crystal-type patterns with hexagonal or square symmetry can be printed with feature periods of less than 300nm. The system can also be used like a standard mask-aligner in either proximity or contact mode in order to print micron-scale structures. Targeted applications include R&D projects in photonics, fabrication of gratings for optical diffraction and spectroscopy, light extraction patterns on LEDs, patterned sapphire substrates and color filters.

"We are proud to introduce a solution that will enable our customers to perform high-resolution photolithography with a low-cost system for the first time," says CEO Harun Solak. "This equipment is a result of a long-term development effort at both the Paul Scherrer Institut and Eulitha," he adds.

The system is available for immediate demonstration at the Eulitha site in Switzerland. The PhableR 100 also is being presented at the 13th International Nanotechnology Exhibition & Conference (nano tech 2014) in Tokyo Big Sight,, Japan (29–31 January).

www.eulitha.com

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Rubicon raising $26.2m in stock issue to fund new-product R&D and capacity expansion

On 7 January, Rubicon Technology Inc of Bensenville, IL, USA (which makes monocrystalline sapphire substrates and products for the LED, RFIC, semiconductor and optical industries) announced the sale of 3,047,500 shares of its common stock, including 397,500 shares issuable to sole book-running manager Canaccord Genuity Inc at $10.07 per share (pursuant to the underwriting agreement's 30-day over-allotment option). The share price on the NASDAQ Global Market on 7 January was $11.44 per share.

Net proceeds are expected to be $26.2m, after deducting the underwriting discount and other estimated offering expenses, assuming no exercise by the underwriter of the over-allotment option.

Rubicon intends to use the net proceeds for research and development of new products, capacity expansion and general corporate purposes.

www.rubicon-es2.com

Intematix issued with red nitride phosphor patent

Intematix Corp of Fremont, CA, USA, which makes customizable, patented phosphors and remote phosphor components for LED lighting products and systems, says that US patent No. 8,597,545 was issued on 3 December by the US Patent and Trademark Office. The patent covers novel formulations for red-emitting, nitride-based phosphors and includes products in the firm's XR phosphor product family.

"This patent confirms XR red nitride phosphor as a proprietary Intematix innovation moving LED lighting to higher color quality and reliability," says chief technology officer Yi-Qun Li. "We look forward to working with our customers on the next generation of LEDs with full-spectrum performance and long lifetimes."

Intematix says that red nitride phosphors play a central role in extending the color range of LED applications like general lighting and displays including TVs, monitors and tablets. The firm adds that its red nitrides, combined with GAL (green aluminate) phosphors (arrangements covered by the firm's previous patents, issued in July and September), enable near-perfect color rendering up to 98 CRI (color rendering index).

The XR red nitride also has color stability, with less than perceptible 2SDCM measured color shift in accelerated aging testing.

Such performance results in lighting applications with long-term color quality and consistency, claims Intematix.

www.intematix.com

Intematix launches ChromaLit Linear remote phosphor

Intematix has announced the commercial availability of ChromaLit Linear, a remote phosphor offering uniform luminance over any length, as well as high flux density and a white off-state finish. The product has been recognized by the Illuminating Engineering Society (IES) in its Progress Report featuring the most promising new lighting products.

Remote phosphor is a lighting system architecture where a separate phosphor component is powered by blue LEDs. LED lighting applications use this architecture and the increased light extraction it enables to reduce LED component count and costs. Lighting uniformity and consistency are also improved and supply chains are simplified, says Intematix.

Linear light sources are in widespread use for illuminating commercial and industrial applications worldwide. Office lighting and other commercial applications have been challenging for white LEDs previously because of the need to diffuse the point sources, reducing system efficacy. Intematix says that the ChromaLit Linear product delivers naturally uniform, high-quality light with conversion efficacy of up to 215 lumens per radiant watt or up to 163 lumens per system watt when used with the most efficient blue LEDs available.

"We can forget about low efficacy and pixelation because this product enables high light output, smooth uniformity, white off-state and new possibilities for applications from under-cabinet to troffers to high bay lighting," says Julian Carey, senior director of strategic marketing.

The ChromaLit Linear remote phosphor solution offers flexibility of length, notes the firm. Surface lumen density scales from 500 to 2500 lumens per linear foot, and the system presents new design directions not possible with fluorescent and white LEDs, it is claimed. ChromaLit Linear has also improved the off-state appearance and illumination quality, Intematix adds. It offers 3 SDCM (standard deviation of color matching) color consistency as standard, color temperature options from 3000K to 5000K, and a color rendering index (CRI) of 80.

Samples of ChromaLit Linear are available now and production quantities with standard lead times.

Lighting industry honors for Soraa co-founder Nakamura

Soraa Inc of Fremont, CA, USA, which develops solid-state lighting technology built on 'GaN-on-GaN' (gallium nitride on gallium nitride) substrates, says that one of its founders Dr Shuji Nakamura, was recently honored by Lux Review Magazine as its 'Person of the Year' and was inducted into Electronic Design's Hall of Fame for his outstanding work in the lighting industry.

Organized by Lux Magazine and the Lighting Industry Association, the Lux Awards are designed to reward both creativity and sustainability. In conferring the award, Lux Magazine referred to Nakamura as "the man who single-handedly created the current LED revolution".

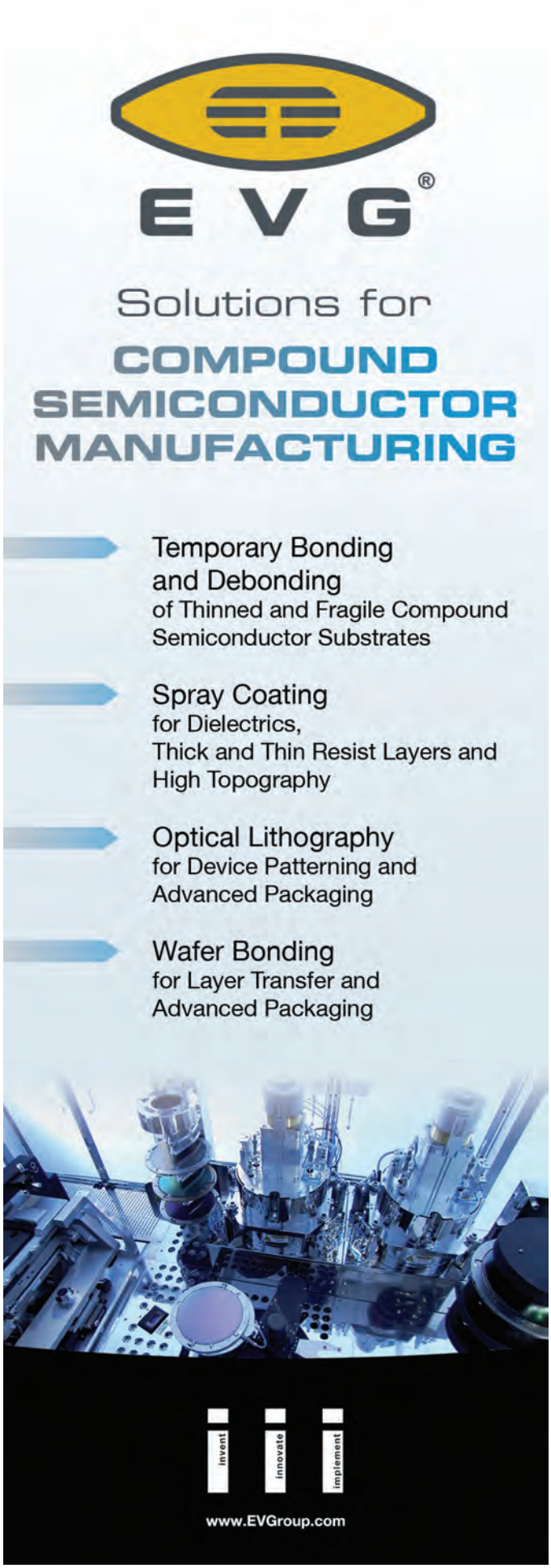
At the end of each year, Electronic Design's editors select a group of new inductees based on level of contribution, industry impact, lasting achievement and feedback from its readers for the publication's Engineering Hall of Fame. "Nakamura enabled an entire industry based on high-brightness LEDs replacing incandescent, gas-discharge, and fluorescent lighting in vehicles, homes, businesses, and outdoors," comment the editors. "He did it by developing a practical way to manufacture efficient blue and ultraviolet LEDs, which are the basis for 'white' LEDs."

"Creating efficient lighting products that do not compromise on performance, offer the highest quality available, and greatly reduce energy waste has always been a driving principle of my work and was the motivation for creating Soraa," says Nakamura, who has been professor in the Materials Department of the College of Engineering, University of California, Santa Barbara (UCSB) since 2000 and is currently also research director of the Solid State Lighting & Energy Center.

Soraa was founded in 2007 by UCSB professors Shuji Nakamura (developer of the blue laser and LED), Steven DenBaars (founder of Nitres) and James Speck (of UCSB's College of Engineering) on the basis that GaN-on-GaN LEDs would produce more light per area of LED and be more cost-effective than technology based on established foreign substrates such as sapphire or silicon carbide (SiC). Now, Soraa's LEDs emit more light per LED material than any other LED; handle more electric current per area than any other LED; and the firm's crystals are up to 1000 times more precise than any other LED crystal, it is claimed.

Nakamura gained B.E., M.S. and Ph.D. degrees in Electrical Engineering from Japan's University of Tokushima in 1977, 1979 and 1994, respectively. Awards include the Nishina Memorial Award (1996), the Materials Research Society Medal Award (1997), the IEEE Jack A. Morton Award, the British Rank Prize (1998), the Benjamin Franklin Medal Award (2002), the Millennium Technology Prize (2006), the Czochralski Award (2007), the Prince of Asturias Award for Technical Scientific Research (2008), The Harvey Award (2009), and the Technology & Engineering Emmy Award (2012). He was elected as a member of the US National Academy of Engineering in 2003.

www.soraa.com



Plessey samples new LED GaN-on-Si mid-power LEDs

Plessey Semiconductors Ltd of Plymouth, UK has announced availability of its next-generation gallium nitride -on-silicon (GaN-on-Si) mid-power LEDs. The product family doubles the luminous efficacy of the firm's first-generation MAGIC (Manufactured on GaN-on-Si I/C) products launched in February. Plessey says that, using standard silicon production techniques, it is able to achieve high-flux-output LEDs at substantially lower cost. The PLW114050 is the first in a family of entry-level LED lighting products to be released.

"We have made great strides forward in refining, productizing and improving our patented MAGIC technology," says chief technology officer Dr Keith Strickland. "We have a roadmap that puts MAGIC ahead of the efficacies achieved by sapphire-based LEDs and, thereby, sets a new milestone in terms of lumen/$ performance," he claims. "By approaching efficacy parity, we are accelerating the widespread adoption of GaN-on-Si LED-based lighting products. Our MAGIC LED products have a cost advantage over comparable sapphire-based LEDs as we use 6", high-yield, standard, automated silicon manufacturing technology," Strickland continues.

"Customers are delighted that a European company is committed to developing and manufacturing world-class GaN-on-Si LEDs," claims chief commercial officer Dr Jose Lopez. "The market currently has many suppliers of LEDs, but the quality and reliability can be variable," he adds. "Plessey is a trusted brand with a 50-year plus track record of manufacturing products to the highest standards."

The PLW114050 is available in a correlated color temperature (CCT) range of 6500–2700K, with a Lambertian distribution in an industry-standard 3020 package. With a drive current of 60mA, the typical forward voltage is 3.2V. Additional package options will be made available.

www.plesseysemi.com

IN BRIEF

DOE SSL advanced technology R&D funding opportunity for 2014

The US Department of Energy (DOE) has announced a solid-state lighting (SSL) R&D funding opportunity 'Solid-State Lighting Advanced Technologies R&D – 2014' (DE-FOA-0000973). A total of up to $10m in funding is directed toward all three existing DOE SSL R&D program areas:

- Core Technology Research — the application of fundamental scientific concepts to SSL technology;
- Product Development — using the knowledge gained from basic or applied research to develop or improve commercially viable SSL materials, devices, or systems;
- US Manufacturing — accelerating SSL technology adoption through manufacturing innovations and improvements that reduce costs and enhance quality and consistency.

DOE will select up to 10 projects. Applications are due by 24 February.

https://eere-exchange.energy.gov

Seoul Semiconductor selected again as only LED maker in Top 20 2013 IEEE Semiconductor Manufacturing Patent Power Ranking

South Korean LED maker Seoul Semiconductor says that, among companies that make LED components only, it was the only one selected by the Institute of Electrical and Electronics Engineers (IEEE) in the top 20 of its 2013 Semiconductor Manufacturing Patent Power Ranking. The firm was also selected in the same category in 2012.

The patent power scorecards by IEEE for each industrial section are based on evaluation of the patent portfolios of more than 5000 leading commercial enterprises, academic institutions, non-profit organizations, and government agencies worldwide. It takes into account not only the size of the organizations patent portfolios but also the quality of their patents with regards to the growth index, impact of the patents, originality, and general applicability of the patents.

Seoul Semiconductor has more than 20 years of experience in semiconductor manufacturing and invests more than 15% of its annual revenue to LED research and development. On average, the firm applies for more than 600 patents every year. Currently, it holds more than 11,000 LED patents, including patents in core LED technologies such as Acrich, Acrich MJT, nPola, TV direct backlight technology, and UV. Seoul Semiconductor says that its patent portfolio in LED technology includes epitaxial growth, fabrication, packaging and system applications.

"Seoul Semiconductor has focused on developing its proprietary technologies in LED lighting for the past 23 years," says Dr Nam Ki-Bum, head director of the R&D center. "As Seoul Semiconductor continues to innovate and introduce new and exciting products for the LED industry it also respects the intellectual property rights of other companies."

www.seoulsemicon.com

Cree appoints Norbert Hiller executive VP Lighting

Cree Inc of Durham, NC, USA has appointed Norbert Hiller as executive VP Lighting. Hiller brings more than two decades of commercial and operational LED lighting leadership to his new role. Hiller has been executive VP LEDs since October 2011.

"Cree has become the industry leader in LED lighting over the last several years and we remain focused on our goal of 100% adoption of LED lighting," says chairman & CEO Chuck Swoboda. "The growth in our LED fixture business combined with the success of the Cree LED Bulb has expanded the scale of our lighting business and increased the focus on sales and marketing. Norbert brings a unique skill set and track record of success to the next phase of Cree's growth."

Norbert Hiller.

Concurrent with Hiller's appointment, Dave Emerson will move into the role of VP & general manager for LEDs. In addition, Ty Mitchell, formerly executive VP Lighting since October 2011, will assume the role of VP Lighting Operations.

www.Cree.com/Lighting

Cree appoints Anne Whitaker to board

LED chip, lamp and lighting fixture maker Cree Inc of Durham, NC, USA says that Anne Whitaker, president, North American Pharmaceuticals, of Sanofi S.A., has been appointed to its board of directors.

"Anne has proven herself to be a leader throughout her career and her extensive experience in strategic management and organizational development will be a tremendous asset," says chairman & CEO Chuck Swoboda.

Whitaker joined Sanofi (a global and diversified healthcare firm) in September 2011. She currently oversees its operations in North America, and is a member of its Global Leadership Team and the US Regional Strategic Management Committee.

A graduate of the University of North Alabama with more than 20 years of experience, Whitaker began her career as a metabolic disease specialist with Upjohn Company. From there she joined GlaxoSmithKline as a sales representative. After holding leadership positions in GlaxoSmithKline's commercial organization, in 2007 Whitaker became VP of Critical and Supportive Care before being appointed senior VP of Leadership and Organization Development from 2008 to 2009. In 2009, she became senior VP & business unit head, Cardiovascular, Metabolic and Urology (CVMU) at GlaxoSmithKline, where she had full commercial responsibility for leading, developing and managing strategic performance of the CVMU business.

www.cree.com

DOE awards clean-energy manufacturing tax credits to two solid-state lighting manufacturers

Two solid-state lighting (SSL) manufacturers are among the 12 businesses that will receive clean-energy tax credits ranging from $700,000 to $30m each (totaling more than $150m collectively), the US Department of Energy (DOE) has announced.

Through Phase II of the Advanced Energy Manufacturing Tax Credit (48C) program — initiated under the American Recovery and Reinvestment Act of 2009 (ARRA) — the tax credits will go toward investments in domestic manufacturing equipment, helping to create thousands of jobs across the USA and increase the country's competitiveness in the global clean-energy market, it is intended.

The DOE and the Treasury worked in partnership to develop, launch and award the funds for the program. The investment tax credit (of 30% for the manufacture of particular types of energy equipment) was made available to 183 domestic clean-energy manufacturing facilities during Phase I of the program, with Phase II awarding the balance that remained out of the $2.3bn in funding.

Supporting projects that must be placed in service by 2017, the credits cover domestic manufacturing of a wide range of renewable-energy and energy-efficiency products, from hydropower and wind energy to the smart-grid and fuel-efficient vehicles. The SSL awardees are:

- LED chip, lamp and lighting maker Cree Inc ($30m) will expand its manufacturing footprint (at its facilities in Durham, NC and Racine, WI), including the purchase, installation and proprietary modification of new machinery that will allow it to produce 304 million next-generation LED lighting systems (LED-based retrofit lamps and integral luminaires).
- Osram Sylvania Inc of Danvers, MA, USA ($1.6m) has developed energy-efficient, single-point LED systems for automotive low/high-beam projectors, reducing wattages by about 70%. The tax credit allows the expansion of production capacity.

http://energy.gov

IN BRIEF

Nichia adds to US patent lawsuit against Everlight

On 22 November, Japanese LED maker Nichia Corp filed an amended complaint in its on-going patent infringement lawsuit against Taiwanese LED maker Everlight Electronics Co Ltd and its US subsidiary Everlight Americas Inc, originally filed on 11 September in the US District Court for the Eastern District of Texas.

In addition to its original claim alleging infringement by Everlight of US Patent No. 7,432,589, the amended complaint alleges infringement of three other US Patents 7,462,870, 7,521,863 and 8,530,250. Nichia also named two new defendants regarding US Patent 8,530,250: Zenaro Lighting Inc (a US subsidiary of Everlight Electronics) and Zitroz LLC (a US distributor of Zenaro's products).

Nichia says it seeks to protect its patents and other intellectual property rights and takes action against infringers in any country, where appropriate and necessary.

Everlight says it will continue to defend and fight for the rights of its clients and shareholders. "Nichia recklessly filed a series of patent litigation against Everlight since 2006. However, in 2011, both the civil and administrative actions brought by Nichia in Taiwan obtained final rulings against Nichia." Everlight has also filed cases such as patent infringement suits against Nichia in the USA, Germany, Japan and China.

"Everlight has continuously shown respect towards intellectual property and currently holds more than 1600 patents in order to protect customer's interests," it continues. "With respect to Nichia's amended complaint, Everlight believes that it is meaningless."

www.nichia.com
www.everlight.com

Cree extends LED bulb portfolio to 75-Watt replacement

LED chip, lamp and lighting maker Cree Inc of Durham, NC, USA has extended its Cree LED Bulb portfolio with the launch of the Cree LED 75-watt replacement bulb (joining the existing 65W-, 60W- and 40W-replacement options).

Compared with a traditional incandescent bulb, the bulb uses 82% less energy and is designed to last 25 times longer. The new bulbs retail for $23.97 — delivering a higher-output LED bulb in a standard form factor that is priced less than competing 75W-replacement LED bulbs, it is claimed.

With the same shape and size as the popular A19 traditional bulb, the Cree LED 75W replacement bulbs can be placed in most lighting fixtures in the home, the firm says. Unlike many low-priced LED bulbs, it is claimed, the firm's omni-directional LED bulbs turn on instantly and are easily dimmable with most standard incandescent dimmers. The bulb is illuminated by Cree LED Filament Tower Technology and provides a compact optically balanced light source within a real glass bulb to deliver warm-white light.

The Cree LED 75-watt replacement bulb delivers 1100 lumens, consumes 13.5W and is available in soft-white (2700K) color temperature. The bulb is backed by Cree's 10-year limited warranty.

www.creebulb.com

LEDway HO Roadway luminaire replaces 400W high-pressure sodium lighting, halving energy use

Cree is building on its LED street light portfolio with the LEDway High Output (HO) LED street light.

With its higher lumen output, it enables the LEDway Series to address large multi-lane freeways and expressway applications, replacing inefficient high-pressure sodium (HPS) lighting up to 400W from a single platform. The LEDway HO LED street light provides highly focused, directional light at nine adjustable lumen output levels, reducing energy consumption by more than 50% compared to HPS street lights in most roadway applications, it is reckoned.

"As we've already seen with thousands of LEDway Series installations throughout North America and Europe, the Cree LEDway HO LED street light represents another example of why municipalities, departments of transportation and investor-owned utilities should move to proven Cree LED lighting over incumbent, inefficient technologies," says Greg Merritt, Cree's VP marketing, lighting. "With virtually no maintenance and using significantly less energy than a 400W HPS, the LEDway HO LED street light dramatically lowers customers' total cost of ownership," he adds, emphasizing Cree's 10-year limited warranty.

Designed for multi-lane freeways, expressways and roadways, Cree's LEDway HO LED street light is enabled with NanoOptic Precision Delivery Grid optic technology to deliver better optical control and more uniform white light than HPS. Also, with the LEDway HO LED street light's adjustable lumen output option, one type of fixture can be used to meet the lighting and energy needs for a variety of applications.

The LEDway High Output LED street light is sold through Cree lighting sales channels throughout the USA and Canada.

www.cree.com/lighting

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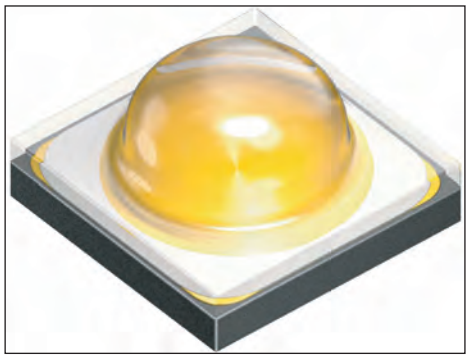
Osram launches Oslon Square LED for longer lifetime at high temperatures

Since excessive heat generation is one of the main reasons why light-emitting diodes fail, Osram Opto Semiconductors GmbH of Regensburg, Germany has launched the Oslon Square, an LED that withstands high ambient temperatures. To ensure that the colors of several LEDs in a luminaire remain uniform even at higher temperatures, they are measured and binned at 85°C (very close to the temperature encountered in lighting applications within buildings, in everything from spotlights to retrofit light sources).

Osram has optimized the heat dissipation of the Oslon Square to allow an increase in the junction temperature. "With our new conversion technology, we can produce significantly thinner converter layers," says Ivar Tangring, SSL Product Development at Osram Opto. "The thinner layers better dissipate the heat, thus enabling the higher temperatures in the LED," he adds. The Oslon Square can hence reach a lifetime of considerably more than 50,000 hours, even at high temperatures of up to 135°C in the LED.

Osram Opto says that measuring and binning at operating temperatures of 85°C is of great significance to users who further process the LEDs into luminaires. Users receive precise information on parameters such as luminous flux or color stability, which they need to optimally define the properties of their products.



The new Oslon Square LED.

Further, the improved temperature behavior leads to higher luminous efficacy in the application (greater luminous flux for the applied electrical power), helping users to optimize the price/performance ratio of their luminaires, says Tangring. Due to the higher permitted junction temperatures, fewer large heat sinks are required, simplifying the design of lamps and luminaires because they can be smaller and therefore less costly.

With housing dimensions of 3mm x 3mm and a beam angle of 120°, Osram Opto says that its Oslon Square is particularly suitable for the various applications in buildings. With a correlated color temperature (CCT) ranging over 2400-5000K, it can generate either warm-white or cold-white light. The color rendering index (CRI) is over 80 and the luminous flux is 202lm (at 3000K, with a drive current of 700mA). Product variations with a different color temperature spectrum and higher color rendering indices are to follow. The typical voltage (at 700mA) is 2.9V (the maximum is 3.2V), while the maximum current is 1.8A (previously it was 1.5A) and the thermal resistance (Rth) is 3K/W (previously it was 3.8K/W).

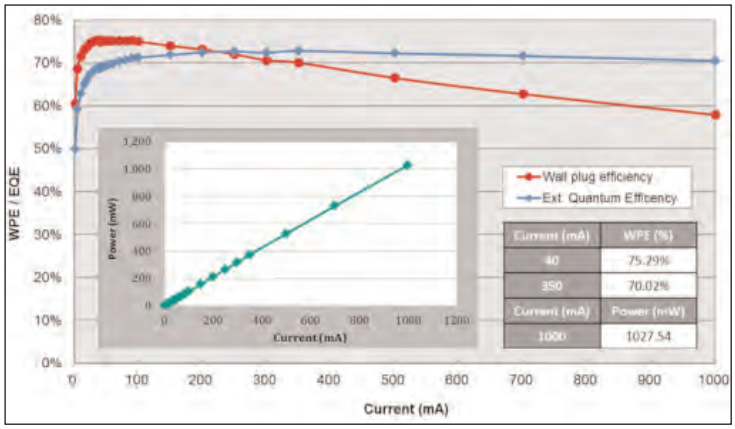
At present, the new LED is undergoing quality testing. The certification process under the LM-80 long lifetime standard is underway. The results of the 3000 hour test were due at the end of 2013, and those of the 6000 hour test in spring 2014.

www.osram-os.com

Epistar launches high-efficiency 850nm IR LED

Epistar Corp (Taiwan's largest LED chipmaker) says that lots of forward-looking technologies have been developed and now applied to LED chip production, such as novel transparent conductive thin film, compound mirror structures, and a new epitaxial structure design for reducing the absorption of light. The new technologies will raise light extraction efficiency and LED performance, says the firm.

Recently, Epistar Lab has made improvements in infrared products and set what are claimed to be new records for the LED industry. According to the latest data, the SFPN42 infrared LED (which has a chip size of 1mm x1mm) has achieved wall-plug efficiency of 75% with an operating current of 40mA and over 70% at 350mA. Power exceeds 1W, and has reached 1027mW with an operating current of 1A.



Wall-plug efficiency and power vs current for SFPN42 LED.

Currently, IR LEDs are adopted mostly in security monitor, smart touch panel and wireless communication systems. In future, Epistar aims to push them into other high-potential market, says the firm.

www.epistar.com.tw

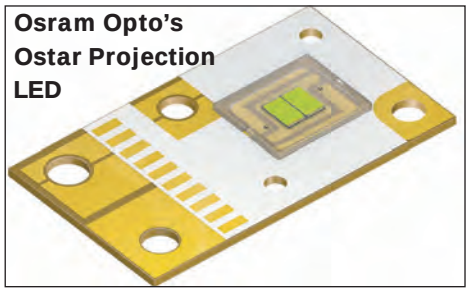
Osram launches high-power versions of Ostar Projection LED for system output of up to 1700lm

Osram Opto Semiconductors GmbH of Regensburg, Germany has launched two high-power versions of its Ostar Projection LED offering such high luminous flux that they can be used in office projectors with brightness levels of up to 1700 lumens.

The firm says that, due to their optimized design, they offer very high luminous flux from the available chip surface. Between 1000 and 8300 lumens can be produced, depending on the color and the version (two- or four-chip) used. An anti-reflection coated glass cover instead of the usual lens, together with external optics, ensures that the light is very well bundled. The new LEDs are matched to various additional optics for highly efficient light output.

At the heart of the LEDs is a 2mm^2 high-current chip based on thin-film and UX:3 technologies. The two new versions of the Ostar Projection contain two chips (P1W) or four chips (P2W) with a total luminous area of 4mm^2 (1.5mm x 2.6mm) and 8mm^2 (2.6mm x 3.2mm), respectively.

In LED projectors, three LEDs in the colors red, green and blue serve as the light source. The LEDs are pulsed one after the other (color sequential mode), making the color filter wheel used in classic lamp projectors unnecessary. The high output of the new LEDs comes



Osram Opto's Ostar Projection LED

from the latest chip technologies and Osram's C^2 ceramic conversion technology for a particularly efficient green. While the P1W version emits light pulses with typical brightnesses of 500lm, 1250lm and 4150lm for blue, red and green (at maximum pulse current) respectively, the P2W version emits light pulses with typical brightnesses of 1000, 2500 and 8300 lumens for blue, red and green. These high brightness levels require maximum current pulses (240Hz, 50% d.c.) of up to 12A for red and 16A for green and blue for the P1W and up to 24A for red and 32A for green and blue (8A per chip) for the P2W, as well as optimized product design to efficiently remove the resulting heat.

"To apply this high current, the four high-power chips of the P2W are connected in parallel," says Andrew Lin, LED product marketing manager. "Only then do the new Osram Ostar Projection LEDs generate their maximum brightness from the chips and turn into real power packs for large imagers," he adds. "This really opens up the use of LED projectors in offices and classrooms."

Osram says that its Ostar Projection LED enables light to be routed as efficiently as possible through the optical system, which is restricted by the etendue (which describes the relationship between the emitting light surface and the projected light surface, and characterizes how 'spread out' the light is in area and angle). The etendue of these LEDs is retained, producing an image with the same etendue as the source and, in conjunction with external optics, an extremely narrow beam of light is produced, says the firm.

To keep the thermal resistance and therefore the temperature rise of the LEDs at an extremely low level, the chips are placed directly on a copper plate (and not in a classic LED package) and screwed down to improve the connection with the heat-sink. Thermal resistance (R_{th}) is 1.1K/W for the P1W and 0.7K/W for the P2W. For both versions, the package size is 27mm x 16mm x 2.1mm.

The two new Ostar Projection LEDs were premiered at Osram Opto's suite in the Las Vegas Hotel at the International CES show 2014 in Las Vegas (7–10 January). Volume production is due to start in March.

www.osram-os.com

SemiNex certified as ISO 9001:2008 compliant

SemiNex Corp of Peabody, MA, USA, which designs and makes InP-based high-power laser diodes for military, industrial, medical, dental and cosmetic applications, says that it has joined over 1 million companies and organizations worldwide in implementing the ISO 9001:2008 set of standards for quality management systems. The firm's quality management system received certification from TUV USA (part of TUV NORD International).

Certification typically takes 7–12 months. SemiNex says it was able to obtain certification in just 3 months, due largely to its existing quality system that had been continually improved over the last 5 years.

"Achieving ISO certification is a reflection of the processes and attention to detail already in place," says president & founder David Bean.

SemiNex says that it approached certification with the mindset that a review of its processes and procedures would be of value both internally and externally. In addition to formalization of the firm's Quality Policy (to design & build laser products that consistently meet or exceed customer expectations), it worked to ensure that all internal procedures and policies reflected this. Externally, the firm believes that customers will benefit from the continuous improvements made in support of ISO certification.

www.SemiNex.com

POET dissolves Special Strategic Committee as firm transitions from research to development

Firm focusing on developing technology design kit during MBE system maintenance

POET Technologies Inc of Toronto, Canada — which, through subsidiary OPEL Defense Integrated Systems (ODIS Inc) of Storrs, CT, USA, has developed the proprietary planar-optoelectronic technology (POET) platform for monolithic fabrication of integrated III-V-based electronic and optical devices on a single semiconductor wafer — has announced completion of the work of its Special Strategic Committee (SSC) and the update of its published milestones. The board of directors has endorsed the firm's commercialization plan put forward by the SSC, which is chaired by executive director Peter Copetti.

The SSC was established last June to investigate and initiate strategic alternatives for the commercialization of the POET technology platform using a multi-faceted approach based on discussions with potential industry partners. The following major recommendations of the SCC have been implemented:

● ***A plan for establishing POET Development Alliances (PDAs)*** — The firm is in discussion with several potential industry partners who have the necessary foundry infrastructure to take the POET technology to the manufacturing stage. The partnership roles encompass fab, tool and engineering resources as well as product and library development for future applications. Ideal partners will be producers of products that can incorporate the POET IP technology to provide the lowest power consumption and cost-effective industry-disruptive system solutions.

● ***Update to Milestone 5 and Milestone 7*** — Both milestones are now expected to be completed in the first 3-5 weeks of 2014. Significant progress has been made and both milestones are in the final phases of testing, says the firm. Specific announcements will be made once the final testing is complete for both the Switching Laser Demonstration and the Optical Thyristor-based Infrared Detector and transistor combinations.

● ***Drive for reduction of feature size to 100nm range (100nm), Milestone 8*** — The firm has introduced new specific milestones associated with reducing feature size to the 100nm range in scale. The POET team has realized sub-micron device operation down to 200nm. The path to maintaining scaled operation down to 100nm has been identified. The firm has scheduled its molecular beam epitaxy (MBE) system to be shut down for cleaning and maintenance for a period of about 6 weeks after completing Milestones 5 and 7. After restarting MBE, the firm expects to complete Milestone 8 and, accordingly, the timeline for completion of this milestone has been moved to first-quarter 2014. The 100nm goal is matched to the commercial III-V foundry capabilities and will demonstrate the greater than 50x speed improvement together with lower power consumption by a factor ranging from 4 to 10 (depending on the application) compared to silicon at smaller nodes. Significant progress has been made on the completion of this milestone, although it has proven to be more difficult to achieve with the limited equipment available to POET. This highlights the importance of developing an alliance with a fab partner where repeating this milestone and improving it will be significantly easier with advanced lithography equipment standard for CMOS processing, believes the firm.

Both milestones [5 and 7] are now expected to be completed in the first three to five weeks of 2014

The firm expects POET's features (monolithic integration of fully complementary transistors together with optical transmitters and transceivers) to disrupt current optical-electrical techniques with faster and less expensive monolithic IC solutions.

For the first time, it is claimed, p-channel and n-channel devices can be integrated monolithically in a III-V semiconductor environment with the potential to fully replace all silicon based CMOS circuitry with higher speed and lower power. Fully integrated single-device optical transceivers (including the full range of digital data processing at speeds of 100Gbps and beyond) will become a reality, as they cannot be manufactured with current silicon technology for power, speed and cost reasons, the firm adds.

● **Design kit preparation**

In addition to optimizing device parameters and yields, the next focus is to establish POET's technology design kits, a comprehensive design rules and device parameter library for POET enabling customers and partners to implement the POET process into their preferred foundries. It also aims to help licensed designs in a POET device ecosystem to proliferate and help existing silicon library functions to migrate to POET technology-based circuitry in a minimum amount of time. In order for the POET team to focus on the preparation of technology design kits, the SCC has recommended that Milestones 9 and 10 are delayed. New completion dates for those milestones will be announced once a primary industry partner has been identified.

● **Operation management and program management**

In addition to appointing a senior VP ►

of operations in November, key management changes are underway at the research facility in Storrs. Efficient program management will be instituted and all documentation and design kit efforts will be handled on-site in a direct manner. This step underscores the current transition from research to development-oriented activities within POET, indicating the maturity of the technology at the present time, says the firm. This management reporting structure should encourage success in finalizing the research stage of POET and provide for the long-term substantiation and transfer of the involved IP, believes the firm. A new development team will be formed with partners to scale the POET technology, bringing it to a mature stage.

Globalization plans

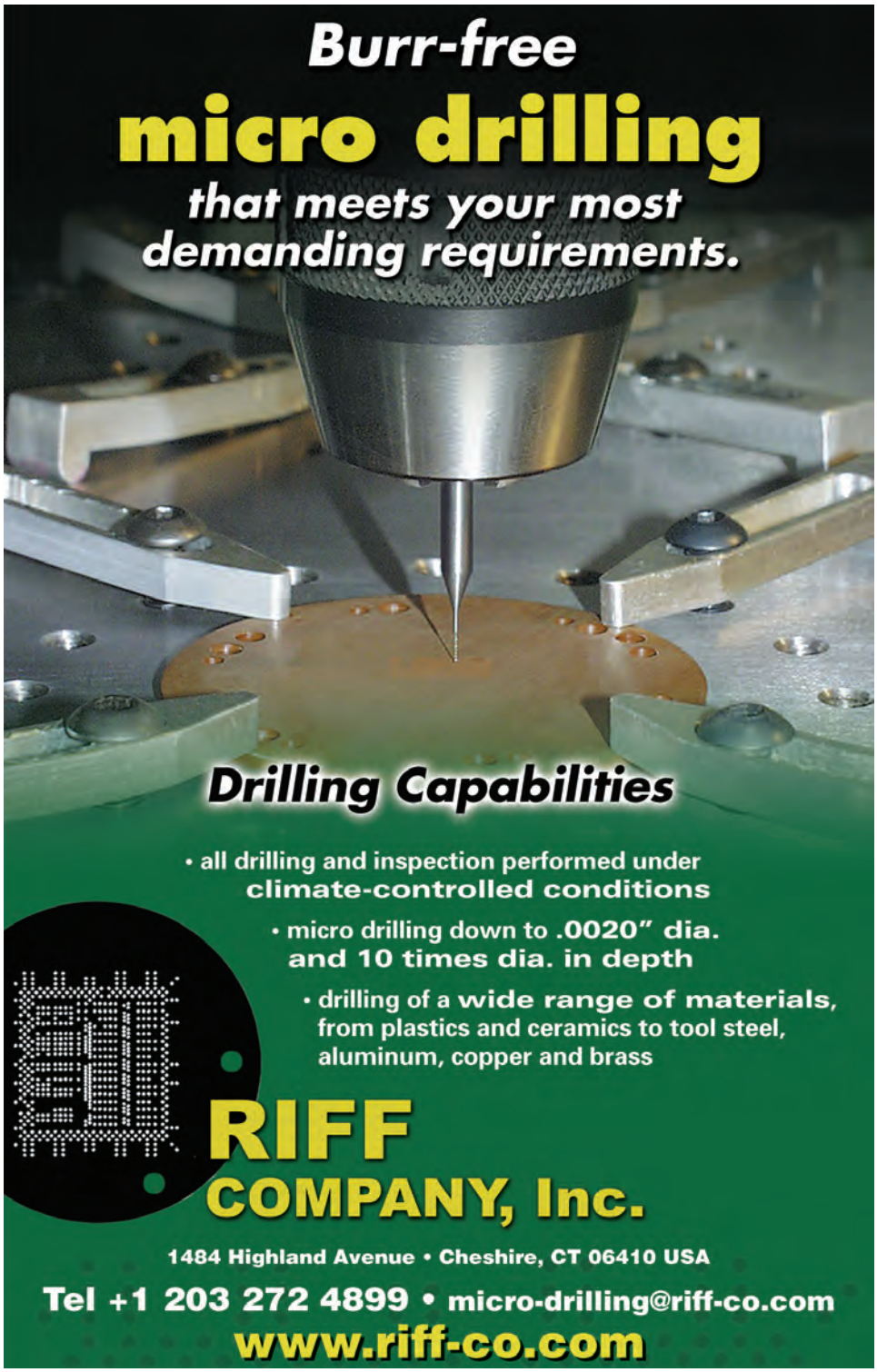
The firm is planning several initiatives to raise global awareness of POET and to increase its global investor base. It intends to split monetization of the IP between multiple commercial markets and military applications and products to maximize returns of all the different aspects of the POET IP.

"The SSC's recommendations are the cornerstones of the company's strategy for unlocking the value of POET's intellectual property," says Copetti. "Preparing for a development alliance with comprehensive documentation and full availability of a technology design kit will definitively enable industry partners to incorporate POET technology into their products, thereby shortening time-to-market for potential products, and helping to commercialize POET in the marketplace quickly," he believes. "We are encouraged by our ongoing discussions to date with potential partners. As the general basic strategic goals recommended by the SSC have been adopted by the board of directors, the SSC will be dissolved and the company will now change its focus from research to development, with a view to 2014 being the major recognition year for the POET technology."

The proprietary POET platform has demonstrated planar monolithic standard CMOS fabrication of gallium arsenide (GaAs)-based integrated circuit devices containing both electronic and optical elements on a single wafer. The firm says that, by offering process IP with the potential for increased speed, density, reliability, lower power and costs, POET offers the ability to disrupt Moore's Law to the next level, overcoming current silicon-based lithography and device bottlenecks in regards to speed and power.

The firm is offering a broad technology basis for several key markets. The development of technology design kits in 2014 will focus on a phased approach. Specific markets and partners will be targeted over time as technology design kits become available.

www.poet-technologies.com



GigOptix raises $12.6m in public offering of stock

On 24 December, GigOptix Inc of San Jose, CA, USA (a fabless supplier of analog semiconductor and optical communications components for fiber-optic and wireless networks) closed its underwritten public offering of newly issued shares of common stock (announced on 18 December).

Offered at a price to the public of $1.42 per share, the 9,573,750 of shares sold in the offering includes 8,325,000 shares plus the underwriter's full exercise on 24 December of their 30-day over-allotment option of 1,248,750 shares of common stock.

GigOptix expects to use the net proceeds of about $12.6m (after underwriting discounts and commissions) for working capital and other general corporate purposes. The company may also use a portion of the net proceeds for licensing or acquiring intellectual property or technologies to incorporate in its products, capital expenditures, to fund possible investments in and acquisitions of complementary businesses, partnerships, and minority investments.

www.gigoptix.com

NeoPhotonics appoints chief financial officer

NeoPhotonics Corp of San Jose, CA, a vertically integrated designer and manufacturer of both indium phosphide (InP) and silica-on-silicon photonic integrated circuit (PIC)-based modules and subsystems for high-speed communications networks, has appointed Ray Wallin as senior VP & chief financial officer.

In over 30 years in the high-tech industry, Wallin has held senior financial management positions at several high-growth semiconductor manufacturing firms and has experience with both public and private companies including expertise in building a sound financial infrastructure within a company, says NeoPhotonics.

Wallin was most recently CFO of Micrel Inc (which provides analog, high-bandwidth communications and Ethernet IC solutions), where he led the finance, investor relations, human resources and IT departments globally. He drove a strategy of improving gross and operating margins, reducing manufacturing and overhead costs, and maintaining a strong balance sheet and cash flow.

Wallin is "a seasoned semiconductor industry veteran with an exemplary track record of managing complex components businesses with global manufacturing operations," says chairman & CEO Tim Jenks. "We are looking forward to Ray's contributions as we continue to grow our business, expand our operations including in Asia, and strive to increase shareholder value," he adds.

"The company is well positioned to maintain its leadership position in the accelerating global adoption of 100G," believes Wallin. "I look forward to helping strengthen the company's systems and controls while working to improve its overall financial performance."

Prior to Micrel, Wallin was CFO of Neterion, which provided 10 Gigabit Ethernet (10GbE) adapters for server and storage environments. As CFO & senior VP at public analog semiconductor firm Sipex Corp, he managed all financial and legal functions. He was also responsible for re-listing the firm on the NASDAQ Capital Market and managing a multi-year restatement process, bringing it current with its periodic SEC reporting requirements.

Prior to Sipex, Wallin was CFO of iWatt and Kendin and had senior finance roles with Cirrus Logic.

Wallin succeeds Cal Hoagland (interim CFO since September). For continuity with ongoing financial reporting and control improvements, Hoagland (a partner with CFO services firm FLG Partners) will continue in an executive consulting role through the filing of the firm's annual report on Form 10-K for 2013.

www.neophotonics.com

Oclaro announces exchange of all convertible debt

Oclaro Inc of San Jose, CA, USA (which provides lasers and optical components, modules and subsystems for optical communications) says that holders of all $25m of the 7.5% exchangeable senior secured second lien notes due 2018 have exercised their right to exchange their notes for shares of common stock.

"This transaction is another indicator of our recovery as we position Oclaro for a healthy future," says CEO Greg Dougherty. "The exchange of this debt to equity is another milestone in Oclaro's recent restructuring efforts," he adds. "It reinforces to our customers, employees and shareholders that we are executing on efforts to improve our balance sheet, which is now largely debt-free."

The rate for the exchanges was 541.7118 shares of common stock per $1000 in principal amount of notes, equal to a price of $1.846 per share. Accordingly, the firm will issue 13,542,791 shares in connection with the exchanges, with cash payable in lieu of fractional shares. In addition, pursuant to the terms of the indenture governing the notes, the exchanging holders were entitled to interest make-whole premium in connection with the exchanges, which totalled about $8.3m.

No notes remained outstanding.

www.oclaro.com

GigOptix raises Q4/2013 revenue guidance from 5% to 7% growth

...but $7.8m still down slightly on $7.9m in Q4/2012

In connection with the Needham Annual Growth Conference in New York City (on 14 January), GigOptix Inc of San Jose, CA, USA (a fabless supplier of analog semiconductor and optical communications components for fiber-optic and wireless networks) announced that it expects revenue for fourth-quarter 2013 to be about $7.8m. This is up 7% sequentially on Q3/2013's $7.3m and above its guidance (provided on 28 October 2013) of 5% growth. However, this is still down slightly year-on-year from $7.9m in Q4/2012.

The firm believes that about 70% of revenue will come from its High-Speed Communications (HSC) product line and 30% from its Industrial (ASIC) product line.

GigOptix cautions that its anticipated revenue results are preliminary, based on the best information currently available, and are subject to completion of financial statements for Q4/2013. The firm expects to report its results for both fourth quarter and full-year 2013 in early February.

www.gigoptix.com

Infinera appoints Brad Feller as senior VP of finance, then chief financial officer from March

Infinera Corp of Sunnyvale, CA, USA, a vertically integrated manufacturer of digital optical network systems incorporating its own indium phosphide-based photonic integrated circuits (PICs), has appointed Brad Feller as senior VP of finance. He joins Infinera after more than five years in senior finance positions at fabless semiconductor company Marvell Technology Group (most recently as interim chief financial officer).

Also, on 1 March, Feller will become Infinera's CFO, replacing Ita Brennan, who previously announced her resignation effective 28 February. Ms Brennan will continue to direct Infinera's finance activities as CFO until then.

"Brad's management experience with large, publicly held technology companies will enable the smooth transition in financial leadership at Infinera and be a valuable asset to us as we continue on a path of solid execution and growth," says CEO Tom Fallon. "His success in guiding strong financial organizations and processes adds to the depth of our executive leadership team," he adds. "The company is well positioned to continue its strong performance in the growing 100G optical upgrade cycle," comments Feller.

Prior to Marvell, Feller served as corporate controller of Integrated Device Technology and in various roles at Ernst & Young LLP in the high-tech practice serving large multinational clients (including Intel, Juniper Networks and Oracle). He is a Certified Public Accountant (inactive) in the State of California and holds a Bachelor of Science degree in Business Administration from San Jose State University.

www.infinera.com

Firecomms signs Victory as sales rep in north central USA

Firecomms Ltd of Cork, Ireland and Tongxiang, China has signed a representative agreement for Victory Sales to offer its fiber-optic transceiver products to key industrial automation, transportation, and medical businesses in north central USA.

"Firecomms' resonant-cavity LED fiber-optic technology delivers major improvements in performance and cost over competing fiber optic products," comments Dan Triplett, corporate line manager, Victory Sales.

As an extension of Firecomms' in-house sales team, Victory provides a sizable team, employing 26 sales engineers out of a total staff of 36, and serving customers in 14 states within the north central region. "With a proven consultative selling technique, the company is very successful in working with key accounts in the north central USA," comments Lawrence Thorne, Firecomms' VP of sales & marketing, The Americas.

In mid-November, Firecomms announced full production and shipping of its new RedLink line of fiber-optic transmitters and receivers for the industrial command, control and communications markets. The RedLink series of DC-capable transmitters and receivers are drop-in compatible with the Versatile Link range of products. RedLink devices are suited to low-speed and DC-capable applications, such as IGBT/thyristor control and fault feedback or field I/O, in areas where immunity from harmful electro-magnetic interference (EMI) or high-voltage signals is required.

www.firecomms.com
www.victorysales.com

Finisar reports fifth quarter of revenue growth to record $290.7m

Datacom product sales up 46% year-on-year

For its fiscal second-quarter 2014 (ended 27 October 2013), fiber-optic communications component and subsystem maker Finisar Corp of Sunnyvale, CA, USA has reported a fifth consecutive quarter of revenue growth, to a record $290.7m. This is up 9.3% on $266.1m last quarter and up 25.3% on $232m a year ago, driven by both datacom and telecom products.

Revenue for datacom products was $204.3m, up 46% on $139.8m a year ago and 10.7% on $184.4m last quarter, driven mainly by increased sales of 10G-and-above Ethernet transceivers. Revenue for telecom products was $86.5m, down 6% on $92.2m a year ago but up 5.9% on $81.6m last quarter, driven mainly by increased sales of wavelength-selective switches (WSS) and reconfigurable optical add-drop multiplexer (ROADM) line-cards.

Like last quarter, Finisar had just one 10%-or-greater customer. The top 10 customers represented 61.4% of total revenue (up from 59.7%).

"We continued to make significant strides in new product development [resulting in the delivery of a record number of new products to customers] that we believe will drive future revenue growth," says CEO Eitan Gertel. "For example, we demonstrated our new 100Gbps CFP4 Ethernet transceiver for short-reach datacom applications.," he adds. "This transceiver provides 75% greater face-plate density and 80% less power consumption than our original CFP,."

As a result of the higher revenue, a favorable product mix and operating leverage, On a non-GAAP basis, gross margin has risen further, from 30.5% a year ago and 35.1% last quarter to 37.1% (above the guidance of 36%).

Operating expenses have risen from $60.9m last quarter to $63.2m, due mainly to higher compensation expenses. Despite this, driven by the revenue growth and improvement in gross margin, operating income has risen further, from $15.8m (operating margin of 6.8% of revenue) a year ago and $32.4m (12.2% of revenue) last quarter to $44.8m (15.4% of revenue, above the expected 13.7–14.7%). Likewise, net income has risen again, from $14.2m a year ago ($0.15 per diluted share) and $31.3m ($0.31 per diluted share) last quarter to $43.8m ($0.43 per diluted share, above the guidance of $0.37–0.41).

During the quarter, cash and cash equivalents rose by $28.1m, from $288.4m to $316.5m.

This was after capital expenditure of $29.7m, up again, from $25.4m in fiscal Q4/2013 and $27.9m last quarter, but again below the expected $32m. Last quarter, Finisar attributed that shortfall to "a slight delay in the timing of payments related to the new manufacturing facility we are building in Wuxi, China".

We expect the shell of the second building [at the firm's new production site in Wuxi, China] to be complete by fall of 2014, and it will be fitted out a floor at a time, as needed to accommodate growth and migration of manufacturing to lower-labor-cost regions

For fiscal third-quarter 2014, Finisar expects revenue and operating income to increase again for the sixth consecutive quarter and to set new company records. Revenue should rise to $290–305m, driven by growth in datacoms, as telecoms business will be relatively flat (due to the impact of 1 month of the annual telecom price reductions that typically take effect on 1 January). Nevertheless, gross margin should still be 37%, reflecting leverage from higher volumes. The firm also expects operating margin to rise further to 15.5%. Earnings per diluted share should be $0.43–0.47.

Capital expenditure is expected to rise further, to $32m, driven primarily by starting construction on the shell of the second building at the firm's new production site in Wuxi. "We expect the shell of the building to be complete by fall of 2014, and it will be fitted out a floor at a time, as needed to accommodate growth and migration of manufacturing to lower-labor-cost regions," says chief financial officer Kurt Adzema.

"Revenue is driven primarily by growth in the world demand for bandwidth for the ever-increasing distribution and use of video, images and digital information," notes executive chairman & co-principal executive officer Jerry S. Rawls. "Another important trend that is benefiting us is the growth in cloud services, with larger data-centers and increasing number of longer, higher-speed connections. This increases the optical content in data-centers and creates more opportunities for Finisar products," he adds. "Over time, both enterprise and carrier spending will continue to increase to provide more bandwidth capacity. We believe Finisar is uniquely positioned with our broad product line, extensive customer engagements, profitable vertically integrated business model and strong balance sheet to capitalize on these market opportunities."

www.finisar.com

Finisar raises $225m in offering of convertible senior notes

In a private placement of 0.50% convertible senior notes (due 2033) to initial purchaser Merrill, Lynch, Pierce, Fenner & Smith Inc (for resale to qualified institutional buyers in the USA), on 16 December Finisar raised $225m (increased from the $200m aggregate principal amount announced initially on 9 December). The firm also granted the initial purchaser a 30-day option to buy up to an additional $33.75m of notes (increased from the $30m announced initially) solely to cover over-allotments.

The notes are unsecured, senior obligations of Finisar, and interest is payable semi-annually at a rate of 0.50% per annum. They will mature on 15 December 2033, unless earlier repurchased, redeemed or converted.

Holders may require Finisar to redeem the notes for cash on 15 December 2018, 15 December 2023 and 15 December 2028 at a redemption price equal to the principal amount plus accrued and unpaid interest to, but excluding, the redemption date. In addition, holders may require Finisar to redeem the notes for cash upon a change of control or a termination of trading of the common stock, or other securities, issuable upon conversion of the notes.

Finisar may not redeem the notes prior to 22 December 2018. On or after22 December 2018, Finisar may redeem for cash all or part of the notes at a redemption price equal to the principal amount of the notes to be redeemed, plus accrued and unpaid interest to, but excluding, the repurchase date.

Prior to 15 June 2033, the notes will be convertible at the option of the holders only upon the occurrence of specified events, and thereafter until the close of business on the second scheduled trading day immediately preceding the maturity date, the notes will be convertible at any time. Upon conversion, the notes will be settled in cash, shares of Finisar's common stock, or any combination the two, at Finisar's option.

The initial conversion rate is 33.1301 shares of common stock per $1000 principal amount of notes (equivalent to an initial conversion price of $30.18 per share of common stock), subject to adjustment in certain circumstances. This initial conversion price represents a premium of about 40% relative to the last reported sale price of Finisar's common stock on 10 December.

Finisar said that it expected to use the net proceeds from the offering for general corporate purposes (including working capital) and might also use a portion of the proceeds to acquire complementary businesses, products or technologies. The firm has since acquired InP-based 100G high-speed receiver and photodetector maker u2t Photonics (see below).

Finisar acquiring Berlin-based u2t Photonics

InP-based receivers, photodiodes and modulators to complement tunable lasers in modules for 100G coherent metro and long-haul

Finisar has agreed to acquire u2t Photonics AG of Berlin, Germany for about $20m in cash (subject to certain adjustments). Finisar will also assume net debt of about $7m. The transaction is expected to close during January, subject to the satisfaction of customary closing conditions.

Finisar will hence add u2t's indium phosphide (InP)-based 100G high-speed receivers and photodetectors to its existing portfolio of high-speed optics technologies. The acquisition will also consolidate Finisar's previously announced partnership with u2t on InP-based IQ Mach-Zehnder modulators for 100G coherent applications.

When combined with Finisar's narrow-linewidth tunable lasers, these receiver, photodiode and modulator technologies and products will provide a full suite of optical components and enable Finisar to offer vertically integrated modules for the 100G coherent metro and long-haul markets, the firm says. u2t's total revenue was about $33m in 2013.

"During our collaboration to acquire the assets of [Berlin-based] COGO Optronics GmbH and develop the InP modulator technology from the Fraunhofer Heinrich-Hertz-Institute (HHI), we realized that Finisar's technical strength, ability to cost-effectively commercialize technology, and global access to customers and markets would combine extremely well with our industry-leading technology and design capabilities," says ut2's CEO & co-founder Andreas Umbach. "The acquisition provides a one-of-a-kind opportunity for our employees and innovative technologies to make a greater impact on the optical communication markets," he adds.

"Finisar is very excited about the near-term applications for the u2t technology and products for the 100G coherent telecom markets," says John Clark, Finisar's executive VP for technology and global R&D. "We are even more excited about the potential to use this technology to help drive data rates higher than 100Gb/s and form factors smaller than the CFP2 module and enabling new market applications in both telecom and datacom," he adds.

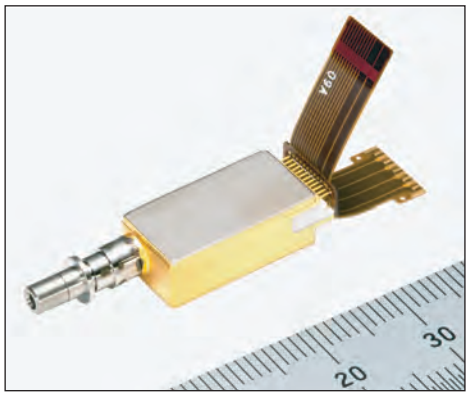
www.u2t.de/en
www.finisar.com

Mitsubishi Electric to launch low-power 4-wavelength integrated 100Gbps EML-TOSA

Tokyo-based Mitsubishi Electric Corp has developed a laser diode-transmitter optical subassembly (TOSA) that enables 100Gbps optical transmission in one fiber using four-channel wavelength-division multiplexing (WDM), which should help to downsize 100Gbps communication facilities and expand high-speed 100Gbps optical transmission networks.

Featuring four 25Gbps electro-absorption modulators with a laser diode (EML, emitting in the 1.3µm wavelength band) and an optical multiplexer integrated in one 8.8mm x 26.5mm x 5.6mm package, the FU-401REA TOSA is claimed to be one of the world's lowest-power and most compact EML-TOSA solutions for IEEE 100GBASE-LR4 applications.

As 10Gbps optical network interfaces give way to 40Gbps and 100Gbps interfaces, installations in confined spaces are requiring the use of smaller and lower-power equipment. The need for downsized, low-power EML-TOSAs led to the development of the FU-401REA TOSA, which will help to meet the demand for smaller equipment and should hence expand the market for 100Gbps EML-TOSAs, the firm reckons.



The new FU-401REA 100Gbps EML transmitter optical subassembly.

By integrating four individual TOSAs into one package, the footprint is reduced by 75% compared to the firm's existing FU-412REA model. The package size complies with common specifications for small CFP2 optical-transceiver modules. The new device also contributes to improved transceiver module efficiency by adopting flexible printed wiring board featuring easy mounting.

In addition, the new EML chip can operate at up to 15ºC higher than the existing FU-412REA. Cooling power is hence reduced by 50%, helping to lower the operating power of the optical-transceiver module. Operating power is 2W maximum.

With an output power of –2dBm to +2dBm, maximum transmission distance is 10km for local-area network LAN-WDM) operation.

The FU-401REA will be exhibited at the Optical Fiber Communication Conference and Exposition (OFC 2014) in San Francisco, CA, USA (11–13 March). Shipments will begin on 1 April.

www.MitsubishiElectric.com

MACOM launches low-power quad-channel modulator driver for 100G coherent CFP and CFP2 modules

M/A-COM Technology Solutions Holdings Inc of Lowell, MA, USA, which makes semiconductors, components and subassemblies for RF, microwave and millimeter-wave applications, has made available samples of the newest addition to its portfolio of modulator drivers for 100G applications.

The MAOM-003405 is a quad-channel 32Gbps modulator driver IC for 100G coherent transponders in CFP and CFP2 form factors. Its low power dissipation, small size and high gain are key features that enable 100G coherent solutions in the size- and power-constrained pluggable form factors, MACOM says.

The MAOM-003405 has a differential input that meets the stringent CFP2 input voltage requirements, while the single-ended output voltage of up to 6.5V_{pp} is suitable for next generation optical modulators. The driver has low power consumption, low RMS jitter, and typical rise/fall times of 12ps, claims MACOM. The four channels are packaged in a single surface-mount package that is optimized for maximum isolation and minimum crosstalk between channels. The device is therefore suitable for real-estate-constrained users looking for a high-performance, low-power 100G modulator driver solution.

"With the previously announced MAOM-003404, MACOM now offers the smallest-size and lowest-power driver solutions for both single-ended and differential optical modulators for use in 100G coherent CFP and CFP2 modules," claims Vikas Manan, engineering director for Optoelectronics products.

"Demand for high-bandwidth services continues to increase and coherent optical processing lays the foundation for increasing bandwidth from 10G to 40G to 100G and beyond," comments Daryl Inniss, VP & practice leader at market research firm Ovum Inc. "It offers the ability to make the network more programmable and unlocks new network architecture possibilities," he adds. "Size and power continues to play an important role in the adoption of coherent-based optical modules. The MACOM solution helps to make the pluggable form factor an appealing technology."

www.macomtech.com

Emcore's quarterly revenue rebounds by 29% to $43.1m

Deferred solar revenue leads to dip in margins

For fiscal fourth-quarter 2013 (to end-September), Emcore Corp of Albuquerque, NM, USA, which makes compound semiconductor-based components and subsystems for the fiber-optic and solar power markets, has reported revenue of $43.1m, down 9.3% on $47.5m a year ago but up 28.7% on $33.5m last quarter due mainly to higher Photovoltaic revenue after a significant increase in international business (including a large shipment of a few million dollars that had been deferred from last quarter). Revenue for full-year fiscal 2013 was $168.1m, up 2.7% on $163.8m in fiscal 2012.

Fiscal Q4/2013 Photovoltaics revenue was $20.5m (47% of total revenue), up 17.7% on a year ago (37% of total revenue) and 71.9% on $11.9m last quarter (36% of total revenue). Full-year Photovoltaics revenue was $71.2m, up 5.2% on fiscal 2012's $64.7m.

Fiber Optics revenue was $22.6m (53% of total revenue), down 24.9% on a year ago (63% of total revenue) but up 4.9% on $21.6m last quarter (64% of total revenue). Full-year Fiber Optics revenue was $97m, up 0.9% on fiscal 2012's $96.2m.

Overall gross margin has risen further, from 9.7% a year ago and 12.1% last quarter to 12.5% in fiscal Q4/2013. Full-year gross margin has risen from 10.9% in fiscal 2012 to 16.8%.

Photovoltaics gross margin was 13.5%, down from 22.2% a year ago and 28.6% last quarter (and significantly lower than the target of about 30%). This was due mainly to the significant increase in lower-margin international revenue plus record concentrated photovoltaic (CPV) solar cell sales of over $6m to the terrestrial solar market (which are typically single-digit gross margin). Nevertheless, full-year Photovoltaics gross margin has risen from 20% to 25.8%, due mainly to higher revenue and lower sales activities in lower-margin terrestrial systems product line following the sale of assets in fiscal 2012.

Fiber Optics gross margin has risen from 2.4% a year ago and 3% last quarter to 11.6%. "We experienced market recovery of our broadband fiber-optics business and operating performance improvement in the telecom product division," notes CEO & president Dr Hong Hou. "While we have seen a significant improvement in our tunable XFP product yields and margins, this manufacturing line is still under-utilized and margins are below our average Fiber Optic gross margins," adds chief financial officer Mark Weinswig. Full-year Fiber Optics gross margin was 10.1%, up from 4.5% in fiscal 2012, when lower revenue due to the impact of the October 2011 flood at Thailand-based subcontract manufacturer Fabrinet resulted in higher overheads (as manufacturing of certain fiber-optics components was moved to company-owned facilities in the USA, involving higher labor and other related costs).

We expect our gross margins in the Fiber Optics segment to improve in future quarters as we complete the ramp-up of our new product line at our contract manufacturer... We continue to improve our cost structure and believe that we can reach breakeven at a quarterly revenue level at $47–48m

Quarterly operating expenses have risen from $11.7m last quarter to $12.5m, due mainly to increases in R&D expenses related to the Solar business.

On a non-GAAP basis, net loss has improved from$6.3m a year ago and $5.9m last quarter last quarter to $5.6m. Full-year net loss has been more than halved from $26.3m in fiscal 2012 to $11.4m for fiscal 2013.

In June, Emcore agreed an equity transfer for the sale of its 40% equity interest in its China-based Suncore terrestrial concentrated photovoltaic (CPV) component- and system-making joint venture to partner San'an Optoelectronics Co Ltd in Xiamen, China for $4.8m. The transaction was recorded and payment was received during fiscal Q4/2013. Due to this other fundraising activities during the quarter, cash, cash equivalents and restricted cash balance rose from $6.6m to $16.9m.

During the past quarter, the Space Photovoltaic division was awarded more than 15 separate orders from several major aerospace firms in the USA and Asia. "This contract serves both the US government and commercial satellite missions, with a total value in excess of $20m," says Hou. As of end-September, order backlog for Photovoltaics (Space Solar) was $57.1m, down only 1.7% on last quarter's record $58.1m.

Consequently, for fiscal first-quarter 2014 (to end-December 2013), Emcore expects revenue of $43–45m, with improvements in both the Fiber Optics and Space Photovoltaic segments.

"We do expect our gross margins to bounce back to their normal levels," says Weinswig. With a "meaningful increase in our Photovoltaics gross margins... We continue to believe that the Photovoltaics business' target gross margin is at roughly 30%," he adds. "We expect our gross margins in the Fiber Optics segment to improve in future quarters as we complete the ramp-up of our new product line at our contract manufacturer [as yield and product costs improve] and our

Fiber Optics revenues increase," Weinswig continues.

Although fiscal Q1 operating expenses will be a little higher due to certain corporate-related costs, operating expenses should subsequently be down to $11.5–12m per quarter. "We continue to improve our cost structure and believe that we can reach breakeven at a quarterly revenue level at $47–48m," says Hou.

"In the light of the challenges in our Fiber Optics business, we have completed realignment in engineering, operations and general management functions over the last several months," says Hou. "Most recently, we welcomed Dr LC Chiu as our new general manager for our Fiber Optics business," he adds. "Chiu is a veteran in the Fiber Optics industry, bringing over 20 years of experience in engineering design, manufacturing, quality and business processes and a wealth of knowledge and expertise in the fiber-optics industry. With his deep technical and operations background, we believe he can drive further improvements in our business for new product introduction, cost reduction and operational efficiency."

In October, Becker Drapkin Management acquired about 8% of the firm's common stock. Steve Becker of Becker Drapkin Management; Dr Gerry Fine, Professor and Center Director of Boston University; and Steve Domenic, general partner of Sevin Rosen Funds, have now joined Emcore's board of directors. "They bring significant experience in all different aspects of business and strategy," comments Hou.

Emcore announces changes to board

Dr Thomas Russell has decided to not stand for re-election to Emcore's board at the end of his term, which expires at the 2014 Annual Meeting of Shareholders. Separately, John Gillen will retire at the meeting.

Also, chairman Reuben F. Richards has been re-appointed to the board's Class C directors. He was formerly a Class A director. He also informed the firm that he will not stand for re-election at the 2015 Annual Meeting of Shareholders and that he will step down as chairman at the 2014 meeting but will remain chairman emeritus until the 2015 meeting, at which time he will step down from the board.

Russell acquired Emcore's majority interest and served as chairman in 1995. The firm became a public company in 1997. Emcore says that Russell has been instrumental in providing strategic and corporate governance, which allowed it to transform from a single-product start-up — making metal-organic chemical vapor deposition (MOCVD) systems — to a leading firm in compound semiconductor technology and applications, citing in particular Russell's interest in advanced solar cell technology. He became chairman emeritus in 2008, and is currently chairman of the board's Nominating Committee and also its Strategy and Technology Committee.

Gillen was appointed to the board in 2003. He is currently chairman of the board's Compensation Committee and also is a member of its Audit Committee.

"Both men have been instrumental in Emcore's transformation and have made significant contributions to the company's strategic direction and governance over the years," comments president & CEO Dr.Hou.

Emcore appoints Steven R. Becker, Stephen Domenik and Gerald Fine to board

Emcore has reached a settlement agreement with Becker Drapkin Management L.P. and its affiliated funds whereby Steven R. Becker, Stephen Domenik and Gerald Fine have been appointed to its board of directors, effective 9 December.

Becker has been a partner at Becker Drapkin Management since 2004. He currently serves on the board of national close-out retailer Tuesday Morning, semiconductor firm Pixelworks Inc and Special Diversified Opportunities. He previously served on the board of Plato Learning Inc (a provider of education services and training), Ruby Tuesday Inc (the operator of a chain of casual dining restaurants), and Hot Topic Inc (a national retailer).

Domenik has been a general partner with venture capital firm Sevin Rosen Funds since 1995. In June 2012, he was appointed to the board of MoSys Inc (a publicly traded IP-rich fabless semiconductor company) and currently sits on the boards of various private companies. Domenik previously served on the board of publicly traded fabless semiconductor company NetLogic Microsystems Inc from January 2001 until it was acquired by Broadcom Corp in February 2012. During his tenure at Sevin Rosen Funds, he led numerous investments in private companies.

Fine has been a Professor of Practice and Director at the Engineering Innovation Center of Boston University since 2012. From 2008 to 2011, he was president & CEO of Schott North America and led operations of all Schott AG businesses in North America, including solar, pharmaceutical packaging, electronic packaging, and lighting and imaging and advanced materials. Fine also served as executive VP, Photonic Technologies for Corning Inc. He previously served on the board of directors of CyOptics Inc (a semiconductor laser manufacturer for telecom applications), Crystal IS Inc (a UV LED substrate manufacturer), Kotura Inc (a provider of silicon components for datacoms and telecoms), and Pixtronix Inc (a provider of low-cost displays for portable devices).

www.emcore.com

Soitec to receive €21.3m in French government support after EC approves financing

€68.9m five-year Guépard program targets higher-efficiency four-junction CPV cells

In early December, concentrating photovoltaic (CPV) system maker Soitec of Bernin, France was informed that the European Commission (EC) has approved financing for the five-year Guépard program, which was launched in May 2012 to develop a new generation of highly efficient photovoltaic cells with unprecedented yield for use in CPV systems.

Guépard was selected in April 2012 as part of the low-carbon energy section of the French government program 'Invest for the Future' (Investissements d'Avenir), which is managed by the French environment and energy management agency (ADEME - Agence de l'Environnement et de la Maîtrise de l'Energie).

As well as program coordinator Soitec, Guépard brings together the French Alternative Energies and Atomic Energy Commission (CEA), and the small/medium-size enterprise (SME) InPACT of Pomblière, France, which manufactures indium phosphide (InP) single-crystal wafers. For all partners collectively, the program represents a total investment of €68.9m over five years. The EC's notification to the French government of its funding approval will give Soitec access to €21.3m in government support (€5.9m in direct subsidies and €15.4m in repayable advances). The firm says that approval demonstrates the value of the Guépard program in developing a high-added-value solar industry in France and in Europe based on CPV technology.

Guépard targets a major technical breakthrough: developing a new generation of solar cells to achieve previously unreachable efficiency in converting solar energy to electricity. Soitec reckons that, with its portfolio of key technologies in the transfer of semiconducting materials, it has the expertise and knowledge required to create four-junction solar cells. The efficiency record of 44.7% reached in September (following preliminary work carried out by Soitec with Fraunhofer ISE, CEA-Leti and Berlin's Helmholtz Centre) confirms the viability of the four-junction concept, the firm adds.

"With the Guépard program, our ambition is to allow our CPV technology to achieve unequalled levels of efficiency and competitiveness," notes Soitec's chairman André-Jacques Auberton-Hervé. The program is "strategically important not only for Soitec but also for the opportunities it will create in France and the rest of Europe," he adds. "We would like to thank the French Prime Minister, the French General Investment Commission, CGI, and the French Environment and Energy Management Agency, ADEME, for the support and the policy of promoting innovation as part of the 'Invest for the Future' program."

www.soitec.com
www.inpactsemicon.com
www.ademe.fr/invest-avenir

Soitec announces financing and construction of CPV plant in Portugal

Concentrating photovoltaic (CPV) system maker Soitec of Bernin, France says that a group of investors — including a large European energy supplier, the largest Portuguese installer of electrical grid infrastructure, and the largest Portuguese Foundation — has completed financing and started construction of a 1.3MWp CPV solar power plant in Portugal. The plant is the first to be funded by the partnership, demonstrating the various stakeholders' confidence in CPV technology and its ability to fulfill Portugal's plans for generating cost-efficient renewable energy, says Soitec.

Financial stakeholders in the project include the firm Enovos, Luxembourg's main energy supplier (operating also in Germany, France and Belgium), and the Calouste Gulbenkian Foundation (a Portuguese private institution of public utility whose statutory aims are in the fields of arts, charity, education and science). The plant's installation is being managed by EIP (Electricidade Industrial Portuguesa) while Luz-On is the project developer and Soitec is supplying the CPV equipment — all being also shareholders of the project company.

The new CPV plant is being built in Alcoutim, in Southern Portugal, one of the sunniest regions in Europe. As one of 11 projects that the Portuguese government has authorized to spearhead the development of CPV in the country, it is intended to demonstrate the suitability of CPV technology. Electricity will be produced by 82 Soitec systems, using the firm's Concentrix CPV dual-axis tracking technology. The CPV modules are reckoned to be more than twice as efficient as conventional photovoltaic modules.

Soitec says that the ability of CPV technology to operate without cooling water and withstand hot ambient temperatures while having minimal environmental impact make it suited to use in locations such as Portugal.

First Solar modules to power 48MW of projects in France; firm's installed capacity in Europe now over 4GW

First Solar Inc of Tempe, AZ, USA says that its cadmium telluride thin-film photovoltaic (PV) modules will power four solar energy plants in France, with a combined capacity of 48MW.

Developed and owned by independent renewable energy producer Photosol of Paris, France, the projects are being constructed in the country's Auvergne and Midi-Pyrénées regions: three plants, with a total capacity of 37MW, are located in the communes of Dompierre sur Bresbe, Gennetines and Marmanhac; a fourth facility, with a capacity of 11MW, is being built in Sarrazac. Engineering, procurement & construction (EPC) services for all four projects are being provided by French engineering company Jayme da Costa Energie, a longstanding Photosol partner since 2011.

The plants have been designed to have a minimal impact on the communities and ecosystems in which they are located: while three of the facilities are built on pastureland — allowing landowners the additional benefit of being able to graze livestock at the sites — the fourth is sited near an oak forest and includes access for wild animals.

"As France actively promotes the adoption of solar energy, these projects will contribute towards the country's efforts to diversify its energy mix," says Photosol's managing director David Guinard. "We expect these projects to make a significant local impact by providing communities with clean energy and contributing significantly to Europe's CO_2 reduction goals," he adds. "Our choice of First Solar's thin-film modules was based on a combination of cost-competitiveness, unrivalled bankability, the ability of its modules to reliably deliver solar power, and the fact that the technology has the smallest carbon footprint, with the fastest energy payback time."

The four new power plants are the largest ever undertaken by the firm [Photosol] and also mark the first time it has partnered with First Solar

Founded in 2008, Photosol has developed solar power plants with a total capacity of 63MW in operation across France and has a project pipeline that exceeds 250MW. The four new power plants are the largest ever undertaken by the firm and also mark the first time it has partnered with First Solar.

"These projects are an excellent example of how France, like other parts of Europe, can diversify its power generation portfolio and achieve energy security by maximizing the use of available land and leveraging its most abundant energy resource," says Luis Pedro Marques, managing director of Jayme da Costa Energie. "We look forward to continuing our partnership with Photosol and First Solar," he adds.

"These projects collectively represent a significant boost to Photosol's installed capacity as this young, dynamic company continues to build on its successes," comments Stefan Degener, First Solar's director of business development for Europe.

First Solar says that it has had a fully fledged European presence since 2004. As a result of the latest deal, its installed capacity in continental Europe now exceeds 4GW, equivalent to the electricity generated by about four nuclear power plants. Its modules power an estimated 1 million homes across the region, while displacing over 1.2 million metric tons of greenhouse gases (based on European Union averages) per year.

www.photosol.fr

First Solar signs power purchase agreements with member cities of Southern California Public Power Authority for 40MW project

Cadmium telluride (CdTe) thin-film photovoltaic module maker First Solar Inc of Tempe, AZ, USA has signed power purchase agreements (PPAs) with member cities of the Southern California Public Power Authority (SCPPA) for electricity to be generated at the $40MW_{AC}$ Kingbird photovoltaic solar power plant in Kern County, California. First Solar is developing — and will construct — the project.

The cities of Pasadena, Riverside, Colton and Azusa signed 20-year PPAs that will supply power from the solar plant to the cities' municipal power utilities. With its $20MW_{AC}$ PPA, the City of Pasadena reaches its goal of obtaining 40% of its power from Category 1 renewable energy. A separate $20MW_{AC}$ PPA was jointly signed by Riverside, Colton and Azusa.

Depending on final permitting, construction on the 320-acre Kingbird project, located near Rosamond, California in the Antelope Valley, could start in mid-2014, and is expected to create up to 200 jobs at its peak. The plant is expected to be commissioned in late 2015.

In its first year, Kingbird will produce enough energy to power more than 11,000 homes, offsetting more than 20,000 metric tons of CO_2 annually (equivalent to taking about 4000 cars off the road each year, and displacing over 18,000 metric tons of water consumption annually).

www.firstsolar.com

Calyxo inaugurates 60MW module production line

Annual capacity able to be extended to 100MW

Calyxo GmbH of Bitterfeld/Wolfen-Thalheim, Germany, the largest manufacturer of cadmium telluride (CdTe) thin-film solar panels in Europe, says that its new production line has been inaugurated in a ceremony attended by guests including Minister of Economic Affairs Dr Tamara Zieschang, mayor Petra Wust, investors, suppliers, customers and the firm's closest partners.

The new fully automated production line has an annual capacity of 60MWp, with the option of extending it to 100MWp. Calyxo's existing production capacity is 85MW.

The firm did research work for its new manufacturing processes over four years. "Construction of the new production line took a total of 5 years, with a total investment of about €54m," says CEO Dr Florian Holzapfel, "a long construction phase" for the solar industry, he acknowledges. "But we have adjusted our strategic decisions in the market place, and now the new production line is a clear sign that we and the Calyxo investors believe in the market of tomorrow," he adds.

Dr Norman Johnston, chairman of the advisory board of Calyxo GmbH and CEO of parent firm Solar Fields.

For product development, Calyxo has cooperated with the Fraunhofer Institute for Silicon Photovoltaics in Halle, Germany, among others. Also, the firm has been supported by the state of Saxony-Anhalt.

In the solar market the firms that survive are not automatically the ones that are strong but those that can adapt to the market and their requirements, believes chief technology officer Dr.-Ing. Michael Bauer.

Over the last year, Calyxo has been able to acquire and implement several EPC (engineering, procurement & construction) projects nationally and worldwide, proving the versatility of the company, it is claimed. With output spanning 75–85Wp, Calyxo's modules allow a variety of applications, from small installations in single family homes to large megawatt plants, the firm says.

www.calyxo.com

Calyxo delivers modules for construction of biggest PV plant in Croatia

Calyxo GmbH of Bitterfeld/Wolfen-Thalheim, Germany, the largest manufacturer of cadmium telluride (CdTe) thin-film solar panels in Europe, and the Frankfurt-based PV project developer Solar Magna Germany AG have begun a collaboration with Fotonapon d.o.o. of Zagreb, Croatia on construction of the largest thin-film PV plant in the former Yugoslavia.

The plant will be installed on a multiple 1000m^2 roof of cement manufacturer CEMEX d.o.o in the Dalmatian coastal town of Split. The hall construction is particularly suitable for energy production by a PV system, it is reckoned. The predetermined inclination angle and the shadow-free environment can expect a high solar harvest.

SolarMagna's construction of the new PV plant in Croatia.

"We have deliberately chosen the thin-film technology of Calyxo from Bitterfeld-Wolfen because another already operating small plant met fully our expectations," says Solar Magna's CEO Tonci Bozic.

The project will be supplied with Calyxo's specially developed insertion system for thin-film PV modules, which is said to enable easy module mounting and significantly reduced installation time.

Further megaWatt-scale projects are already developed and ready to be started in 2014, says Calyxo.

Calyxo supplies modules for 2.2MW solar park in Ohio

US contractor Rudolph/Libbe has begun construction of a 2MW thin-film solar park for the Toledo Zoo in Toledo, Ohio. The solar array, which will offset about 30% of the zoo's electricity needs, will consist of about 28,000 CdTe modules produced by Calyxo.

Toledo-based solar component manufacturer Nextronex will provide inverters, combiner boxes and distributed architecture for the solar park.

The PV system is being installed on a 22-acre brownfield site in south Toledo and is expected to be completed in early to mid-2014.

www.rudolphlibbe.com

China's Suqian City to provide $32.5m via JV with Ascent to build 25MW CIGS PV manufacturing plant

Ascent Solar Technologies Inc of Thornton, CO, USA, which makes lightweight, flexible copper indium gallium diselenide (CIGS) thin-film photovoltaic modules on flexible polyimide that it integrates into its EnerPlex series of consumer products, has signed a definitive agreement to establish a joint venture entity with the Government of the Municipal City of Suqian in Jiangsu Province, China. The deal reinforces and supersedes the prior framework agreement announced on 9 July.

Suqian is a prefecture-level city in northern Jiangsu Province with an area of 3303 square miles and a population over 5 million. Located between the Yellow River and the Yangtze River, the city is connected to both Beijing and Shanghai in less than 3 hours by high-speed train. Suqian is one of the fastest-growing prefecture-level cities in China, with a gross domestic product (GDP) of $25bn in 2012 and growing nearly 13% annually.

Suqian will provide RMB200m ($32.5m) in cash as well as 5-year rent-free use of 331,000ft^2 of factory and office space in the Suqian Economic and Industrial Development Science Park. The JV will build a 100MW factory over 6 years to make Ascent's CIGS PV modules and related consumer products.

Ascent will buy the factory within 5 years at the initial construction cost, and will also hold the right to purchase Suqian's ownership stake in the JV after 5 years at 1.5 times of Suqian's cash cost.

In the initial phase of the project, Ascent and Suqian will form a JV in which Suqian will inject $4.8m in cash and have a majority stake of 75%. Ascent will inject $1.6m and hold a minority stake of 25%. Subsequently, during 2014 Suqian will further inject the balance of the committed $32.5m while Ascent will contribute its proprietary technology and intellectual property, as well as certain equipment from its Colorado facility, thereby increasing its shareholdings progressively up to 80% ownership. By first-quarter 2016, the JV is expected to operate an end-to-end manufacturing plant of 25MW capacity and related consumer products.

Suqian will also provide a package of additional incentives including:

- a 5-year corporate tax holiday and a further 50% tax rebate over the next 5 years;
- full rebate of value-added tax for the first 2 years and 50% rebate for the subsequent 3 years;
- free accommodation for up to 3 years for key scientists, engineers and management personnel of the JV;
- as Phase 2 of the program is implemented, Ascent will have the option to purchase about 215,000ft^2 of land zoned for commercial usage at a favorable price 10% above the government's prevailing cost, which may generate income for Ascent.

"This partnership enables us to accelerate our transformational consumer-centric strategy with the EnerPlex consumer brand and specialty off-grid applications, given China's huge and growing consumer base and readily available contract manufacturers," comments president & CEO Victor Lee.

"The Suqian Government is fully committed to this partnership and shall provide the utmost support and incentives to Ascent," says Lan Shao Min, governor of the Municipal City of Suqian. "CIGS, and more specifically Ascent's proprietary CIGS technology utilizing a flexible plastic substrate, is the next breakthrough in photovoltaics," he believes. "The aim of our alliance with Ascent is to build a state-of-the-art industrial park in Suqian for solar and solar-related products, anchored by Ascent's manufacturing presence, as well as equipment suppliers, contract manufacturers and other supporting industries," he adds.

"The funding and other subsidies will enable Ascent to develop the scale of manufacturing needed to bring the cost of CIGS down substantially, and provide product for the large demand we expect to see in the next few years," says Ascent's chairman Dr Amit Kumar. "The combination of cost reduction and high-margin EnerPlex products, along with other specialty market applications, will enable Ascent to transition to its next stage as a high-growth company," he believes. "The alliance with Suqian will provide a means for Ascent to build positive cash flow from numerous sources."

www.AscentSolar.com

Ascent Solar expands retail distribution network into Japan

Ascent has formed two distribution partnerships for its EnerPlex line of consumer products in Japan. Osaka-based Kyodo International Corp specializes in supporting the entry of consumer electronic goods into the Japanese market. Tokyo-based NARA Co Ltd has a brings both large electronics as well as consumer-oriented electronics to market in Japan.

"Japan represents a strong consumer market for our EnerPlex brand, a highly tech-savvy and affluent customer base which is also highly engaged in the renewable energy marketplace," says John Maslanik, Ascent's manager of business development. "These partnerships open new opportunities for Ascent's revolutionary solar technology to be integrated into larger power-generation projects."

www.goenerplex.com

XsunX aims to grow monthly systems sales and installations to 1MW in Southern California in 2014

XsunX Inc of Aliso Viejo, CA, USA, which is developing hybrid copper indium gallium (di)selenide thin-film (CIGS) photovoltaic (TFPV) cell technologies and 'CIGSolar' manufacturing processes, says that the response to its Southern California-wide marketing campaign has received broad interest, indicating sizeable pent up demand for commercial and industrial solar systems, it reckons.

"In spite of the holidays, the response we are receiving from our marketing efforts has been outstanding," says CEO Tom Djokovich. "Several potential customers each week are requesting quotes, with many projects requiring 100kW or more in PV system sizing," he adds. "Our goal in 2014 is to grow our commercial and industrial PV systems design and installation business to at least 1MW of new systems per month. The initial results from our campaign are better than what we expected. Based on these early results, we are gearing up to meet the demand."

XsunX believes that its focus on commercial and industrial PV systems sales is well timed. Businesses traditionally consume and pay more for power than residential users. Recent approval of rate and time of use charges for commercial and industrial users by the California Public Utilities Commission (CPUC) is driving business owners to seek new ways to control and reduce energy costs, the firm notes. Thus, installation of solar systems has become a leading energy solution for commercial and industrial users.

Also, governmental policies and incentives for solar PV investments continue to improve, resulting in outstanding return on investment for businesses, XsunX reckons. "What we essentially have is a worsening public utility market driving businesses to find better solutions," Djokovich comments. "XsunX is well positioned and focused on servicing the Southern California market, which represents one of the largest commercial and industrial PV systems markets in the nation," he reckons.

XsunX adds 50kW in signed projects to CIGS PV system development and installation services pipeline

XsunX has added 50kW in signed projects to its growing PV system development and installation services pipeline.

The firm has been working to develop solar projects for a diverse set of clients ranging from professional service companies to ranch land and large-scale industrial reclamation. It adds that it has been working directly with new business clients to document the financial benefits available from solar for their businesses.

To help expand and accelerate the growth of its PV system development and installation services business, XsunX has launched a media marketing campaign that targets major southern California communities ranging from Ventura to the Inland Empire, LA, Orange County and portions of San Diego county. This region represents one of the largest commercial PV system markets in the country and thousands of potential commercial PV system clients, believes XsunX.

"Solar has become far more than just a way to cut utility costs," says CEO Tom Djokovich. "A commercial PV system can provide clients with a 100% cash value return on their investment in as little as three years, and well in excess of a 1000% return on every dollar invested over the life of the system," he concludes.

www.xsunx.com

XsunX adds 20kW commercial PV system sale in Southern California; now offering $1m project financing

XsunX has announced the sale of an additional 20kW commercial solar system in Southern California.

Southern California represents one of the largest commercial PV system markets in the USA. "Business owners with large facilities and large electric bills are contacting us to see how XsunX can help them," says CEO Tom Djokovich. "We are just now starting to get our message out."

XsunX has specifically targeted the commercial and industrial PV installations market for several reasons. While the sales cycle can be more complex and lengthy, the projects offer the firm the ability to generate system sales approaching 1MW or more and potentially millions of dollars in contract value. In addition, commercial PV systems offer clients the largest cash benefits, and return on investment.

To help secure sales, XsunX can now offer system financing to its customers. "Our goal was to make buying a commercial PV system as easy for our clients as buying a car," says Djokovich. "We recently qualified to offer up to $1m of project funding, which completes our ability to offer the best project financial analysis, PV systems design and technologies, and zero down low interest financing."

Japan's Solar Frontier to build its fourth CIS PV module manufacturing plant

150MW plant in Tohoku to supplement three plants in Miyazaki

In December, Tokyo-based Solar Frontier — the largest manufacturer of CIS (copper indium selenium) thin-film photovoltaic (PV) solar modules — announced that it is to construct a CIS solar module manufacturing plant on a 70,000m^2 site in the No.2 Sendai North Central Industrial Park of Ohiramura, Miyagi Prefecture in the Tohoku region of Japan.

With a total floor area of 15,000m^2 and a planned workforce of about 100, the Tohoku Plant's nominal annual production capacity will be 150MW. Production should start in March 2015. This will be Solar Frontier's fourth manufacturing facility, following its three plants in Miyazaki.

The Tohoku Plant will leverage Solar Frontier's latest mass-production technology, incorporating features that increase manufacturing process efficiencies. This should enable the manufacture of high-performance CIS solar modules at improved conversion efficiencies and cost levels, it is reckoned. The plant will also serve as a blueprint for future manufacturing facilities outside Japan, in line with worldwide growth in demand and Solar Frontier's mid-term plans to build future plants outside Japan.

Solar Frontier plans to invest about 13bn yen to build the plant, including a Domestic Business Promotion Grant from Japan's Ministry of Economy, Trade and Industry (METI), a Miyagi Business Promotion Grant from Miyagi Prefecture, and a promotion subsidy from Ohiramura for the entry of new enterprises. Products manufactured at the Tohoku Plant will be intended mainly for sale in the local region.

"By extending new mass-production technologies proven at the Tohoku Plant to manufacturing and sales outside of Japan, Solar Frontier will establish itself as a strong global player," says Hiroto Tamai, president & representative director at Solar Frontier. "By constructing the Tohoku Plant, Solar Frontier will help to revitalize the Tohoku economy, through collaboration with local industries and the creation of new jobs," he adds.

In 2013, Solar Frontier celebrated the 20th anniversary of its R&D work on CIS technology. The firm has grown steadily since opening its first 20MW plant in 2007, growing revenue in the residential, commercial and utility-scale markets. It now has gigawatt-scale manufacturing capacity, including the Kunitomi Plant (one of the world's largest), which opened in 2011 in Miyazaki. Its production processes are claimed to be much more energy efficient and environmentally friendly than those used to manufacture crystalline silicon PV modules.

Solar Frontier has also developed products and systems that deliver high added value, including the thin, lightweight Solacis neo module from its 60MW MP2 factory, its CrossOne installation system for rooftop applications, and its optimized utility-scale systems. In research and development, in January 2013 Solar Frontier achieved record conversion efficiency of 19.7% with a cadmium-free thin-film solar cell (of about 0.5cm^2 in area).

www.solar-frontier.com

Solar Frontier forms EPC alliance with BELECTRIC and Shoseki

Solar Frontier has formed a strategic EPC (engineering, procurement & construction) alliance with fellow Showa Shell Sekiyu subsidiary Shoseki Engineering & Construction Co Ltd (SEC) and Germany-based BELECTRIC — the world's largest solar EPC firm — to combine their expertise and capabilities in CIS-based solar power plants for the growing Japan megasolar market.

The alliance will leverage BELECTRIC's expertise in megasolar installation, SEC's market knowledge and network of suppliers, and Solar Frontier's technical strength in economical solar module performance. This combination is designed to deliver greater value in overall megasolar projects, says Solar Frontier. The new alliance in Japan builds on the foundation established between Solar Frontier and Belectric, who have worked together since 2010 and established the joint venture PV CISTems GmbH of Gruenwald, near Munich, Germany in 2012 to work on projects around the world.

The firms have already worked together on the Kunitomi Megasolar project in Miyazaki, Japan, which began operating in March 2013. The new alliance agreement formalizes their cooperation going forward, aiming to achieve further efficiency in execution, faster project completion, and optimized return on investment. A project in Kagoshima that started in November will be the first for the trio under the new formalized alliance.

The solar and megasolar market in Japan is rapidly moving toward demand for 'total solutions', say the firms. Solar Frontier, BELECTRIC, and SEC therefore aim to fulfill this demand by working together. The alliance is expected to strengthen the positions of all three in the growing Japanese megasolar market.

www.belectric.com

Solar Frontier, IBM and Tokyo Ohka Kogyo raise CZTS cell efficiency record from 11.1% to 12.6%

Last November, Tokyo-based Solar Frontier — the largest manufacturer of CIS (copper indium selenium) thin-film photovoltaic (PV) solar modules — set a new conversion efficiency record for CZTS solar cells (0.42cm^2) at 12.6%. The latest record was achieved in joint research with IBM and Tokyo Ohka Kogyo (TOK), and has been independently verified by Newport Corp (which provides advanced technology products and solutions, including photovoltaic conversion efficiency certification).

CZTS stands for key ingredients copper, zinc, tin sulphur and selenium. Inexpensive and with abundant supply, these materials offer CZTS a cost-competitive advantage over other photovoltaic technologies. The efficiency of 12.6% eclipses the previous record of 11.1%, also set by Solar Frontier and its joint-research partners.

"Breaking our previous record at such a fast pace shows the potential of CZTS for mass production in the future, and we are now in a position to drive that efficiency even higher," says chief technology officer Satoru Kuriyagawa.

Solar Frontier's Atsugi Research Center in Kanagawa has also achieved record conversion efficiencies of 17.8% on a 30cm x 30cm CIS submodule and 19.7% for non-cadmium CIS cell. Solar Frontier's CIS modules, manufactured in Japan, are offered in commercial volumes at up to 13.8% efficiency, the highest of any mass produced thin-film modules.

http://onlinelibrary.wiley.com/doi/10.1002/aenm.201301465/abstract

GS Hong Kong Solar opens 40MW manufacturing plant

Thin-film copper indium gallium diselenide (CIGS) solar cell maker GS Hong Kong Solar has officially opened its new 150,000ft^2 manufacturing plant, which has a phase-1, full-production capacity of 40MW per year. GS Solar notes that it is simultaneously breaking ground on a 750kW CIGS solar field, and is commissioning a 35MW plant in China to open in autumn 2014.

GS Solar has expanded from its former 40,000ft^2 factory to the new 100,000ft^2 facility and is beginning construction of its 34,000ft^2 factory in Berlin, Germany. The firm notes that the addition of the two new 40MW and 35MW facilities will increase its annual capacity from 5MW. GS Solar also plans to bring an additional 100MW into production at the end of 2009, raising its total annual capacity to 175MW.

"Production from this facility will help satisfy the strong demand for solar product across the world," comments managing director Naseer Sayed. The additional plant will "help meet the 2015 goal of the government initiative of achieving solar electricity cost competitiveness with grid electricity, especially through the use of flexible CIGS thin-film technologies in building-integrated applications," he adds.

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Solarion begins series production of flexible modules

Solarion AG of Leipzig, Germany has begun the series production of its flexible CIGS thin-film photovoltaic solar modules, the first of which is a flexible solar foil directly laminated onto 0.7mm rolled sheet aluminium. The SOL90AL module has been designed and developed to satisfy strong market demand for flexible lightweight PV products.

Founded in 2000 as a spin off from the Leibniz Institute for Surface Modification, in 2002 Solarion established Europe's first industrial pilot line for manufacturing flexible CIGS thin-film cells on a polymer substrate. Its technology is based on patented ion-beam-assisted deposition of the CIGS absorber in a roll-to-roll process. Advantages are low deposition temperature, improved solar cell energy conversion, higher process speed, and lower energy and material costs. Now, Solarion's first production line, with an annual capacity of 20MW, has been started.

In the new SOL90AL module, the sheet metal extends beyond the solar laminate on two sides to allow fast and easy mechanical fastening to a variety of substructures, eliminating the need for expensive racking systems. Additional penetration-free mounting methods on various roofing materials and membranes are also made possible.

With a weight of 0.78lb/ft^2 (3.8kg) and a format of 1350mm x 875mm, the SOL90AL is easy to handle and universally installable onto roofs with weight restrictions, says Solarion. Most often, roof construction analysis does not need to be undertaken, enabling greater savings compared with conventional PV add-on systems.

A new UV-resistant junction box is mounted to the module's front-side, allowing simple module stringing. Rear-side junction box mounting may be available upon request.

SOL90AL modules have been certified by VDE according to standards IEC/EN 61646 and 61730-1 and -2.

Module power ratings start at 65W. Ratings of 80W and higher are due to be launched during 2014.

www.solarion.de

Cadmium selenide quantum dot layer boost for three-junction solar cells

Wavelength conversion of high-energy ultraviolet photons has been shown to increase triple-junction solar cell power efficiency by 10%.

Researchers in Taiwan have used cadmium selenide (CdSe) quantum dots (QDs) to increase the power conversion efficiency of three-junction solar cells by around 10% [Ya-Ju Lee et al, Optics Express, Vol. 21, pA953, 2013]. The team was associated with National Taiwan Normal University, Chang Gung University, and WIN Semiconductors Corp.

The aim of using CdSe QDs was to convert high-energy ultraviolet photons to a wavelength that would boost the performance of current-limiting cells. Multi-junction tandem solar cells are connected in series so that the same current must run through all of them. This limits the performance to that of the poorest sub-cell. Boosting the performance of current-limiting cells to more closely match that of the others should therefore increase conversion efficiency.

The QD bandgap that controls the energy of the converted photons is determined largely by the dot diameter. Photoluminescence experiments suggest that the peak wavelengths are 640nm for

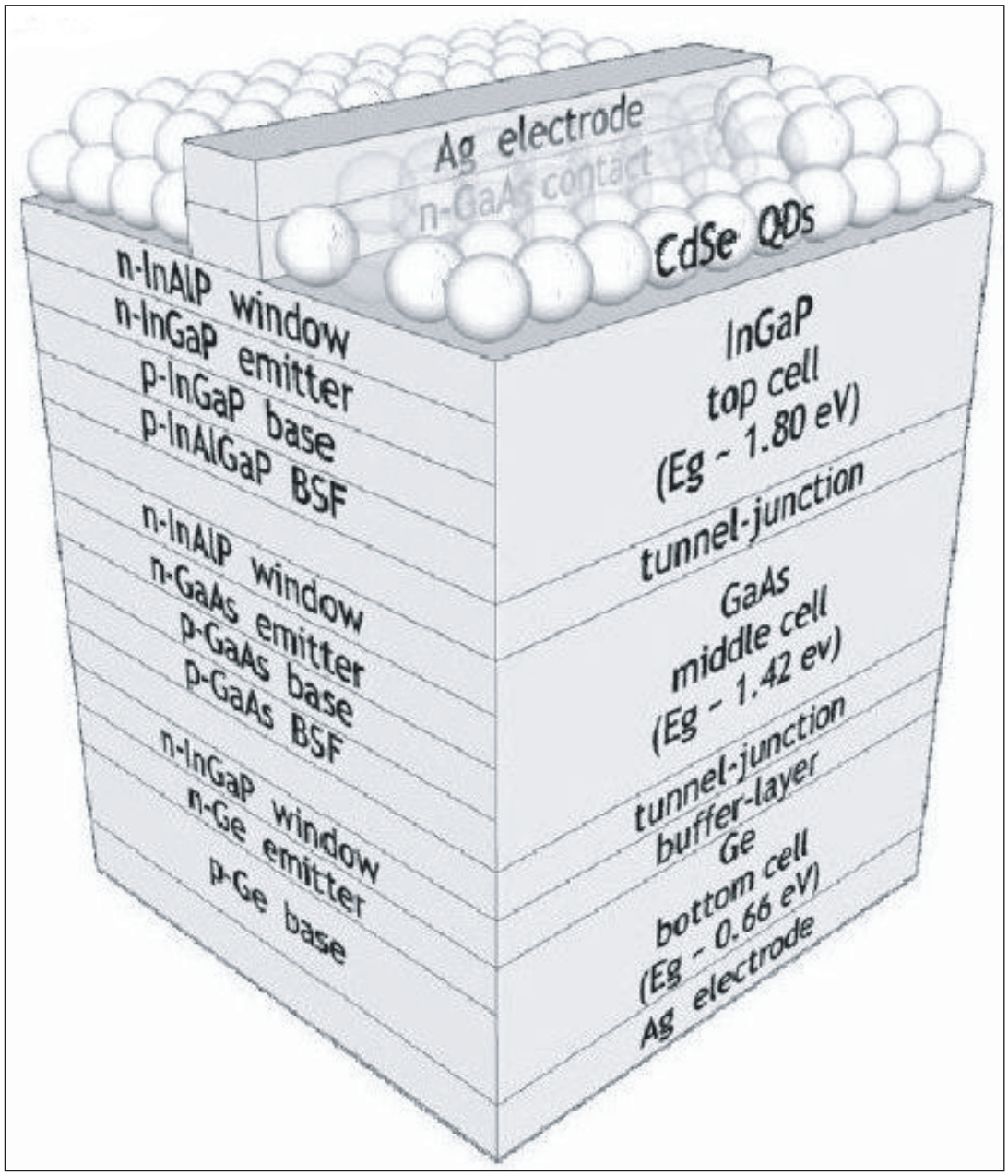

Figure 1. Schematic of InGaP/GaAs/Ge triple-junction solar cell with CdSe QDs spread on top surface to tailor solar spectrum and enhance photocurrents of current-limiting GaAs middle sub-cell (and InGaP top cells) to more closely match that of the Ge bottom sub-cell.

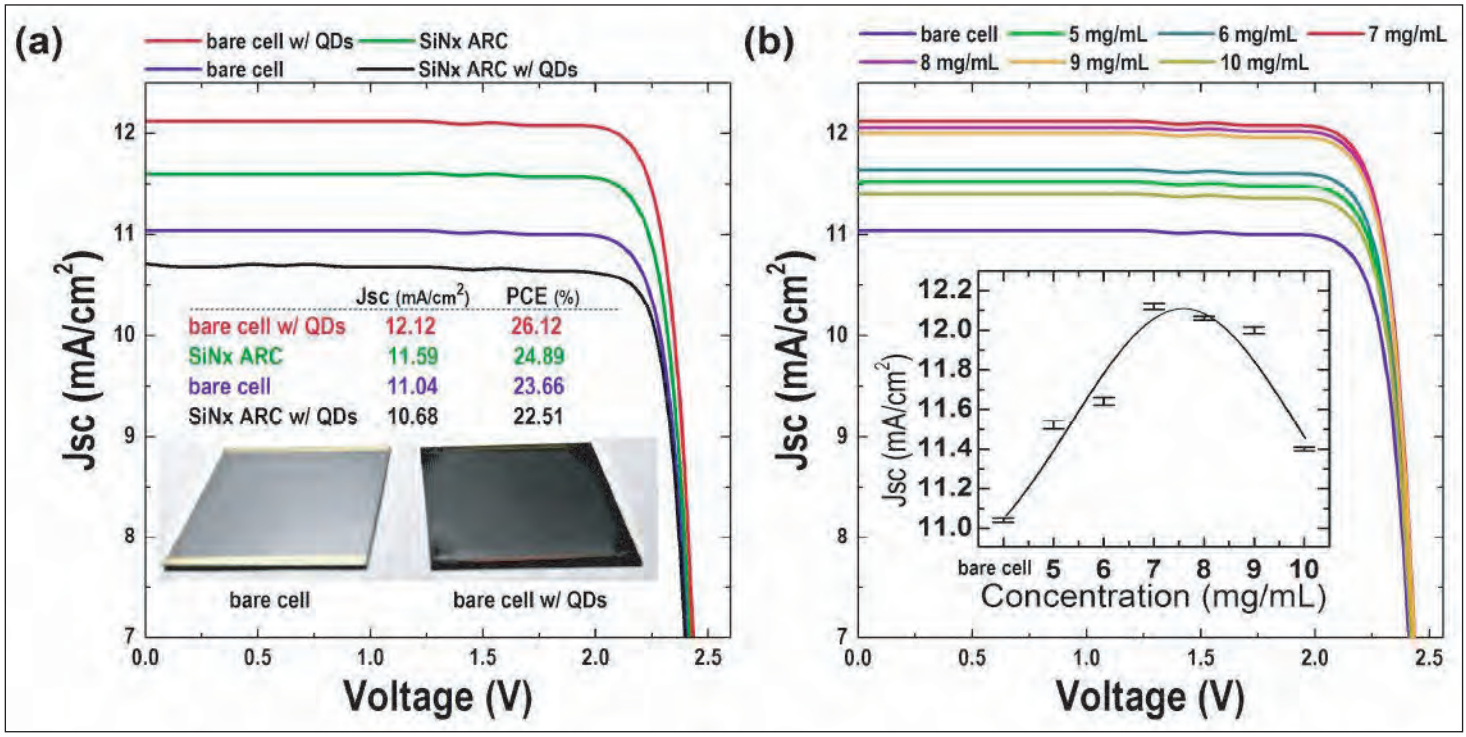

Figure 2. (a) Current density–voltage (J–V) performance of tandem solar cells with and without 4.2nm-diameter CdSe QDs and silicon nitride anti-reflection coats under AM1.5G sunlight illumination (100mW/cm², 1-sun). The QDs came from a solution with optimum concentration of 7mg/mL for the spin-on process. Inset: photograph of actual 1cm x 1cm devices. (b) Characteristics with varied concentration of CdSe QD spin-on solution. Inset: summary of short-circuit current density (0V) as function of QD concentration.

6.6nm-diameter dots and 480nm for 2.1nm-diameter dots.

The gallium arsenide (GaAs) and indium gallium phosphide (InGaP) absorbing layers along with tunnel junctions of the three-junction solar cell (Figure 1) were grown on p-type germanium (p-Ge) substrates using metal-organic chemical vapor deposition (MOCVD). The substrate also acted as a sub-cell/absorbing layer. The top tunnel junction was aluminium gallium arsenide/indium gallium phosphide (p-AlGaAs/n-InGaP) and the bottom one was p-GaAs/n-GaAs.

The CdSe QDs were formed in a sol-gel process. The colloidal CdSe quantum dots in toluene solution were spun onto the top indium aluminium phosphide (InAlP) window layer. After deposition, the toluene was evaporated under a fume hood. The electrodes were silver (Ag). The solar cell chips measured 1cm x 1cm.

The researchers carried out a range of simulations to estimate the optimum QD diameter. A 4.2nm CdSe QD gave a simulated 19% enhancement in power conversion efficiency over a device without QDs. Above 4.2nm diameter, short-circuit current performance of the InGaP-based sub-cell significantly declined in the calculation. The simulations also suggest that without QDs the GaAs sub-cell has the lowest current (9.38mA/cm²) with the InGaP cell just above it (9.60mA/cm²). The Ge sub-cell has a predicted short-circuit current just below 12mA/cm². Hence, the GaAs and InGaP layers both give current-limiting effects.

Adding the QDs brings the expected currents closer together. The QDs were also expected to have an anti-reflective effect that should be beneficial for all the layers in trapping photons in the structure.

Guided by the simulations, the processed device also used a 4.2nm-diameter QD. The device was compared with tandem solar cells that were completely bare of QDs or that included a 100nm-thick silicon nitride (SiN) layer as an anti-reflective coat. A device that combined QDs on top of a 100nm anti-reflective SiN layer was also processed.

The performance of such devices (Figure 2a) showed that a cell with only QDs performed best with a power conversion efficiency of 26%. The worst performer was the device with both QDs and anti-reflective SiN. The open-circuit voltage of the devices was 2.51V. The fill factors were in the range 85.4–85.9%.

The effect of using different QD solution concentrations in the spin-coating process was also tested (Figure 2b). The optimum concentration was 7mg/mL. Reflectance measurements found that this concentration also gave the minimum reflection of the incoming radiation. This is attributed to refractive index matching between the QD layer and top InGaP sub-cell that directs converted photons into the device. ■

www.opticsinfobase.org/oe/abstract.cfm?uri=oe-21-S6-A953

Author: Mike Cooke

Hole conductivity in zinc sulfide telluride and blue-green light emission

Results suggest that a pn junction is formed between nitrogen-doped ZnSTe and chlorine-doped ZnS, creating a blue-green LED structure.

Japan's Tottori University has produced blue-green light-emitting diode (LED) structures using zinc sulfide telluride (ZnSTe) material [Kunio Ichino et al, Appl. Phys. Express, vol6, p112102, 2013]. The researchers see their work as rather preliminary, with the importance being "that the results suggest p-type conductivity of the ZnSTe:N layer and the formation of a ZnS-based pn junction."

Zinc sulfide is a material with a wide energy bandgap of 3.73eV that would promise ultraviolet optical applications if a convenient method could be found to produce hole/p-type conductivity. Although there have been reports of p-ZnS, no light-emitting devices based on ZnS pn junctions have been demonstrated. Previously reported ZnS light emission is likely due to metal-insulator-semiconductor structuring.

Zinc telluride has a narrower gap of 2.26eV and is naturally p-type/hole conducting. The p-type conductivity can be enhanced to hole concentrations of $10^{19}/cm^2$ by doping with nitrogen. Hence the investigation of ZnSTe as a medium for p-type conductivity would seem promising.

The diode structures were grown on (001) gallium phosphide (GaP) substrates using 275°C molecular beam epitaxy (MBE) – see Figure 1. The layers consisted of a 1.5µm chlorine-doped zinc sulfide (n-ZnS:Cl) buffer and 2.5µm nitrogen-doped zinc sulfide telluride (ZnSTe:N) with telluride fractions up to 30%. The n-ZnS carrier density was estimated at $10^{17}/cm^3$.

The substrates were supplied by Shin-Etsu Chemical and Sumitomo Metal Mining. The Shin-Etsu product was not intentionally doped, but had an electron carrier (n-type) concentration of $2x10^{16}/cm^3$. The Sumitomo substrate was semi-insulating.

The MBE sources were zinc and tellurium metals (Osaka Asahi Metal) and elemental sulfur (Furukawa Denshi). The nitrogen doping was achieved using radio frequency plasma generated from nitrogen gas (EIKO). The chlorine source was zinc chloride.

The growth process took account of the fact that sulfur is preferentially incorporated, compared with tellurium. In particular the sulfur flux was reduced to decrease the evaporation temperature from 155°C to 110°C. The tellurium flux was simultaneously varied to deliver different compositions.

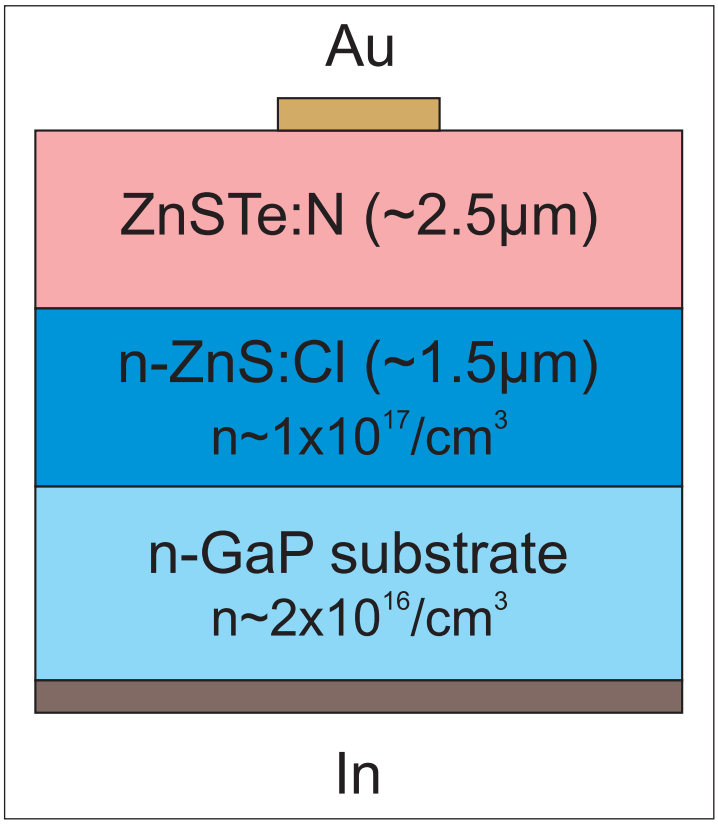

Figure 1. Schematic of Au / $ZnS_{1-x}Te_x$:N / n-ZnS / n-GaP diode structure.

After material growth, gold (Au) and indium contacts were added to the top ZnSTe:N layer and bottom n-GaP substrate, respectively. A 5mm x 8mm chip with 15% Te-fraction in the top layer showed clear rectifying behavior with significant current flow only when the top gold p-contact was positively biased. A diode without N-doping of the top ZnSTe layer showed almost no current flow under positive or negative bias.

The researchers comment: "The polarity of the

rectification can be due to either an Au/n-ZnS(Te) Schottky contact in such a case that the ZnSTe layer is n-type or highly resistive, or a p-ZnSTe/n-ZnS junction when the ZnSTe layer is p-type. Since the Au/$ZnS_{1-x}Te_x$:N contact has been found to be ohmic [...] the latter is probable."

Although attempts by the researchers to determine p-type behavior of ZnSTe:N layers by Hall effect measurements with a different material structure were impeded by the voltage being too low to be detected, electron-beam-induced current (EBIC) analysis of the LED structure using a scanning electron microscope (SEM) found a peak at the ZnSTe:N/n-ZnS interface. "This means that a depletion layer, or an internal electric field exists at the ZnSTe:N/n-ZnS interface, and suggests that the ZnSTe:N layer is p-type," they write.

The performance of devices with Te fractions away from 15% were found to be degraded. SEM analysis also showed deterioration in crystal quality in all ZnSTe:N structures as growth proceeds.

Although electroluminescence was visible to the naked eye (Figure 2), the researchers say that the optical power and efficiency were too low for practical use. Because the spectral analysis shows broad peaks, the researchers suggest that the light comes from hole injection into the n-ZnS giving self-activated deep-level, rather than band-edge, emission. It seems that electrons injected in the other direction recombine with holes without emitting light. At a current of 10mA, the forward voltage was 30V.

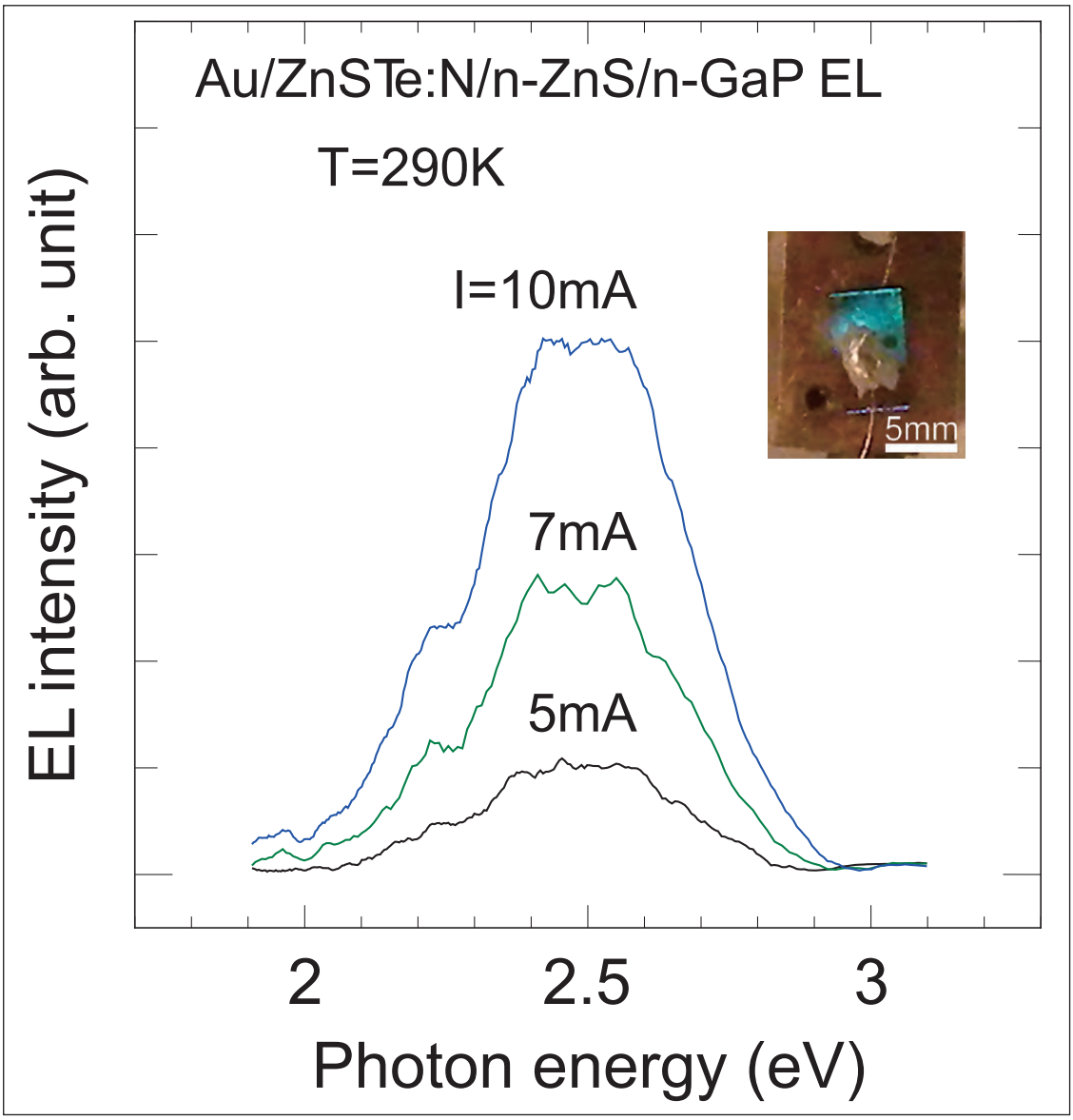

Figure 2. Electroluminescence (EL) spectra of $ZnS_{0.85}Te_{0.15}$:N/n-ZnS diode structure under forward current (I) of 5mA, 7mA and 10mA at 290K. (Photon energy 2.5eV corresponds to a 496nm wavelength.) Inset: EL image (I = 10mA). The silver paste bonding a gold wire overlays three top gold contacts in this device.

When the forward bias is further increased, the electric field would be concentrated at the interface high-resistivity layer, and at a certain point the hole injection from the ZnSTe:N layer into the n-ZnS layer would start to occur, giving rise to the EL emission

There is a 'threshold' for light emission of about 4mA. The threshold behavior is seen as being consistent with electron injection into the ZnSTe:N dominating at small bias. "When the forward bias is further increased, the electric field would be concentrated at the interface high-resistivity layer, and at a certain point the hole injection from the ZnSTe:N layer into the n-ZnS layer would start to occur, giving rise to the EL emission," the researchers add. ■

http://apex.jsap.jp/link?APEX/6/112102

Author: Mike Cooke

Low-resistivity n-type aluminium gallium nitride for more efficient LEDs

Researchers in Japan have increased the wall-plug efficiency of a 390nm violet-emitting device by 15%.

Researchers at Meijo University and Nagoya University, Japan, have produced low-resistance n-type aluminium gallium nitride (n-AlGaN) [Toru Sugiyama et al, Appl. Phys. Express, vol6, p121002, 2013]. Using the n-AlGaN as part of an ultraviolet light-emitting diode (LED), the researchers managed to increase wall-plug efficiency (WPE) by around 15%.

The low-resistance n-AlGaN was produced on sapphire by metal-organic vapor phase epitaxy (MOVPE). The growth began with a low-temperature (LT) buffer layer, followed by a 3µm layer of unintentionally doped GaN. Silane (SiH_4) was used as the source for the silicon doping of a 1.5µm AlGaN low-resistivity layer for Hall resistivity and other characterization studies.

The 390nm violet LED was produced using a similar sample with 2µm n-AlGaN as a base (see Figure 1). The active emitting multiple quantum well (MQW) consisted of three pairs of 2.7nm GaInN wells and 12nm AlGaN barriers. The p-layers of the LED were a 20nm AlGaN electron-blocking layer, a 100nm AlGaN cladding layer and a 10nm GaN contact layer.

The LED processing consisted of annealing at 800°C in air for 10 minutes to activate the p-type layers, inductively coupled plasma (ICP) mesa etch and deposition of n-type electrode metal, deposition of a nickel-gold semi-transparent electrode on the p-GaN contact, and deposition of the p-type pad electrode. The devices measured 350µm x 350µm.

The researchers found that adding a small amount of aluminium to AlGaN allowed much higher levels of silicon doping to be reached without damaging the crystal structure. Silicon doping in pure GaN is limited to concentrations around $1x10^{19}/cm^3$, beyond which the surface of the material becomes rough. By contrast, the

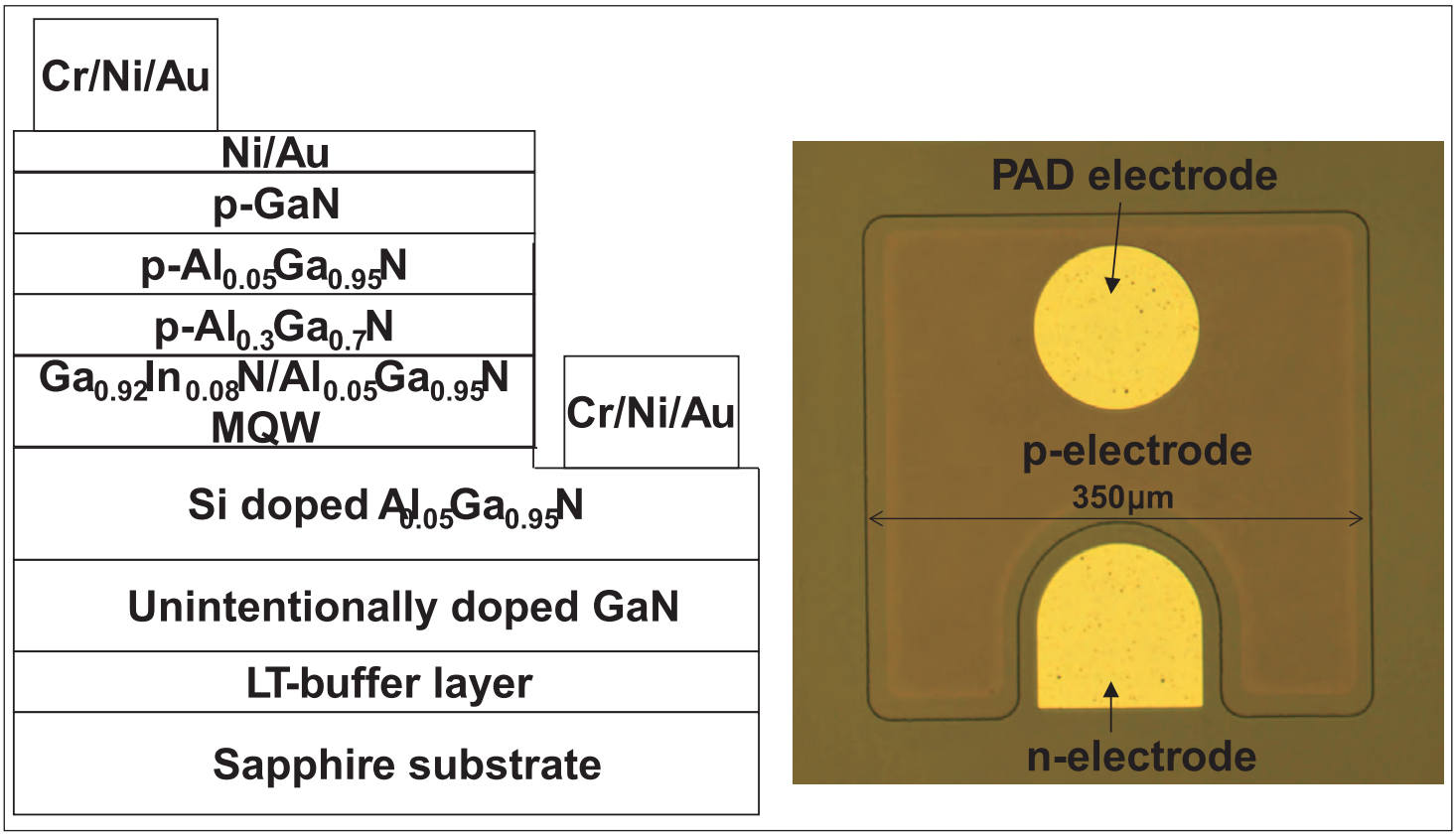

Figure 1. Schematic structure and top view of violet LED.

AlGaN layers produced in the research were smooth, with no visible cracks even when doped to $4x10^{20}/cm^3$.

The use of n-AlGaN allows resistivities of $5.9x10^{-4}/\Omega$-cm to be reached with carrier concentration of $1.4x10^{20}/cm^3$ and mobility of $70cm^2/V$-s. Resistivity reduction in silicon-doped GaN layers saturated around $2.7x10^{-3}/\Omega$-cm with a carrier concentration of $4x10^{19}/cm^3$.

Lower-resistivity n-GaN has been achieved by researchers in Germany (Otto-von-Guericke-Universität, TU-Berlin) with germanium doping at $6.3x10^{-4}\Omega$-cm. The Meijo/Nagoya n-AlGaN is therefore less resistive than in the Germany-based work.

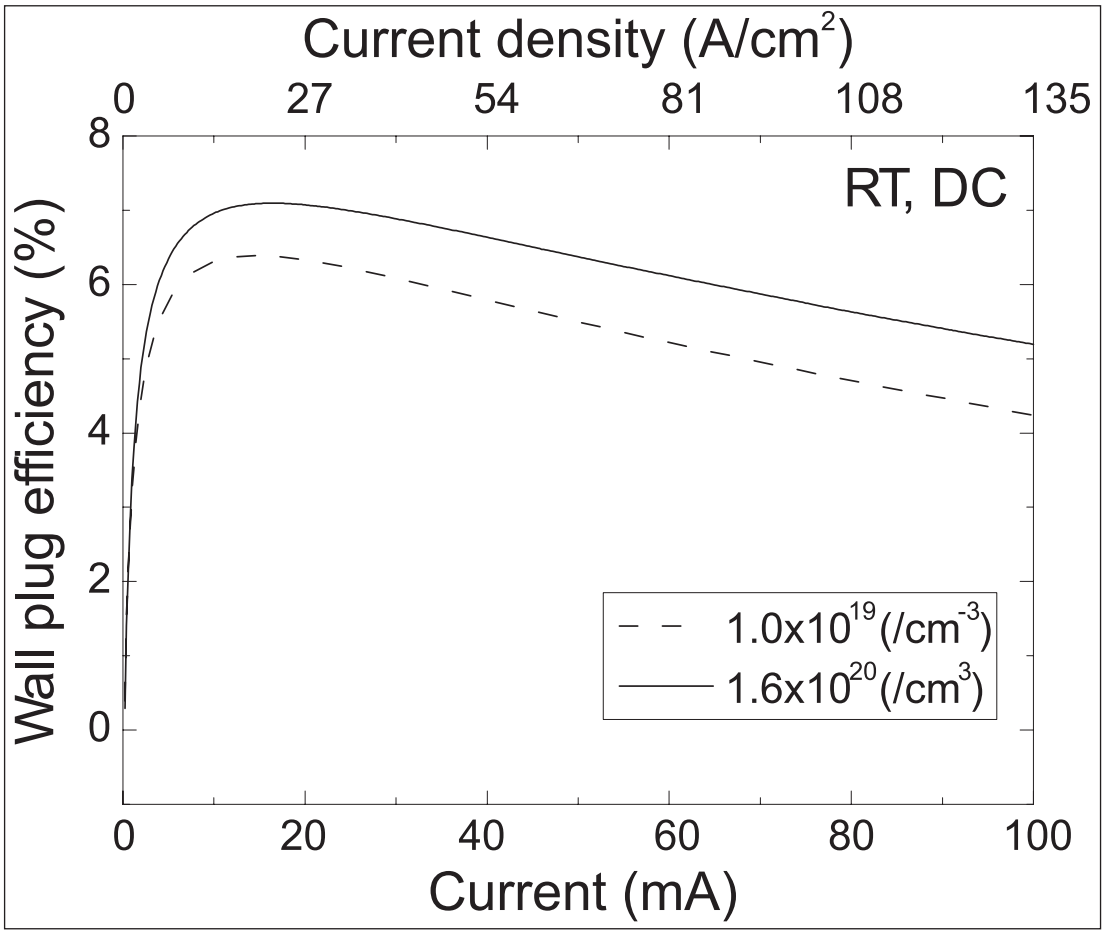

Figure 2. WPEs versus injection current.

The researchers also compared LEDs with n-AlGaN contact layers with two different levels of silicon doping, giving carrier concentrations of $1x10^{19}/cm^3$ and $1.6x10^{20}/cm^3$. The reduced resistivity of the higher silicon doping was found to reduce the forward voltage for a given drive current, indicating more efficient use of the energy. The reduction was around 1V at 100mA drive current.

There was also a slight increase in light output power for a given drive current. The improvement increased to about 5% at higher currents. The researchers believe that this effect is due to the smaller amount of heat generated by the lower-resistivity n-AlGaN in continuous direct current operation. Droop and overflow effects in the two devices are likely the same due to the similar structure.

The improved performance led to a ~15% increase in wall-plug efficiency for the violet LED (Figure 2). The researchers believe that these results could be extended into application in shorter-wavelength devices, including deep ultraviolet (200–300nm) LEDs. ■

http://apex.jsap.jp/link?APEX/6/121002

Author: Mike Cooke

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Semipolar nitride laser diodes without AlGaN cladding

Light output power of 2.15W achieved in pulsed operation.

University of California Santa Barbara (UCSB) has developed semipolar (20$\bar{2}\bar{1}$) nitride semiconductor laser diodes (LDs) without using aluminium gallium nitride (AlGaN) as the cladding material for optical confinement [A. Pourhashemi et al, Appl. Phys. Lett., vol103, p151112, 2013].

The use of AlGaN in polar c-plane laser diodes creates a highly confined and intense optical field that is subject to failure through catastrophic optical mirror damage (COMD). One reason for the use of AlGaN with c-plane devices is the need to keep the structures thin enough to accommodate the effects of polarization-related electric fields.

In semipolar devices these electric fields are less strong and the structures do not have to be so thin. Thicker cladding regions based on other nitride semiconductor material structures could reduce the optical field intensity and delay COMD. Semipolar devices are also being developed on the basis that the reduced polarization-related electric fields could also lead to more efficient light emission.

Contact	p^{+}-GaN:Mg	20nm
Cladding	p-GaN:Mg	400nm
Cladding	p^{-}-GaN:Mg	200nm
Waveguide	p^{--}-$In_{0.06}Ga_{0.94}N$:Mg	60nm
Electron blocking	p-$Al_{0.15}Ga_{0.85}N$:Mg	17nm
Multiple quantum well	4x($In_{0.2}Ga_{0.8}N$/GaN)	4x(4.5nm/13.5nm)
Barrier	n-GaN:Si	20nm
Waveguide	n-$In_{0.06}Ga_{0.94}N$:Si	60nm
Template	n-GaN:Si	1µm
Substrate	Semipolar (20-2-1) GaN	

Figure 1. Schematic for laser diode epitaxial structure.

The UCSB team also believes that improving the efficiency of blue and ultraviolet nitride semiconductor laser diodes could lead to laser-based white lighting systems, avoiding the problem of efficiency droop at high current in GaN-based light-emitting diodes (LEDs) [see, for example, www.semiconductor-today.com /news_items/2013/OCT/UCSB_211013.shtml].

Mitsubishi Chemical Corp supplied the semipolar (20$\bar{2}\bar{1}$) gallium nitride (GaN) substrates that UCSB used to create the LD epitaxial structures (Figure 1) through metal-organic chemical vapor deposition (MOCVD). The p-type GaN layers had a varying doping profile from very low (p^{-}) to high (p^{+}) in the thin contact layer. This was to avoid absorption losses by moving the high doping region far away from the optical fields.

Simulations on the structure suggest a transverse confinement factor of 4.7% from the relatively wide active region and the indium gallium nitride/gallium nitride ($In_{0.06}Ga_{0.94}N$/GaN) waveguide/cladding separate-confinement heterostructures (SCH).

UCSB used the epitaxial material to make 8µm x 900µm ridge waveguide laser diodes through reactive ion etch. Then silicon dioxide was applied to the sides of the ridges and the surrounding areas as insulation. The p- and n-electrodes consisted of palladium/gold and aluminium/gold, respectively.

The facets were created using a dicing saw and mechanical polishing. A highly reflective coating of eight alternating quarter-wavelength layers of silicon

dioxide (SiO_2) and tantalum pentoxide (Ta_2O_5) was applied to the back facet. An anti-reflective coating for the front facet consisted of a single period of SiO_2/Ta_2O_5 quarter-wavelength layers.

The performance of the laser diodes was characterized under pulsed drive currents (Figure 2a). The light output power showed a lasing threshold at 392mA current (5.30kA/cm^2 density). The slope efficiency was 1.35W/A, corresponding to a differential efficiency of 49%. The maximum output power was 2.15W at 2.02A (28.1kA/cm^2).

The researchers estimate that peak optical power density at the front facet was 70.2MW/cm^2. This is similar to the values causing COMD in high power c-plane InGaN/GaN LDs (40–70MW/cm^2). COMD occurs at lower power densities of ~30MW/cm^2 in gallium arsenide laser diodes.

In fact, the limitation for the UCSB device was not thermal degradation ('roll-over') or COMD, but rather the inability of the power supply to give currents above 2.02A.

The external quantum efficiency (EQE) actually increases with increasing current, reaching 39% at 2.02A. This is very unlike the case for light-emitting diodes where 'efficiency droop' typically occurs after a few tens of milliamps.

The researchers comment: "This marked difference in behavior can be explained by the clamping of the carrier density that occurs in a LD above threshold, which in turn clamps non-radiative recombination processes and eliminates efficiency droop above threshold."

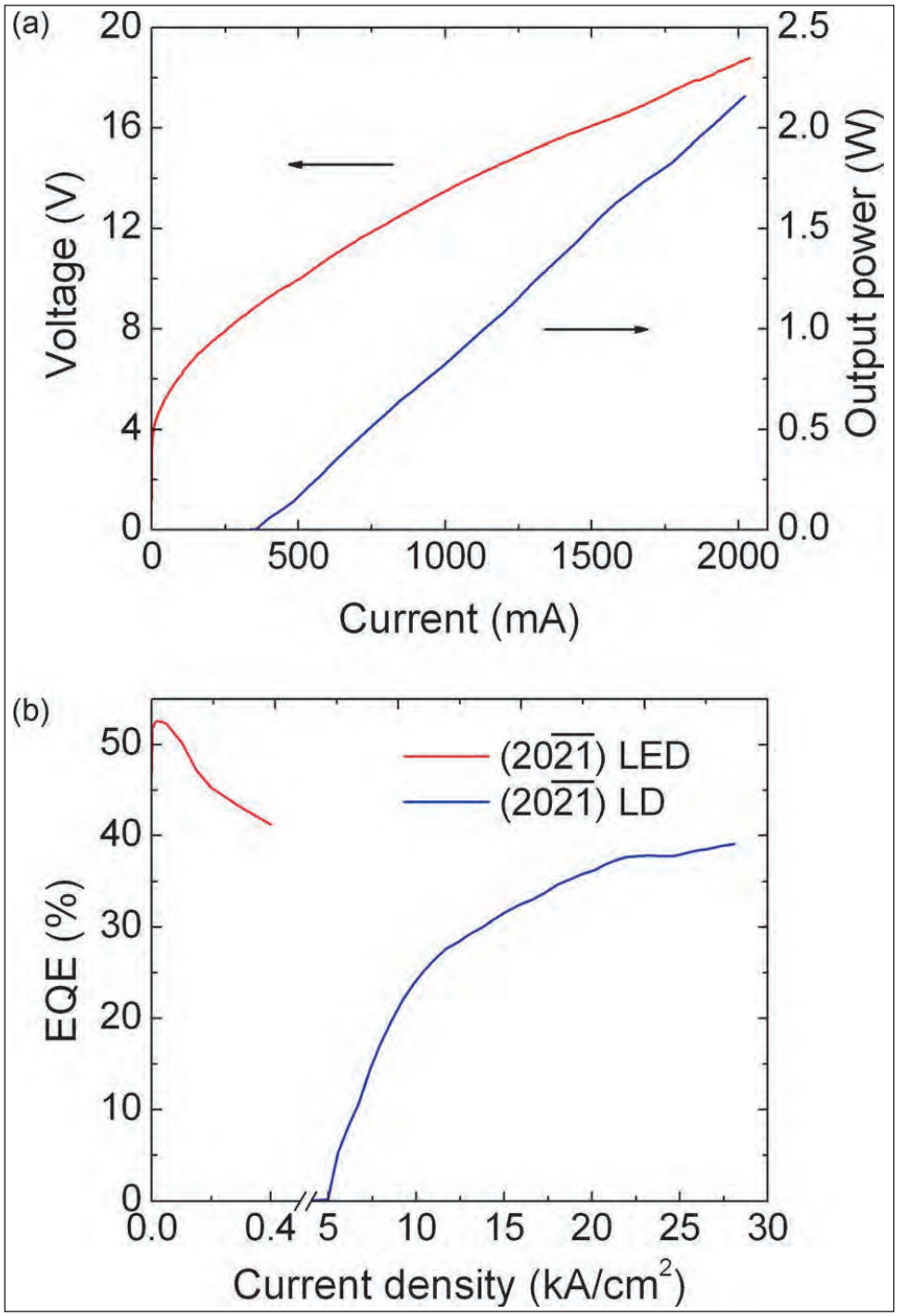


Figure 2. (a) Light output power–current–voltage (L–I–V) characteristics of UCSB LD. (b) Comparison of EQE for UCSB's blue (~460nm wavelength) semipolar (20$\bar{2}$1) LD with a blue semipolar (20$\bar{2}$1) LED.

The researchers compared the EQE performance (Figure 2b) with a blue (20$\bar{2}$1) LED that reaches a peak EQE of ~40%. The laser diode reaches 39% EQE at a current density that is 75 times that of the peak EQE of the LED.

The threshold voltage of 9V was "rather high", compared with other semipolar LDs, according to the researchers. The series resistance after turn-on was 6Ω. At maximum power output of 2.15W, the voltage was 18.7V. This high operating voltage cuts wall-plug efficiency, despite the high EQE, "limiting the usefulness of such LDs in practical applications".

The researchers report that they are investigating the source of the high series resistance, and experiments in progress indicate that the major contributor is the p-contact region. The team therefore believes that optimizing the p-contact region should give a "marked reduction on the overall operating voltage".

Measurements between 20°C and 80°C gave an exponential increase in threshold current that is described by a characteristic temperature of 91K. ■

http://dx.doi.org/10.1063/1.4824773

Author: Mike Cooke

Limited area epitaxy applied to semipolar GaN laser diodes

Effects of misfit dislocations avoided, allowing true green laser diodes with a wavelength 523nm.

University of California Santa Barbara (UCSB) has been using limited area epitaxy (LAE) to improve the performance of lasers diodes (LDs) grown on free-standing semipolar (20-21) gallium nitride (GaN) substrates [Matthew T. Hardy et al, J. Appl. Phys., vol114, p183101, 2013]. The researchers were particularly interested in achieving efficient true green emission. Laser diodes in the green wavelength range (520–570nm) have been difficult to achieve so far.

Laser diode materials grown in semipolar or nonpolar crystal directions should avoid large spontaneous and strain-dependent electric fields arising from differences in polarization of the various layers of the usual polar c-plane (0001) heterostructures. The polarization-dependent electric fields reduce the overlap between electrons and holes, reducing recombination into photons. Reduced recombination results in lower efficiency and higher threshold voltages and currents.

One drawback of epitaxy in semipolar directions is that significant shear stress arises, and slippage in the c-plane can arise in thicker layers of material. This slippage causes misfit dislocations (MDs). The effect is worse when there are pre-existing threading dislocations (TD) arising from the substrate.

LAE performs epitaxy on a series of mesas. This can block the TD glide effects that lead to MDs by preventing the TDs from entering the patterned areas of the mesas.

The UCSB epitaxial material was grown using atmospheric-pressure metal-organic chemical vapor deposition (AP-MOCVD). Mitsubishi Chemical provided the free-standing GaN substrates.

The mesa structures for the LAE were achieved using dry etching. By orienting the mesas along the a-direction of the crystal structure, TD glide can be blocked. Although blocking of TD glide was achieved in some preliminary experiments with an etch depth as small as 250nm, the LDs were produced with 1µm depth "in the interests of process stability".

Various blue and green LD structures (Figure 1) were grown to test the effect of using LAE. For the blue LD, a planar device with GaN cladding was also created as a comparison (Figures 1a and 1b).

The use of LAE allowed the creation of modulation-doped AlGaN/GaN short-period superlattice (SPSL) structures as cladding. The n-type cladding was grown on a 600nm n-GaN buffer. The SPSL consisted of 160 periods of 2.5nm/2.5nm layers of alternating material. On the p-side of the device the SPSL was 145 periods of 2.5nm/2.5nm layers.

The active multiple quantum well (MQW) was 3 periods of 3.5nm InGaN separated by 10nm GaN barriers. The waveguide structures consisted of 40nm InGaN on either side of the MQW.

The green LDs (Figures 1c and 1d) were grown using LAE with and without SPSL cladding structures. The MQW InGaN was 2.7nm and the barriers 10nm. The researchers comment: "The quantum wells were thinner to mitigate increased strain and quantum-confined Stark effect in the high-InN-fraction InGaN QWs, and AlGaN barriers were used to suppress dark triangle defects (DTDs)."

The p-type layers for the blue LDs were grown at a lower temperature of 890°C. This temperature is about 60°C lower than normally used by UCSB for blue LDs.

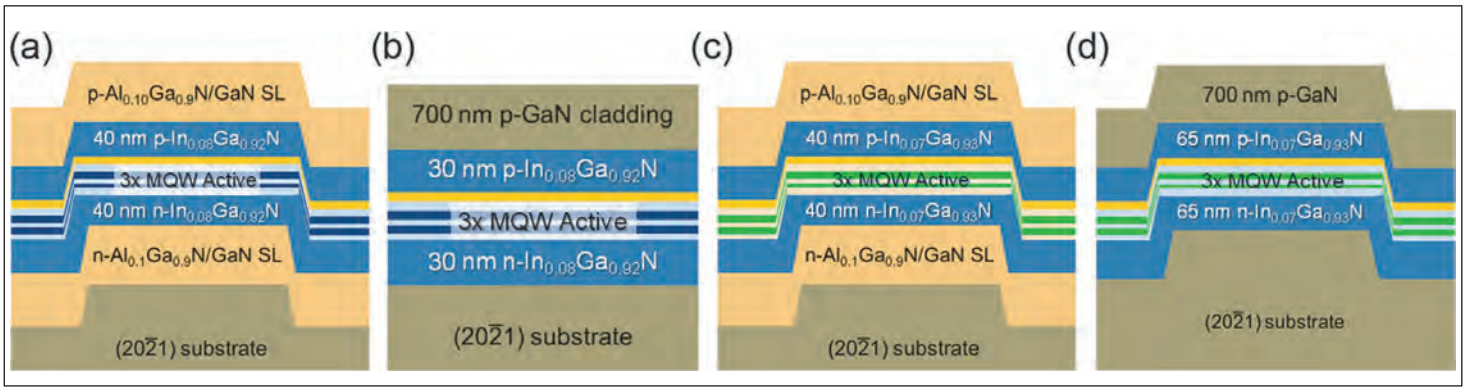


Figure 1. Schematic epitaxial structure for (a) LAE AlGaN-clad blue LD, (b) GaN-clad 'standard' blue LD, (c) LAE AlGaN-clad (blue-)green LD and (d) LAE GaN-clad true green LD.

The researchers used the lower temperature to simulate the growth conditions often used for producing green LDs.

The LD materials were formed into ridge-waveguide devices aligned to the LAE mesas. Silicon dioxide dielectric was sputtered onto the field and sidewalls of the structures. The p-contacts of palladium/gold were made through self-aligned vias in the dielectric.

The facets for the blue LDs were created by dry etching. The green device facets were achieved through a polishing process. Facet coatings for the green LD consisted of quarter-wavelength layers of silicon dioxide and tantalum pentoxide. The back facet was seven periods, giving estimated 99% reflectivity, and the front two periods (75%).

The blue LD with AlGaN cladding had a threshold current of 4.5kA/cm^2, a value "competitive with state-of-the-art blue LDs". The reduction in threshold is attributed to a significant increase in optical confinement.

The threshold performance of the other devices (Table 1) was less impressive. The researchers say that the extremely high threshold voltage of 23V for the blue-green AlGaN-clad LD "can be attributed to the low AlGaN growth temperature of 890°C and un-optimized p-doping."

A true green device was achieved using a GaN cladding (Figure 2). The relatively high 15V threshold is again blamed on low-temperature growth of the p-GaN at 840°C.

The GaN cladding gave a lower optical confinement of 1.9%, compared with 2.5% for AlGaN. However, the use of AlGaN cladding also required the use of AlGaN barriers in the MQW active region to avoid DTDs due to the higher growth temperatures needed. The AlGaN barriers were grown at a very low temperature of 755°C. Such AlGaN is thought to be at risk of oxygen impurity incorporation, which can degrade performance.

The LAE successfully suppressed MD formation in the GaN-clad LD, allowing the use of 65nm InGaN waveguide layers. Without LAE, similarly structured devices are subject to MD formation in waveguide layers thicker than 35nm. The increase from 35nm to 65nm effects an increase in optical confinement from 1.34% to 1.88%. ■

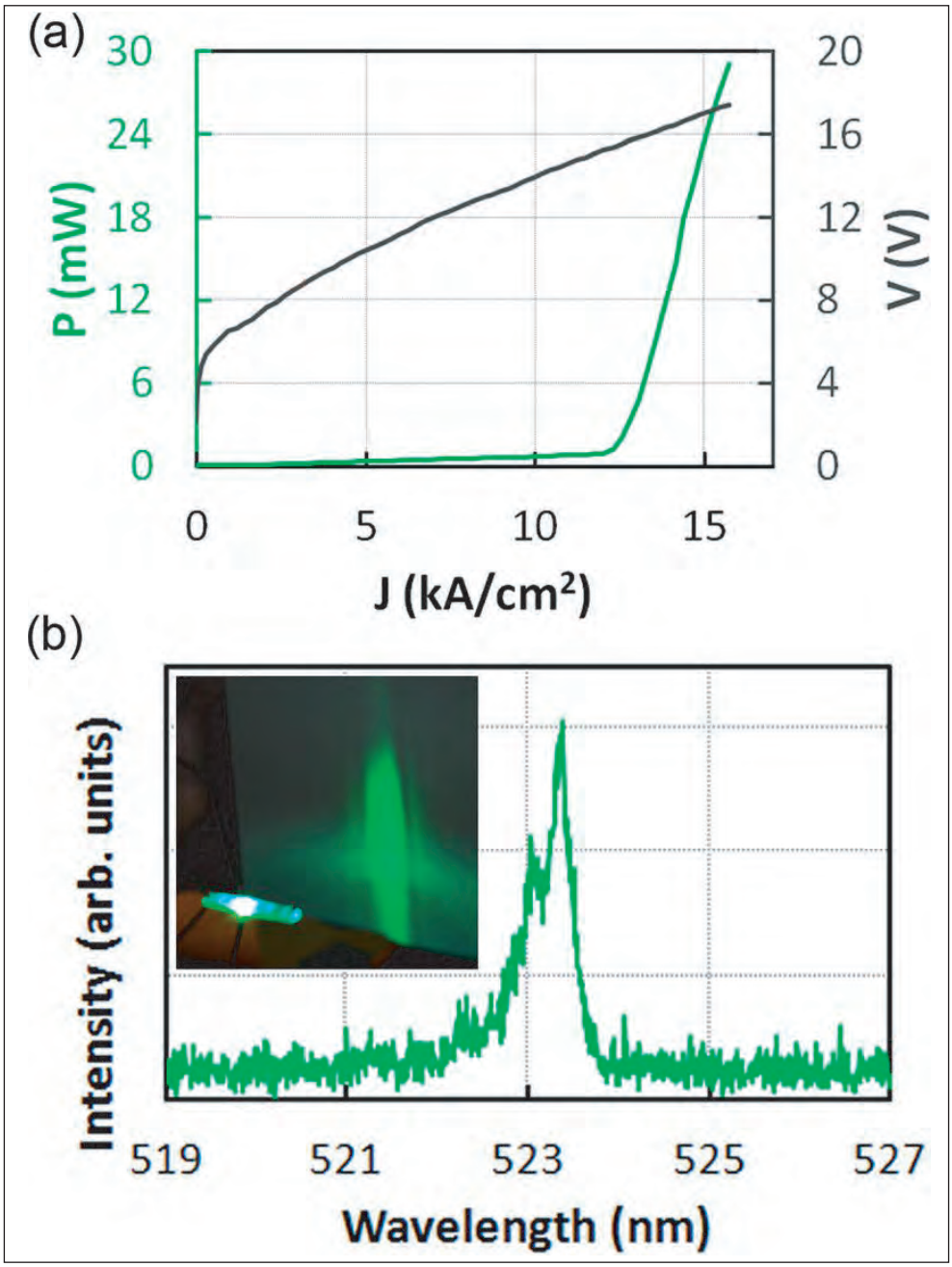


Figure 2. (a) Optical output power and voltage as function of current density for GaN-clad LAE true green LD; (b) lasing spectra (far-field pattern inset).

Table 1. Threshold performance of various LDs under pulsed operation.

Color	Cladding	Ridge	Threshold
Blue (456nm)	AlGaN	2.5x1800µm	4.5kA/cm^2
Blue (456nm)	GaN (planar)	2.5x1800µm	>8kA/cm^2
Blue-green (515nm)	AlGaN	4x1200µm	26kA/cm^2/23V
True green (523.4nm)	GaN	8x1200µm	12kA/cm^2/15V

http://dx.doi.org/10.1063/1.4829699

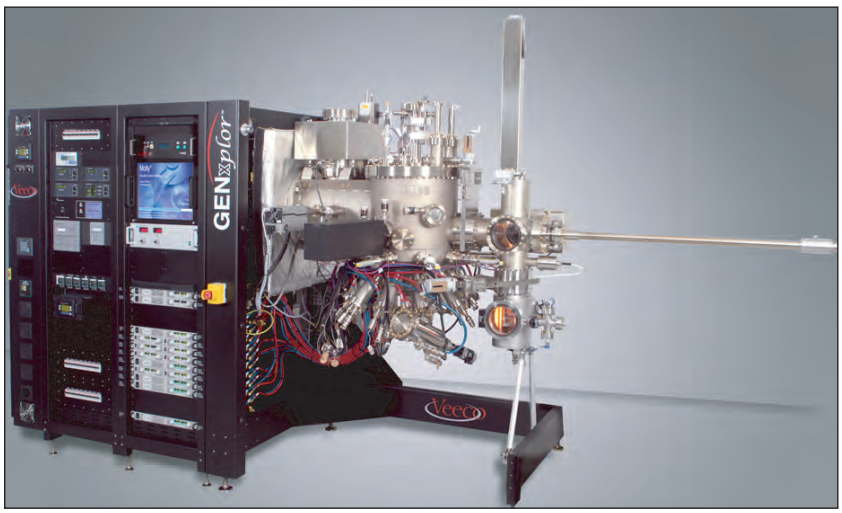
Author: Mike Cooke

Veeco develops fully integrated MBE system for R&D applications

Gerry Blumenstock of Veeco's MBE business unit discusses how the firm's latest molecular beam epitaxy deposition system has been developed, while professor Michael Santos explains its tailoring for research in his III-V MBE Group at University of Oklahoma.

Epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA has had much success in molecular beam epitaxy (MBE) over the years with systems designed for production. However, the last introduction of a Veeco MBE system for R&D was the launch of the GEN10™ in late 2008, which accommodates a single wafer with a diameter of up to 3".

But recently, at the China MBE Conference in Shanghai in August, Veeco launched a new MBE deposition system, the GENxplor™, which is said to be the industry's first fully integrated MBE system for the compound semiconductor R&D market.



Veeco's new GENxplor R&D MBE system.

The GENxplor uses Veeco's proven GEN10 growth chamber design to deposit epitaxial layers on substrates up to 3" in diameter. However, a new single-frame architecture combines all vacuum hardware with on-board electronics, enabling the system to be up to 40% smaller in footprint than other MBE systems, saving on lab space. Because the manual system is integrated on a single frame, installation time is reduced, Veeco adds. The open-architecture created by the cantilevered growth chamber design also improves ease-of-use by providing convenient access to effusion cells (with user accessibility to all 10 source ports and the configurable base flange) and allowing easier serviceability compared to other MBE systems, says the firm. Also, the integrated Molly software allows easy set-up, integrating easy recipe writing, automated growth control, and always-on data recording.

Coupled with Veeco's recently introduced retractable sources, the GENxplor system incorporates process flexibility, facilitating research on a wide variety of materials including not only gallium arsenide, nitrides and II-VI materials but also oxides, for emerging technologies such as ultraviolet (UV) LEDs, high-efficiency solar cells, and high-temperature superconductors.

"The compound semiconductor R&D community asked for a more affordable, flexible, and easy-to-use MBE system," comments Gerry Blumenstock, senior director of marketing for Veeco's MBE business unit in St. Paul, MN, USA. "We have repackaged Veeco's industry-leading MBE technology into a novel 'all-in-one' design that combines the reactor and electronics on a single frame," he adds.

"The trend in leading-edge MBE R&D is to operate a tool that has open architecture and multi-system integration to allow researchers to grow materials in novel ways," notes Blumenstock.

Also, there is direct scalability to the Veeco GEN20™, GEN200® and GEN2000® MBE production systems, which have the same growth architecture but with volume throughputs. "In designing the GENxplor we took a page out of MOCVD's book," says Blumenstock. "People came from New York and New Jersey [home to Veeco's metal-organic chemical vapour deposition (MOCVD) unit] and we have shared resources," he adds. Consequently, development of the GENxplor system took just 14 months from concept to launch, rather than the 24 months that is usual for a new system.

Development in collaboration with universities

Veeco has developed the GENxplor in concert with customers, the first of which include University of Oklahoma and the UK's University of Nottingham. Most tools that are sold have custom components, tailored to the specific needs of the user.

The firm first talked with University of Oklahoma about the concept of the GENxplor in 2012. Subsequently, at the end of October 2013, Oklahoma became the first university to receive commercial shipment of a GENxplor system, which was installed and ready for use by the end of November. Of the total cost of the system, 70% has been funded by grants from the US National Science Foundation (NSF) and the remaining 30% funded by a matching grant from the university. "The University of Oklahoma is at the forefront of compound semiconductor materials research, so it is quite fitting that they are receiving the first GENxplor," comments Blumenstock. "It has been designed specifically for the R&D community, combining an easy-to-use platform with our world-class MBE performance," he adds.

"We have two other Veeco MBE chambers in our lab [a GENII for III-V materials and a GENII for II-VI materials] that have performed very well," comments Dr Michael Santos, professor in Engineering Physics and head of the University of Oklahoma's III-V MBE Group. The GENII system includes four chambers: (1) a growth chamber for III-V materials; (2) a growth chamber for IV-VI and fluoride materials; (3) a surface analysis chamber equipped for Auger electron spectroscopy (AES) and x-ray photoelectron spectroscopy (XPS); and (4) a chamber for scanning probe microscopy (SPM). The group had considered acquiring a Veeco GEN930™ MBE system, due to its compactness allowing it to fit into the lab, yet the GENxplor is even smaller.

"The proven growth chamber and enhanced features of the GENxplor, including robust process flexibility and convenient access to effusion cells, are ideal for the materials research we are conducting for technologies such as lasers, photodetectors, and solar cells," Santos says.

The group's research projects (which involve collaboration with Denmark's University of Copenhagen, Japan's Tohoku University, and the USA's University of Arkansas and Amethyst Research Inc) include:

- spin effects in indium antimonide (InSb) quantum wells;
- topological insulators in narrow-bandgap materials;
- interband cascade lasers, detectors, and thermophotovoltaic devices;
- antimonide materials for solar cell applications.

Recent projects have been funded by the National Science Foundation, the Air Force Office of Scientific Research (AFOSR), the Department of Energy (DOE), NASA, Intel Corp, Microsoft Corp, the Japan Science and Technology Agency, and the Oklahoma Center for the Advancement of Science and Technology.

Although the solar work has only recently started, Santos says that all the projects will be transitioned from GENII to GENxplor.

Oklahoma's GENxplor is configured with nine sources at the moment, says Santos, but can accommodate at least 10. In addition, due to having different inserts, the same uni-block molybdenum substrate holder can accommodate both 3-inch GaAs wafers and 2-inch gallium antimonide (GaSb) or indium arsenide (InAs) wafers. Hence, as well as growing antimonides and arsenides in the new system, the plan is also to investigate different materials, including bismides.

In addition, in the new system all effusion cells have been improved. In the case of antimony, a valved cracker (only available on Veeco systems) allows more precise control, enabling quick switching between antimony and arsenic sources. This useful in, for example, arsenide/antimonide superlattices in interband cascade lasers (which are targeted for energy-efficient longer-wavelength emission) as well as 'third-generation' interband cascade photovoltaic cells, for which the arsenide/antimonide energy-band line-up enables high efficiency.

One objective at Oklahoma is to connect the two systems (GENII and GENxplor), which have different analysis and materials capabilities. Currently, it is common for wafers to be transferred between two separate GENII systems. Also, according to Veeco, it will be possible to transfer wafers between GENxplor systems. However, in GENII systems wafers are situated vertically, whereas in GENxplor systems the wafers are face down, so sample transfer is different. Therefore, "in the near future" Veeco and Oklahoma aim to collaborate on developing a GENxplor-to-GENII transfer station, operating under high vacuum, says Santos.

This should be aided by Veeco's Process Integration Center in St Paul, which is fully equipped to conduct process demonstrations, arrange rapid-start programs, provide early access to evaluate system upgrades and support joint technology developments, especially since the facility which features both a GEN10 system and a GENxplor system.

- At the 30th North America Molecular Beam Epitaxy Conference (NAMBE 2013) in Banff, Canada (5–11 October), Santos' group presented its latest MBE-based research, including 'Heterostructural Integration of II-VI and III-V Materials on Si-based Substrates' and 'High Electron Mobilities of InSb Epilayers and Quantum Wells on Ge-On-insulator Substrates with Post-growth Hydrogenation'. ■

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GaN-on-Si opportunity for extending the life of CMOS silicon fabs?

Announcements of gallium nitride light-emitting diode samples produced on silicon in 150mm and 200mm facilities gives hope for others. Mike Cooke reports on the cost-reducing potential and obstacles faced by the industry.

Much of the recent effort to expand the scope of gallium nitride (GaN) and related semiconductor materials to more applications and markets has centered on developing epitaxial growth methods on silicon (Si) substrates. The drive behind this work is economic. Crystalline silicon is much lower cost (~\$0.1/cm^2) than the alternatives such as sapphire (~\$0.8/cm^2), silicon carbide (~\$6.6/cm^2), and especially bulk or freestanding GaN.

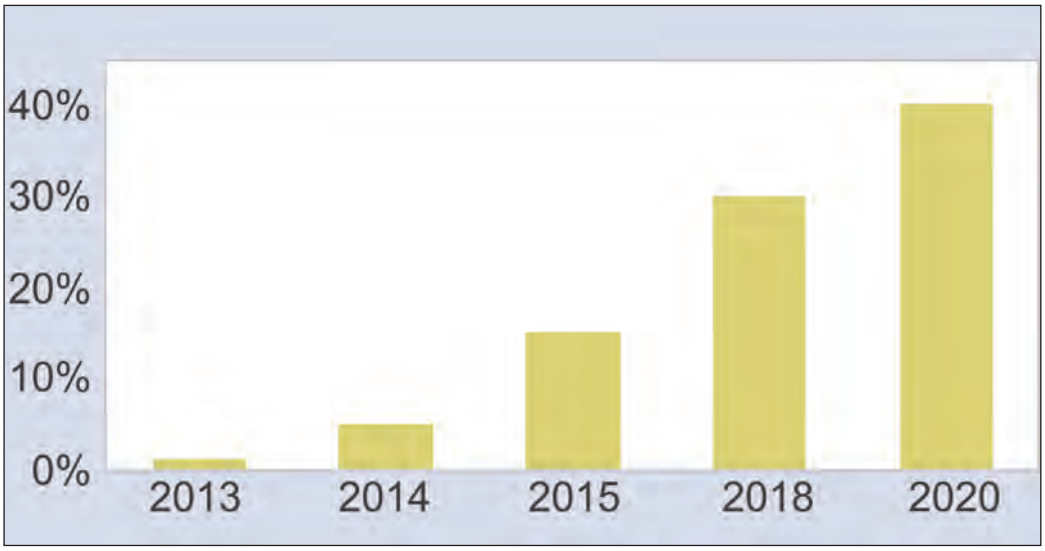

Figure 1. IHS GaN-on-Si LED market share outlook in terms of revenue for the packaged LED market.

Silicon could also enable another factor — 'economies of scale', where production in volume is much less expensive than making a few pieces. In particular, silicon wafers are available in diameters up to 8-inches. Actually, advanced CMOS production uses 12-inch diameter substrates (and some want to move to 18inch/450mm), but the crystal orientation is different — (001), rather than the (111) orientation that is most suitable for gallium nitride growth.

LED production on sapphire is carried out on wafers of at most 150mm diameter, with the majority being on substrates of 100mm or less. Silicon carbide (SiC) is similarly restricted to around 100mm diameter.

Another factor is that, as CMOS production migrates to larger substrates, older facilities become more desperate to fill production schedules at a profitable rate. Converting to GaN production could extend the useful life of such fabs.

These are some of the selling points, but there are also serious obstacles to lower-cost production. The attractions of GaN and related semiconductor materials — e.g. green, blue, violet etc light emission and high critical field for power transistors — are seriously impacted by defects that arise in the growth process. The density of defects tends to be higher when there is a greater mismatch with the underlying substrate. Unfortunately, the mismatch with silicon at 17% is higher than the alternatives: 16% for sapphire, 3.3% for 6H SiC, and 0% for GaN.

Also, the infrastructure of CMOS production is different from that of the light-emitting devices that presently form the bedrock of GaN-based mass production. While most of the processing steps of CMOS are in tools that process single wafers, the epitaxial growth equipment for LEDs and laser diodes handle large numbers of substrates at a time.

The single-wafer approach of CMOS was developed to enhance process control and thus increase yields of extremely complicated sub-micron devices. The structures of LEDs and laser diodes are much simpler,

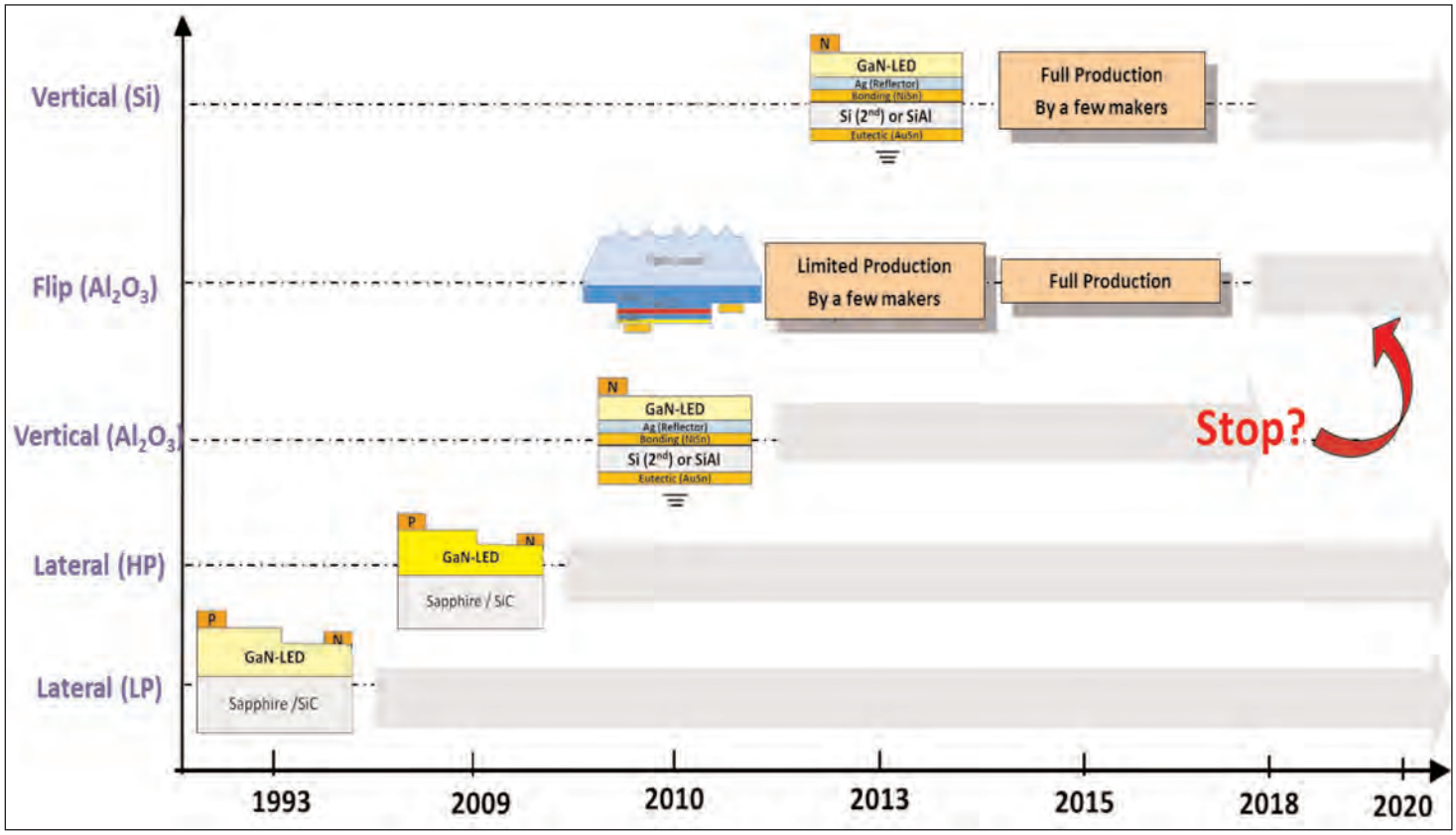

Figure 2. IHS projected roadmap for GaN LED production.

and there has not yet been a similar pressure for such exacting process control. As a result, batch-type processing is a more natural method to increase production volumes.

Despite the difficulties and obstacles to growth on silicon, research and development has progressed to the stage that samples from Japanese companies Fujitsu and Panasonic are beginning to appear in the power switching arena [for example, see Mike Cooke, Semiconductor Today, p82, November 2013]. These devices are normally-off transistors produced on silicon with hopes of application in cost-sensitive power switching devices.

The more challenging light-emitting application has also begun to see commercial development, with Plessey and Toshiba both announcing samples of 'second generation' devices in recent months.

Market researchers at IHS Inc forecast that the share of GaN-on-Si wafers in the LED market (Figure 1) will increase at a compound annual growth rate (CAGR) of 69% between 2013 and 2020, reaching 40% of all GaN LEDs manufactured ['GaN LEDs on Silicon', November 2013]. Such high CAGRs are typical for 'hockey stick' graphs starting from a baseline near zero.

During 2013, the researchers estimate that 95% of GaN LEDs were produced on sapphire, while only 1% (~0%) were made on silicon. Growth in GaN-on-Si LED manufacturing is also expected to grab market share from silicon carbide substrates, which are often used for high-brightness devices because of the material's superior thermal conductivity. Although silicon's thermal conductivity is somewhat less than that of silicon carbide, it is much better than sapphire's.

The market researchers believe that repurposing existing silicon manufacturing facilities for GaN-on-Si LED production would require minimal investment. "Many of the CMOS semiconductor manufacturers already have excellent inspection tools, unlike traditional LED companies," comments Dkins Cho, senior analyst for lighting and LEDs at IHS. "This could help increase their process yield through in-situ monitoring. However, it is unlikely the repurposing will happen overnight; instead we forecast a shift during the coming years."

However, there remain some challenges, according to IHS. Silicon strongly absorbs the radiation emitted from GaN-based LEDs and therefore creates difficulty for traditional lateral current flow chips that emit through the substrate (Figure 2). One way around this is to remove the silicon substrate. In principle, this has the added benefit of vertical current flow through the LED, which should improve efficiency. Unfortunately, the conventional laser lift-off silicon substrate removal process tends to reduce process yield.

Another analyst group, Lux Research, is less sanguine on the prospects for GaN-on-Si LEDs. In its June 2013 report 'Dimming the Hype: GaN-on-Si Fails to Outshine Sapphire by 2020', these researchers point out that sapphire is moving to lower substrate costs, improved wafer yields, availability of larger substrates and

Figure 3. Kaga Toshiba Electronics Corp, where Toshiba's GaN-on-Si LEDs are produced.

increased die throughput. "As a result, GaN-on-Si, with unproven performance and reliability, must race to stay relevant as the window of opportunity closes."

Both Plessey and Toshiba reflect IHS' assertion that GaN LED on silicon production will occur in repurposed silicon fabs.

Plessey in the UK acquired CamGaN, a spin-out from Cambridge University research, in December 2011. CamGaN's technical knowhow, intellectual property and patents have now been converted into commercial production at Plessey's existing 6-inch facility in Plymouth, UK. The company claims its 'MAGIC' trademarked devices deliver "industry-standard performance at a dramatically reduced cost of manufacture, with estimated savings of up to 80%".

The latest devices double the efficacy of its previous samples announced in February 2013. "We have a roadmap that puts MAGIC ahead of the efficacies achieved by sapphire-based LEDs and, thereby, sets a new milestone in terms of Lm/$ performance," says Plessey's chief technology officer Dr Keith Strickland.

A variety of 'white' LEDs are sampling under the descriptions 'warm', 'neutral' and 'cool', with color temperatures in the range 2700–5500K. The color rendering indices are in the range 70–80 with 60mA injection current. The respective forward voltage is typically 3.2V. The luminous flux is in the range 7.9–12.3lm.

Meanwhile Toshiba boasts that it has developed a process that can produce GaN-based LEDs on 200mm-diameter silicon wafers. The Japanese company also points out that it can use existing silicon facilities (Figure 3).

The new Toshiba device is a 1W 'white' product under the LETERAS trademark. The color temperatures range between 2700K and 6500K with color rendering minima of 80 and 70, respectively. The luminous flux range is 104–135lm. These devices run with a 350mA injection current and forward voltage of 2.85V.

Researchers from Toshiba reported at the 2013 International Electron Devices Meeting (IEDM) in December on a method for reducing threading dislocation densities in 200mm GaN-on-Si wafers by using silicon nitride multiple-modulation interlayers. Early in 2013 Toshiba acquired the GaN-on-Si technology and related assets of California-based LED chip and lighting array maker Bridgelux Inc.

Another company that has been developing GaN on Si is Azzurro Semiconductors in Germany. In particular, it has been focusing its recent research effort towards providing 150mm epitaxial template wafers for GaN-based LED production. The company says that its wafers are suitable for standard Si-semiconductor equipment in terms of wafer size, low bowing and opaqueness. Company researchers have been reporting promising results in the past year [see Mike Cooke, Semiconductor Today, p78, October 2013].

The metal-organic chemical vapor deposition (MOCVD) tool manufacturers are also working on

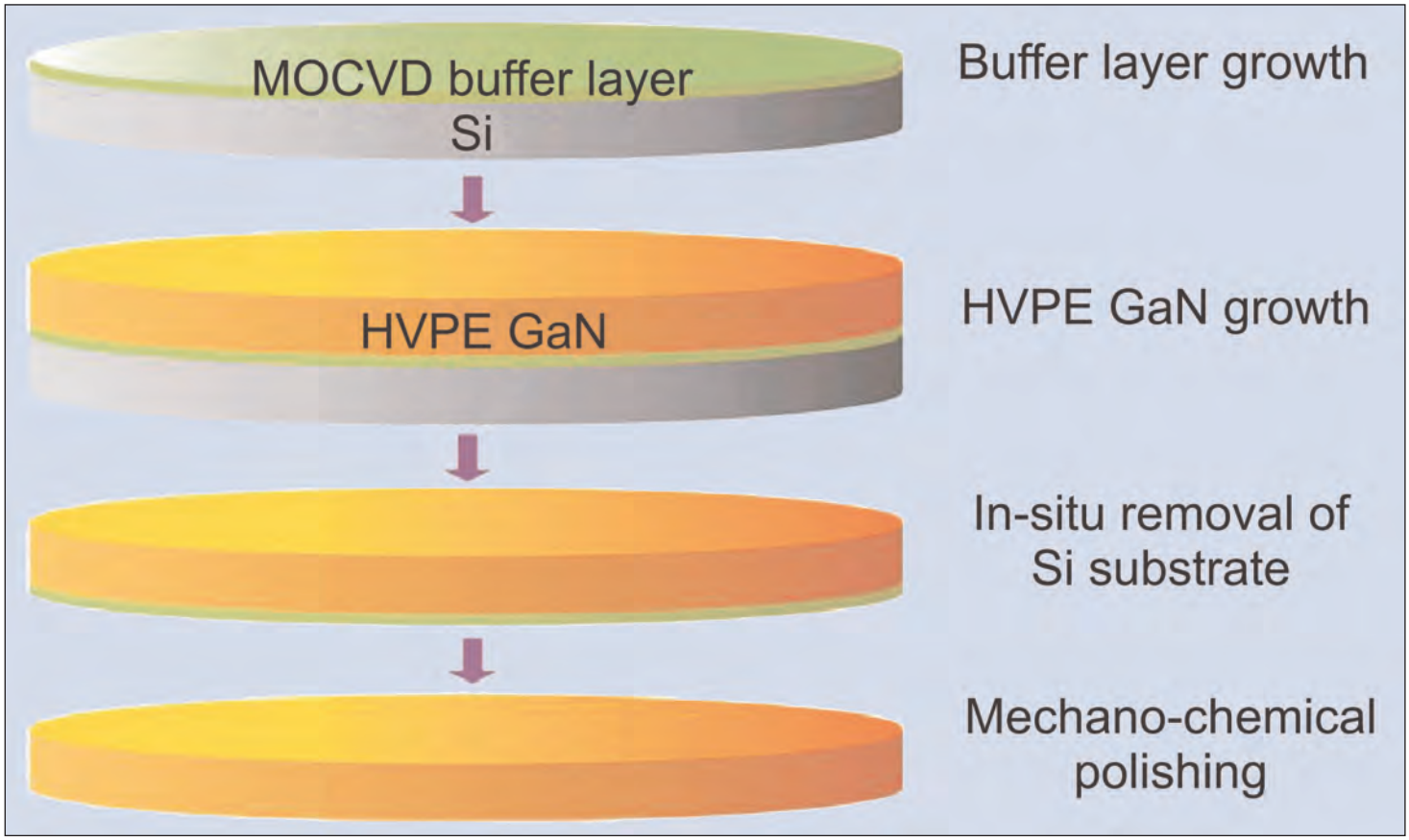

Figure 4. Schematic Samsung/SNU process steps for fabricating freestanding GaN-on-Si substrate using in-situ Si etching.

meeting the needs of this potential new market.

Although Veeco's sales effort for GaN-on-Si equipment is presently focused on power electronics applications, the company announced in September 2013 a collaboration agreement with the Belgium-based research center Imec. However, the two organizations have been working together on GaN-on-Si since 2011. The aim is to lower the cost of production of GaN-on-Si power devices and LEDs.

Jim Jenson, senior VP, general manager, Veeco MOCVD, comments: "This technology can be used to create lower-cost LEDs that enable solid-state lighting, more efficient power devices for applications such as power supplies and adapters, PV inverters for solar panels, and power conversion for electric vehicles."

Aixtron supplies the University of Cambridge with MOCVD equipment for research that includes GaN LEDs on silicon. The commissioning of an Aixtron Close Coupled Showerhead (CCS) MOCVD reactor capable of handling 150mm wafers at Cambridge was announced in April 2013. Plessey is another customer of Aixtron. The company also supplies GaN-on-Si MOCVD equipment to a number of companies focused on power switching/conversion electronics.

Aixtron has also set up a training and demonstration center at the Suzhou Institute for Nanotechnology and Nanobionics (SINANO), which works on LED and GaN-on-Si research.

An interesting new development is the prospect of the production of high-quality freestanding GaN on silicon. Researchers at Samsung Electronics and Seoul National University (SNU) in Korea produced high-quality freestanding GaN substrates from hydride vapor phase epitaxy (HVPE) on silicon templates [Moonsang Lee et al, Appl. Phys. Express, vol6, p125502, 2013].

HVPE is a faster growth process for GaN than MOCVD, allowing layers of ~100μm rather than 1–10μm to be produced. Usually, the substrate with the seed GaN layer needs to be more nearly lattice matched than silicon to obtain high-quality material. Also, problems such as cracking can occur when the foreign substrate is removed to give freestanding GaN.

The main difference with normal attempts to grow freestanding GaN on silicon is that, instead of waiting for the material to cool, the Samsung/SNU researchers separated the GaN from the silicon substrate at high temperature.

Growing high-quality GaN on silicon should lead to larger-diameter wafers and therefore economies of scale. Although the experimental work was carried out on 2-inch silicon wafers, the researchers believe that production on 8-inch diameter substrates should be possible in the near future.

High-temperature separation of the substrate avoids a problem arising from the different rates of thermal

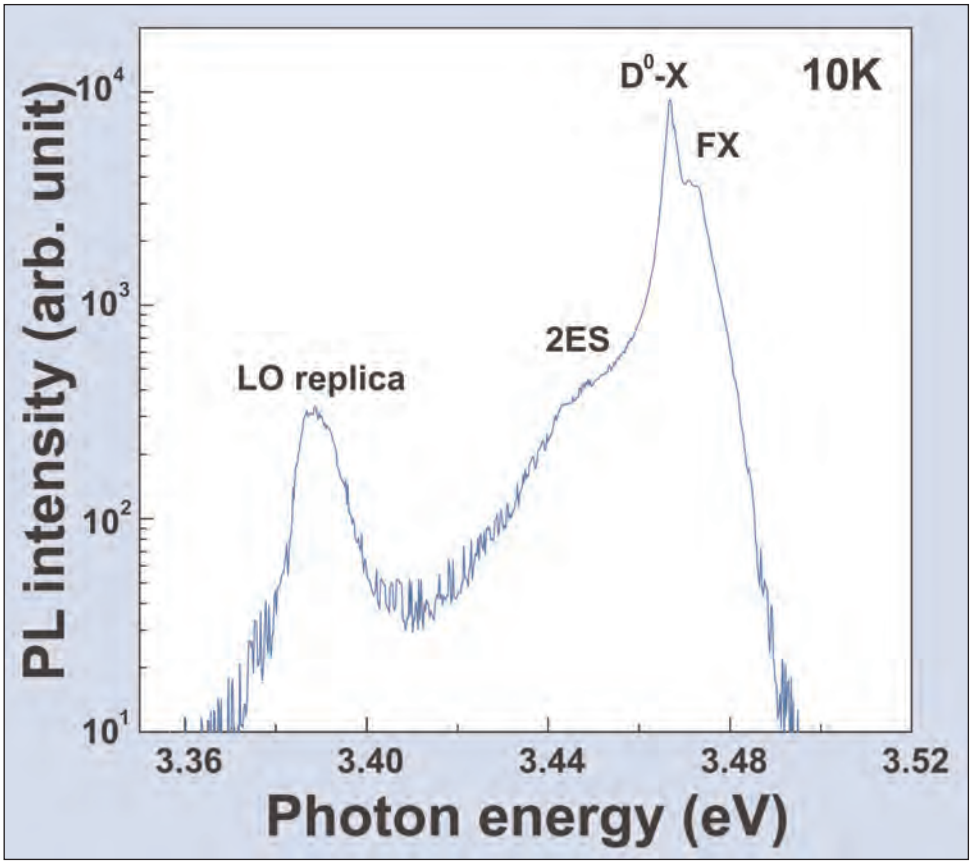

Figure 5. PL spectrum of Samsung/SNU freestanding GaN at 10K: FX is attributed to free exciton; D^0–X is neutral donor bound-exciton; 2ES is second excited state; LO replica is longitudinal optical phonon replica.

expansion of 5.59×10^{-6}/K for GaN and 3.37×10^{-6}/K for silicon. As the grown GaN material cools to room temperature on silicon, the different rates of contraction lead to cracks and bowing of the wafer.

Simulations suggested that, while the mismatch with silicon causes tensile stress in GaN at room temperature, above 900ºC the GaN layer experiences mild compression. The researchers therefore believed that removing the silicon at high temperature could avoid the cracking and defect problems often found in producing freestanding GaN.

In the Samsung/SNU method (Figure 4), the 2-inch (111) silicon wafer was first cleaned to remove oxygen and to give a hydrogen-terminated surface. Buffer and transition layers were grown using MOCVD.

The buffer consisted of 100nm aluminium nitride (AlN). This layer reduced lattice mismatch and prevented silicon from diffusing from the substrate into the nitride semiconductor layers — an effect known as 'melt-back' that inhibits GaN growth.

The transition layer was a series of aluminium gallium nitride (AlGaN) layers with a "unique epitaxial structure" developed by Samsung along with researchers from Sejong and Hanyang universities [http://proceedings.spiedigitallibrary.org/proceeding.aspx?articleid=1385248]. The structure is designed to reduce dislocations and compensate for stress during growth.

The MOCVD processing was completed with a 500nm gallium nitride (GaN) layer (250arcsec x-ray rocking curve).

The HVPE of 400μm of GaN was carried out in a chamber that was also capable of in-situ etching. The HVPE process consisted of pre-reacting hydrogen chloride (HCl) with Ga liquid to form GaCl gas. The gas was transported to the growth zone at 1000ºC to react with ammonia (NH_3) to give GaN deposition on the MOCVD template. Nitrogen was used as a carrier gas for the HVPE.

The process was completed by etching away the silicon substrate at 1000ºC using HCl gas. The reactor was then cooled to room temperature to yield the freestanding GaN. Microscopic inspection of the product showed an absence of cracks or defects such as melt-back and pits.

The (0002) x-ray rocking curve gave a peak with full-width at half maximum (FWHM) of 65arcsec for the Ga face and 200arcsec for the N-face. The difference is attributed to bowing and the fact that the N face comes from material at the junction with the MOCVD template layers. However, the amount of bowing is much reduced at about 20μm, compared with the hundreds of microns typical for freestanding GaN produced on foreign substrates that are removed at room temperature.

The estimated pit density after 30 minutes etching in phosphoric acid (H_3PO_4) was less than $10^6/cm^2$ over the whole wafer. This value is comparable to or better than for thicker material (~1mm) grown on sapphire. Low etch pit densities indicate a reduced numbers of dislocations.

Photoluminescence (PL) at 10K (Figure 5) showed an edge peak close to that of freestanding GaN produced on sapphire. The researchers see their photoluminescence results as confirming the high crystal quality. However, the neutral donor bound-exciton (DBE) transition (D^0–X) at 3.467eV (FWHM 3.1meV) is slightly red-shifted compared with strain-free ammonothermal GaN or material from homoepitaxy. The researchers see the red-shift as indicating slight tensile stress in their freestanding GaN from residual strain due to the quality difference of the Ga- and N-face surfaces. ■

The author Mike Cooke is a freelance technology journalist who has worked in the semiconductor and advanced technology sectors since 1997.

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Electrostatic protection for gallium nitride circuits

ESD pHEMT clamp needed for high-frequency and high-power use.

Researchers in USA and Taiwan have developed a nitride semiconductor electrostatic discharge (ESD) clamp using gallium nitride (GaN) pseudomorphic high-electron-mobility transistor (pHEMT) technology "for the first time" [Zhixin Wang et al, IEEE Electron Device Letters, published online 10 October 2013]. The researchers are at University of Central Florida and Chang Gung University,

GaN transistor technology is being developed for radio frequency (RF) and microwave applications such as power amplification. Compared with gallium arsenide (GaAs) transistors, the wide bandgap and high critical field allow higher power densities to be achieved in GaN components.

ESD protection is a vital part of development efforts to make GaN a viable and commercial high-frequency and high-power technology. There has been a limited amount of research in this area so far. A recent ESD development in GaAs technology has been a clamp based on pHEMTs. The new research makes a similar development for GaN devices.

"The targeted applications are ESD protection of I/O pins of GaN-pHEMT-based power and low-noise amplifiers used in wireless communication applications with an operating voltage in the range 2–4V,," the team says.

The circuit for the ESD clamp (Figure 1) was laid out (Figure 2) on a substrate that included an aluminium gallium nitride (AlGaN) barrier and gallium nitride (GaN) buffer on silicon. The clamp consisted of a depletion-mode (normally-on) pHEMT with various Schottky diodes to provide trigger and pinch-off diode chains. A current-limiting resistor is also part of the device.

In a set up with an enhancement-mode (normally-off) pHEMT, the pinch-off chains would not strictly be necessary, in theory. The pinch-off chain also limits the leakage current through the clamp during normal operation when there is no electrostatic charge to dissipate from the core circuit. However, pinch-off diodes

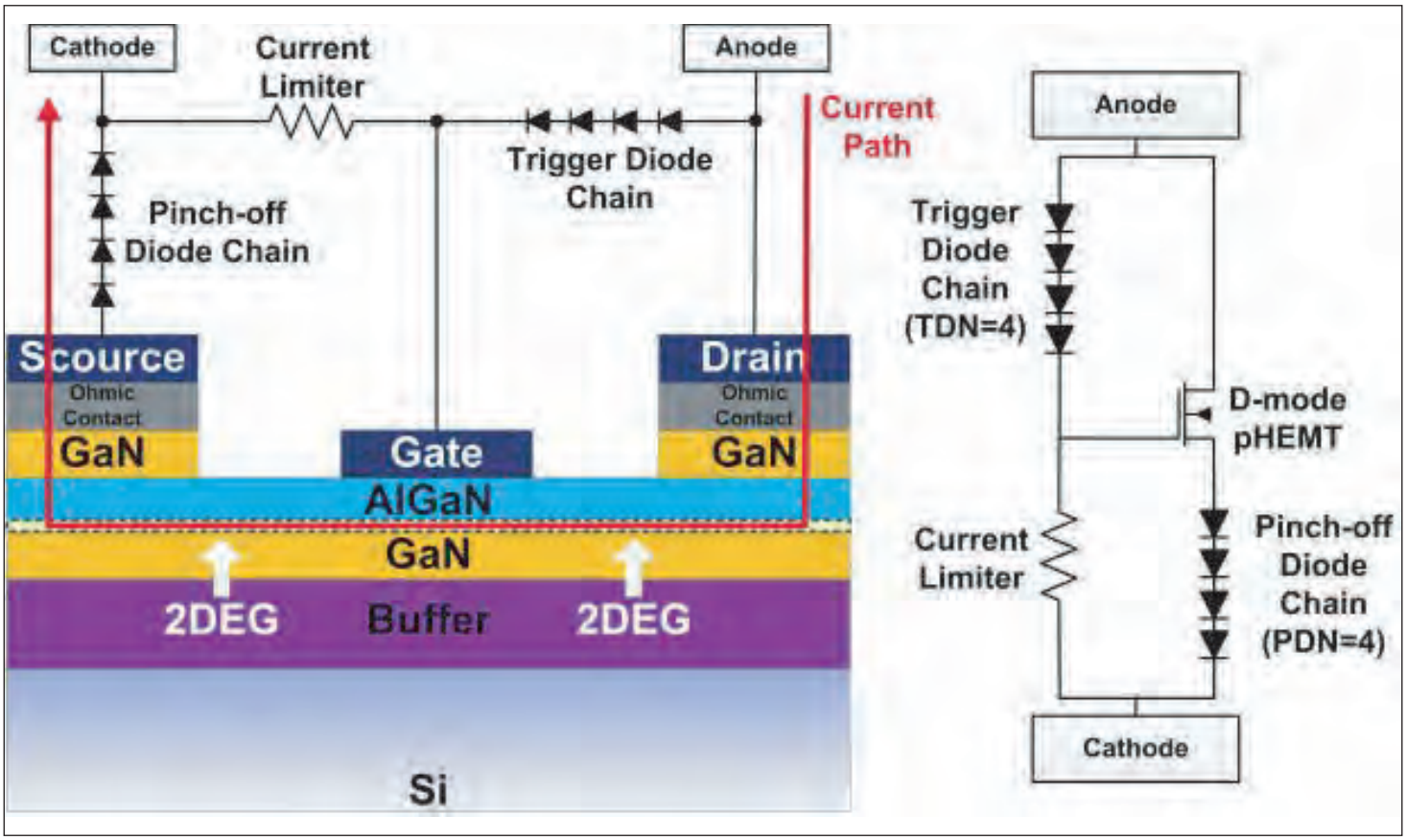

Figure 1. (Left) Cross-sectional diagram of proposed ESD protection clamp, consisting of single-gate depletion-mode GaN pHEMT, trigger diode chain, pinch-off diode chain, and resistor (current limiter). Red line is current path when clamp is on. (Left) Equivalent circuit of GaN-pHEMT-based ESD clamp.

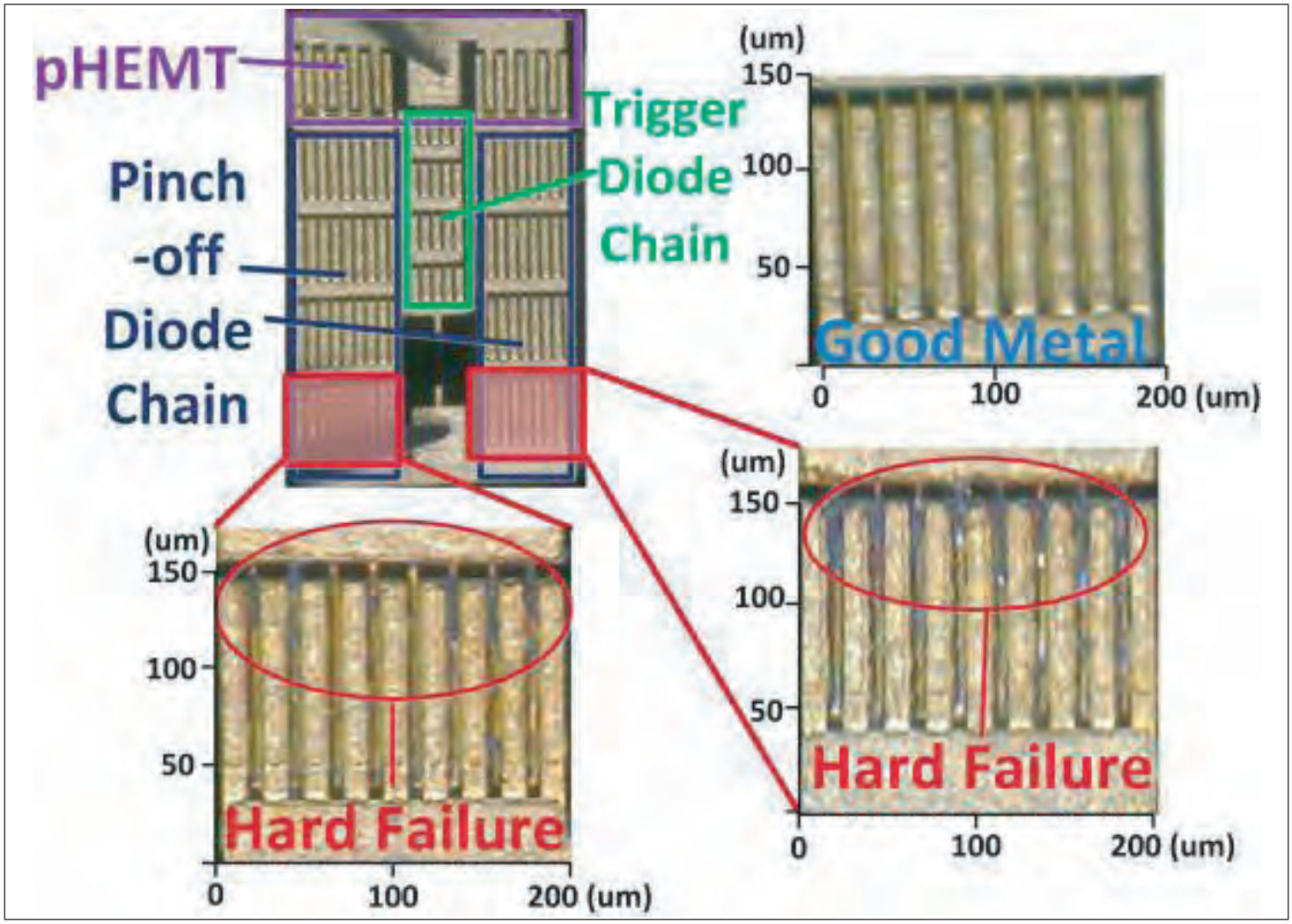

Figure 2. Photo of GaN pHEMT clamp, with enlarged pictures showing hard failures on pinch-off diode chain.

increase the on-resistance of the clamp.

Dimensions of the pHEMT device were 188µm x 184µm. The diode dimensions were 106µm x 111µm and 196µm x 169µm for trigger and pinch-off, respectively. The threshold voltage of the pHEMT was –2V. The gate length was 0.35µm.

Table 1. Comparisons of trigger voltage, leakage current, on-state resistance and failure current with different trigger and pinch-off diode numbers.

Trigger diodes	Pinch-off diodes	Trigger voltage (V)	Leakage current (A)	On-resistance (Ω)	Failure current (A)
2	4	4.6	1.50e-4	3.54 to 377	2.73
3	4	5.2	2.23e-5	3.42 to 348	2.97
4	4	6	1.93e-6	3.36 to 335	3
4	3	4	9.42e-5	3.46 to 9.75	3.72
4	2	N/A	>2e-3	N/A	N/A
4	1	N/A	>2e-3	N/A	N/A

The clamp was characterized (Table 1) using a transmission line pulsing (TLP) stress tester (Barth 402). The pHEMT-based clamp gives reduced leakage current and on-resistance and higher failure current, compared with structures based just on Schottky diodes. For example, a pHEMT clamp with four trigger and four pinch-off diodes had 2µA leakage and 3A failure currents. A five diode-only clamp of similar area and trigger voltage had ~10µA leakage and ~2A failure currents.

The effect of reducing the pinch-off diode number below 3 is that the pHEMT is not fully turned off in normal operation of the core circuit and the leakage is larger than 2mA, far beyond the value needed for applications.

Hard failures occurred in the pinch-off chains (Figure 2). The pHEMT and trigger chains showed no damage. Inspection of the pinch-off diodes showed damage near the anode end of the devices, suggesting problems with non-uniform current crowding. The researchers believe that diodes with larger numbers of shorter fingers could provide a more uniform current and therefore higher robustness for such ESD clamps. ■

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Author: Mike Cooke

First small-signal data from p-channel gallium nitride transistor

Gallium nitride could open up complementary logic for applications in harsher environments and higher temperatures.

RWTH Aachen University has reported the first small-signal response frequency characteristics for p-channel gallium nitride (GaN) heterostructure field-effect transistors (HFETs) [Herwig Hahn et al, Jpn. J. Appl. Phys., vol52, p128001, 2013].

Although the performance of these devices is much inferior to n-channel HFETs, p-channel transistors are of interest for producing GaN-based logic circuits. Complementary logic uses n- and p-channels devices in tandem to give lower power consumption and high switching speed, relative to direct-coupled transistor circuits where only one type of device is used.

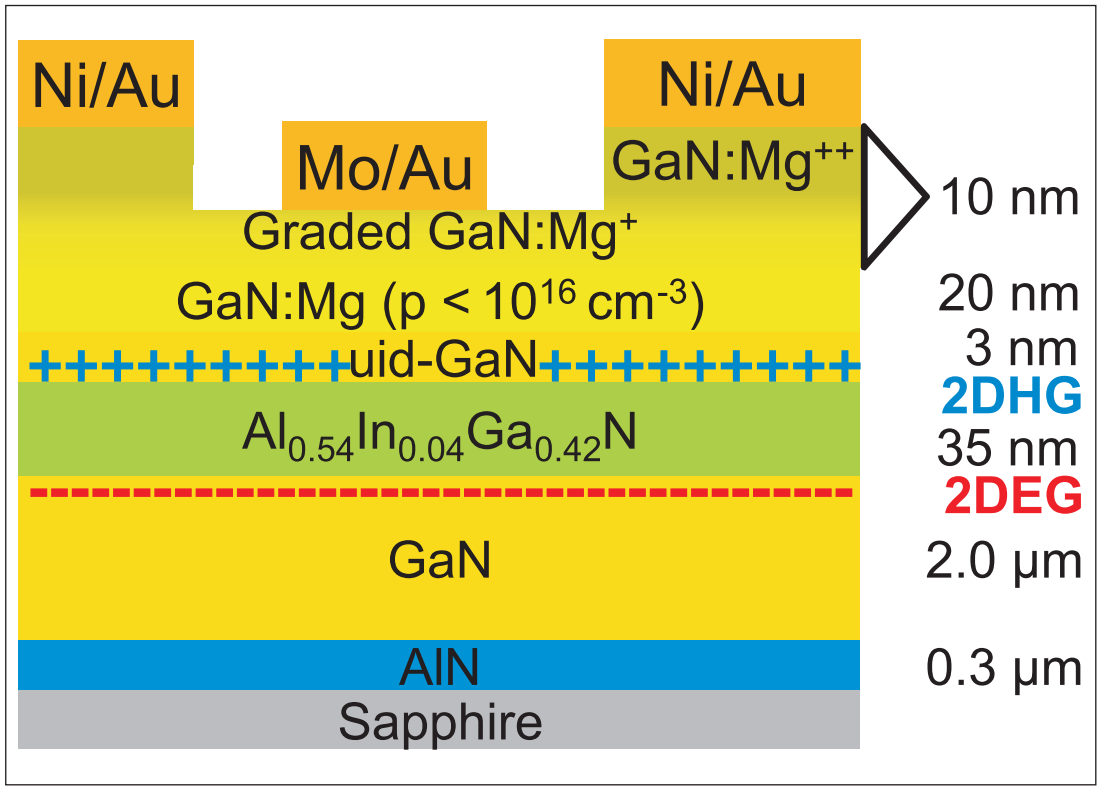

Figure 1. Schematic cross section of double heterostructure field-effect transistor with p-channel.

For mainstream logic applications, silicon is the material of choice, but GaN-based logic could extend capabilities to harsher environments and higher temperatures. The p-channel HFET side of complementary logic has only intermittently been explored in a GaN setting. RWTH Aachen reported on DC characteristics for a GaN p-HFET earlier this year [H Hahn et al, IEEE Transactions on Electron Devices, vol60, p3005, 2013].

The latest small-signal measurements were on a device grown on 2-inch sapphire using metal-organic chemical vapor deposition (MOCVD) in an Aixtron system (Figure 1). The device layers include a 35nm AlInGaN back-barrier. The positive polarization difference between the back-barrier and underlying 2µm GaN buffer caused a two-dimensional electron gas (2DEG) to form.

Above the back-barrier a negative polarization difference caused a two-dimensional hole gas (2DHG) to accumulate in the overlying unintentionally doped (uid) GaN cap. The properties of the hole gas were $2x10^{13}/cm^2$ carrier density, $12cm^2/V\text{-}s$ mobility, and 26kΩ/square sheet resistance.

Further epitaxial layers consisted of GaN with varying doping levels of magnesium to create p-type hole conductivity. Ohmic contacts consisted of nickel/gold annealed in an oxygen-rich atmosphere. A 'digital etch' was used to create a recess between the source and drain ohmic contacts, removing the highly doped $GaN:Mg^{++}$ layer to significantly reduce gate leakage. The gate stack consisted of molybdenum/gold. Pads consisting of nickel/gold were applied to all the contacts.

The HFET structure consisted of a double-finger gate of 100µm width and 1µm length. The source–drain and

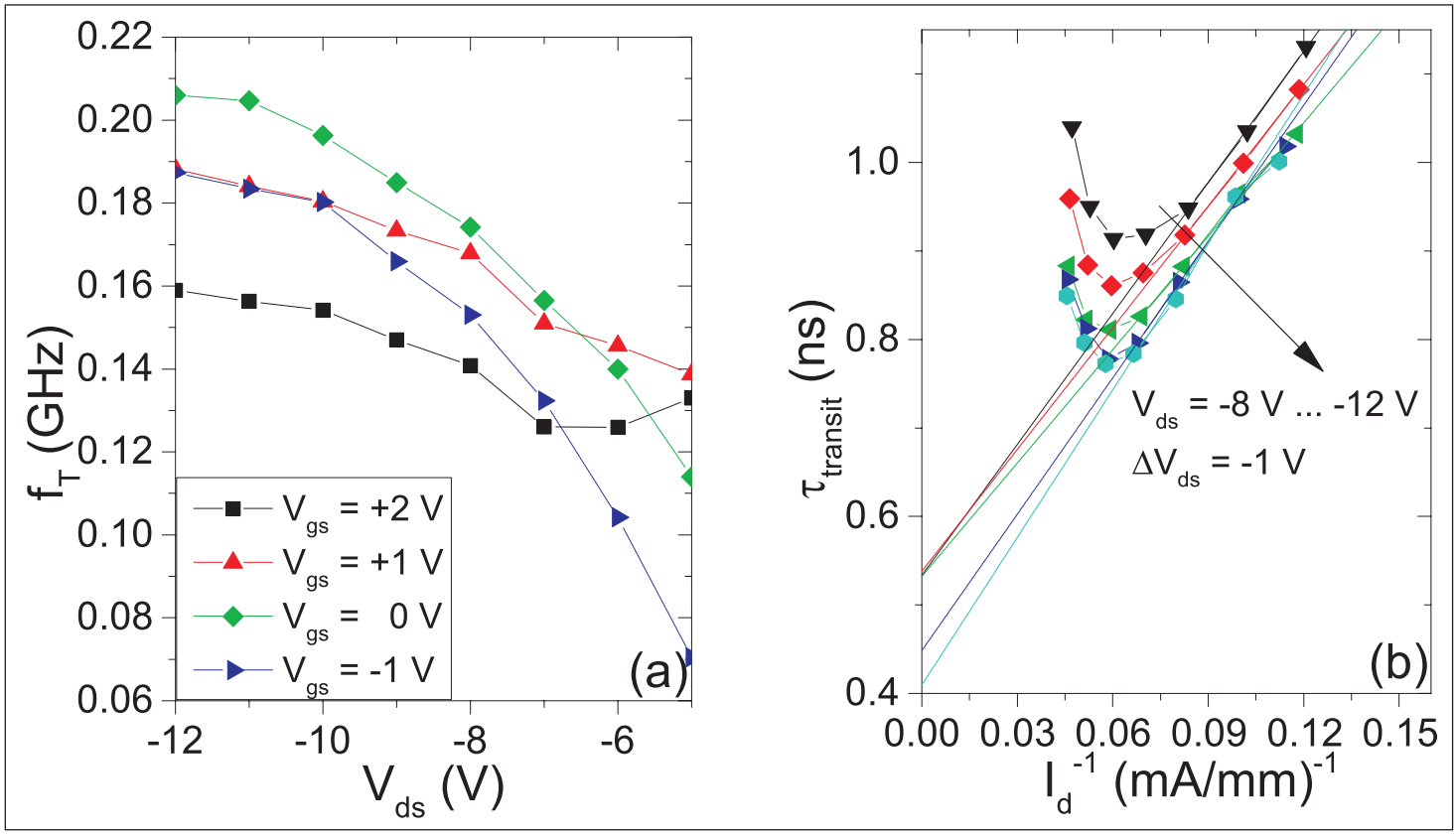

Figure 2. (a) Behavior of fT versus bias points and (b) extracted saturation velocity.

source–gate separations were 2.5µm and 1.5µm, respectively.

The frequency cut-off (f_T) and maximum oscillation (fmax) were estimated at 206MHz and 640MHz. "These values are about a factor of 50 lower than the values of n-channel devices fabricated in our group," the researchers point out.

By measuring f_T away from the optimum bias point (Figure 2) and making some assumptions using the transit time and drain current that should be adequate for the relatively large gate length of 1µm, the researchers estimated a hole saturation velocity of 2.4×10^5cm/s, "which is lower than that of electrons in GaN roughly by a factor of 50–100."

In DC testing, the maximum drain current was –25mA/mm at –3V gate voltage. The threshold voltage was extrapolated at +3.5V. The maximum transconductance was 6mS/mm. While this would be a small value for n-channel HFETs (which are also known as high-electron-mobility transistors, or HEMTs), it is among the highest reported for p-channel devices.

The researchers foresee improvements via "reducing the gate-channel separation, downscaling the device dimensions, or reducing the parasitic resistances" (e.g. sheet and ohmic contact). ■

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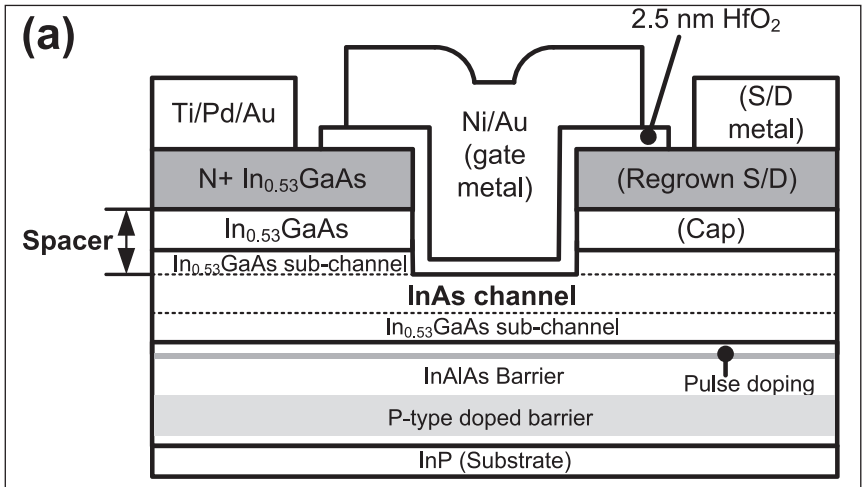
Vertical spacers for tighter integration of III-V MOSFETs

UCSB has demonstrated a device with the highest peak transconductance for any III-V MOSFET to date.

University of California Santa Barbara (UCSB) researchers have been studying the effect of using undoped vertical spacers in the source and drain contacts to reduce off-state leakage in indium arsenide (InAs)-channel metal-oxide-semiconductor field-effect transistors (MOSFETs) [Sanghoon Lee et al, Appl. Phys. Lett., vol103, p233503, 2013]. The team used the technique to achieve the highest peak transconductance value for any III-V MOSFET to date.

III-V MOSFETs are being developed with a view to high performance in very large-scale integration (VLSI) ICs. Although some promising results have been reported, the devices tend to be larger than desired due to the need to reduce leakage currents in the off-state. In particular, the source and drain contacts are difficult to shrink or to move closer to the gate edge. One reason for this is the need to reduce the size of the electric fields that cause leakage at high drain bias. The UCSB vertical spacers are designed to reduce these fields without increasing source-drain distances.

Solid-source molecular beam epitaxy (SS-MBE) on indium phosphide (InP) substrates was used to create samples for three device types (Figure 1). Under the channel was a series of indium aluminium arsenide (InAlAs) layers: a 50nm unintentionally doped buffer, a 250nm p-type barrier, a 2nm pulse-doped n-type region, and a 5nm unintentionally doped setback. The transistor layers consisted of a 3nm indium gallium arsenide ($In_{0.53}Ga_{0.47}As$) sub-channel, 6nm InAs strained channel, and 3nm I$In_{0.53}Ga_{0.47}As$ upper cladding. The structure was capped with 5nm of $In_{0.53}Ga_{0.47}As$, which was doped n-type in one case (sample A) and undoped in two cases (samples B and C).



Sample	A	B	C
Spacer (nm)	3	8	8
InAs channel (nm)	6	6	4.5

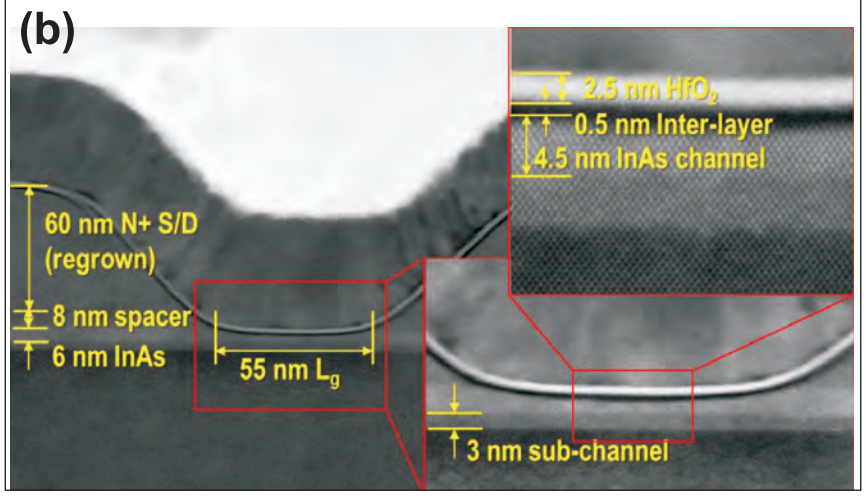


Figure 1. (a) Schematic cross-section of device structure. Table defines differences between three experimental samples. (b) High-angle annular dark field (HAADF) scanning transmission electron microscopy (STEM) cross-sections of 55nm-gate-length device based on sample C.

The source/drain regions were created by first forming a dummy gate of patterned 150nm spin-on hydrogen silsesquioxane (HSQ) and then selective re-growth of 60nm of heavily n-type I$In_{0.53}Ga_{0.47}As$ using metal-organic chemical vapor deposition (MOCVD).

Transistor fabrication started with mesa isolation and dummy gate removal using a buffered oxide etch. Digital etch of the gate region removed all of the cap and some or all of the upper cladding. In sample C, the

digital etch continued 1.5nm into the InAs channel.

The processing continued in an atomic layer deposition (ALD) system, where the samples were cleaned and passivated before depositing hafnium dioxide as a gate insulator. The devices were then annealed at 400°C for 15 minutes in forming gas (5% hydrogen, 95% nitrogen). Nickel/gold was used for the gate electrode. The source/drain electrodes were titanium/palladium/gold.

In two 75nm-gate-length devices based on samples A and B, the increased spacer height of 8nm (compared with 3nm) reduced off-state leakage five-fold at a gate potential of –0.3V and drain bias of 0.5V. The peak transconductances (g_m) of devices A and B were roughly the same over the range of gate lengths 60nm to 1µm. The peak gm with a 60nm gate was 2.7mS/µm, which the researchers claim as a record "in any III-V MOSFET technology to date". The increased spacer height of sample B also reduced, and hence improved, the subthreshold swing (SS) by 10–15% over the same gate length range. At 60nm gate length, SS was 125mV/dec.

Although the on-resistance extrapolated to zero gate length was slightly higher in sample B (190Ω-µm, compared with 181Ω-µm for sample A), the discrepancy was within fitting error, according to the researchers.

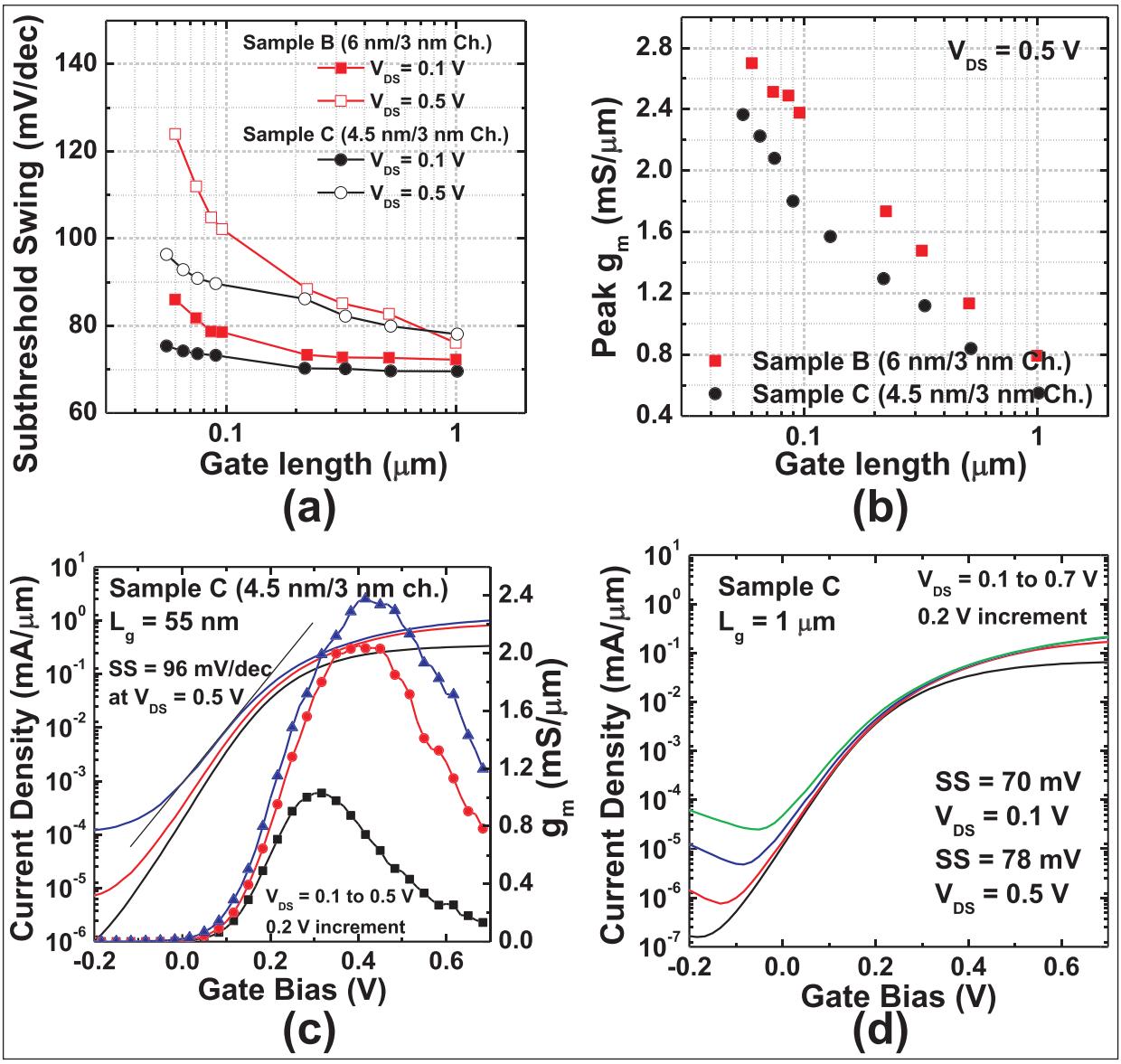


Figure 2. (a) Subthreshold swing versus gate length (L_g), at 100mV and 500mV drain bias (V_{DS}), for samples B and C. (b) Peak transconductance versus L_g, at 500mV V_{DS}, for samples B and C. (c) Drain current versus gate potential and transconductance of sample C at 55nm L_g. (d) Drain current versus gate potential of sample C at 1µm L_g.

The effect of bringing the gate closer to the channel in sample C devices was to reduce peak gm by about 10%, while improving SS (Figure 2). The better SS is attributed to the better electrostatic control of the gate and the larger bandgap arising from the quantum confinement of the channel (~0.50eV compared with ~0.44eV, according to Schrödinger–Poisson modeling). The reduced g_m is possibly due to surface roughness scattering effects.

A 55nm-gate sample C transistor had an SS of 96mV/dec and gm of 2.4mS/µm at 0.5V drain bias. With a 1µA/µm drain current threshold, the voltage was 60mV and the drain-induced barrier lowering (DIBL) was 130mV/V. A 1µm gate length with sample C reduced SS to 70mV/dec. This value gives an estimate for the interface trap density of $5x10^{12}/cm^2$-eV. ■

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Author: Mike Cooke

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E-mail info@plansee.com
www.plansee.com

10 Gas and liquid handling equipment

Air Products and Chemicals Inc
(see section 7 for full contact details)

Cambridge Fluid Systems
12 Trafalgar Way, Bar Hill,
Cambridge CB3 8SQ,
UK
Tel: +44 (0)1954 786800
Fax: +44 (0)1954 786818
www.cambridge-fluid.com

CS CLEAN SYSTEMS AG
Fraunhoferstrasse 4,
Ismaning, 85737,
Germany
Tel: +49 89 96 24 00 0
Fax: +49 89 96 24 00 122
www.cscleansystems.com

Power + Energy Inc
106 Railroad Drive,
Ivyland, PA 18974,
USA
Tel: +1 215 942-4600
Fax: +1 215 942-9300
www.powerandenergy.com

SAES Pure Gas Inc
4175 Santa Fe Road,
San Luis Obispo,
CA 93401,
USA
Tel: +1 805 541 9299
Fax: +1 805 541 9399
www.saesgetters.com

11 Process monitoring and control

k-Space Associates
2182 Bishop Circle
East, Dexter,
MI 48130, USA
Tel: +1 734 426 7977
Fax: +1 734 426 7955
www.k-space.com
k-Space Associates Inc specializes in in-situ, real-time thin-film process monitoring tools for MBE, MOCVD, PVD, and thermal evaporation. Applications and materials include the research and production line monitoring of compound semiconductor-based electronic, optoelectronic, and photovoltaic devices.

KLA-Tencor
One Technology Dr,
1-2221I, Milpitas,
CA 95035,
USA
Tel: +1 408 875 3000
Fax: +1 408 875 4144
www.kla-tencor.com

LayTec AG
Seesener Str. 10–13,
10709 Berlin,
Germany
Tel: +49 30 89 00 55 0
Fax: +49 30 89 00 180
www.laytec.de
LayTec develops and manufactures optical in-situ and in-line metrology systems for thin-film processes

Inc

with particular focus on compound semiconductor and photovoltaic applications. Its know-how is based on optical techniques: reflectometry, emissivity corrected pyrometry, curvature measurements and reflectance anisotropy spectroscopy.

Optical Reference Systems Ltd
OpTIC Technium,
St Asaph Business Park,
St Asaph, LL17 0JD,
UK
Tel: +44 (0)1745 535 188
Fax: +44 (0)1745 535 186
www.ors-ltd.com

WEP
(Ingenieurbüro Wolff für Elektronik- und Programmentwicklungen)
Bregstrasse 90, D-78120
Furtwangen im Schwarzwald,
Germany
Tel: +49 7723 9197 0
Fax: +49 7723 9197 22
www.wepcontrol.com

12 Inspection equipment

Bruker AXS GmbH
Oestliche Rheinbrueckenstrasse 49,
Karlsruhe, 76187,
Germany
Tel: +49 (0)721 595 2888
Fax: +49 (0)721 595 4587
www.bruker-axs.de

13 Characterization equipment

J.A. Woollam Co. Inc.
645 M Street Suite 102,
Lincoln, NE 68508,
USA
Tel: +1 402 477 7501
Fax: +1 402 477 8214
www.jawoollam.com

Lake Shore Cryotronics Inc
575 McCorkle Boulevard,
Westerville, OH 43082,
USA
Tel: +1 614 891 2244
Fax: +1 614 818 1600
www.lakeshore.com

14 Chip test equipment

Keithley Instruments Inc
28775 Aurora Road,
Cleveland, OH 44139,
USA
Tel: +1 440.248.0400
Fax: +1 440.248.6168
www.keithley.com

SUSS MicroTec Test Systems
228 Suss Drive,
Waterbury Center, VT 05677,
USA
Tel: +1 800 685 7877
Fax: +1 802 244 7853
www.suss.com

15 Assembly/packaging materials

ePAK International Inc
4926 Spicewood Springs Road,
Austin, TX 78759,
USA
Tel: +1 512 231 8083
Fax: +1 512 231 8183
www.epak.com

Gel-Pak
31398 Huntwood Avenue,
Hayward, CA 94544,
USA
Tel: +1 510 576 2220
Fax: +1 510 576 2282
www.gelpak.com

Wafer World Inc
(see section 3 for full contact details)

Williams Advanced Materials
2978 Main Street,
Buffalo, NY 14214, USA
Tel: +1 716 837 1000
Fax: +1 716 833 2926
www.williams-adv.com

16 Assembly/packaging equipment

Ismeca Europe Semiconductor SA
Helvetie 283, La Chaux-de-Fonds,
2301, Switzerland
Tel: +41 329257111
Fax: +41 329257115
www.ismeca.com

Kulicke & Soffa Industries
1005 Virginia Drive,
Fort Washington,
PA 19034,
USA
Tel: +1 215 784 6000
Fax: +1 215 784 6001
www.kns.com

Palomar Technologies Inc
2728 Loker Avenue West,
Carlsbad, CA 92010,
USA
Tel: +1 760 931 3600
Fax: +1 760 931 5191
www.PalomarTechnologies.com

TECDIA Inc
2700 Augustine Drive, Suite 110,
Santa Clara, CA 95054,
USA
Tel: +1 408 748 0100
Fax: +1 408 748 0111
www.tecdia.com

17 Assembly/packaging foundry

Quik-Pak
10987 Via Frontera,
San Diego, CA 92127,
USA
Tel: +1 858 674 4676
Fax: +1 8586 74 4681
www.quikicpak.com

18 Chip foundry

Compound Semiconductor Technologies Ltd
Block 7, Kelvin Campus,
West of Scotland,
Glasgow,
Scotland G20 0TH,
UK
Tel: +44 141 579 3000
Fax: +44 141 579 3040
www.compoundsemi.co.uk

United Monolithic Semiconductors
Route departementale 128,
BP46, Orsay, 91401,
France
Tel: +33 1 69 33 04 72
Fax: +33 169 33 02 92
www.ums-gaas.com

19 Facility equipment

MEI, LLC
3474 18th Avenue SE,
Albany, OR 97322-7014,
USA
Tel: +1 541 917 3626
Fax: +1 541 917 3623
www.marlerenterprises.net

20 Facility consumables

PLANSEE High Performance Materials
6600 Reutte, Austria
Tel: +43 5672 600 0
Fax: +43 5672 600 500
E-mail info@plansee.com
www.plansee.com

W.L. Gore & Associates
401 Airport Rd, Elkton,
MD 21921-4236, USA
Tel: +1 410 392 4440
Fax: +1 410 506 8749
www.gore.com

21 Computer hardware & software

Ansoft Corp
4 Station Square, Suite 200,
Pittsburgh, PA 15219, USA
Tel: +1 412 261 3200
Fax: +1 412 471 9427
www.ansoft.com

Crosslight Software Inc
121-3989 Henning Dr.,
Burnaby, BC, V5C 6P8,
Canada
Tel: +1 604 320 1704
Fax: +1 604 320 1734
www.crosslight.com

Semiconductor Technology Research Inc
10404 Patterson Ave., Suite 108,
Richmond, VA 23238, USA
Tel: +1 804 740 8314
Fax: +1 804 740 3814
www.semitech.us

22 Used equipment

Class One Equipment Inc
5302 Snapfinger Woods Drive,
Decatur, GA 30035,
USA
Tel: +1 770 808 8708
Fax: +1 770 808 8308
www.ClassOneEquipment.com

23 Services

Henry Butcher International
Brownlow House, 50–51
High Holborn, London WC1V 6EG,
UK
Tel: +44 (0)20 7405 8411
Fax: +44 (0)20 7405 9772
www.henrybutcher.com

M+W Zander Holding AG
Lotterbergstrasse 30,
Stuttgart,
Germany
Tel: +49 711 8804 1141
Fax: +49 711 8804 1950
www.mw-zander.com

24 Consulting

Fishbone Consulting SARL
8 Rue de la Grange aux Moines,
78460 Choisel,
France
Tel: + 33 (0)1 30 47 29 03
E-mail: jean-luc.ledys@neuf.fr

25 Resources

SEMI Global Headquarters
3081 Zanker Road,
San Jose, CA 95134, USA
Tel: +1 408 943 6900
Fax: +1 408 428 9600
www.semi.org

Yole Développement
45 rue Sainte Geneviève,
69006 Lyon, France
Tel: +33 472 83 01 86
www.yole.fr

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event calendar

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20–22 January 2014
14th Topical Meeting on Silicon Monolithic Integrated Circuits in RF Systems (SiRF 2014)
Newport Beach, CA, USA
www.silicon-rf.org/sirf2014

22–24 January 2014
TMCS IV: Theory Modelling and Computational Methods for Semiconductors
Salford, UK
E-mail: info@tmcsuk.org
www.tmcsuk.org/conferences/TMCSIV

28–30 January 2014
6th International Symposium on Optronics in Defence and Security (OPTRO 2014)
OECD Conference Center, Paris, France
E-mail: optro2014@aaaf.asso.fr
www.optro2014.com

1–6 February 2014
SPIE Photonics West 2014
Moscone Center San Francisco, CA, USA
E-mail: customerservice@spie.org
http://spie.org/photonics-west.xml

1–6 February 2014
OPTO 2014 – Optoelectronic Materials, Devices and Applications (part of Photonics West)
Moscone Center, San Francisco, CA, USA
E-mail: customerservice@spie.org
http://spie.org/opto.xml

10–11 February 2014
SolarTech Germany 2014
Berlin, Germany
E-mail: pl@greenworldconferences.com
www.greenworldconferences.com

12–14 February 2014
LED Korea
Convention and Exhibition Center (COEX), Seoul, Korea
E-mail: semiconkorea@semi.org
www.led-korea.org

23–26 February 2014
LED CHINA 2014
China Import and Export Fair Pazhou Complex, Guangzhou, China
E-mail: led-trust@ubm.com
www.LEDChina-gz.com

23–27 February 2014
SPIE Advanced Lithography 2014
San Jose Convention Center and Marriott Hotel, CA, USA
E-mail: customerservice@spie.org
http://spie.org/advanced-lithography.xml

25–27 February 2014
15th Strategies in Light Conference
Santa Clara Convention Center, CA, USA
E-mail: registration@pennwell.com
www.strategiesinlight.com

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2–6 March 2014
International Symposium on Advanced Plasma Science (ISPlasma 2014)
Meijo University, Nagoya, Japan
E-mail: isplasma@intergroup.co.jp
www.isplasma.jp

9–13 March 2014
Optical Fiber Communication Conference and Exposition / National Fiber Optic Engineers Conference (OFC / NFOEC 2014)
Moscone Convention Center, San Francisco, CA, USA
E-mail: info@ofcconference.org
www.ofcnfoec.org

16–20 March 2014
29th annual IEEE Applied Power Electronics Conference and Exposition (APEC 2014)
Fort Worth Convention Center, TX, USA
E-mail: apec@apec-conf.org
www.apec-conf.org

18–20 March 2014
SEMICON China
Shanghai New International Exhibition Centre, China
E-mail: semichina@semi.org
www.semiconchina.org

18–20 March 2014
Laser World of Photonics China
Shanghai New International Exhibition Centre, China
E-mail: laser@mmi-shanghai.com
www.photonicschina.net

18–20 March 2014
Laser Optics – International Trade Fair and Congress for Optical Technologies and Microsystems
Berlin ExpoCenter City, Berlin, Germany
E-mail: kubeerkens@messe-berlin.de
www.laser-optics-Berlin.de

18–20 March 2014
Image Sensors (IS2014)
Park Plaza Victoria, London, UK
E-mail: rstead@smithers.com
http://image-sensors.com

20–22 March 2014
LED Taiwan 2014, co-located with Taiwan International Lighting Show 2014
TWTC Nangang Exhibition Hall, Taipei, Taiwan
E-mail: jsu@semi.org
www.ledtaiwan.org

25–27 March 2014
IPC APEX EXPO 2014
Las Vegas, NV, USA
E-mail: registration@ipc.org
www.IPCAPEXEXPO.org

25–27 March 2014
Intersolar China 2013
China National Agricultural Exhibition Center (CNAEC), Beijing, China
E-mail: pang@intersolarchina.com
www.intersolarchina.com

31 March – 3 April 2014
GOMAC Tech 2014 (39th annual Government Microcircuit Applications & Critical Technology Conference)
Embassy Suites Hotel, North Charleston, SC, USA
E-mail: mgoldfarb@pcm411.com
www.gomactech.net

14–17 April 2014
SPIE Photonics Europe 2014
SQUARE Brussels Meeting Centre, Belgium
E-mail: customerservice@spie.org
http://spie.org/photonics-europe.xml

23–25 April 2014
SEMICON Singapore
Marina Bay Sands Expo & Convention Center, Singapore
E-mail: semiconsingapore@semi.org
www.semiconsingapore.org

5–9 May 2014
SPIE DSS 2014, incorporating: SPIE Security + Defence 2014 SPIE Sensing Technology + Applications 2014
Baltimore Convention Center, MD, USA
E-mail: customerservice@spie.org
http://spie.org/defense-security-sensing.xml

11–15 May 2014
Compound Semiconductor Week 2014, inc: 41st International Symposium on Compound Semiconductors (ISCS 2014) 26th International Conference on Indium Phosphide and Related Materials (IPRM 2014)
Montpellier, France
E-mail: csw2014@csw2014.org
www.csw2014.org

11–16 May 2014
225th Electrochemical Society (ECS) Meeting
Orlando, FL, USA
E-mail: meetings@electrochem.org
www.electrochem.org/meetings/biannual/fut_mtgs.htm

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