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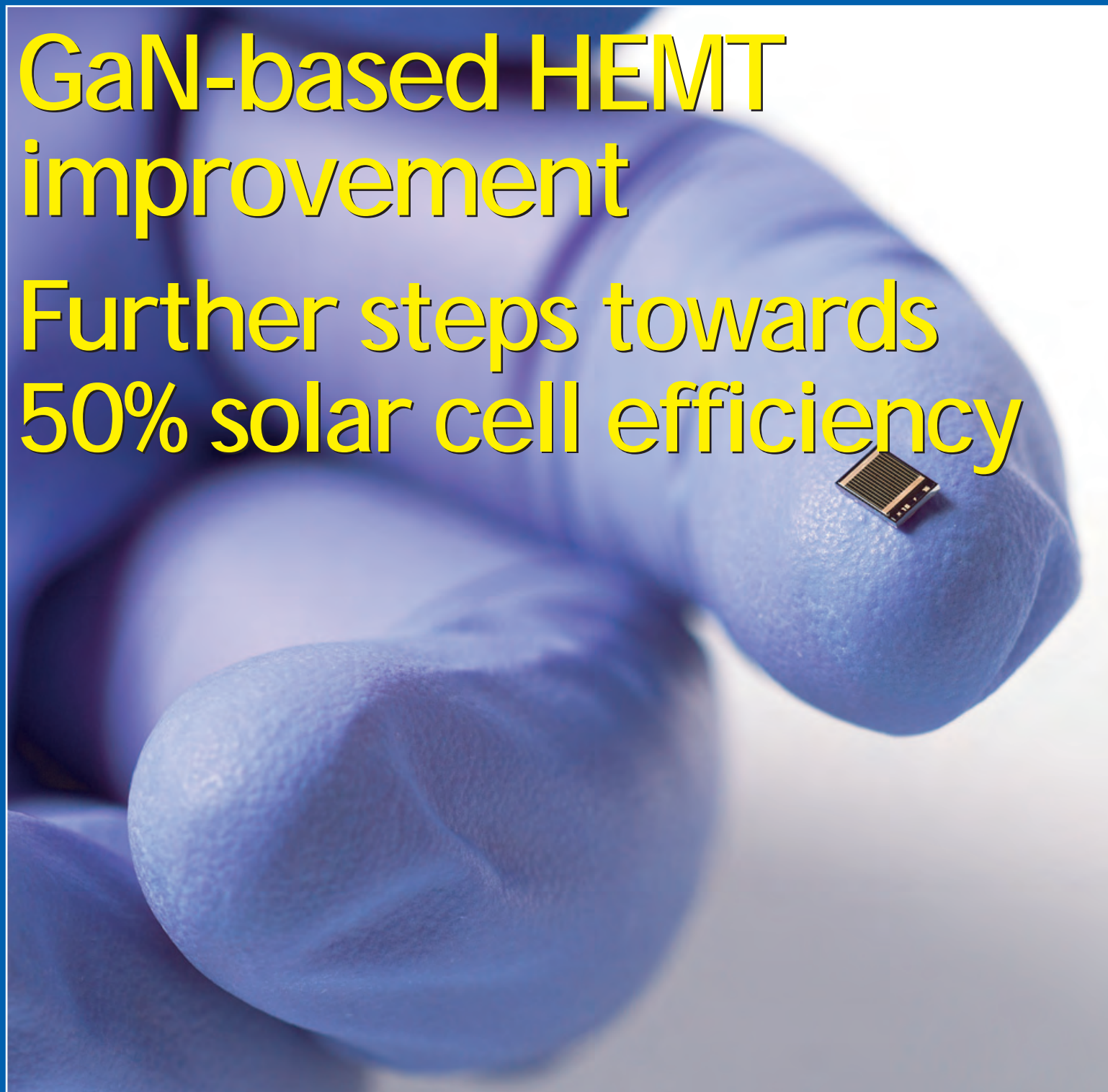
C O M P O U N D S & A D V A N C E D S I L I C O N

Vol. 8 • Issue 7 • September 2013

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GaN-based HEMT improvement

Further steps towards 50% solar cell efficiency



RFMD launches 6" GaN-on-SiC; expands China assembly
Oclaro sells Zurich business to II-VI • News from ECOC 2013

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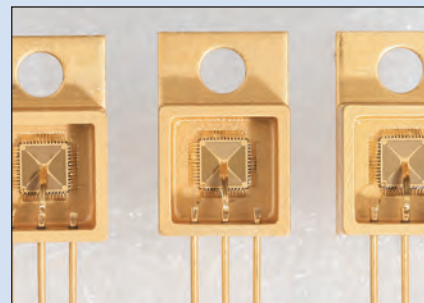
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COMPOUNDS & ADVANCED SILICON

Vol. 8 • Issue 7 • September 2013



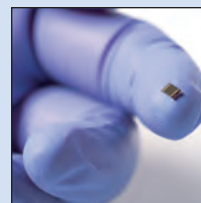
p18 Germany's Fraunhofer IAF and FBH have developed GaN voltage converters with an efficiency of 98%.



p40 The new variant of Osram Opto's Ostar Headlamp Pro LED, used in an intelligent headlight system.



p61 Viacheslav M. Andreev (left) and Zhores I. Alferov (right) after receiving the 2013 Karl Böer Solar Energy Medal of Merit, together with Klaus Thiessen.



Cover: After three years of research, Fraunhofer ISE, Soitec, CEA-Leti and Helmholtz Center have achieved a record 44.7% solar cell efficiency by using a four-junction cell structure. Efficiency has been increased from 43.6% in less than 4 months.

p58

III-Vs remaining at core of technical advances

The feature article on pages 66–69 of this issue focuses on the rapid (albeit small) step-by-step increments in the record for photovoltaic cell solar energy conversion efficiency. Typifying the progression in the technology, just before this issue went to press, a German–French team involving Fraunhofer ISE, SOITEC, CEA-Leti and Helmholtz Zentrum Berlin reported a new record of 44.7%, an increase from the 43.6% they reported just in May, and leapfrogging the 44.4% figure achieved by Sharp in June and the 44.1% production-ready cell reported by Solar Junction in August (see page 58). The latest achievement is another step towards the goal of 50% efficiency at the cell level, as set out by the EU–Japan project ‘New Generation PV’ (which involves both Fraunhofer and Sharp).

Also this issue, on page 45, we report the sale by optical component manufacturer Oclaro of its Oclaro Switzerland subsidiary and associated laser diodes business to II-VI Inc. As well as the GaAs-based high-power laser diode, VCSEL and 980nm pump laser wafer fabrication plant in Zurich (originating from the acquisitions of Nortel Networks in 2002 and Avalon Photonics in 2006), the business also includes a related R&D facility in Tucson (stemming from Oclaro’s acquisition of the high-power laser diode business of Newport Spectra Physics in 2009. That followed the merger between Bookham and Avanex to form Oclaro in 2009. Most recently, Oclaro acquired rival optical component maker Opnext last year.

Oclaro’s sale of its GaAs-based laser business was necessitated by the firm’s continuing losses, dwindling cash reserves and consequent bank loan. As CEO Greg Dougherty notes in reporting the firm’s June-quarter results (see pages 44–45), “We have built a company that is far too complex for its size. We have not effectively integrated our acquisitions and not realized the corresponding synergies such as using more of our own components within our modules and subsystems”. In addition, he adds “We have not completed our various outsourced manufacturing transition on schedule... Our R&D investments have been spread too thinly over too many technologies and products”. Dougherty reckons the key for Oclaro to be successful is to “simplify our company in terms of geography and organizational structure” (beyond the latest reduction in sites by four).

The proceeds of the sale will allow Oclaro to begin restructuring, reducing its global footprint and streamlining its organization, as well as focusing primarily on optical communications components, such as InP-based tunable lasers etc.

So, despite the firm having expanded from Bookham (founded in the UK in 1988) to the USA (via acquisition of Cierra Photonics and New Focus in 2003, then Onetta in 2004, followed by shifting headquarters to San Jose), it seems that its focus is returning to the technology that originated from Bookham’s acquisition in 2002 of Marconi’s optical components subsidiary in Caswell, UK. Founded as Plessey’s research site in the 1940s before becoming part of GEC then GEC Marconi in the late 1980s/early 1990s, it is reassuring that the company has retained some of its core III-Vs heritage.

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Semiconductor Today covers the R&D and manufacturing of compound semiconductor and advanced silicon materials and devices

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- conference reports;
- event calendar and event previews;
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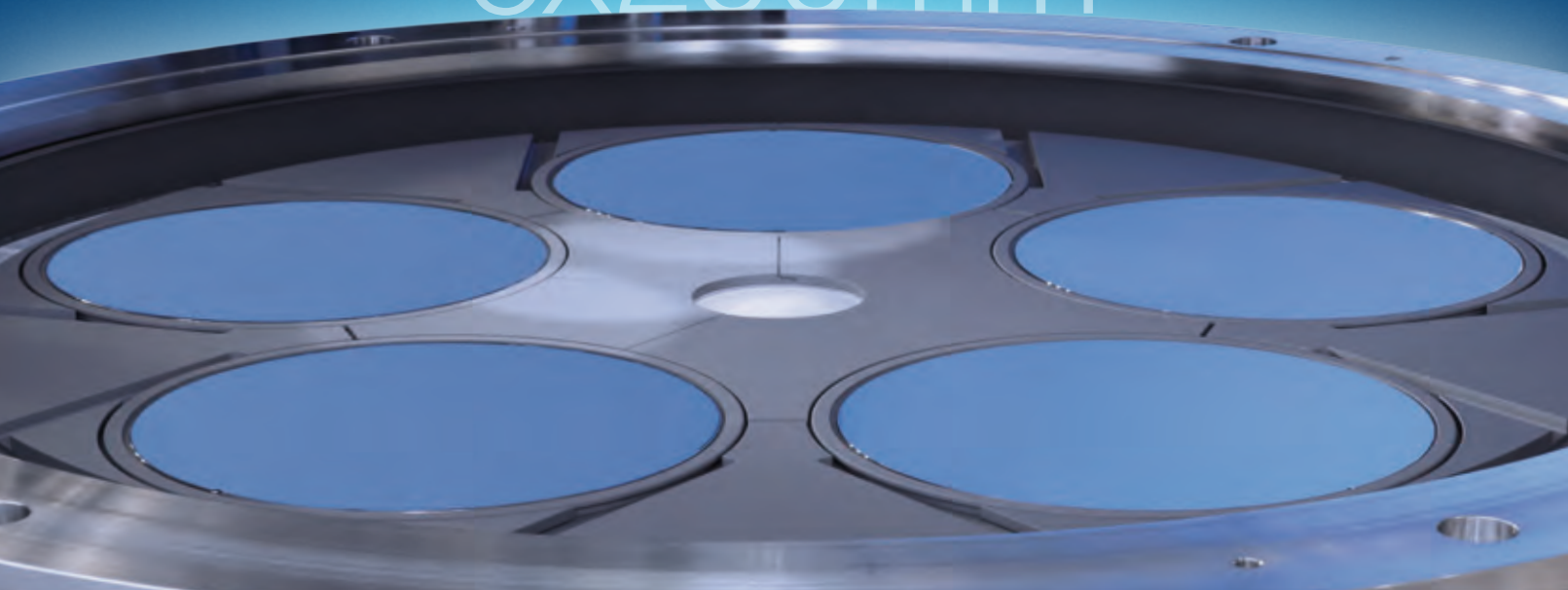
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SiC & GaN key to market for solar inverter discrete devices

Devices with wide-bandgap semiconductors will offer the greater competitive advantage in micro-inverters and small string inverters, reckons market analyst firm Lux Research.

Wide-bandgap semiconductors — specifically, silicon carbide (SiC) and gallium nitride (GaN) — will lead the charge as the market for solar inverter discrete devices, driven by the downstream demand for solar modules, grows to \$1.4bn in 2020, forecasts Lux Research. This reflects a solid compound annual growth rate (CAGR) of 7%, which is slightly lower than the 9% for all renewables and grid-based power electronics.

As devices featuring GaN and SiC hit the market, they will offer the biggest competitive advantage in small systems — micro-inverters and small string inverters, for residential and commercial solar installations — with a powerful proposition: lowering levelized cost of electricity (LCOE), and increasing margins on electricity sold through leases and power purchase agreements (PPAs), says Lux Research. They will also deliver improved performance and reliability, it adds.

“The holy grail for solar inverters is the implementation of wide-bandgap semiconductors — specifically, silicon carbide and gallium nitride,” says analyst Pallavi Madakasira, one of the lead authors of the report ‘Reaching for the High Fruit: Finding Room for SiC and GaN in the Solar Inverter Market’. “The performance benefits from both are such that inverter suppliers could charge a premium price and still achieve a significantly lower LCOE,” she added.

To understand the performance benefits of switching to GaN and SiC, Lux Research analysts modeled the three major types of inverters — microinverters, string inverters and central inverters — with Si, SiC and GaN components, and found that:

- *Higher efficiencies in smaller inverters.* Power electronics with discrete devices made from GaN and SiC (rather than incumbent silicon) can increase efficiencies for solar micro- and string inverters to over 98%. The diodes increase harvested energy by more than 1.5% while the transistors can increase it by more than 4%. GaN-on-silicon offers the lowest-cost solution while

GaN-on-SiC and SiC-on-SiC offer far superior efficiency.

- *Micro-inverters will command the highest premiums.* SiC and GaN have the greatest price premium power (>\$0.10/Wp) in micro-inverters, without increasing LCOE. Though a niche solution, the micro-inverter segment is also an attractive segment for SiC and GaN to see early adoption and ramp up volumes.

- *Indirect benefits add to the value proposition.* GaN and SiC also result in indirect cost savings in the form of a reduced failure rate of passive components, footprint reduction, and savings in installation cost. Also, their superior thermal conductivity reduces the size of the heat-sink in inverters.

- *Industry consolidation is near.* After an industry shakeout, companies like SMA and Power-One (which took an early lead in SiC technology) are well positioned, with negligible debt. Consequently, start-ups like Enecsys and mPower-Solar are under pressure to either implement SiC or GaN (and absorb the extra cost) or lose their foothold in the market, reckons Lux Research.

www.luxresearchinc.com

GaN to push microwave RF power semiconductor market to \$250m by 2018

Spending on microwave RF power semiconductors has been kick-started by the availability of new gallium nitride (GaN) devices for 4–18GHz, says market intelligence firm ABI Research in its new report ‘Microwave RF Power Semiconductors’ (part of the firm’s High-Power RF Active Devices Research Service). Point-to-point communications, SATCOM, radars of all types and new industrial/medical applications will all benefit from the introduction of these high-power GaN devices, the firm adds.

“While GaAs devices are presently the backbone of microwave RF power, it is GaN that will drive growth going forward,” says research director Lance Wilson. “GaN can operate at much higher voltages and at power levels that were difficult or impossible to reach using GaAs.”

As well as the above-mentioned application segments, microwave GaN is finally reaching the performance points that can start to seriously challenge travelling-wave tube applications for new designs that have historically used the latter, notes ABI.

The report examines microwave RF power semiconductor devices that have power outputs of greater than 3W and operate at frequencies of 4–18GHz. The new report is part of ABI Research’s ongoing effort to track the major changes in the RF power industry. With the current release, analysis of the six main vertical segments (C-band GaAs, C-band GaN, X-band GaAs, X-band GaN, Ku-band GaAs, and Ku-band GaN) is further expanded to 28 application sub-segments.

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Anadigics launches ProVantage power amplifier family

Broadband wireless and wireline communications component maker Anadigics Inc of Warren, NJ, USA has introduced the ProVantage power amplifier (PA) product family.

Based on the firm's InGaP-Plus technology, ProVantage solutions extend battery life and ensure high data throughput in LTE, WCDMA/HSPA, CDMA/EVDO, and TD-SCDMA mobile devices, says the firm.

The new PAs help to extend battery life by offering three selectable bias modes that optimize efficiency for low, medium and high output power levels, as well as a shutdown mode with low leakage current. ProVantage solutions are also designed for use with an external switch mode power supply (SMPS), such as average power tracking (APT), to further increase efficiency and reduce current consumption at

low and medium operating powers.

The AWT5001 offers efficiency of 48% at +28.2dBm (WCDMA) for Band 1 (1920–1980MHz); the AWT5002 offers 48% @ +28.6dBm (WCDMA) for Band 2 (1850–1915MHz); the AWT5004 offers 48% @ +28.5dBm (WCDMA) for Band 4 (1710–1755MHz); the AWT5005 offers 48% @ +28.6dBm (WCDMA) for Band 5 (824–849MHz); the AWT5008 offers 47% @ +28.5dBm (WCDMA) for Band 8 (880–915MHz); and the ALT5020 offers 42% @ +27.7dBm (LTE) for Band 20 (832–862MHz).

The complete family of ProVantage solutions is offered in compact 3mm x 3mm x

ProVantage complements its ProEfficient and ProEfficient-Plus solutions

0.9mm packages and feature internal voltage regulation and integrated DC blocks on the RF ports to reduce PCB space requirements.

"We recognize the tremendous diversity in mobile device requirements, ranging from voice-centric feature phones to power-hungry smartphones and tablets," says Navi Miglani, product marketing director of Cellular Products. "Our new ProVantage power amplifiers are optimized to deliver outstanding value by providing a best-in-class combination of high power mode efficiency, linearity, and reduced system costs," he adds. The addition to the firm's cellular products portfolio complements its ProEfficient and ProEfficient-Plus solutions and enables Anadigics to target a wider range of market segments.

www.anadigics.com

TriQuint's WLAN modules and 4G/Wi-Fi coexistence filters used in Broadcom's 5G Wi-Fi reference designs

RF front-end component maker and foundry services provider TriQuint Semiconductor Inc of Hillsboro, OR, USA says that its TriConnect 5GHz WLAN front-end modules and premium LTE/Wi-Fi coexistence filters are being used in the 5G Wi-Fi reference designs of Broadcom Corp. 5G Wi-Fi (IEEE 802.11ac) technology delivers faster throughput, longer operating range and extended battery life for smartphones, tablets and other consumer devices.

By creating more reliable whole-home coverage, Broadcom's 5G Wi-Fi technology aims to tackle the digital content and wireless device challenge. The firm's family of 5G Wi-Fi solutions improves wireless range in the home, allowing consumers to watch HD-quality video from more devices, in more places, simultaneously. The increased speed enables consumers to download web content from a mobile

device faster and quickly synch large files, such as videos, in a fraction of the time, it is claimed.

Broadcom's 5G Wi-Fi reference designs are widely used by engineers developing next-generation consumer devices. The firm's highly integrated combo chips offer a complete dual-band 5G Wi-Fi system with Bluetooth, FM radio and software on a single, compact silicon die. TriQuint says that its ultra-small RF components deliver the demanding RF performance required to fully realize the speed, range and power saving benefits of 802.11ac (the latest evolution of Wi-Fi).

Analysts expect over 100 million 802.11ac-enabled devices to ship by the end of 2013, rising at a compound annual growth rate (CAGR) of 430% to nearly half of all Wi-Fi chipset shipments for the consumer electronics market by 2017. TriQuint says that its

TriConnect WLAN products have already captured multiple design wins with leading smartphone makers: its TQP887051 5GHz WLAN front-end module has been approved for Broadcom reference design BCM4335, while its LTE/Wi-Fi coexistence filter is included on reference designs BCM4335 and BCM4339.

TriQuint introduced the industry's first 802.11ac-ready module for mobile devices last year. "Since then, we have leveraged TriQuint's advanced in-house technology portfolio, the industry's largest, to develop our next-generation Wi-Fi products," says Tim Dunn, the firm's VP of Mobile Devices. "Our 802.11ac technology expertise also expands our future market opportunity for consumer electronics applications such as in-home video distribution."

www.broadcom.com

www.triquint.com

RFMD expands assembly capacity in China to accommodate product demand

Internal assembly boosted; will include advanced flip-chip capabilities

RF Micro Devices Inc of Greensboro, NC, USA says that it has completed a recently announced expansion of its test, tape & reel and assembly facility in Beijing, China. In addition to newly qualified internal assembly capacity for power amplifiers (PAs), switch-based products and antenna control solutions, RFMD is also qualifying advanced flip-chip capabilities for its 2G, 3G and 4G LTE and TD-LTE products.

RFMD expects that the expansion will enable it to quickly accelerate internal assembly to accommodate

broad customer demand for its expanding portfolio of RF solutions. The capacity expansion efforts and resulting increase in internal assembly are expected to contribute to the firm's stated goal of expanding non-GAAP gross margin by 300–400 basis points by the March 2014 quarter, compared to non-GAAP gross margin of 34.4% achieved in the March 2013 quarter.

On 26 August, RFMD announced it was on track to achieve another major gross margin expansion initiative - the ramp of its new low-cost

CMOS power amplifier (PA) for entry-market 2G handsets.

RFMD says that its RF solutions are broadly adopted across multiple growth markets and applications, including smartphones, handsets, tablets, notebooks, Wi-Fi, CATV, and high-reliability applications. According to Cisco, the 'Internet of Things' is expected to grow at a compound annual growth rate (CAGR) of 25% during 2012–2020, reaching about 50 billion connected devices by 2020.

www.rfmd.com

Skyworks' low-noise amplifier FEMs used to ramp GPS/GNSS solutions in emerging markets

Analog semiconductor maker Skyworks Solutions Inc of Woburn, MA, USA says that its highly integrated, low-noise amplifier front-end modules are being used by various OEMs to enable global positioning systems (GPS) and global navigation satellite systems (GNSS) in smartphones, tablets and other mobile devices in emerging markets.

The devices are the first semiconductors to support China's BeiDou navigation satellite system (BDS), the country's second-generation system that is enabling GPS in consumer platforms in addition to other public safety applications such as transportation systems, water conservancy, forest-fire prevention and disaster relief.

Skyworks is the first semiconductor firm with solutions that are supporting widespread GPS capability in smartphones and other handheld devices throughout China and across Asia, claims David Stasey, VP & general manager of analog solutions. "Given our early investments addressing China's BeiDou system, our unique capabilities and leadership position in GPS and location-based technologies, we are

well positioned to capitalize on the growing demand for these devices in emerging, high-growth markets."

GNSS is a series of satellites that provide autonomous geo-spatial positioning with global coverage. It allows small electronic receivers to determine their location (longitude, latitude and altitude) to within a few meters using time signals transmitted along a line-of-sight by radio from satellites. Receivers then calculate the precise time as well as position, which can be used as a reference.

According to Frost & Sullivan, there will be an increasing prominence of Position, Navigation and Timing (PNT) data derived from GNSS and associated Value Added Services (VAS) in the next 10-20 years. In their Market Insight report 'Global Navigation Satellite System Market Assessment – In Pursuit of New Business Opportunities' they predict that Asia-Pacific will continue to represent the fastest growing region through 2021, with the market more than doubling in 10 years from \$29bn to over \$74bn by 2021. In their GNSS Market Report, the Global Semicon-

ductor Association forecasted that global shipments will exceed 1 billion units before 2020, driven by growth in emerging economies.

The SKY65709-81 is a front-end module (FEM) with an integrated low noise amplifier and pre-filter designed for the BDS, GPS, GNSS and Galileo receiver applications. Fabricated using advanced silicon technology, the device features high linearity, excellent 14.5dB gain, a high 1dB input compression point and a superior 2dB noise figure. With minimal external components, the embedded pre-filter provides low in-band insertion loss and excellent rejection of the cellular, personal communication system and wireless local-area network frequency bands. It also uses surface-mount technology in the form of a small-form-factor, 6-pin, 1.7mm x 2.3mm multi-chip module (MCM) package, allowing for a highly manufacturable and low-cost solution. In addition, the SKY65709-81 is pin-to-pin compatible with Skyworks' non-BDS, GPS FEMs including the SKY65708-11, SKY65708-51 and SKY65709-51.

www.skyworksinc.com

IN BRIEF

Inphi appoints tech investment expert Brathwaite to board

Inphi Corp of Santa Clara, CA, USA, a provider of high-speed mixed-signal ICs for the communications and computing markets, says that Nicholas Brathwaite has joined its board of directors.

"We are excited about his in-depth knowledge and wealth of expertise in driving innovation for high-tech, global companies," comments president & CEO Ford Tamer.

Brathwaite is a founding partner of Riverwood Capital, a growth equity, middle-market technology investment firm with investments in Asia, Latin America and the USA. Brathwaite has been involved with semiconductor companies, hardware development and electronic services (including manufacturing) since 1986.

Brathwaite served as CEO of Aptina Imaging Corp for about two years and is currently its chairman. Previously, he joined Flextronics International Ltd in 1995 as its VP of technology and then from 2000 to 2007 served as its chief technology officer. Flextronics acquired nChip, where he then held the position of VP & general manager of operations from 1992 to 1996. Brathwaite also spent six years with Intel Corp in various engineering management positions in technology development and manufacturing.

Brathwaite has served as a director of Power Integrations since January 2000 and as a member of the board of Lighting Science Group since April 2011. He also served as a member of the board of directors of Tessera Technologies Inc from February 2008 until May 2011 and Photon Dynamics Inc prior to its acquisition in 2008.

www.inphi.com

Imec, KULeuven and AIST report process paving way to increased mobility of beyond-10nm MOS Tensile-strained GeSn MOSFET devices on silicon developed using solid-phase epitaxy

KULeuven (Katholieke Universiteit Leuven), nanoelectronics research center Imec of Leuven, Belgium and the National Institute of Advanced Industrial Science and Technology (AIST) of Tsukuba, Japan have developed a solid-phase epitaxy process to integrate germanium-tin (GeSn) metal-oxide semiconductor field-effect transistor (MOSFET) devices on silicon.

For the first time, it is claimed, operation of a depletion-mode junctionless GeSn pMOSFET on silicon was demonstrated (a key step toward achieving tensile strain in MOSFET devices, and increasing their mobility).

To improve performance in next-generation scaled complementary metal-oxide semiconductor (CMOS) devices, researchers are exploring the integration of novel materials with superior electron mobility. This includes GeSn, a promising semiconductor candidate for the channel material, due to its superior physical properties. GeSn enables increased switching speed of MOSFET devices and can be used in fast optical communication. While most prototype GeSn-channel MOSFETs are fabricated on Ge substrates, silicon integration is preferred for CMOS compatibility.

However, epitaxial growth of GeSn on silicon substrates poses several challenges, including limited solubility of Sn in Ge (0.5%), its compositional fluctuations, Sn segregation,

and large lattice mismatch (>4%). It is hence critical to suppress these effects to obtain high-performance devices with GeSn layers.

Researchers at KULeuven, imec and AIST developed a solid-phase epitaxy process, achieving ultra-thin (~10nm) single-crystalline GeSn layers on silicon substrates showing tensile strain, which is attractive for strain engineering of Ge channels. Furthermore, it reduces the difference between the direct and indirect band transition, resulting in a direct-bandgap group IV material. Lastly, due to its non-equilibrium deposition conditions, the new method enables the development of GeSn with high Sn concentrations.

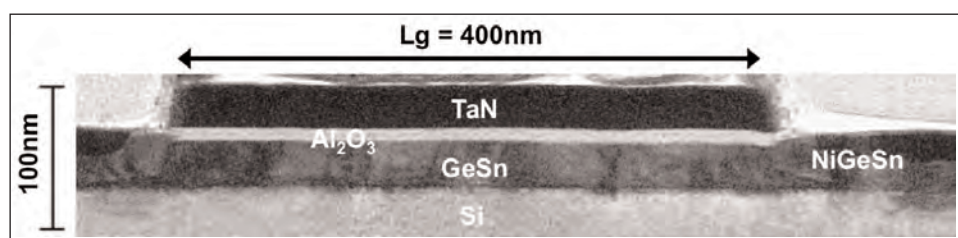
By decreasing the channel thickness with reactive ion etching (RIE) from ~30 to ~10nm, the researchers improved the on/off ratio by more than one order of magnitude. Additionally, hole depletion in the ultra-thin (~10nm) GeSn layers on silicon resulted in good transfer characteristics with an on/off ratio of 84. In the future, research will focus on optimizing the GeSn MOSFET on silicon devices to further increase the channel mobility.

More details on these results were presented on 25 September at the 45th International Conference on Solid State Devices and Materials (SSDM 2013) in Fukuoka, Japan.

www.imec.be

www.aist.go.jp

www.kuleuven.be/english



TEM image of NiGeSn metal S/D MOSFET, observed along [11-2]: the channel direction is [-110] and the surface orientation is (111).

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Pasternack launches SiGe-based 60GHz waveguide modules and development system

RF and microwave product maker Pasternack Enterprises Inc of Irvine, CA, USA has launched 60GHz waveguide transmitter/receiver modules and a development system. The 60GHz frequency range is desirable to engineers and developers wanting to experiment with transmitting high-bandwidth data at extremely high speeds, notes the firm. Existing solutions currently available are expensive and difficult to integrate into systems, it adds. Due its silicon-germanium (SiGe) construction, Pasternack's solution is equally effective at a fraction of the cost, the firm claims, making it practical for a wide range of configurations and budgets.

The 60GHz development system and Tx/Rx modules enable experimentation and development in the

globally unlicensed 60GHz ISM (industrial, scientific & medical) frequency band. Common applications include point-to-point links, GigE wireless LAN (local-area networks), radiometry, uncompressed HD video, FMCW (frequency-modulated continuous-wave) radar, scintillometry, remote sensing, campus networks, and multi-gigabit wireless communications.

To facilitate rapid evaluation of its 60GHz waveguide modules, Pasternack has partnered with Vubiq, an industry expert in designing 60GHz RF systems, to create a development system that makes it easy to design new products and applications in the emerging millimeter-wave ISM band. This system makes it easy to effectively operate the Pasternack's modules with a user-friendly USB/PC

interface to test I/Q (vector), FSK and ASK modulation for 802.11ad or 802.11aj or other proprietary applications, the firm says.

The development system includes 60GHz transmitter/receiver waveguide modules with WR15/WG25 flange interfaces, transmitter/receiver PCBs, board/waveguide mounting brackets, two bench top tripods, GUI software, MCX connector expansion boards, and phased matched MCX to SMA coaxial cables. To enable more effective experimentation and system development, Pasternack also offers compatible low- and high-gain horn antennas to support variable range testing. The 60GHz Tx/Rx modules are sold individually, but are designed to work as a pair for optimum performance.

www.vubiq.com

www.pasternack.com

TowerJazz subsidiary awarded Trusted Foundry status

Jazz Semiconductor Inc (a US subsidiary of Tower Semiconductor Ltd of Migdal Haemek, Israel) says that its subsidiary Jazz Semiconductor Trusted Foundry (JSTF) has been accredited trusted status. JSTF has been accredited as a Category 1A Trusted Supplier by the US Department of Defense (DoD) as a provider of trusted semiconductors in critical defense applications. The Trusted Foundry Program was established to ensure the integrity of the people and processes used to deliver national security critical microelectronic components, and is administered by the DoD's Defense Microelectronics Activity (DMEA).

The creation and accreditation of JSTF will help to broaden existing business relationships previously disclosed with major defense contractors such as Raytheon, Northrop Grumman, BAE Systems, DRS, Alcatel-Lucent, and L-3 Communications.

"TowerJazz has an intrinsic culture of community service at all of our sites, ranging from a focus on male/female employment and management ratio equality to minority population integration into the work force, and educational and vocational development of populations that otherwise have limited exposure to opportunities," says TowerJazz's CEO Russell Ellwanger. "In the United States there was no 'pure play' trusted foundry capability available. Our aerospace and defense customers asked that we would go this route to enable them greater freedom to serve their great country's needs; a country that stands as a banner for democratic process throughout the world," adds Ellwanger.

"Primarily for this purpose, we went beyond our initial commitment to the US State Department to continue support of our ITAR customers and engaged in rounds of discussion with the US

Department of Defense toward participation in the Trusted program in our Newport Beach facility. And, as in all activities where one serves purposes of great principle, it is also good business."

By achieving Trusted status, TowerJazz continues to demonstrate its ongoing commitment to its aerospace and defense customers as well as with capacity expansion and new technologies at its US facility in areas such as high-speed SiGe, Readout Integrated Circuits (ROICs), imaging, and MEMS.

"Specific recent activities to further support our customers include a long-term lease extension and implementation of new technology focused on the aerospace and defense market, including CMOS image sensors and ROICs for IR sensors," states Mike Scott, director – TowerJazz Aerospace and Defense business unit.

www.towerjazz.com

AWSC selects Mentor for GaAs wireless IC verification

Mentor Graphics Corp of Wilsonville, OR, USA says that Advanced Wireless Semiconductor Company (AWSC) has selected its Calibre nmDRC and nmLVS products as their golden signoff physical verification solution for gallium arsenide ICs for mobile and other wireless applications. AWSC is a pure foundry service located in Hsin-shi, Taiwan, which specializes in fabricating monolithic microwave integrated circuits (MMIC) with GaAs HBT, pHEMT/IPD and GaAs/Ge CPV processes.

As part of their foundry offering, AWSC will provide the Calibre design rule decks to its customers to help ensure that their designs are error free and meet all foundry requirements before submitting them to AWSC manufacturing.

"We moved to Calibre for our new offerings to take advantage of its highly efficient commands and unique capabilities not available in other products, such as equation-based DRC, which makes it easier to implement complex design rules for RF applications," said Louis Lu, manager of product development engineering at AWSC. "Calibre is widely used by our fastest growing customers, and it works seamlessly in any of the design flows our customers use, including the Agilent ADS custom RF design platform. Also very important in our decision is the high level of product support and application knowledge we receive from Mentor."


"We're pleased to see the adoption of Calibre for state-of-the-art RF ICs such as those fabricated by AWSC," says Shu-Wen Chang, director of Calibre Foundry Programs at Mentor. "AWSC's adoption of Calibre for advanced GaAs ICs for RF applications is part of a growing world-wide trend to use the most advanced Calibre technologies for larger feature size applications. Our mutual customers are pushing much more complex designs through processes initially developed for simpler geometric data, particularly in mobile applications (e.g. smart phones,

tablets.) where AMS/RF processes are increasingly important."

An example of advanced features being used by AWSC is the Calibre nmDRC product's equation-based DRC (eqDRC) facility, which fills the void between traditional DRC and DFM process simulators, says the firm. Some design rules are simply too complex to capture with traditional DRC measurements and rule tables. Equation-based DRC allows these rules to be expressed as

complex multi-variable equations, enabling precise and accurate characterizations of complex 2D and 3D interactions that have a direct impact on manufacturability. Equation-based DRC brings user extensibility and fast runtimes to a whole host of new design and process interactions. It also provides precise numerical feedback allowing users to make reliable design tradeoffs, and to quickly determine the best fix.

www.mentor.com



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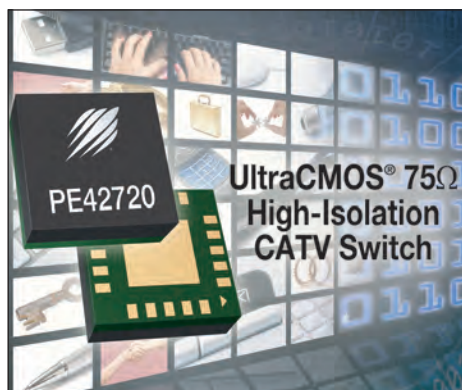
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Peregrine launches 75Ω RF switch for broadband cable

Peregrine Semiconductor Corp of San Diego, CA, USA, a fabless provider of radio-frequency integrated circuits (RFICs) based on silicon-on-sapphire (SOS), says its PE42720 75Ω RF switch is now available for broadband cable systems. Manufactured on Peregrine's UltraCMOS technology, the HaRP-enhanced single-pole, double-throw (SPDT) switch features high linearity, leading isolation performance and excellent video feedthrough, it is claimed, a combination that supports higher data rates in cable modem termination systems (CMTS), multi-service head-ends, cable television (CATV) optical transceivers, fiber hubs, optical network terminals and CATV amplifier modules.

Optimized for high linearity and isolation performance, the PE42720 supports increasing data rates as required by the industry transition to DOCSIS 3.1. High linearity minimizes distortion in the cable network to support new modulation schemes such as 4096-QAM, while the ability to support high isolation between RF ports minimizes unwanted signal interference. This combination is critical as DOCSIS



3.1 relies on orthogonal frequency-division multiplexing (OFDM) to improve spectral efficiency, allowing a 50% increase in data rates up to 10Gb/s downstream and 1Gb/s upstream.

"As the cable television market moves to OFDM to increase data rates, manufacturers will need to make improvements in efficiency in all parts of the system by reducing noise, intermodulation distortions, and ingress," says Mark Schrepferman, director of the commercial and industrial product line with Peregrine's High performance Solutions business unit. "Peregrine has been supporting these requirements for years in the wireless

markets, and we are pleased to bring the exceptional linearity and isolation performance that can only be achieved using Peregrine's UltraCMOS technology and HaRP enhancements to broadband cable applications."

The new switch features high isolation performance of at least 60dB across the entire broadband frequency range of 5MHz to 3GHz (65dB at 1GHz (typ) and 64dB at 2GHz). The device features excellent video feedthrough of 5mV_{pp} for reduced distortion, and delivers low insertion loss (0.7dB @ 1GHz and 0.8dB @ 2GHz), which enhances overall system performance by reducing RF path noise figure. In addition, high linearity with a CTB/CSO of -104dBc improves dynamic range of CATV systems. The PE42720 supports 1.8V and 3.3V control logic and ESD performance of 2500V HBM on all ports.

Peregrine has also made available the PE42720 Evaluation Kit. The PE42720 is available now in volume production, supplied in a 4mm x 4mm 20-lead LGA package priced at \$1.06 in 10,000-quantity orders.

www.psemi.com

RFaxis begins volume production of single-chip/single-die Wi-Fi/Bluetooth RF front-end IC

Fabless semiconductor firm RFaxis Inc of Irvine, CA, USA, which designs RF semiconductors and embedded antenna solutions for the wireless connectivity and cellular mobility markets, has begun volume production of RFX8422S, which is claimed to be the first single-chip/single-die Wi-Fi/Bluetooth combo RF front-end IC (RFeIC) in pure CMOS. Also, RFaxis has started sampling its RFX8422, a drop-in replacement of RFX8422S, for applications that require a reduced maximum package height of 0.4mm.

"RFaxis is launching new Wi-Fi/Bluetooth RF front-end solutions at price points never heard of until

now," reckons chairman & CEO Mike Neshat.

The RFX8422S and RFX8422 RFeICs provide key RF functions for dual-mode Wi-Fi/Bluetooth operation in a typical smartphone or other mobile devices. Both parts include a high-efficiency linear power amplifier (PA), low-noise amplifier (LNA) and single-pole triple-throw (SP3T) antenna switch, all integrated into a monolithic die, and are offered in an ultra-compact 2.5mm x 2.5mm 16-pin quad-flat no-lead (QFN) package. Developed and manufactured in the industry's most cost-effective bulk CMOS process, the RFX8422S and

RFX8422 family of complete '3-in-1' RFeICs are pin-compatible with similar offerings from competitors currently on the market.

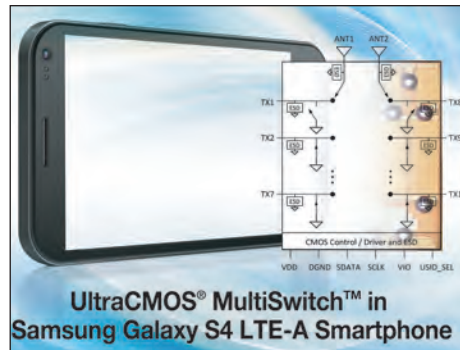
"By taking full advantage of the cost-effectiveness of CMOS, we can now offer complete Wi-Fi/Bluetooth combo 3-in-1 RFeICs at lower prices than the existing 2-in-1 solutions with far less functionality from competitors," claims Neshat. "Due to cost/price considerations, our competitors' 2-in-1 offerings only provide the LNA and SP3T switch, and are lacking the PA, which is most critical for extending the operating range of a wireless device."

www.rfaxis.com

Peregrine's new UltraCMOS antenna MultiSwitch used in Samsung Galaxy S4 LTE-A smartphone

Peregrine Semiconductor Corp of San Diego, CA, USA, a fabless provider of radio-frequency integrated circuits (RFICs) based on silicon-on-sapphire (SOS), is supplying the main antenna switch driving RF performance in Samsung's Galaxy S4 LTE-Advanced (LTE-A) smartphone. The PE421280 MultiSwitch (launched at the end of July) was selected for its ability to support simultaneous multi-band operation of up to 14 frequency bands while delivering what is claimed to be exceptional linearity, insertion loss performance and small size.

The Galaxy S4 is touted as the first implementation on the 4G LTE-A network. The LTE-A protocol uses carrier aggregation (the simultaneous reception of multiple frequency band) to improve data throughput. According to Samsung, a 3 minute download over 4G LTE would only take about 1 minute on 4G LTE-A.



"Peregrine's MultiSwitch devices are designed specifically to solve the challenges of carrier aggregation as used in LTE-A platforms," says CEO Jim Cable. "Based on our UltraCMOS technology, the devices feature not only the linearity required for simultaneous, multi-band switching performance, but also the integration,

MultiSwitch devices are designed to solve the challenges of carrier aggregation

low power, and manufacturability required of high-volume consumer applications."

The PE421280 antenna switch features a combination of two SP7T (single-pole, seven-throw) switches in a single IC to support 14 different frequency bands including simultaneous multi-band operation. With HaRP technology enhancements, the PE421280 delivers high linearity with an IIP3 of +75dBm, as well as low insertion loss (0.35dB @ 900MHz; 0.45dB at 1900MHz) and high isolation (38dB at 698–2170MHz; 33dB at 2500–2690MHz). The switch also features what is claimed to be industry-leading 2fo and 3fo for LTE of less than –80dBm at 700MHz. High-linearity and high-isolation performance are critical to ensure that radio signals do not spill into other bands during multi-band operation, says Peregrine.

www.psemi.com

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US DOE awards \$2m to develop HEV traction systems

A collaborative team led by Arkansas Power Electronics International Inc (APEI) of the Arkansas Research & Technology Park (ARTP), Fayetteville, AK, and including Toyota Motor Engineering and Manufacturing North America Inc, GaN Systems Inc, the University of Arkansas' National Center for Reliable Electric Power Transmission, and the US National Renewable Energy Laboratory (NREL), has received a \$2m US Department of Energy (DOE) award as one of 38 new projects in a \$45m effort to develop technologies that will reduce transportation costs and improve fuel efficiencies.

The team will develop new electric motor traction drives for hybrid electric vehicles, with technology based on silicon carbide (SiC) and gallium nitride (GaN) power semiconductors.

"By partnering with universities, private industry, and our national labs, the Energy Department is helping to build a strong 21st century transportation sector that cuts harmful pollution, creates jobs, and leads to a more sustainable energy future," said Energy Secretary Ernest Moniz. "By improving the fuel economy of our cars and trucks, we can save families and

businesses money at the pump and better protect our air and water."

"Our motor drive technology reduces power losses by more than 50%, and we can reduce the size and weight of the motor drive electronics by up to 90%," said APEI's president & CEO Alex Lostetter. "These improvements lead to significant savings in vehicle cost, increases driving distances, and reduces fuel expense. We're very excited to be working with Toyota to get this technology into the next generation of Prius hybrid-electric vehicles."

www.apei.net

ROHM launches 80mΩ 1200V SiC MOSFETs

ROHM Semiconductor of Santa Clara, CA (the US arm of system LSI, discrete components and module product maker ROHM Co Ltd of Kyoto, Japan) has launched two 80mΩ 1200V silicon carbide MOSFETs, the SCT2080KE and SCH2080KE, designed to deliver cost-effective performance. The SCH2080KE is reckoned to be the first SiC MOSFET co-packaged with a discrete anti-parallel SiC Schottky barrier diode (SBD), and features a forward voltage three times smaller than that of the body diode. The combination of the switching performance, low on-resistance, and high breakdown voltage make the

devices suitable as replacements for silicon power MOSFETs and insulated-gate bipolar transistors (IGBTs) in solar inverters, DC-DC converters, uninterruptible power supplies (UPS) and motor drives.

ROHM says that its SiC MOSFETs offer as much as 90% lower switching loss compared to silicon devices due to the absence of tail current and the diode's fast recovery performance. This allows designers to increase switching frequency to reduce size, cost and weight of passives. These benefits also enable the design of higher-efficiency systems by implementing simpler, less expensive cooling systems.

"ROHM's SiC MOSFETs help customers save board space, simplify layout, and reduce BOM costs," claims senior product marketing manager David Doan. "Importantly, ROHM's SiC MOSFETs are free from issues related to gate oxide breakdown, Vth stability, and degradation of the body diode during reverse conduction."

The SCT2080KE and SCH2080KE MOSFETs are available now in mass-production quantities. Also, the firm has plans to expand its SiC MOSFET product line with models with lower on-resistance and higher breakdown voltage.

www.rohm.com

Toshiba adds 10A model to family of 650V SiC Schottkys

Toshiba Corp has expanded its family of 650V silicon carbide (SiC) Schottky barrier diodes (SBD) with the addition of a 10A product to its existing line-up of 6A, 8A and 12A products (which operate with a forward voltage of 1.7V maximum, and are supplied in two-pin TO-220 packages). Mass production shipments have begun.

Applications of SBDs include power factor correction (PFC) circuits, photovoltaic inverters and power

conditioners for photovoltaic systems, and uninterruptible power supplies.

As they are fabricated from wide-bandgap semiconductor material, SiC SBDs provide higher breakdown voltage than is possible for silicon SBDs. Also, as unipolar devices, they have very short reverse recovery time and temperature-independent switching behavior, making them suitable as replacements for silicon fast-recovery diodes (FRDs) in order to improve power supply efficiency

(by up to 50%, says Toshiba).

In general, SiC power devices offer more stable operation than existing silicon devices – even at high voltages and currents – as they greatly reduce heat dissipation during operation, says Toshiba. They can also meet diverse industry needs for smaller, more effective communications devices, it adds, and their industrial applications range from servers to inverters.

www.semicon.toshiba.co.jp

RFMD introduces first 6" GaN-on-SiC wafers for RF power transistors

All GaN processes converting to high-volume 6" fab to reduce cost and address growth opportunities

RF Micro Devices Inc of Greensboro, NC, USA has introduced what it claims are the world's first 6-inch gallium nitride on silicon carbide (GaN-on-SiC) wafers for manufacturing RF power transistors for both military and commercial use. The firm is converting all GaN production and development to 6"-diameter wafers using its existing high-volume, 6" GaAs foundry in order to reduce platform cost for the growing GaN device market.

"This merging of production of GaN and GaAs is part of our 'GaN-in-GaAs Fab' strategy to repurpose existing fab capacity to better address growth opportunities from innovative new GaN-based products," says president & CEO Bob Bruggeworth.

According to analyst firm Strategy Analytics, the GaN microelectronics market is expected to rise at a compound annual growth rate (CAGR) of 28%, more than tripling to \$334m by 2017, led by both military (radar, electronic warfare, communications) and commercial (power management, cellular, CATV, land mobile radios) applications.

"By leveraging our technology leadership and high-volume expertise in 6" GaAs production, RFMD will now be able to add 6" GaN capabilities to deliver new RF power products that we expect will accelerate revenue growth in our communications, CATV, power conversion, radar, jamming, aerospace and open foundry businesses," says Dr Jeff Shealy, VP of

RFMD Power Broadband.

GaN technology supports broad frequency bandwidths and high breakdown voltages in a small area. A 6" GaN wafer offers 2.5 times more usable area over competing 4" GaN wafer platforms currently available, resulting in 2.5 times more RF power devices per wafer. Greater area-per-wafer and consequently lower cost per unit area (in dollars per square millimeter) is key to enabling affordable, high-performance power monolithic microwave ICs (MMICs) for military and commercial applications, says RFMD.

The firm expects to complete qualification of its 6" GaN platforms in 2014.

www.rfmd.com

GaN Systems presents device technology for smaller, lighter and more efficient power electronics in electric & hybrid vehicles

At the 2013 Electric & Hybrid Vehicle Conference & Expo in Novi, MI, USA (17–19 September), GaN Systems Inc of Ottawa, Ontario, Canada, a fabless provider of gallium nitride (GaN)-based power switching semiconductors for power conversion and control applications, is presenting a paper on new wide-bandgap semiconductors and their role in transforming automotive power electronics.

Manufacturers are currently designing vehicles to be launched onto the market in 2018, coinciding with the timeframe for GaN to attain price parity with silicon devices, according to market forecasters such as IMS Research. This development will overcome the limitations of silicon and transform power electronics in EHV's,

reckons GaN Systems.

At the for the three-day conference Julian Styles, the firm's director Business Development USA, is joining speakers from players in the EHV industry, explaining the technological advances in semiconductor materials that herald the replacement of traditional silicon in power converters for new generation electric and hybrid vehicles. GaN Systems says that the audience will gain insight into how wide-bandgap power semiconductors based on GaN bring benefits including greater efficiency, weight reduction and lower cost to power electronics for EHV's.

Styles will also give insight into devices available now and in the near future, and share the trends that are driving technological

advances in semiconductors for electric and hybrid vehicle applications.

"EHV's are full of power electronics, from battery management, auxiliary power, braking, valve timing, cruise control, security systems, instrument clusters — all of which are currently suffering the limitations imposed by silicon, as it doesn't switch quickly or cope with elevated temperatures," says CEO Girvan Patterson. "New-generation GaN and SiC semiconductors overcome these difficulties and are lighter, smaller and easier to package," he adds. "These new devices will lead to dramatic improvements in automotive power electronics and present a major opportunity for the industry."

www.gansystems.com

Fraunhofer IAF and Ferdinand-Braun-Institut boost GaN voltage converter efficiency to 98%

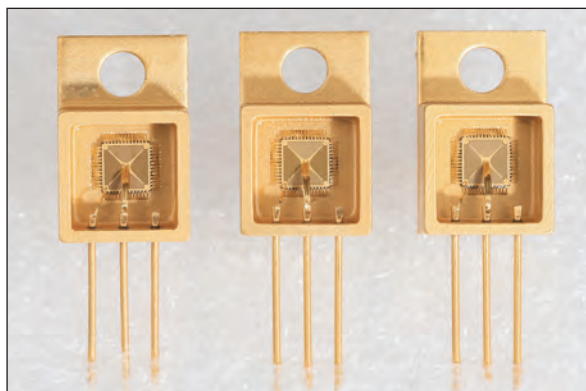
GaN devices reach breakdown voltage over 600V and currents of 100A

To increase the efficiency of voltage converters and minimize heat losses, researchers at the Fraunhofer Institute for Applied Solid State Physics IAF in Germany are developing transistors based on gallium nitride, characterized by low on-resistance and high switching speed. Voltage converters have recently achieved an efficiency level of 98% — this saves energy in electro-mobility and photovoltaics.

In order to foster the development of electro-mobility it is essential to reduce the energy consumption caused by electric cars, says Fraunhofer IAF. Efficient voltage converters can minimize losses and thus save energy during operation and the charging of batteries.

Now, researchers at Fraunhofer IAF and the Ferdinand-Braun-Institut (FBH) in Berlin have managed to develop GaN devices for applications in electro-mobility and photovoltaics where the efficiency of the transistors in the voltage converters has been increased to 98%. Practical tests have shown a performance of up to 1kW. "We have closed the gap to the international state-of-the-art," says Dr Michael Schlechtweg, head of department at Fraunhofer IAF. In contrast to conventional devices based on silicon, GaN transistors allow losses in voltage converters to be reduced by more than half.

The devices are the result of the research project 'PowerGaNPlus', which was supported by €3m of funding over three years from The German Federal Ministry of Education and Research (BMBF). The funding was part of different R&D projects on the topic 'Power Electronics for Increased Energy Efficiency' in the program 'IKT 2020 – Research for Innovation'. The aim is to establish Germany as the leading provider for technologies of electro-mobility and to contribute to future-oriented mobility. The



GaN transistors for efficient power electronics: currents of up to 100A and breakdown voltages beyond 600V are possible. (© Fraunhofer IAF)

BMBF hence supports particularly innovative partnerships between science and industry.

Practical tests show robust GaN devices

Regarding the development of GaN technology, Fraunhofer IAF cooperates with Robert Bosch GmbH, among others, to test the real-life behavior of the devices. Stress tests conducted so far have not only shown the devices' good performance but also gave a first indication of high short-circuit strength. "Validation of the devices developed within the project with a breakdown voltage of more than 600V showed encouraging performance," says Dr Walter Daves, who supervised the project at Robert Bosch GmbH. "Already in this early development stage, low conduction and switching losses comparable to considerably more mature and commercially available silicon carbide transistors were demonstrated during operation of the gallium nitride devices in circuits ready for application," he adds. "The stress tests conducted so far have also hinted at high short-circuit strength and thermal stability." The devices reached maximum currents of up to 100A during on-resistance operation.

The transistors have already been tested for applications in battery chargers for electric cars and

(together with inverter manufacturer KACO new energy GmbH of Neckarsulm, Germany) also in photovoltaic inverters. Also working with Fraunhofer IAF in the project are IXYS Semiconductor GmbH, United Monolithic Semiconductors GmbH, Universität Erlangen-Nürnberg, and RWTH Aachen.

New opportunities for GaN technology

Whereas silicon-based devices are slowly reaching their physical limits, GaN technology offers new opportunities for power electronics, says Fraunhofer IAF. Since GaN devices can be operated under higher voltages and temperatures than conventional power devices based on silicon, this allows a reduction in cooling effort, making compact, light-weight and cost-effective voltage converters feasible. Compared with silicon transistors, GaN allows switching frequency to be increased by at least a factor of three. Also, due to the higher breakdown strength and power density of the material, the devices are considerably more efficient than their silicon equivalent. This will reduce the energy consumed while charging the battery of an electric car or feeding in energy from solar parks into the grid.

"Besides using gallium nitride transistors in electro-mobility and photovoltaics, they will also be able to increase efficiency and save energy in household applications, production technology or in generators for plasma and laser systems," says Dr Patrick Waltereit, project leader at Fraunhofer IAF. "Our continuous goal will be to increase reliability, thermal stability and switching frequency in order to use the full potential offered by gallium nitride technology."

www.fbh-berlin.com
www.iaf.fraunhofer.de

EPC launches eGaN FETs for use in both power semiconductor and RF applications

Family of GaN transistors capable of amplification to multi-GHz range

Efficient Power Conversion Corp (EPC) of El Segundo, CA, USA, which makes enhancement-mode gallium nitride on silicon (eGaN) power field-effect transistors (FETs) for power management applications, has extended its range of high-speed, high-performance transistors with the EPC8000 family of products.

Breaking new ground for power transistors, it is claimed, the third-generation devices have switching transition speeds in the sub-nanosecond range, making them capable of hard-switching applications above 10MHz. Even beyond the 10MHz for which they were designed, the products exhibit good small-signal RF performance with high gain well into the low-GHz range, making them a competitive choice for RF applications, the firm claims.

"These products take EPC and gallium nitride transistor technology to a level of performance that enables applications that were previously beyond the capability of MOSFETs,"



An eGaN FET in the EPC8000 family.

says co-founder & CEO Alex Lidow. "We now have eGaN FETs that can be used in both power semiconductor and RF applications," he adds.

Products in the family are available with on-resistance values from 125mΩ through 530mΩ, and three blocking voltage capabilities, 40V, 65V and 100V. The transistors have several new features that further enable designers to take full advantage of the high performance that GaN FETs offer, says EPC. These features include reduction in QGD, reducing voltage transient switching losses, improved Miller ratio (providing high dv/dt immunity), low-inductance pads (for improved connection to both gate and drain

circuits), orthogonal current flow between the gate and drain circuits (for enhanced CSI reduction), and a separate gate return connection (also for enhanced CSI reduction).

Examples of applications benefiting from the low-power, compact, high-frequency EPC8000 family of devices include hard-switching power converters operating in the multi-megahertz range, envelope tracking in RF power amplifiers, and highly resonant wireless power transfer systems for wireless charging of mobile devices.

Also available now is the EPC9027 development board, featuring the EPC8007 devices and the LM5113 gate driver IC in a half-bridge configuration. Additional development boards will be available to support designers in evaluating and incorporating other EPC8000 family products into their power conversion systems.

Evaluation units of the EPC8000 family of products are available in 10-piece packs, starting at \$430, through Digi-Key Corp.

eGaN FET range gains 150V, 25mΩ & 100V, 16mΩ power transistors

EPC has launched two new members of its family of enhancement-mode gallium nitride on silicon (eGaN) power field-effect transistors (FETs).

The EPC2016 is a 3.36mm², 100V_{DS}, 11A device with maximum on-resistance $R_{DS(on)}$ of 16mΩ with 5V applied to the gate.

The EPC2018 is a 5.76mm², 150V_{DS}, 12A device with maximum $R_{DS(on)}$ of 25mΩ with 5V applied to the gate.

The transistors deliver high performance due to their ultra-high switching frequency, extremely low $R_{DS(on)}$, and low gate charge Q_g (3.8nC typical, 5.2nC maximum for the EPC2016 and 5nC typical, 7.5nC maximum for the EPC2018),

all in a very small LGA package (2.1mm x 1.6mm for the EPC2016; 3.6mm x 1.6mm for the EPC2018).

Compared to a state-of-the-art silicon power MOSFET with similar on-resistance, the EPC2016 and EPC2018 are much smaller and have many times superior switching performance, says EPC. Applications that benefit from eGaN FET performance include high-speed DC-DC power supplies, point-of-load converters, class D audio amplifiers and other circuits needing fast switching speeds.

"The low on-resistance, low output capacitance, fast switching, and no reverse recovery reduce the switching losses in power con-

version applications and allow for higher efficiency and improved sound quality in Class D audio applications," says co-founder & CEO Alex Lidow.

In 1000-piece quantities, pricing is \$1.61 for the EPC2016 and \$6.54 for the EPC2018. Both are available through distributor Digi-Key Corp.

To support designers in evaluating and incorporating eGaN FETs into their power conversion systems, the EPC9010 development board (featuring the EPC2016 devices and the LM5113 gate driver IC in a half-bridge configuration) is available.

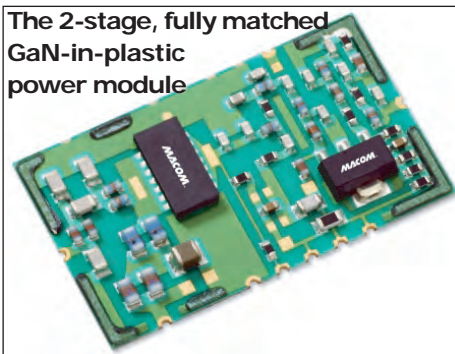
www.digikey.com

First surface-mount L-band 90W GaN power module

M/A-COM Technology Solutions Inc of Lowell, MA, USA, which makes semiconductors, components and subassemblies for RF, microwave and millimeter-wave applications, has announced the newest entry in its portfolio of GaN in Plastic packaged power products. Optimized for L-band commercial air-traffic control, military radar and long-range perimeter monitoring applications at 1.2–1.4GHz, MACOM's new MAMG-001214-090PSM two-stage, fully matched GaN in Plastic power module scales to peak pulse power levels of 100W in a 14mm x 24mm package size, delivering twice the power of comparably sized competing products, it is reckoned.

MACOM's new high-gain GaN in Plastic power modules are claimed to be the only gallium nitride (GaN)-based modules to support surface-mount technology (SMT) assembly, providing significant cost and process advantages compared to ceramic-packaged flange-mount components, it is claimed. Delivering benefits in size, weight and power (SWaP) while enabling high-volume manufacturing efficiency, MACOM's new GaN power modules extend the performance attributes of its discrete GaN in Plastic power

The 2-stage, fully matched GaN-in-plastic power module



transistors and establish new standards for GaN module integration, the firm adds.

Under pulsed conditions, the modules deliver output power greater than 90W, with 30dB typical associated power gain and 58% typical power added efficiency. Supporting 50V operation and up to 3ms pulse width/duration for improved time on target, MACOM's GaN in Plastic power modules reduce overall power consumption and cooling requirements compared to existing options.

The module features a land grid array (LGA) pattern for enhanced thermal flow and 'True SMT' assembly. All inputs and outputs are formed on the back of the module and include edge castellations for ease of assembly inspection. The module's flexible design allows for

gate and/or drain pulsing, and includes a gate voltage sense port for use in temperature compensation or pulse droop compensation. Leveraging thermal management techniques to ensure high reliability, the calculated mean-time-to-failure (MTTF) at 200°C is about 600 years.

"Building on a long history of providing similarly sized, very high-power LGA module solutions in GaAs, MACOM's GaN in Plastic power modules represent a pivotal evolution in GaN semiconductor technology, providing high overall power performance in a light, ultra-compact 14mm x 24mm package while enabling the greatest possible ease of assembly," says engineering director Damian McCann. "This modular, SMT-optimized approach unlocks the full promise of GaN in Plastic for radar applications and introduces unprecedented efficiencies from design to manufacturing."

The new GaN in Plastic L-band 90W power modules are now sampling to customers.

MACOM is exhibiting at European Microwave Week (EuMW 2013) in Nuremberg, Germany (6–11 October).

www.macomtech.com/gan

MACOM's 600W GaN-on-SiC pulsed power transistor delivers highest reliability rating and lowest pulse droop

MACOM has launched a ceramic gallium nitride on silicon carbide (GaN-on-SiC) high-electron-mobility transistor (HEMT) power transistor for avionics applications.

The MAGX-001090-600L00 is a gold-metalized, matched RF power transistor optimized for pulsed avionics applications, such as secondary surveillance radar in air-traffic control systems. It provides 600W of output power with a typical 21.4dB of gain and 63% drain efficiency. The device has very low thermal resistance (R_{th}) of 0.050C/W and what is claimed to be best-in-class load mismatch

tolerance of 5:1. In addition, it has the lowest pulse droop of 0.2dB and can be used effectively under more demanding Mode-S ELM operating conditions.

MACOM says that its GaN transistor technology has been fully qualified with accelerated, high-temperature lifetime tests, and that the device has a predicted mean time to failure (MTTF) of over 600 years at a maximum junction temperature of 200°C. It also has a very high breakdown voltage, providing reliable and stable operation even in extreme load-mismatch conditions.

"MACOM's GaN power technology offers a significant advantage in higher gain, higher efficiency and improved reliability compared to similar silicon bipolar and LDMOS power transistors," claims product manager Paul Beasley. "The device also provides the highest load-mismatch tolerance in its class — a critical parameter to ensure the highest reliability and performance in demanding avionics applications."

Evaluation boards for the MAGX-001090-600L00 are available from stock.

www.macomtech.com/gan

Microsemi launches 750W GaN-on-SiC RF power transistor for aviation applications

Microsemi Corp of Aliso Viejo, CA, USA (which designs and makes analog and RF devices, mixed-signal integrated circuits and subsystems) has expanded its family of RF power transistors based on gallium nitride HEMT on silicon carbide technology with a new 750W RF transistor. The MDSGN-750ELMV can be used in a full range of air-traffic control and collision avoidance equipment. Targeted applications include commercial secondary surveillance radar (SSR), which is used globally to interrogate and identify aircraft in airport locales and regional centers within about a 200 mile range.

The MDSGN-750ELMV delivers 750W of peak power with 17.2dB of power gain and typical 70% drain

efficiency when operating at 1030/1090MHz, providing what is claimed to be the most power in one single-ended device of its type covering this band. The single-ended design with simplified impedance matching replaces lower-power devices that require additional levels of combining. A single output stage pair provides 1.5kW of peak output power with margin, while combining four output stage pairs delivers a full system >5kW peak output power.

In addition, the new RF device is capable of handling the demanding commercial Mode-S ELM (Extended Length Message) pulsing conditions for both the 1030MHz ground-based interrogators and 1090MHz airborne transponders and can be used in the

output stage of high-performance ground. ELM makes air travel safer by facilitating the communication of shared weather and air-traffic situational awareness information to aircraft within a regional locale. It is also suitable for use in commercial air-to-air traffic alert and collision avoidance systems (TCAS) and in IFF (Identify Friend or Foe) systems, which are essential in protecting friendly aircraft within a specific area.

The MDSGN-750ELMV is offered in a single-ended package and is fabricated with 100% high-temperature gold (Au) metallization and wires in a hermetically solder-sealed package for long-term reliability. Loaner demonstration units are available.

www.microsemi.com

Aethercomm launches 50W, 6–18GHz GaN RF amplifier for aerospace & defense applications

Aethercomm Inc of San Marcos, CA, USA, which designs and makes high-power RF amplifiers, subsystems and systems for use in radar, electronic warfare, communication systems, and test & measurement, has launched a SSPA 6.000-18.000-50 high-power super-broadband GaN RF and microwave amplifier operating at 6–18GHz for aerospace and defense applications.

Packaged in a modular housing of 8.5 by 3.5 by 1.38 inches, the solid-state power amplifier (SSPA)

offers high output power of 50W over a multi-decade bandwidth with power-added efficiency, and operates at a base plate temperature of -40°C to 55°C . The device has a typical P3dB of 40W at room temperature with a minimum of 25W.

Noise figure at room temperature is 12dB typical. The amplifier offers a typical large-signal power gain of 47dB with a typical gain flatness of $\pm 1.0\text{dB}$. The power and gain flatness across the band is extremely flat for the bandwidth, says the firm.

Input VSWR is 2.0:1 maximum. Class AB quiescent current is 8.5A typical employing a $+26\text{V}_{\text{DC}}$ supply.

The SSPA includes an external DC blanking command that enables and disables the module in under 20 μs . A logic low or open circuit commands PA OFF; a logic high commands it ON.

Standard features are over/under voltage and reverse polarity protection. Input/output RF connectors are SMA female. DC and command voltages are accessible via a DSUB connector.

www.aethercomm.com

Comtech launches GaN amplifier for X-band radar

Comtech Telecommunications Corp says that subsidiary Comtech PST Corp in Melville, NY, USA is introducing the model BMC858109-600 gallium nitride power amplifier for X-band radar applications.

The AB linear design operates over the 8.5–10 GHz radar frequency range. Features of the RF and microwave amplifier include options

for control of phase and amplitude to allow for integration into high-power systems that use conventional binary or phased-array combining approaches for power levels to 10kW.

Features include RF input & output sample detectors; pulse width and duty factor protection; thermal and load VSWR protection; optional

digital interface for control and status monitoring; and optional phase and amplitude control.

The power amplifier operates in temperatures of $0-55^{\circ}\text{C}$, resists shock and vibration per mil-std-810F, operates at altitudes to 10,000 feet, measures 10 by 8.5 by 1 inches, and weighs five pounds.

www.comtechpst.com

IQE confirms first-half sales up 84% year-on-year to £63m

Wireless drives record sales as firm diversifies to other mass markets

After giving a trading update for first-half 2013 in late July, epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK has confirmed record revenue of £63m (up 84% from £34.3m for first-half 2012).

EBITDA (earnings before interest, taxes, depreciation, amortization, share-based payments and exceptional items) is £10.5m (up from £4m in first-half 2012). Cash inflow from operations more than doubled from £2.8m to £6.3m. IQE says that such strong conversion of operating profit into cash and the completion at the end of 2012 of its two-year capital expenditure (CapEx) expansion program marks a return to free cash generation. After investment in CapEx and product development of £4.5m (down from £10.6m in first-half 2012), IQE generated free cash inflow of £1.8m (compared with outflow £7.8m in first-half 2012).

Sales growth was driven primarily by the wireless division (more than doubling from £25.4m in first-half 2013 to £53.7m in first-half 2013, or about 85% of total revenue). This was boosted by strong performance from strategic acquisitions made over the past 18 months, including the MBE epiwafer manufacturing unit of RF Micro Devices Inc of Greensboro, NC, USA as well as the Kopin Wireless MOCVD-based heterojunction bipolar transistor (HBT) epiwafer manufacturing business of Kopin Corp of Taunton, MA, USA. In particular, revenue from Kopin Wireless (acquired on 15 January) was £15.6m in first-half 2013 (if the transaction had completed at the beginning of first-half 2013, this would be £16.6m).

Revenue from the Photonics segment has risen from £8.3m in first-half 2013 to £8.9m in first-half 2013, while revenue from the Electronics segment fell from £0.6m to £0.42m.

"These record financial results are a clear testimony to the transformation we've achieved over the last 18 months," says chief executive Dr Drew Nelson. "Our two strategic wireless acquisitions have been successfully integrated and are performing very strongly. These deals represented the final building blocks in our wireless strategy, and we are now firmly focussed on delivery," he adds.

"Although the recent weakness in the global smartphone market, ahead of new product launches, has injected a greater degree of uncertainty in the short term, the overall wireless story remains as exciting as ever," Nelson continues. "The demand for greater connectivity, the increasing complexity of wireless communications and the explosion in data traffic continue to drive increasing demand for compound semiconductors. We are uniquely positioned to exploit this long-term growth trend as the clear leader in providing a broad range of high-performance wireless products," he reckons.

"We have built a strong IP portfolio and are primed to exploit the adoption of compound semiconductors in a number of mass market applications,"

Sales growth was driven primarily by the wireless division (more than doubling from £25.4m in first-half 2013 to £53.7m in first-half 2013, or about 85% of total revenue)

and industrial applications utilizing advanced lasers (vertical-cavity surface-emitting lasers, or VCSELs).

IQE notes the following business highlights in first-half 2013:

- significant milestones achieved in solar CPV (now primed for rapid mass market adoption);
- photonics transitioning to volume production, including data centre and communication applications (VCSEL);
- significant progress with gallium nitride (GaN) technology for power semiconductors and LEDs (nearing new product launches);
- internal business units created (IQE Wireless and IQE Infrared) to address evolving market needs; and
- program to realise significant recurring synergies (of at least £7m per annum, from second-half 2014) is on track.

"Advanced solar (CPV) is a disruptive technology which is gaining traction in the energy market. Advances in cell and system efficiency are accelerating the adoption of CPV, which is widely expected to be a \$200–500m market for compound semiconductor materials in the next 3–5 years," says Nelson. "Having successfully hit all major technical and operational milestones [set out at the time of IQE's investment in III-V multi-junction PV cell maker Solar Junction Corp of San Jose, CA, USA in February 2012], and recently posted new world record efficiencies from our production platform, we are now qualified for high-volume manufacturing to commence over the coming months," he adds.

"Our significant progress in strengthening and broadening the wireless business, whilst building a solid platform of technologies which are poised for strong growth in our other target markets, mean we remain confident of achieving market earnings expectations for the full year," notes Nelson.

"The operational leverage of our business model should create significant earnings growth as our revenues increase."

www.iqep.com

Ultratech/Cambridge NanoTech expands operations

New facility enables next-generation ALD development

Ultratech Inc of San Jose, CA, USA, which designs and manufactures lithography, laser-processing and inspection systems used to make semiconductor devices and high-brightness LEDs (HB-LEDs), has moved its Ultratech/Cambridge NanoTech division to Waltham, MA. The new facility will expand its operations for next-generation atomic layer deposition (ALD) equipment development as well as enabling scientific research.

Last December, Ultratech acquired the assets of Massachusetts-based ALD equipment maker Cambridge NanoTech Inc, which was spun off from Harvard University's Gordon Lab in 2003 and has since installed hundreds of system in research and manufacturing worldwide. After investing in the new facility, Ultratech/Cambridge NanoTech has now enhanced its ability to develop process technology for ALD applications.



Interior view of new Ultratech/Cambridge NanoTech facility.

Ultratech says that, since ALD provides coatings and material features with advantages compared to other existing techniques for depositing nanometer-thin films, it is expected to be in high demand in volume manufacturing environments for integrated optics, micro-electro-mechanical systems (MEMS), implantable devices in the biomedical sector, and batteries and fuel cells in the energy market.

"We have retained the same team

that Cambridge NanoTech customers have worked with in the past," notes Ultratech's chairman & CEO Arthur W. Zafiropoulos. "The completion of the new facility marks our successful integration of the Cambridge NanoTech assets into Ultratech's nanotechnology product group," he adds. "By investing in the expansion of these operations, we expect to generate increased revenue in new and existing markets. Ultratech, and our ALD unit, Ultratech/Cambridge NanoTech, will continue to focus on technology solutions that support our global customers' advanced product and technology roadmaps."

Ultratech/Cambridge NanoTech exhibited at the 13th annual International Conference on Atomic Layer Deposition (ALD 2013) in San Diego, CA, USA (28–31 July).

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IN BRIEF

Japan's Air Water opts for Aixtron system to develop GaN-on-SiC-on-Si

Deposition equipment maker Aixtron SE of Herzogenrath, Germany says that Air Water Inc of Azumino, Japan has installed a fully automated Aixtron AIX G5 HT Planetary Reactor (in 8x6" configuration) for the MOCVD growth of GaN epitaxial layers.

Following the installation, Air Water announced the release of gallium nitride-on-silicon carbide (GaN-on-SiC) on silicon substrates for this year. Furthermore, to address future market demand, Air Water is also considering upgrading the system to an Aixtron AIX G5+, which can handle up to 5x200mm (8") silicon substrates.

Compared to traditional silicon substrates, the additional SiC layer offers the advantage of protecting the Si substrate in the initial GaN nucleation process. Due to its crystal structure, SiC is considered to be an ideal template for GaN growth, so the SiC-on-Si substrate enables the growth of superior crystal quality GaN layers onto large areas, bringing efficiency and cost savings to high-power and LED applications, it is claimed.

Air Water is a Japanese industrial gas manufacturer and has developed SiC growth on silicon for both power device and LED applications as part of the semiconductor gas business. The firm has already produced high-quality 3C-SiC (111) on silicon substrates up to 8" in diameter, and has also announced the release of these products for GaN epitaxial growth required to manufacture electronic devices for LED and power electronic applications.

www.aixtron.com

Veeco and imec collaborate to further develop GaN-on-Si for LEDs and power electronics

Epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA and Belgium's nanoelectronics research centre imec are collaborating on a project aimed at lowering the cost of producing gallium nitride on silicon (GaN-on-Si)-based power devices and LEDs.

"The productivity, repeatability, uniformity and crystal quality of Veeco's metal-organic chemical vapor deposition (MOCVD) equipment has been instrumental in helping us meet our development milestones on GaN-on-Si for power and LED applications," says imec's chief scientist Barun Dutta. "The device performance enabled by the epi has helped us realize state-of-the-art D-mode (depletion mode) and E-mode (enhancement mode) power devices. Our goal is to establish an entire manufacturing infrastructure that allows GaN-on-Si to be a competitive technology."

Imec's multi-partner GaN-on-Si R&D program gathers the industry

to jointly develop GaN LED and power devices on 200mm silicon substrates compatible with a 200mm CMOS-compatible infrastructure. By joining forces at imec, companies share costs, talent and intellectual property to develop advanced technologies and bring them to the market faster.

"We have been working with imec on this program since 2011 and are encouraged by our progress," says Jim Jenson, senior VP & general manager, Veeco MOCVD. "Our work is mutually rewarding, as we are both focused on being able to realize lower costs while maintaining world-class performance on GaN-on-Si devices. 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."

www.imec.be

www.veeco.com

LayTec's in-situ seminar at ICNS

LayTec AG of Berlin, Germany, which makes in-situ metrology systems for thin-film processes, focusing on compound semiconductor and photovoltaic applications, held its 18th international in-situ seminar on 25 August in conjunction with the ICNS in Washington DC, USA, where international experts presented their latest in-situ results of nitride growth monitoring:

- Alois Krost (Otto-von-Guericke University Magdeburg, Germany): Growth and characterization of GaN on silicon wafers;
- Yvon Cordier (CNRS-CRHEA, France): Assessment of strain in GaN films by using in-situ and ex-situ characterization techniques;
- Fabrice Oehler (University of

Cambridge, UK): Current challenges for in-situ monitoring of polar and semi-polar III-Nitrides.

Neil Gerrard, managing director of LayTec UK Ltd, presented a newly developed method for pre-selecting patterned sapphire substrate (PSS) wafers according to pre-bow and PSS uniformity. Customers took the opportunity to check their PSS wafers on-site.

Head of R&D Kolja Haberland discussed new product developments, while chief customer officer Oliver Schulz explained the new concept of LayTec Premium Care.

To download the talks from LayTec's website, request the password via info@laytec.de

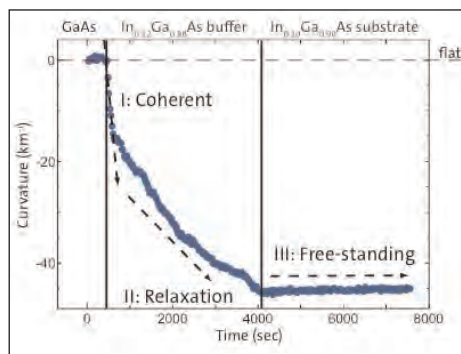
www.laytec.de

Optimizing InGaAs metamorphic buffer for laser diodes

LayTec AG of Berlin, Germany says that Ryo Nakao at NTT Photonics Laboratories is using LayTec's Epi-Curve TT in-situ metrology system to improve layer thickness and indium content in order to fabricate a thin indium gallium arsenide (InGaAs) metamorphic buffer with low thermal resistance. The temperature characteristics of laser diodes (LDs) on GaAs substrate depend on the quality and the thermal resistance of InGaAs metamorphic buffer layer.

At July's Electronic Materials Symposium 2013 in Japan, NTT presented a new method for optimizing the metamorphic buffer layer for free-standing quasi-InGaAs substrates. LayTec's in-situ tool helps users to understand the MOVPE growth conditions and shows the changes in wafer curvature caused by residual strain during MOVPE.

The Figure shows in-situ curvature data for a 1250nm metamorphic InGaAs buffer layer and a quasi-



InGaAs substrate layer. The growth can be separated into three parts: (1) coherent (pseudomorphic) growth of the buffer; (2) growth with relaxation; (3) free-standing (unstrained) growth. During relaxation, the in-plane lattice constant of the $\text{In}_{0.12}\text{Ga}_{0.88}\text{As}$ layer increases. After the buffer has reached 1250nm, its lattice constant exactly matches the lattice constant of $\text{In}_{0.10}\text{Ga}_{0.90}\text{As}$. The wafer curvature hence does not change during the subsequent growth of $\text{In}_{0.10}\text{Ga}_{0.90}\text{As}$ layer. The authors call this final

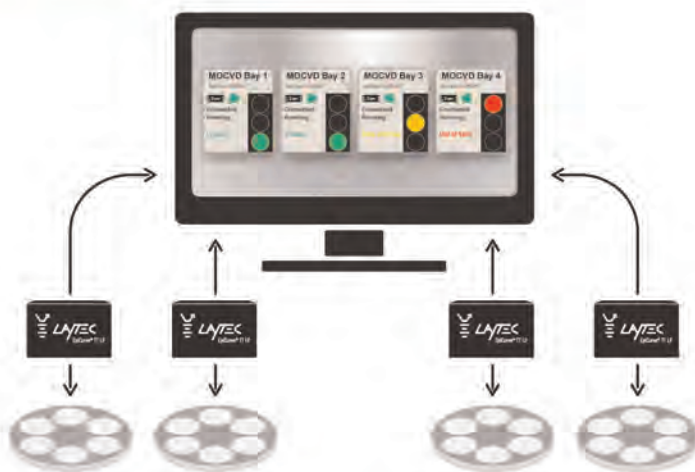
growth phase 'free-standing' because the $\text{In}_{0.10}\text{Ga}_{0.90}\text{As}$ layer grows with its natural lattice constant and creates a quasi-substrate similar to an $\text{In}_{0.10}\text{Ga}_{0.90}\text{As}$ wafer for the later device growth.

Further experiments with the same indium content and different buffer thicknesses showed that if the relaxation is not sufficient (buffer thickness=1000nm), the quasi- $\text{In}_{0.10}\text{Ga}_{0.90}\text{As}$ substrate growth is compressively strained. However, over-relaxation (1600nm) results in a tensile strain.

The researchers plotted these changes to obtain a map of the correlation between thickness and curvature (Ryo Nakao et al. EMS-32 proceedings (2013)). For a free-standing quasi-InGaAs substrate, they choose a buffer thickness with no further variation in curvature over time during $\text{In}_{0.10}\text{Ga}_{0.90}\text{As}$ growth.

www.laytec.de/epicurve

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IN BRIEF

Etch system order from SITP Shanghai

Oxford Instruments has won an order from the multi-disciplinary Shanghai Institute of Technical Physics of the Chinese Academy of Sciences (SITP-CAS) for a PlasmaPro 100 etch system, to be used for semiconductor research.

"SITP has PECVD and RIE systems installed that are mainly focused on non-metal films, which have been applied to light-sensitive devices, passivation and multi-layer metal layout isolation, with excellent results," says SITP's Heliang Xu. "Our recently purchased PlasmaPro 100 ICP system will be used for thick dielectric etch, where good results have already been obtained with the CMOS image sensor devices," he adds.

www.oxford-instruments.com

Oxford Instruments seminars for nanotech researchers in India

Following its seminar in Bangalore last December, UK-based etch and deposition system maker Oxford Instruments is planning two more seminars this year in India. 'Bringing the Nanoworld Together' (BTNT 2013) will be held at Mohali (29 November) in association with the Indian Institute of Science Education and Research Mohali and the Institute of Nano Science and Technology, and at Mumbai (2–3 December) in association with the Indian Institute of Technology Bombay. The seminars will focus on nanotechnology tools and their use in multiple fields.

Both events will feature two parallel sessions focusing on thin-film processing, and materials characterization, surface science and cryogenic environments and a wide range of topics will be covered within each technical area. These sessions will include guest international

speakers from renowned research institutions, speakers from the host institutes, and technical experts from Oxford Instruments.

The thin-film processing sessions will review the latest etch and deposition technological advances, including: ALD, magnetron sputtering, ICP PECVD, nanoscale etch, MEMS, and MBE.

Materials characterization, Surface Science and Cryogenic Environment sessions will cover multiple topics and technologies including: ultra-high-vacuum SPM, Cryo-free low-temperature solutions, XPS/ESCA, an introduction to atomic force microscopy (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.

www.oxinst.com/btnt2013

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www.oxford-instruments.com/plasma



Nanoplus orders OIPT systems for laser bar facet coating and compound semiconductor etching

UK-based etch, deposition and growth system maker Oxford Instruments Plasma Technology (OIPT), part of Oxford Instruments plc, has received an order from integrated laser company Nanoplus in Germany for an ion beam deposition and a plasma etch system for use in the production of novel types of semiconductor laser. Nanoplus produces semiconductor lasers over several wavelength ranges (some exclusively) for many different customers with a wide range of applications.

OIPT's Ionfab300 Plus ion beam deposition is a multi-batch cassette loading tool allowing many devices to be produced for several applications and various customers in one load. It will be used by Nanoplus for laser bar facet coating with

anti-reflective and high-reflection multilayers. OIPT's PlasmaPro System100 RIE will be used for GaAs and InP compound etching.

"Our Ionfab optical coating tools are becoming the tools of choice for many types of precision optical coatings worldwide, in particular in laser applications," says Dr David Pearson, OIPT's

OIPT's Ionfab300 Plus ion beam deposition will be used by Nanoplus for laser bar facet coating with anti-reflective and high-reflection multilayers.

OIPT's PlasmaPro System100 RIE will be used for GaAs and InP

senior Ion Beam technologist.

"Nanoplus is an internationally leading supplier of single-mode DFB lasers for sensing, metrology, spectroscopy and telecom applications. We even have one of our sensors on NASA's Mars Curiosity Rover," says Nanoplus' founder professor Alfred Forchel, "We chose Oxford Instruments systems for their versatility, superior process capabilities and excellent customer support," he adds.

"Our tools offer the ideal platform for production as well as research & development in many new application areas, and laser bar facet coating is just one of these," comments Frazer Anderson, Business Group director at Oxford Instruments.

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IN BRIEF

Plasma-Therm appoints Scientech as distributor for Greater China

Plasma process equipment maker Plasma-Therm LLC of St Petersburg, FL, USA has appointed Scientech as its distributor for Greater China (China, Hong Kong and Taiwan).

"Plasma-Therm's 15 years of consecutive customer service awards, including recognition as the #1 supplier of semiconductor equipment worldwide for 2013, along with Scientech's proven commitment to customer satisfaction, creates a perfect partnership," says Plasma-Therm's CEO Abdul Lateef.

"Scientech boasts highly trained engineers in semiconductor, LED, FPD, and scientific instruments industries," says Scientech's CEO M.T. Hsu.

"We see great potential for growth in China and Taiwan, and it is obvious that, to be successful in the region, we require not only capable sales representation but an organization with long experience, deep service infrastructure and a commitment to customer satisfaction above all," says Jim Pollock, Plasma-Therm's executive VP of sales. "By choosing Scientech as our partner, we have established the critical mass needed to serve our customers in the Greater China Region to the highest levels for sales, service and after-sale support."

Founded in 1979 in Taipei, Taiwan, Scientech was one of the first distributors of semiconductor equipment in Greater China. Scientech currently has more than 500 staff and multiple factories/offices throughout the region, including six locations in Taiwan and nine within mainland China.

www.plasmatherm.com

Park Systems launches AFM system targeting semiconductor manufacturing

Park Systems Corp of Suwon, South Korea has introduced the NX-HDM, a fully automated automatic defect review and sub-angstrom surface roughness atomic force microscopy (AFM) system for device substrates and disk media (claimed to be the first metrology tool capable of providing this level of accuracy and automation). Currently, about 90% of Park's AFM sells is to the hard-disk drive (HDD) manufacturing market, but with the launch of this new system the firm is actively pursuing business from the semiconductor industry.

The firm claims that the NX-HDM sets a new standard in automatic defect review AFM technology by increasing throughput by up to 1000% and offering a 30% higher success rate than prior systems; analyzing, identifying and scanning media for all wafer sizes up to 150mm.

"For researchers working with hard-disk media and other flat substrates, the process of identifying nanoscale defects is time consuming with conventional tools, hindering throughput," says CEO & chairman Sang-il Park. "The automatic defect review (ADR) speeds up and improves the way it identifies, scans and analyzes defects in substrates and media," he adds. "Beta-test runs with Park NX-HDM demonstrate a 10x increase in throughput for defect review in an automated process when compared with more traditional manual methods of defect review. Moreover, we perfected the remapping and defect identification algorithm, and the success rate of the new NX-HDM is 30% higher than its previous generation, XE-HDM."

Park says that the NX-HDM for HDD, LED, solar and general semiconductor device industries speeds up the automatic defect review for media and substrates. The survey



Park Systems' NX-HDM system.

scan, zoom-in scan, and analysis of imaged defect types are automated with a wide range of automated optical inspection (AOI) tools. In addition, True Non-Contact Mode, combined with the industry's lowest noise floor, provides accurate and reliable measurements for the sub-angstrom surface roughness of diverse media and substrates, says the firm.

The Park dual servo system with two symmetric, low-noise position sensors are incorporated on each axis of the XY scanner to retain a high scan orthogonality for wide scan ranges and sample sizes. The secondary sensor corrects and compensates for non-linear and non-planar positional errors caused by a single sensor.

"There has never been a metrology tool capable of providing accurate and reliable measurements for the sub-Angstrom roughness of the substrate surfaces," reckons Ryan Yoo, VP of global sales & marketing. "By delivering the industry's lowest noise floor of less than 0.5Å, Park NX-HDM can acquire accurate, repeatable, and reproducible sub-angstrom roughness measurements for the flattest substrates and media."

www.parkAFM.com

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Picodeon to ramp up research and manufacturing of thin-film deposition tools after €5m investment

Finland-based nanotech firm Picodeon Ltd, which specializes in thin-film coatings and surface treatments, is to accelerate the development and manufacture of its thin films and thin-film deposition tools following completion of a €5m round of funding by private investment and project management firm Enso Ventures Ltd. Picodeon also recently started a new project funded by TEKES (the Finnish Funding Agency for Technology and Innovation) with a value over €1m.

The investment will fund further research into thin-film applications and the development of new thin-film materials, as well as the production of a market-ready range of laser deposition equipment.

Picodeon's patented Coldab technology is an ultra-short pulsed laser deposition (US PLD) process that enables high-quality nanometer-scale thin-film coatings of materials such as metals, composites, oxides and polymers to be deposited on a wide range of substrates.

The process is produced by Picodeon's patented coating equipment, where material is vaporized in a laser-ablation process forming a plasma plume which condenses on the substrate to form a thin film. Applications include hard optical coatings for displays, screens and other transparent products (ranging from super-hard low-friction thin-films to optical thin-films with anti-finger print properties). However, in July, Picodeon delivered a project to a semiconductor manufacturer for the US PLD deposition of a gold (Au) thin film. Picodeon cites semiconductor applications of Coldab thin-film technology as including high-K and low-K dielectric coatings, as well as coatings for micro-electro-mechanical systems (MEMS).

"This investment round enables Picodeon to continue the commercialization and production of its innovations related to nanotechnology thin-film solutions and equipment," comments

CEO Marko Mylläri. "Enso Ventures is an ideal investor for us as they are committed to a long-term business development plan," he adds.

"Picodeon is investing nearly €2m in the development of new automated thin-film coating equipment which will be up and running by January 2014," Mylläri continues. "This is a unique machine to demonstrate the volume manufacturing potential of PLD coatings. It will show that the PLD process is not just a laboratory research concept, but that it is scalable into industrial applications by using Picodeon's innovations."

Picodeon says that it has a portfolio of global patents including 18 granted patents and nearly 100 patent applications. "The patent portfolio plays a critical role in our business model and in the value produced by the company," concludes Mylläri.

www.ensoventures.com

www.picodeon.com

Gas distribution with semi-automatic valve manifold box

SEMI-GAS Systems, a division of Applied Energy Systems Inc of Malvern, PA, USA and a manufacturer of ultra-high-purity gas handling and distribution systems, is offering a simplified line of semi-automatic valve manifold boxes that facilitate pressure regulated gas delivery to multiple points-of-use.

With fewer components to fail, Nanoturion Single Emergency Shut Off (ESO) semi-automatic valve manifold boxes (VMBs) minimize production downtime, system maintenance and equipment costs, says the firm. The VMBs are ideal for use in critical semiconductor, LED and research and development applications.

SEMI-GAS semi-automatic VMBs are available in 4-, 6-, and 8-stick models, each featuring a simplified

rail-mounted stick design for easy maintenance and expansion to accommodate fab additions, process changes and new tool installations. Individual process sticks are pressure regulated and the lines are isolated for localized gas control.

To minimize human-system interaction and ensure the safest operating conditions, each unit includes a GigaGuard Emergency Shutdown System (ESS) controller that continuously monitors system conditions and automatically interrupts gas flow in the event of an alarm. Emergency shutdown can also be operator activated via an abort button and/or via a remote shutdown input. LED lights display constant system status and accompany an audible alarm to signal hazardous conditions. The controller's 11 pro-

grammable inputs are easily tailored to meet user specific requirements and allow for supplemental network and communications.

The standard 4-stick model is compact at 37" tall, 22" wide and 12" deep and includes a UL-approved fire sprinkler as well as integrated wall- or rack-mount attachment points. The enclosure is constructed of welded 11 Ga steel, with a 1/4" thick safety glass window and a self-closing, self-latching door.

"This basic version of our Nanoturion VMB product line is perfect for the segment of our customer base who seek a simplified, low cost, safe method of distributing process gases," says Jim Murphy, SEMI-GAS division manager.

www.semi-gas.com



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Bruker launches LumiMap electroluminescence tool for optical & electrical characterization on HB-LED epiwafers

At the 15th China International Optoelectronic Exposition (CIOE 2013) in Shenzhen, Bruker Corp launched its LumiMap electroluminescence system for high-brightness light-emitting diode (HB-LED) epiwafer process metrology. Joining a suite of other Bruker HB-LED epi metrology tools, LumiMap incorporates many of the features of Bruker's flagship metrology products. Proprietary patent-pending features of the new system include the durable conducting probe, a unique wafer edge contact solution, and advanced I-V curve modeling for accurate and repeatable forward voltage value measurement. These features enable LumiMap to deliver accurate and repeatable forward and reverse IV characteristics, spectral intensity, wavelength and spectral width measurements on 2–6" epi wafers, with a wide range of current settings, says the firm.

"LumiMap provides more accurate and reliable electrical and optical epiwafer measurements than the traditional indium dot method," says Dr Ryan Lee, executive VP & chief technology officer of Foshan

Nationstar Optoelectronics Co Ltd. "A reliable electro-luminescence quality check immediately after MOCVD will help us further improve epiwafer yield and reduce costs."

LumiMap is an alternative to conventional, multi-step, operator-dependent indium dot methods of epiwafer characterization. The system features rapid, non-destructive, no post-measurement chemical cleaning, software-controlled measurement locations, and repeatable optical and electrical measurement capabilities through forming a temporary LED device on an epiwafer. The results obtained by LumiMap are well correlated with those on the final HB-LED device, providing an early warning of process shifts, which in turn reduces the risk of expensive scrap events and improves yields. Simple wafer exchange and intuitive software provides an easy-to-use interface for production quality control, as well as epi process development. The long measurement lifetime of the proprietary conducting probe meets the strictest industry cost of ownership requirements.

"Bruker is pleased to bring a new technology solution to HB-LED manufacturing, rounding out our other HB-LED metrology technologies in 3D optical microscopy, atomic force microscopy and XRD/XRF for PSS wafers and epiwafer multi-quantum layer characterization," says Dr Xiaomei Li, VP of Segment Marketing of the Bruker Nano Surfaces division. "LumiMap ideally serves stringent HB-LED manufacturing cost reduction goals at a time when the industry is poised for unprecedented growth."

"LumiMap electroluminescence technology fills the current lack of fast, non-destructive, reliable and repeatable optical and electrical measurement solutions to improve epiwafer yield and LED device quality at the epiwafer stage," says Robert M. Loiterman, executive VP & general manager of Bruker's Stylus and Optical Metrology Business. "With LumiMap, the HB-LED industry can now get accurate electrical and optical feedback in minutes rather than days, reducing scrap events and operating costs."

www.bruker.com

Hidden launches mass spectrometer for fast gas processes

Hidden Analytical Ltd of Warrington, UK has launched the HPR-20 QIC TMS gas analyser, specifically configured for the analysis of fast transient pulses and of rapid compositional changes in gaseous processes. Developed for the researcher, the system is suited to studies of diverse thermally triggered and chemically triggered reactions.

The multi-mode Windows MASsoft Professional software features quantitative analysis and statistical data reduction programs, peak area integration, and the APSI-MS soft ionization mode to enhance spectral purity. The system includes provision for import of two external



Hidden's HPR-20 QIC TMS gas analyser.

signals to enable simultaneous integration of parameters such as temperature and weight with the mass spectrometer data.

Operating with sample pressures from near-atmospheric up to 30 bar,

the bench-top mass spectrometer uses a fast digital detection system for minimized signal response times and features the Hidden triple-stage mass filter for optimum sensitivity, species identification and corrosion resistance. Coupling to the process is via a flexible, heated capillary interface of length 0.9m (3ft) with a throughput of just 20mL/minute. Measurement rate is up to 500 data points per second over a 7 decade dynamic range, with a compositional change at the sample point recorded in less than 150ms. Pulse profile resolution (5% to 95% peak height) is 60ms, says the firm.

www.hiddenanalytical.com

Rudolph launches NSX 220 automated macro defect inspection system

At SEMICON Taiwan 2013 (4-6 September), Rudolph Technologies Inc of Flanders, NJ, USA, which makes defect inspection, process control metrology, and data analysis systems and software for manufacturing ICs as well as flat-panel displays, solar cells and LEDs, launched its NSX 220 automated macro defect inspection system, which provides defect inspection for traditional back-end processes in semiconductor, MEMS and LED packaging and test at a reduced price point.

NSX 220 joins the established NSX 320 system in the NSX family of automated macro defect inspection and metrology systems for final manufacturing facilities. The first NSX 220 system was installed in July at a major out-sourced assembly and test (OSAT) facility in Asia, says the firm.

"The NSX 220 system is a streamlined version of our NSX 320 system," says Mike Jost, VP & general manager of Rudolph's Inspection business unit. "The NSX 220 system is designed for traditional macro defect inspection of wafers up to 300mm at conventional semiconductor, MEMS and LED final manufacturing facilities, while the NSX 320 system serves next-generation advanced packaging processes with defect inspection and three-dimensional metrology for wafers up to 450mm. The NSX 220 system benefits from many of the hardware and software innovations that made the NSX 320 system the market leader in advanced packaging, but is targeted for back-end facilities that do not need the full suite of capabilities offered by the NSX 320 system."

The NSX 220 is an automated macro defect inspection system that uses gray-scale image analysis (with color image capture) to provide fast, accurate inspection and metrology in final manufacturing applications for wafers up to 300mm in size. It can detect traditional advanced macro defects such as scratches, mechanical damage, foreign materials, voids and probe damage, while also performing two-dimensional measurements on bumps, probe marks and edge trim processes. The system operates over a range of resolutions (10–0.5µm) with both brightfield and optional darkfield illumination. The software platform, leveraged from the NSX 320 system's success, uses host-based image processing and delivers significant improvements in usability and productivity over older-generation NSX Series equipment. Using centrally-managed recipe creation and editing, multiple NSX 220 tools can share a single recipe and be matched across the fab.

An optional suite of yield management software optimizes the productivity of both the NSX 220 and 320 systems and minimizes the need for operator assistance. Discover Software is designed for use with Rudolph inspection systems to allow real-time analysis for faster solutions and intelligent defect sampling for reduced offline review.

www.rudolphtech.com

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The Business of Science®

Kyma's AlN template production ramp leverages equipment design improvements

Kyma Technologies Inc of Raleigh, NC, USA, which provides crystalline gallium nitride (GaN), aluminum nitride (AlN) and aluminum gallium nitride (AlGaIn) materials and related products and services, has provided an update on its aluminum nitride (AlN) template manufacturing capability.

The fabrication of most of Kyma's products starts by using the firm's patent-protected plasma vapor deposition of nanocolumns (PVDNC) crystal growth process, which is implemented on its patented and proprietary PVDNC crystal growth tools.

The AlN templates are produced for both commercial sale and internal use for fabricating GaN templates,

bulk GaN substrates, and related products.

Until 2011 Kyma's PVDNC effort relied on early-generation PVDNC crystal growth tools which were useful for the firm's R&D stage but were not designed for high volumes. To keep up with growing demand for AlN and GaN products and the interest in larger-diameter products, in 2011 Kyma designed and built its first PVDNC production tool, which featured a larger-diameter platter and much faster growth cycle time. Related announcements made in 2011 and 2012 include:

(1) the expansion of AlN template manufacturing capacity; (2) the demonstration of a 12" AlN-on-Si template; and

(3) the demonstration of a 10" AlN-on-sapphire template.

Primary applications for Kyma's AlN templates are for visible LEDs and power switching electronics. Recently, demand has also grown for ultraviolet (UV) LED applications. There is interest in both AlN-on-sapphire and AlN-on-silicon for LED applications, while interest for power electronics applications is focused mostly on AlN-on-silicon.

Chief marketing officer Dr Ed Preble and technical sales engineer Tamara Stephenson have just completed a sales and marketing trip in the Asia-Pacific, focusing on application of Kyma's materials for LED applications.

www.kymatech.com

Kyma CEO takes role as NSF I-Corps program business mentor

Kyma has announced the participation of its CEO Keith Evans in the role of business mentor for a UNC Charlotte-led team in the National Science Foundation Innovation Corps (NSF I-Corps) program.

The primary aim of NSF I-Corps is to foster entrepreneurship that will lead to the commercialization of technology that has been supported previously by NSF-funded research. I-Corps Teams have three essential members: the principal investigator, the entrepreneurial lead and the mentor. Over a period of six months, each I-Corps Team learns what it will take to achieve an economic impact with its innovation. The I-Corps Curriculum enables Teams to systematically identify and address knowledge gaps in order to understand the most appropriate path forward for their technology concept.

The principal investigator for the team is professor Edward Stokes, professor of electrical and computer engineering at UNCC. His graduate student Matthew Conway took on the role of entrepreneurial lead.

Over the past couple of years, with support from NSF's Major Research Instrumentation (MRI) program, professor Stokes' research group has been developing a High-Pressure MOCVD for III-Nitride Semiconductor Devices. The group's high pressure MOCVD tool design benefits from advanced computer flow dynamics (CFD) simulations carried out by UNCC professor Mesbah Uddin, associate professor of mechanical engineering and engineering science and director of motorsports.

In the I-Corps program, the team evaluated a number of business models with a goal of finding one or more exciting paths for commercialization of the high-pressure MOCVD technology. In the I-Corps program, the team evaluated a number of business models with a goal of finding one or more exciting paths for commercialization of the high-pressure MOCVD technology.

"Our team learned an enormous amount during the 'customer discovery' process about the needs

and perspectives of potential commercial users of our research," Stokes said. "Their answers to our questions were not always what we thought they would be. The I-Corps program was especially beneficial in giving all the participating graduate students a crash course in real-world business. Finally, we deeply appreciated the opportunity to interact closely during the process with an experienced CEO like Keith Evans as our mentor," he adds.

"The I-Corps program is an outstanding opportunity for academics with potentially disruptive technologies to experience both the exhilaration and the many challenges of a high-tech startup experience," said Evans. "Ed and Matt put a lot of quality time and energy into it, and the program helped us to gain critically important insight into several business growth opportunities, including but not limited to those which might benefit from HP MOCVD."

www.nsf.gov

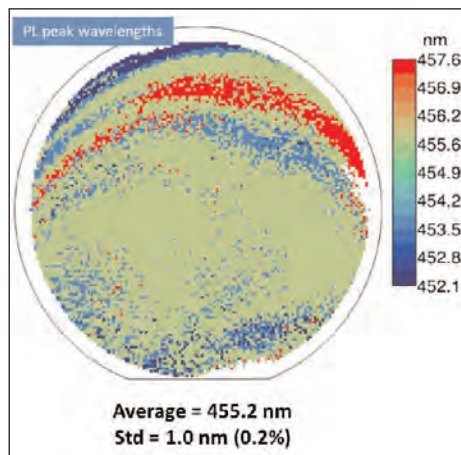
AZZURRO demonstrates '1 bin' wavelength LED wafer

Record 1nm standard deviation wavelength uniformity achieved in R&D; 3nm in production

At the 10th International Conference on Nitride Semiconductors (ICNS-10) in Washington DC, USA (26–28 August), AZZURRO LED Technologies of Dresden, Germany announced that it has demonstrated '1-bin' wavelength LED wafers. While showing production values of less than 3nm wavelength uniformity, the 1.0nm result came straight from development. The firm says that the record 1.0nm result demonstrates the capability to achieve '1 bin' gallium nitride on silicon (GaN-on-Si) LED wafers with AZZURRO's technology.

Formed in July to enable the LED industry's migration to GaN-on-Si, AZZURRO LED Technologies is a business unit of AZZURRO Semiconductors AG of Dresden, Germany, which makes GaN epitaxial wafers based on large-area silicon substrates for both LED and power semiconductor applications.

AZZURRO says that, after questions about achieving competitive brightness and efficiency levels have been answered by various GaN-on-Si contenders, the yield question has remained open. The large mismatches in both crystal lattice structure and thermal expansion coefficient between GaN and silicon cause a high degree of bowing in LED wafers during and



Wafer uniformity map, showing 1.0nm (0.2%) standard deviation.

after growth. This in turn has large negative impact on uniformity levels for wavelength, forward voltage and output power. AZZURRO uses its proprietary and patented strain-engineering and growth technologies to overcome these obstacles.

What is claimed to be breakthrough uniformity from production for wavelength (<3nm or 0.6%), forward voltage (1.3%) and output power (3.9%) for highly reduced binning were presented at ICNS-10, together with what is reckoned to be excellent crystal quality values for 150mm-diameter blue-emission GaN-on-Si LED wafers (where all values are standard deviation). At the same time, what

AZZURRO describes as equally impressive values for 200mm LED wafers show the technology's scalability. Manufacturability parameters such as low bow (<20μm) and good thickness uniformities (1.7%) are not compromised, notes AZZURRO.

The firm says that, based on these achievements, its technical team continues to push for the ultimate '1 bin' wafer as a target, and hence demonstrated the benchmark result for wavelength with 1.0nm (0.2%) uniformity and a minimum/maximum value of 5nm (one wavelength bin).

AZZURRO says that the latest results from production and R&D show that — in addition to the cost advantages from lower-cost substrates and using standard silicon fabs for LED chip processing — GaN-on-Si LED wafers with the right strain-engineering technology can also help to reduce binning dramatically.

"With these results we show that our GaN-on-Si technology can bring the LED industry closer to the aim of making '1 bin' LED wafers," comments AZZURRO's co-founder & CMO Alexander Loesing, who also heads the LED Technologies business unit.

www.azzurro-semiconductors.com

Bridgelux ranked among Inc. 500|5000 fastest-growing private firms

Bridgelux Inc of Livermore, CA, USA, which manufactures LED lighting technologies and solutions, has been ranked among Inc. Magazine's 500|5000 seventh annual ranking of the fastest-growing private companies in America for the third consecutive year (joining an elite group of companies including Microsoft, Intuit, Oracle and Facebook). For 2013, Bridgelux was ranked 871 among the Inc. Magazine top 5000 companies.

In the past year the company has launched its Vero LED arrays, which have high luminous efficacy of 120 lumens-per-watt and a unique chip-on-board LED design for future interconnected smart lighting solutions. Globally, Bridgelux strengthened its relationship with Toshiba to boost technology collaboration and signed a global distribution agreement with Future Electronics to broaden its reach into rapidly emerging markets for LED

lighting components.

"It is a true testament to the growth and expansion of the LED industry," comments CEO Brad Bullington on the firm's ranking. "Bridgelux is dedicated to building, innovating and delivering on cost effective, highly efficient lighting, and the consecutive confirmation from Inc. Magazine is a reflection of our progress and success."

www.bridgelux.com

www.inc500conference.com

Luminus Devices and Lightera complete merger

Merged firm to accelerate technology development & market expansion

Luminus Devices Inc of Billerica, MA, USA, which makes PhlatLight (photonic lattice) LEDs for solid-state lighting applications, and Lightera Corp of Sunnyvale, CA (a US affiliate of LED maker Sanan Optoelectronics Co Ltd of Xiamen, China that designs and develops LED components and system products for lighting applications) say that they have completed all merger activities (announced on 11 June). Luminus is now a subsidiary of Lightera, and will continue to operate under the name Luminus Devices.

The merged entity aims to utilize combined resources to accelerate the commercialization of new solutions and expand opportunities in core markets, including consumer displays, entertainment lighting and medical lighting. Expected synergies and corporate R&D expertise will increase the emphasis on advanced LED technology development for both the general lighting and specialty lighting markets.

"With solid financial backing, increased R&D resources, and access to the technology innovation

in Silicon Valley, we are in a position to more aggressively commercialize our existing portfolio while inventing new LED technologies in order to remain the leader in our core markets and enter new markets with a compelling value proposition," says Decai Sun, chairman & CEO of the combined firm.

Luminus Devices will continue to operate out of its Billerica headquarters and will gain access to Lightera's R&D operation in Sunnyvale.

www.lighterausa.com
www.luminus.com

Lumileds' LUXEON Q high-power LED boosts efficacy and flux in standard 3535 surface-mount package

Philips Lumileds of San Jose, CA, USA says that its new LUXEON Q LED delivers superior performance in a high-power emitter that serves as a direct drop-in replacement for products using the standard 3535 surface-mount package. LUXEON Q is the first high-power LED based on LUXEON flip-chip die, Lumileds' high-performance chip-scale package (CSP) device architecture.

Efficacy for the LUXEON Q is 135lm/W at a correlated color temperature (CCT) of 5700K with a color rendering index (CRI) of 70 and 115lm/W at a CCT of 3000K and 80 CRI (at a junction temperature of 85 °C and drive current of

350mA). "Our LED is especially competitive when it's driven harder," notes Kathleen Hartnett, product line director for LUXEON Emitters. "For instance, at 1 Ampere, a flux of more than 300lm at an efficacy of 102lm/W at 85 °C is achieved in neutral white at 4000K. The high efficacy at high drive current of the LUXEON Q emitter is achieved as a result of the industry-leading wall-plug and conversion efficiency of Philips Lumileds next-generation CSP architecture," she claims.

The LUXEON Q takes advantage of a fully developed ecosystem for 3535 components (including a wide

range of optics) to speed time-to-market for omnidirectional indoor and outdoor luminaires. Applications include high-bay and low-bay luminaires, downlights, outdoor wall packs, replacement lamps and specialty luminaires. "Customers are starting with a familiar LED package and can quickly build their products from there using readily available optics and other compatible components," says Hartnett.

The LUXEON Q emitter line is available in CCTs of 2700K, 3000K and 3500K at 80 CRI and CCTs of 4000K and 5700K at 70 CRI.

www.philipslumileds.com

Soraa appoints 1000Bulbs.com as online distributor of MR16 lamps

Soraa Inc of Fremont, CA, USA, which develops solid-state lighting technology built on 'GaN on GaN' (gallium nitride on gallium nitride) substrates, has appointed 1000Bulbs.com as an online distributor of its new MR16 lamps.

The Soraa MR16 is claimed to be the highest-performance LED MR16 halogen replacement lamp on the market. Compared with the Sun's

color rendering index (CRI) of 100, Soraa's Vivid series of LEDs has a CRI of 95. Soraa has also developed a heat adjustment technology that ensures the lamp will not over-heat in any environment.

With LEDs built from pure GaN substrates, the lamp consists of a single light source, producing crisp, clean lines with minimal light scatter, it is claimed, and suiting use

with track lighting systems in museums, art galleries, and retail stores.

Available in correlated color temperatures of 2700K and 3000K, the lamps have a life span of up to 30,000 hours and come with a three-year warranty.

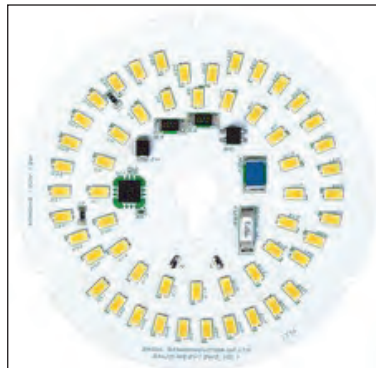
The entire Soraa line is available at www.1000Bulbs.com.

www.soraa.com

Seoul Semiconductor boosts Acrich2 module luminous efficacy to 140lm/W

South Korean LED maker Seoul Semiconductor says that its AC-driven Acrich2 LED modules are now achieving luminous efficacies of 140lm/W, nearly 20% up on previous versions. The technology has been incorporated into lighting fixtures already being sold in major North American lighting retailers and is now the highest-luminous-efficacy AC LED module in the global solid state lighting market, it is claimed.

The latest product being released is 10W and can achieve 1400 lumen in cool-white and 1250 lumen in warm-white color temperatures. It hence achieves the same level of luminous efficacy that a DC LED module of 180lm/W would offer, the firm says. The increased efficacy



The 140lm/W-efficient 120V Acrich2 module.

saves an additional 20% of power compared to the older versions. In addition, new arrangements of LEDs on the board optimize the light pattern for specialized solutions such as flush-mount ceiling lights for living rooms, kitchens and porches.

Seoul Semiconductor says that Acrich2 is the world's first module with an on-board IC and multi-junction technology (MJT) LEDs that can be directly plugged into the wall without a ballast, driver or converter. Newer variations of the Acrich2 family include smart functions such as dimming inputs and surge suppression circuits, boosting added value for lighting designers.

"Efficiency and design flexibility have been dramatically improved with the latest Acrich2 modules giving 140lm/W," says VP of marketing Marten Willemsen. "Acrich2 modules have already been adopted by well-known lighting manufacturers and are selling in major retail stores," he adds. "We believe the success of the Acrich2 LED modules will increase our market share in both the indoor and outdoor LED lighting markets."

● Acrich LEDs are powering streetlights installed on Weiyang road in China. This is the second installation of Acrich AC LED module streetlights, following Yangzhou city in April.

The LEDs in the Acrich2 AC LED modules are the Acrich MJT 4040, the new high power version of the Acrich multi-junction technology (MJT) family of high-voltage LEDs. The Acrich-powered solution provides a power factor of up to 0.99 and luminance efficacy of 100lm/W. Power consumption has been cut by more than 55% compared with high-pressure sodium lamps.

www.seoulsemicon.com/en



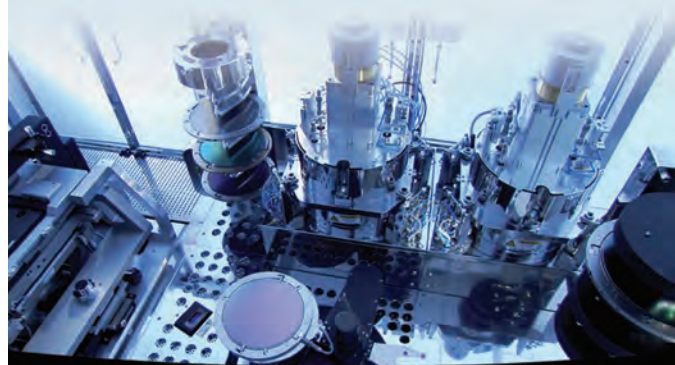
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www.EVGroup.com

IN BRIEF

Cree launches high-density class of XLamp CXA arrays

LED chip, lamp and lighting fixture maker Cree Inc of Durham, NC, USA has launched what it claims are the industry's first high-density (HD) LED arrays, doubling the system intensity of spot lights compared to previous arrays.

The firm says that the lumen density of the new HD class of CXA Arrays enables a major reduction in system cost and power consumption. The first HD Array, the CXA1520 LED, enables lighting manufacturers to create products that deliver the same intensity and light quality as 39W ceramic metal halide (CMH) at up to 50% lower power, Cree reckons.

The High-Density Cree XLamp Array extends Cree's robust CXA family to give lighting manufacturers a single integrated array family to address lighting applications from general-purpose floods to specialty retail spot lights. The XLamp CXA1520 LED Arrays deliver up to 3478 lumens at 33W (at 85°C). Available in ANSI White and four-step EasyWhite binning, they feature correlated color temperatures (CCTs) of 2700K through 5000K, with 70, 80 and 95-CRI (color rendering index) options.

"The new CXA1520 LED Array shares the same light-emitting size as the CXA1507 and CXA1512 LED Arrays," says Tom Tang, chairman & CEO of Tons Lightology Inc, which already has several designs based on CXA1507 and CXA1512 LED arrays. "This allows us to address very high-output applications without changing the optics."

XLamp CXA1520 LED Array samples are available now, and production quantities are available with standard lead times.

www.cree.com/cxa

Cree's TW Series bulb first to meet California Energy Commission spec

Cree says its latest TW (TrueWhite) Series LED bulb emits natural LED light and sets a new standard with a color rendering index (CRI) of 93. Cree's new TW Series bulb looks like a light bulb, lights like a light bulb, and is available for \$19.97 for the 60-watt replacement.

Cree's TW Series LED bulb is the first to meet the California Energy Commission (CEC) LED bulb specification. The CA specification focuses on six quality attributes for LED lamps, including color temperature, color consistency, color rendering, dimmability, lifetime and light distribution. The new CA standard requires all retrofit lamps to achieve a CRI of 90 or better. The higher the CRI of a bulb, the more accurate the actual color of the objects it illuminates.

The Sacramento Municipal Utility District (SMUD) has long been a proponent of energy-efficient lighting technologies for its customers. SMUD will provide a rebate for the new Cree TW Series LED Bulb. "SMUD sees huge value in reducing the lighting portion of electric bills and is a staunch supporter of the new CA LED Quality lighting standard," said Elisabeth Brinton, SMUD

chief customer officer.

"The Voluntary California Quality LED Lamp Specification was created to move consumers away from inefficient lighting of the past century and toward more efficient LED lighting technology," said Michael Siminovitch, director, California Lighting Technology Center. "The new Cree TW Series is the first bulb to meet the CA Specification and is exactly what consumers need to see in order to finally transform this marketplace."

Cree's TW Series LED bulb uses 78% less energy and lasts 25 times longer than typical incandescent light bulbs. The bulbs turn on instantly, are dimmable with most standard incandescent dimmers and are backed by Cree's 10-year limited warranty. With a retail price of \$17.97 for the soft white 40-watt replacement (450 lumens) and \$19.97 for the soft white 60-watt replacement (800 lumens), the Cree bulb quickly pays for itself, says the firm (based on TW Series LED Bulb 60-watt replacements at 13.5 watts, \$0.11 per kilowatt-hour, 25,000 hour lifetime and average use of six hours per day).

www.creebulb.com

Cree launches parking garage luminaire

Cree has launched the VG Series parking garage luminaire, which is designed to deliver optimal, low-glare illumination by eliminating direct view of the LEDs with a revolutionary optical system. The VG Series lowers total cost of ownership and can deliver payback in less than two years (compared with metal halide and based on commercial usage of 24 hours per-day and the national average of \$0.11 per kWh electric costs), says the firm.

The VG Series delivers energy savings of up to 73% compared with the metal halide fixtures they replace, while simultaneously deliv-

ering exceptional illumination quality, which can help to create a safer feeling in garages. The low-glare luminaire features a composite optical system combining a highly efficient internal reflector and a precisely designed prismatic lens. Designed with simplified mounting solutions for seamless installation in most parking garages, the VG Series also delivers up to 10% desirable upright, reducing the 'cave effect' that is typical with existing LED luminaires and many conventional solutions lighting parking garages today.

www.cree.com/lighting/VGseries



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IN BRIEF

Headlamp Pro used in 7" automotive headlight

Osram Opto's Ostar Headlamp Pro LED has been used by Peterson Manufacturing Company of Grandview, MO, USA in its new 7" round automotive headlight, representing Peterson's entry into LED automotive forward lighting.

Peterson says the LED provides a compact light source with multi-chip-on-board technology and silicon casting featuring ceramic chip-level conversion (C^2) and the latest chip technology (UX:3). The firm comments that the LED displays outstanding brightness and luminance due to pure surface emission and low thermal resistance (R_{th}) for thermal stability, and improved corrosion resistance.

As a high-end, high-power light source, the Ostar Headlamp Pro achieves the same output as a halogen lamp. Available in 2-, 3-, 4- and 5-chip versions, the compact multichip LED produces sufficient light from a small footprint (20mm x 20mm) that can be used for high-beam applications. With luminance of $40 \times 10^6 \text{cd/m}^2$ and a radiating surface of 5.5mm, the 5-chip version is suitable for automotive exterior lighting. Other benefits of the LED include a uniform light pattern, long lifetime and a scalable chip arrangement, allowing precise configuration to specific application requirements.

Peterson says its new 7" round aftermarket LED headlight has two Ostar Headlamp Pro LEDs per headlamp (one for low beam, one for high beam). The firm found the LED light sources to be much more efficient than halogen lights, drawing only 0.7–1.9A. A color temperature range of 5400–6300K closely simulates natural daylight. The solid-state dual-volt design is compatible with all 12V and 24V vehicles.

<http://pmlheadlights.com>

Ostar Headlamp Pro as first LED for Advanced Forward Lighting Systems

Osram Opto Semiconductors GmbH of Regensburg, Germany claims that, with its new Ostar Headlamp Pro, it has developed the first LED designed specifically for Advanced Forward Lighting Systems (AFS, i.e. headlight systems that, for example, adapt their illumination direction to the direction of the bend when driving through curves). The five chips of the new multi-chip LED (contained in a 20mm x 21mm package) can be individually controlled and thus flexibly switched on and off according to the driving situations and positions of other road users.

Osram Opto says that, due to LED technology, Advanced Forward Lighting Systems can be implemented more simply than before because no mechanical assemblies are required to move parts of the headlight or the complete headlight. With LEDs such as the new Ostar Headlamp Pro, the individual chips are specifically switched on and off via intelligent control. The control uses sensors and electronic components for high beam light without glare by flexibly concealing areas within the light cone of the headlight according to the specific driving situation and with dynamic adaptation to the positions of other road users. It is also due to LEDs that adaptable cornering lights and spot lights can be easily implemented for illuminating possible obstacles at the edge of the carriageway.

Osram Ostar Headlamp Pro

Multi-chip LEDs with higher performance classes are needed for use in headlights. Osram Opto says that the Ostar Headlamp LED range features high-performance-capable technology, homogeneous luminance and temperature stability, and is hence especially suitable for high-power applications (the reason why LEDs of this family have been used since 2008 for various automotive lighting functions). In particular, for

New variant of Ostar Headlamp Pro



the Ostar Headlamp Pro, typical light intensity (at 500mA/25°C) is 710lm (minimum). "Osram Ostar Headlamp Pro is now the first LED specifically developed for use in AFS," says Peter Knittl, who is responsible for LED Automotive Marketing at Osram Opto. "Its five chips each with one square millimeter can be controlled individually, forming the basis for intelligent light solutions," he adds.

Optimal vision for vehicle drivers

"Intelligent headlight systems with our light-emitting diodes give car drivers optimal vision even on the edges of roads or with approaching vehicles, offering better protection from possible accidents," says Knittl. "Thanks to the five individually controllable chips, more than one road user can be concealed from view and the intermediate area is still completely illuminated," he adds. A distinct bright-dark contrast of 1:65 between illuminated and non-illuminated chips is required so that the AFS is as effective as possible and the light beam on the road is optimally transmitted. This means that concealed chips must be genuinely dark and must not be illuminated by their adjacent chips. An integrated shutter also enables a clearly defined light beam from the headlight.

The Osram Ostar Headlamp Pro was unveiled at the 10th International Symposium of Lighting Technology (ISAL 2013) in Darmstadt, Germany (24–25 September).

www.osram-os.com



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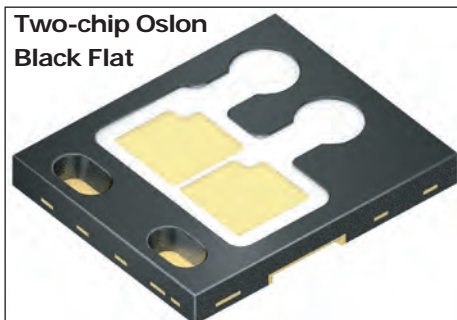
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Osram's Oslon Black Flat now available with two chips

Osram Opto Semiconductors GmbH of Regensburg, Germany has introduced a new two-chip version of its Oslon Black Flat Oslon Black Flat LED, targeting automotive applications.

As with other LEDs in the Oslon Black Flat family, the new version features a high level of brightness and is suitable for all headlight functions. Due to the firm's UX:3 chip technology (which improves thermal resistance), the new Oslon Black Flat features high light output even with high currents (more than 500 lumens at 1A). The high brightness is emitted from a very compact package, with dimensions of 3.1mm x 3.75mm and a height of 0.5mm. "We are bringing into our portfolio a significantly slimmer LED than the previous version to enable even more compact headlight systems," says LED product marketing manager Michael Martens. The new 2-chip LED is suitable for all headlight functions such as low beams and high beams and fog lamps, and is ideally suited for daytime running lights with light



guides (where optical in-coupling is key), reckons Osram Opto.

Cost savings via SMT

The new LED's main advantage is that, as an SMT (surface-mount technology) component, like other electronic components it can be attached directly to the printed circuit board and then processed with other components as part of a standard soldering process. "This soldering capability enables integration of the LED into a simple, standardized process and reduces the complexity of the processing steps, which saves a good deal of time and costs," says Martens.

Good stability and homogeneous light distribution

Further benefits of the Oslon Black Flat LEDs are their homogeneous distribution of light, very good contrast ratio and cyclic stability, says Osram Opto. The black QFN (quad flat no leads) housing expands in a similar manner to the circuit board during high temperature cycle loads. Soldered joints are hence considerably stronger and exposed to much less strain.

A special sealing technology, together with the sophisticated package and a ceramic phosphor converter, enables a highly uniform distribution of light as well as good contrast conditions on roads, claims Osram Opto. This is abetted by the chip encapsulation (which allows a defined bright/dark border in the light beam) as well as the high contrast of the luminous surface of both chips in relation to the package.

Samples of the Oslon Black Flat are available now, and volume start-up is planned for the beginning of 2014.

www.osram-os.com

Opto Diode launches high-output 850nm IRLED for night-vision

Opto Diode Corp of Newbury Park, CA, USA has launched the OD-669-850 high-power GaAlAs infrared IRLED illuminator. Suitable for night-vision illumination tasks, it features high optical output, from 800mW (minimum) to 1250mW (typical) and a peak emission wavelength of 850nm.

Spectral bandwidth at 50% is typically 40nm, and the half-intensity beam angle is 120°. All surfaces on the standard 2-lead, TO-66 electrically isolated package are gold plate.

The OD-669-850's operating and storage temperatures range from -40°C to +100°C with a maximum junction temperature of 100°C.

Power dissipation (under absolute maximum ratings at 25°C) is 6W, with a continuous forward current of 370mA, a peak forward current of 1A and reverse voltage at 5V. The lead soldering temperature (at 1/16-inches from case for 10 seconds) is 260°C.

www.optodiode.com

DILAS launches conduction-cooled, 200µm-fiber-coupled modules at 1470nm and 1530nm for medical applications

Diode laser maker DILAS of Mainz, Germany has expanded its conduction-cooled, fiber-coupled diode laser modules at 1470nm and 1530nm to include 200µm, NA0.22. With 12W output power, the sealed modules are suitable for the medical market, primarily for surgical appli-

cations that demand high-power, stable sources with the smallest fiber diameters, says the firm.

The new modules are based on the firm's single-bar configurations, which deliver the output power via a standard 200µm, NA0.22, SMA-905 fiber connector.

With operating current of <60A and voltage of <1.4V, the modules feature options such as a monitor photodiode, a visible pointer, serial fiber interlocks, and a user-exchangeable protection window, providing flexibility for integration into larger systems.

www.DILAS.com

Vishay releases high-power, high-speed 940nm infrared emitter for gesture remote control applications

Vishay Intertechnology Inc of Malvern, PA, USA has broadened its optoelectronics portfolio by introducing an aluminium gallium arsenide (AlGaAs) multi-quantum well (MQW)-based high-power, high-speed 940nm infrared emitter for gesture remote control applications. Offering high radiant power of 40mW at 100mA, the VSLB9530S is offered in a clear molded, leaded TELUX package with an oval lens designed to support an angle of half intensity of $\pm 18^\circ$ in the vertical direction and $\pm 36^\circ$ in the horizontal direction, says the firm.

The device's unique angular distribution makes it suitable for gesture remote control of TVs and gaming systems, where it provides spectral matching with silicon photodetectors. The IR emitter's wider angle in the horizontal view helps maintain position flexibility for users, while the narrower angle in the vertical plane focuses the distributed radiant intensity.

The TELUX package of the VSLB9530S measures 7.62mm by 7.62mm by 4.6mm and provides a low thermal resistance of 200K/W. While standard IR emitters typically offer drive currents to 100mA, the low thermal resistivity of the VSLB9530S allows continuous drive currents up to 150mA, which pushes the achievable radiant intensity to 60mW/sr at 150mA. The device offers high modulation bandwidth of 24MHz and is suitable for high-pulse-current operation.

The infrared emitter offers fast switching speeds down to 15ns, low forward voltage down to 1.31V at 150mA, and an operating temperature range from -40°C to $+95^\circ\text{C}$. Compatible with wave solder processes according to CECC 00802, the VSLB9530 is compliant

to RoHS directive 2011/65/EU, halogen-free per JEDEC JS709A, and conforms to Vishay's 'Green' standards.

Samples and production quantities are available now, with lead times of 6–8 weeks for large orders.

www.vishay.com

The device's unique angular distribution makes it suitable for gesture remote control of TVs and gaming systems, where it provides spectral matching with silicon photodetectors

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Oclaro's revenue falls 4% quarter-on-quarter

Losses trimmed; financial restructuring underway

For its fiscal fourth-quarter 2013 (ended 29 June), Oclaro Inc of San Jose, CA, USA, which provides lasers and optical components, modules and subsystems for optical communications, has reported revenue of \$136.1m, down 3.9% on \$141.6m last quarter.

Datacom revenue was \$43m (31.5% of total revenue, up from 28% last quarter). Telecom revenue was \$76m (56% of revenue), down on \$83.1m (59%) last quarter.

"Like many in our peer group, we have seen a bit more strength in Datacom and Telecom," comments chief financial officer Jerry Turin. Industrial and Consumer revenues were \$17m (12.5% of the total). Oclaro's 10%-or-greater customers were Cisco (13%) and Huawei (11%).

R&D expenses were \$23.9m, cut from \$25.2m. SG&A (selling, general & administrative) expenses were \$21.6m, cut from \$22.5m. Combined these represent a 4% reduction in operating expenses quarter-on-quarter. "We anticipate making significantly more reductions in the future," notes Turin. In addition, Oclaro received a \$18.9m credit associated with proceeds under insurance claims relating to the flooding in October 2011 at Thailand-based primary contract manufacturer Fabrinet Co Ltd). "Any remaining cash proceeds from insurance settlement will be limited to \$2.5–3.5m," Turin believes.

Despite the drop in revenue, on a non-GAAP basis gross margin has risen from 10% to 11%. Net loss was \$30.3m, cut from \$33.4m last quarter. Adjusted EBITDA was –\$21.1m, an improvement from –\$23.7m. During the quarter, cash, cash equivalents, restricted cash and short-term investments rebounded from \$80.5m to \$87.6m.

"Continued losses underscore the urgency of our turnaround plans," commented CEO Greg Dougherty.

"Our sale of the Zurich business [Oclaro Switzerland and its associated laser diodes business division to

II-VI Inc on 12 September] demonstrates that we are taking action to create a stable future," he adds.

"We expect to collect \$14.5m of the receivables of the Zurich business that the terms of sale allow us to retain, up to \$8m of additional Zurich deal proceeds upon the clearing of traditional closing conditions in the future," said Turin. "We expect to pay in the range of \$5–6m in professional fees and related costs associated with the Zurich deal. If II-VI exercises its option to purchase our amplifier business and that deal closes, we would expect to collect another \$83m," he added.

"With the resulting cash, we can now take the necessary steps to restructure the company. Our goal will be to focus Oclaro primarily on the optical communications market, and leverage our photonics innovation and long-term customer relationships to return to profitability."

Reorganization

Dougherty explains how he will use proceeds from the sale to rebuild Oclaro: "The first thing that we have done is to fully repay our bank borrowing. We plan to begin a substantial restructuring plan which will focus on aligning our operating expenses and manufacturing overhead with our revenues, further reducing our global footprint and streamlining our organization, the objective being to quickly and dramatically reduce our cash burn.

"We have built a company that is far too complex for its size. We have not effectively integrated our acquisitions and not realized the corresponding synergies such as using more of our own components

With the resulting cash, we can now take the necessary steps to restructure the company. Our goal will be to focus Oclaro primarily on optical communications

within our modules and subsystems. We have not completed our various outsourced manufacturing transition on the schedule and costs that were established. Our R&D investments have been spread too thinly over too many technologies and products while they are often also focused on manufacturing transfers," Dougherty added.

"The keys for us to be successful are to simplify our company in terms of geography and organizational structure, to prioritize our activities so that we excel at what we choose to do, such as in R&D where we will invest our resources so that we can offer differentiated products in large and fast-growing markets, and to improve our execution through more focused and greater accountability," Dougherty continued.

"The results of this action should bring us substantial improvements in efficiencies and cost structure. We have already begun to take some actions to put us on the right path. Some examples of these are: for our Wavelength Selective Switch (WSS) product line, the platform itself is behind the market and it would require significant investment in terms of dollars and time to enable switching when using a flexible grid. We've decided to no longer invest R&D in this product area. We have consolidated all of our WSS operations at our Korean manufacturing site and have shutdown the WSS activities at facilities in New Jersey and Israel. The de-emphasis of WSS — in addition to the sale of the Zurich business, including the Tucson site — have already reduced our number of sites by four, and we plan to continue to take actions to simplify our global footprint.

"To better serve our customers with our technology we have focused our components R&D on indium phosphide (InP) tunable lasers with and without an integrated Mach-Zehnder modulator for 100G coherent, our micro-iTLA, our 100G coherent

Oclaro sells Zurich GaAs laser business to II-VI for \$115m and receives \$5m for option to sell amplifier & micro-optics business for \$88m

Oclaro has sold its Oclaro Switzerland GmbH subsidiary and associated laser diodes business to II-VI Inc (a provider of engineering materials and optoelectronic components) in a transaction valued at \$115m. II-VI also acquired an exclusive option to purchase Oclaro's optical amplifier and micro-optics business for \$88m in cash.

"The sale of our gallium arsenide laser diode business is an important first step in our plan to restructure," says CEO Greg Dougherty. "The Zurich-based business, including the team and its rich legacy, is a valuable asset," he adds. "We will use the proceeds from the sale to fully repay our bridge financing and to begin restructuring the company for the future. We intend to further simplify our operating footprint, reduce our cost structure and focus our R&D investment in the optical communications market

where we can leverage our core competencies."

Of the total transaction value of \$115m, Oclaro has received \$92m in cash. Oclaro will retain existing accounts receivable of the business, estimated at \$15m. The remaining \$8m is being held by II-VI subject to traditional post-closing conditions.

As part of the deal, II-VI has purchased the Oclaro Zurich, Switzerland company, which includes its GaAs fab, as well as the corresponding high-power laser diodes, vertical-cavity surface-emitting laser (VCSEL) and 980nm pump laser product lines, including intellectual property, inventory, equipment and a related R&D facility in Tucson (all of which are associated with these businesses). Revenues for the Zurich business were \$87m for the fiscal year ended 29 June 2013.

Oclaro will continue back-end manufacturing of the 980nm

pump laser and some high-power laser diode products at its plant in Shenzhen, China, and supply them to II-VI under a manufacturing services agreement. Staff in Shenzhen will continue to be employed by Oclaro. Also, various supply and transition service agreements have been established between the firms to ensure a smooth transition.

The option to purchase Oclaro's optical amplifier and micro-optics business, for which II-VI separately paid \$5m in cash, will expire if not exercised within 30 days. If this option is exercised and II-VI purchases the amplifier and micro-optics business, the option price will be applied to the purchase price. If II-VI does not exercise this option, the \$5m payment will be retained by Oclaro.

Total proceeds hence already received by Oclaro are \$97m.

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► lithium niobate modulators, our integrated 10 gigabit tunable [TOSA] with low power consumption, laser modulators for tunable XFP+, and lasers (either direct or externally modulated) for high-density 40G and 100G client interfaces.

"On the client side, we have strong customer traction on our 40G and 100G products. We are focused on reducing size and power consumption without compromising performance for all of the leading form-factors such as CFP, CFP2 and QSFP+.

"For high-speed Internet, Ethernet and enterprise networks, we have seen increased penetration of our 100G CFP Gen2, which is available on both single- and dual-rate variance, as well as our CFP2. For data-center connectivity, we are planning to ramp up our 40G client QSFP+. We continue to leverage our 10G tunable technology to migrate fixed-wavelength transceivers to tunable XFP and SFP+. And finally, we have enjoyed a lot of success recently with our transceivers for use in

wireless backhaul infrastructure," concluded Dougherty.

"In support of this strategy and to create a more variable and flexible business model, we remain committed to transitioning to outsource back-end manufacturing with the transfer out of our Shenzhen manufacturing scheduled for completion in fiscal 2015."

Forecast

For fiscal first-quarter 2014 (ending 28 September 2013), Oclaro expects revenue of \$134–138m, non-GAAP gross margin of 9–11%, and adjusted EBITDA of –\$24m to –\$19m. Guidance includes the expected results of the Zurich business through to the transaction's closing date of 12 September.

"Guidance for September implies continuing operating cash burn going forward, and we also expect to incur significant restructuring cost in the future," noted Turin.

"In the mean time, we continue to have our line in place with Wells Fargo. Our ability to draw on that

line in the future though will be subject to negotiation of certain terms and conditions scheduled to take place over the upcoming weeks. We no longer have any borrowings outstanding from Providence."

"We now have the funds to begin our restructuring and turnaround," commented Dougherty. "Earlier in September, we finalized two transactions with II-VI Inc. The first transaction, the deal valued at \$115m, was the sale of our high-power laser, VCSEL, 980nm pump laser businesses, including our Zurich subsidiary and GaAs fab, as well as our Tucson R&D facility. By the second transaction, II-VI has secured an exclusive 30-day right to purchase our amplifier and micro-optics business for a total of \$88m," he added. "To secure this right they paid a non-refundable fee of \$5m, so the total cash proceeds received for both transactions was \$97m."

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Matthew Peach, Contributing Editor

Oclaro showcasing 100G products and technology for client-side and coherent line-side applications at ECOC

Oclaro Inc of San Jose, CA, USA, which provides lasers and optical components, modules and subsystems for the optical communications, industrial, and consumer laser markets, has announced the continuing expansion of its 100G product offerings for both datacom and telecom implementations.

Also, the firm hosted customer meetings and highlighting its client- and line-side product portfolio at the 39th European Conference and Exhibition on Optical Communication (ECOC 2013) in London, UK on 23–25 September.

Featured products designed for line-side applications, and based on indium phosphide technology, include highly integrated components that enable next-generation coherent pluggable transceivers for 100G and 200G applications in both the CFP and CFP2 form factors. Oclaro has recently started sampling its components to select customers for system-level testing, and results show that the performance meets the requirements of both metro and regional DWDM (dense wavelength division multiplexing) networks. Some of the recent progress is also being discussed in the technical and Market Focus presentations listed below.

Oclaro has also separately announced the following product news:

- volume production of the client-side, dual-rate 100G LR4 CFP2 transceiver module;
- sampling of its 10G SFP+ 2km-reach transceiver for wireless backhaul applications;
- availability of the 10G DWDM tunable SFP+ transceiver;
- volume production of its narrow-linewidth micro-iTLA; and
- an advanced Raman and hybrid-EDF amplification solution for next-generation networks.

Oclaro's presentations at ECOC included the following:



Oclaro's TL5300 Series LambdaFLEX micro-iTLA tunable laser.

InP-enabled 100G/200G coherent
Market Focus Theatre presentation — 'Next Generation High Bit Rate Coherent Interfaces': Andy Carter, chief scientist and optical technology expert at Oclaro spoke about the role of InP-based components to achieve next-generation small-form-factor and pluggable coherent transceiver designs.

Technical Conference Presentation Mo.3.C.2 — 'Progress in Indium Phosphide-based Photonic Components and Subsystems for Digital Coherent Systems at 100Gbit/s and above': Oclaro's technology & systems director Wladek Forsiak presented an invited paper focusing on progress in InP-based photonic components and subsystems that enable cost-effective, compact and scalable new transceiver solutions for 100G and beyond.

Technical Conference presentation Th.1.B.3 — 'Narrow Linewidth, High Power, High Operating Temperature Digital Supermode Distributed Bragg Reflector Laser', Sam Davies, senior R&D engineer for Oclaro, discussed the use of monolithic InP-based lasers for high production volumes to support metro/regional and long-haul systems and future laser-modulator integration that will further reduce the cost and size of coherent transmitter solutions.

10G DWDM tunable SFP+
Poster presentation — 'Monolithic Integration of AlInGaAs DS-DBR

Tunable Laser and AlInGaAs MZ Modulator with Small Footprint, Low Power Dissipation and Long-Haul 10Gb/s Performance': Andrew Ward, principal engineer and scientist from Oclaro Caswell, UK, focused on tunable pluggable transceiver modules that meet the requirements for full tunability together with transmission perform-

ance to support metro/regional and long-haul DWDM systems while delivering on a dramatically lower size and power dissipation compared with 300-pin transponders.

Amplification

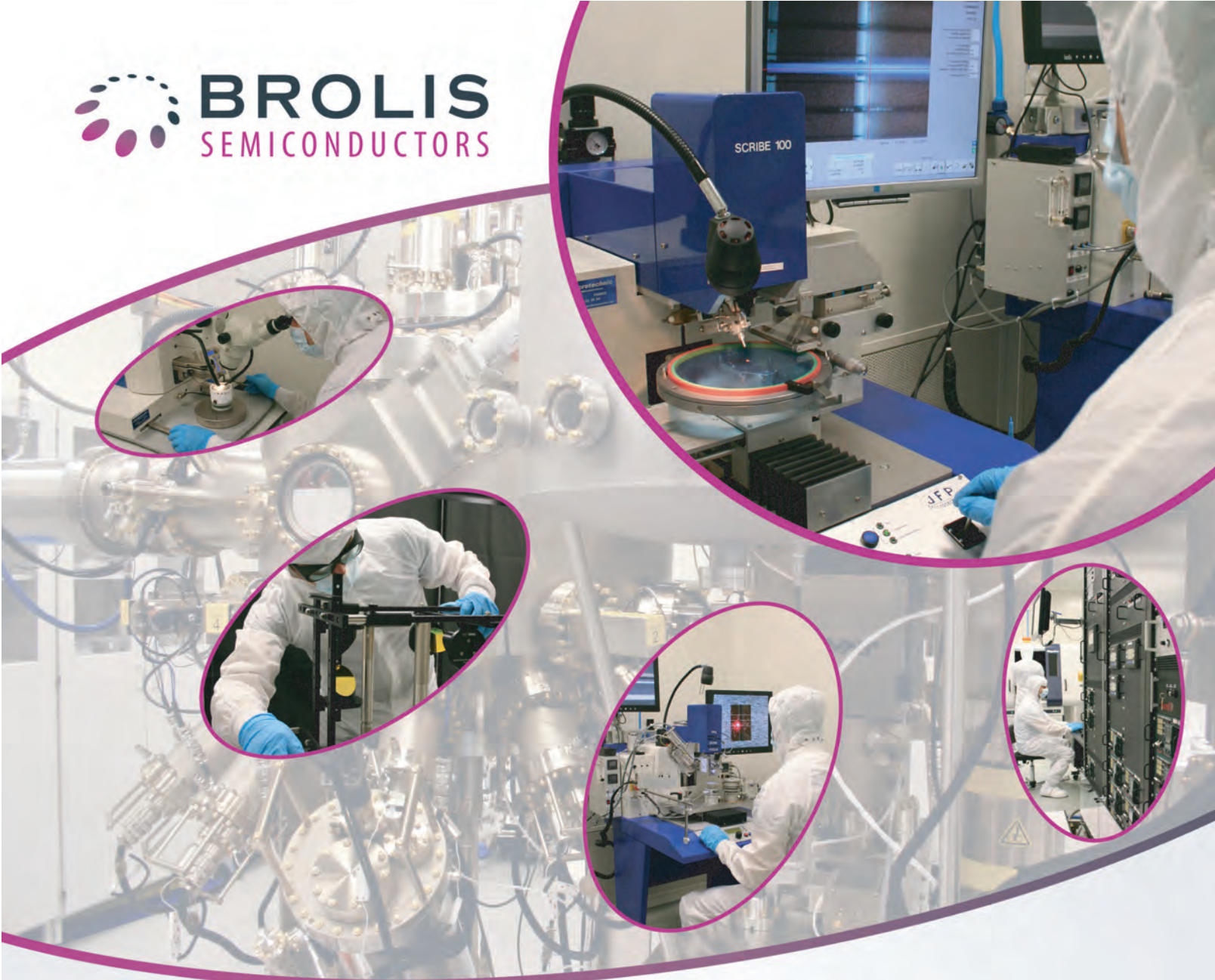
Market Focus Theatre presentation — 'Advanced amplification technologies for optical mesh networking': Per Hansen, VP for Optical Network Solutions at Oclaro, provided an overview on future meshed network amplification requirements that have spawned advances in amplifier designs, uncooled multi-chip pumps, amplifier components and features for operational simplicity including 'intelligent' hybrid Raman-EDFAs.

Client-side 100G

ECOC Workshop — 'VSR Interconnect Workshop: Technologies for Short Reach Optical Interconnects': Kiyo Hiramoto, product marketing manager with the Oclaro Japan modular device business unit, highlighted Lens-integrated Surface-emitting DFB Laser (LISEL) arrays operating at 25–40Gb/s per channel. LISEL technology is predicted to be an alternative to VCSELs in the future development of 40G and 100G client-side, ultra-small transceiver technology and beyond for optical backplane and interconnects that support data-center applications.

www.ecoc2013.org

www.oclaro.com



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Oclaro samples 2km-reach multi-rate 10G SFP+ CPRI transceiver for wireless backhaul

Oclaro is sampling the TRS5013WV, a low-cost 10G Ethernet SFP+ transceiver for single-mode-fiber applications up to 2km.

The 10G SFP+ CPRI transceiver is a pluggable module optimized for wireless backhaul and is compliant with the IEEE 10G Ethernet transceiver standards as required by the Common Public Radio Interface specification covering the CPRI rates from 2457.6Mb/s (Option 3) to 9830.4Mb/s (Option 7).

The SFP+ CPRI transceiver uses a Fabry-Perot (FP) laser to keep design costs low while offering high performance with a reach of 2km over single-mode fiber and an extended temperature range of -40°C to +85°C, covering the majority of antenna backhaul connections. The transceiver is also compliant with OBSAI specifications and applications.

Mobile devices continue to grow in numbers and usage as the preferred

interface for high-bandwidth media consumption and video communications, says Oclaro. This is driving a rapid increase in bandwidth needs throughout the wireless backhaul network, including the very cost-sensitive 'last mile' to the antenna. A high percentage of these CPRI links tend to span less than 2km. However, a CPRI-compliant SFP+ transceiver cost-optimized for these short distances has not been available until now, and the industry has had to rely on more expensive transceivers with a reach of 10km. Oclaro's 10G SFP+ CPRI transceiver fills the need for these distances while meeting the harsh environmental requirements for wireless backhaul applications, says the firm.

"Upgrades of wireless networks to 4G create a strong demand for optical connectivity to support the wireless infrastructure," comments Vladimir Kozlov PhD., founder & CEO of LightCounting Market Research.

"A high percentage of the connections between the base-station and antenna towers are relatively short, requiring transceivers that can support distances up to 2km. Demand for 10Gb/s connectivity will be strong within the wireless industry. Over the past three years, this market segment has experienced annual growth rates of 50–100% per year. This has led the transition to higher data rates: from 3Gb/s to 6Gb/s and now 10Gb/s," he adds.

"Today's announcement is another milestone in our quest to offer high-performance cost-efficient transceiver solutions and help enable a bandwidth-rich wireless network infrastructure," says Atsushi Takai, VP & general manager, Oclaro Japan Inc, Pluggable Division of Modules & Devices business unit.

The 10G SFP+ transceiver for CPRI wireless backhaul applications is sampling now and is due for mass production at the end of 2013.

Oclaro releases narrow-linewidth micro-iTLA to volume production

Oclaro has begun volume production of its next-generation tunable laser platform.

The narrow-linewidth micro-iTLA (integrable tunable laser assembly) is targeted specifically at coherent systems, where a high-performance laser is needed for both the transmission and the local oscillator laser. The micro-iTLA features high optical output power and off-grid tuning suitable for applications in 100G and next-generation 200G coherent networks based on the PM-QPSK and 16-QAM modulation formats.

"100G coherent shipments are increasing dramatically, and we expect that shipments in 2014 will be above 40,000 ports," says Daryl Inniss, practice leader for Components at market research firm Ovum Ltd. "Each of these coherent ports will require one or two narrow-linewidth lasers, and we're excited

to see component manufacturers such as Oclaro support the growth of 100G by introducing and ramping production of components such as this narrow-linewidth micro-iTLA," he adds.

"We are pleased to have successfully completed qualification, and are actively engaged with multiple customers and have completed several design-wins with our new tunable laser platform," says Yves Hardy, VP of Transmission Product Management at Oclaro. "With this product offering, Oclaro is simplifying the migration to coherent at both the line-card and module level, and the technology is also enabling next-generation 100G and 200G pluggable form factors."

The micro-iTLA is compliant to the OIF Multi-Source Agreement, and incorporates a form factor that is three times smaller than the stan-

dard iTLA and has a significantly reduced power consumption, both of which enable further size reductions in coherent modules to be supported while reducing thermal concerns. The ultra-high optical power output, combined with power and frequency fine tuning, gives greater flexibility to network designers, says Oclaro. The proven reliability of the indium phosphide (InP) chip technology and packaging allows users to manufacture high-reliability systems, the firm adds.

Oclaro makes tunable products for transmission systems, and this platform is part of its roadmap of next-generation products that builds on the legacy of its InP portfolio.

The micro-iTLA has been shipping to key customers throughout 2013. Oclaro is now ramping production to support demand in Q4/2013.

www.oclaro.com

Oclaro announces standards-compliant multi-rate 10G DWDM tunable SFP+ optical transceiver

Oclaro Inc of San Jose, CA, USA, which provides lasers and optical components, modules and subsystems for the optical communications, industrial, and consumer laser markets, has unveiled a standards-compliant, multi-rate DWDM tunable SFP+ optical transceiver that supports rates between 9.95Gb/s and 11.3Gb/s and is tunable across the entire C-band with 96 channels on the 50GHz grid defined by ITU-T.

The transceiver module complies with revision 4.1 of the SFF-8431 specification for 'Enhanced Small Form Factor Pluggable Module SFP+'. The tunable SFP+ supports multiple receiver interfaces, including PIN or APD photodetectors for the optical interface as well as limiting or linear electrical interfaces, based on customer requirements.

The tunable SFP+ transceiver module targets next-generation enterprise, metro and regional opti-

cal network equipment, continuing the replacement of fixed-wave-length modules and of non-pluggable ports. Oclaro says that this form factor allows network equipment manufacturers to reduce the size and power consumption for 10G connections while supporting network operators' rapidly increasing capacity needs driven by data-heavy network applications. It will also allow form-factor commonality between client- and line-side, offering greater flexibility in equipment configurations.

"I expect the volume of 10G DWDM SFP+ transceivers to grow significantly over the coming years," says Andrew Schmitt, principal analyst, Optical at market analyst firm Infonetics Research. "The advent of 10G tunable SFP+ transceivers in the market will accelerate that trend as tunability is critical for minimizing inventory and enabling

flexible rapid service provisioning," he adds. "This is an important step towards meeting the world's growing bandwidth demands with space-, power- and cost-efficiency network solutions." Schmitt believes.

"We are leveraging the technology building blocks and chip designs that enabled our leadership in 10G tunable MSA transponders and tunable XFP – in particular the monolithically integrated laser Mach-Zehnder [ILMZ] design," says Tadayuki Kanno, president, Oclaro Japan Inc & general manager, Modules & Devices business unit. He specifically cites the firm's in-house compact, low-power tunable TOSA (transmit optical subassembly) based on a proprietary monolithically integrated laser Mach-Zehnder (ILMZ) chip.

The tunable SFP+ transceiver will be sampling in fourth-quarter 2013.

www.oclaro.com

Oclaro announces volume production and OTU-4/100GbE FPGA interoperability for dual-rate 100G CFP2

Oclaro says that its dual-rate 100G CFP2 LR4 transceiver, which is fully interoperable with the second-generation 100G CFP LR4 transceiver, supporting both OTU-4 and 100GbE interfaces, has joined that module in volume production.

About 30 customers have already qualified or are in the process of qualifying the 100G pluggable LR4 transceiver modules. The 100G MSA-compliant CFP2 LR4 module recently completed interoperability testing with the Xilinx Virtex-7 H580T FPGA for OTU-4 based on the OIF CEI-28G-VSR board interface specification. Both the CFP and CFP2 LR4 modules have now passed testing for both data rates.

Oclaro says a fully interoperable pair of CFP and CFP2 LR4 transceivers offer network equipment manufacturers the flexibility to rapidly and easily capitalize on the

smaller form factor and lower power consumption of the CFP2, while offering customers an upgrade path from deployed equipment with CFP cages to increase system front-panel bandwidth with higher module density and/or to lower system power consumption per 100G interface. As the CFP MSA standard continues its growth as the form factor of choice for adoption in many 100G enterprise and data-center applications, Oclaro reckons it is well placed to help users lead this next phase of high-speed networking.

"Xilinx and Oclaro have successfully achieved interoperability between the Xilinx Virtex-7 H580T FPGA and the Oclaro 100G CFP2 LR4 optical module, showing an error-free connection at 28.0Gb/s," notes Gilles Garcia, director of Wired Communications at Xilinx.

"Together with previously demonstrated interoperability at 25.7Gb/s, system OEMs designing transport, networking and data-center applications can now realize 100 Giga-bit Ethernet and 100G OTL4.4 applications with lower cost and power, enabling either more efficient or higher-density network line-cards," he adds.

"We are delighted to see the interest from our customers for both our 100G CFP and CFP2 LR4 transceiver products. This confirms the value of our strategy to continuously work to reduce size and power while providing backward compatibility when possible to ease customer adoption," says Yoshikazu Era, general manager, Oclaro Japan Module Division.

The second-generation CFP and CFP2 transceivers are in volume production and available now.

OIF showcases record number of interoperability demonstrations at ECOC

At the 39th European Conference on Optical Communications (ECOC 2013) in London, UK (23–25 September), the Optical Internetworking Forum hosted a record number of multi-vendor interoperability demonstrations.

Addressing a wide range of technologies supporting 100G and 400G architectures, 11 firms verified the interoperability of their products in nine separate demonstrations illustrating the feasibility of building and implementing next-generation 100G and 400G capabilities into products today.

‘OIF Interoperability 2013 – Enabling the Next-Generation of 100G Architectures’ addresses a variety of OIF-supported technologies including CEI-28G-VSR chip-to-module interfaces for CFP2 and QSFP28 pluggable module form factors, CEI-25G-LR backplane applications, module thermal specifications, and SerDes interconnect solutions.

“The OIF has defined a robust 25G channel technology that the industry is now adopting for 25G, 50G, 100G and 400G applications,” says OIF Physical and Link Layer Interoperability Working Group chair Ed Frlan of Semtech Corp in Camarillo, CA, USA (which supplies analog and mixed-signal semiconductors for high-end consumer, computing, communications and industrial equipment). “By showing that the technology interoperates with multiple vendors in hardware that is available today, the industry can now leverage the investments made in 25G technology for future 100G and 400G applications,” he adds.

The following firms participated in OIF Interoperability 2013: Amphenol, Applied Micro, Cisco, Finisar, Fujitsu Optical Components, Inphi, Molex, MoSys, Semtech, TE Connectivity, and Xilinx.

Technologies demonstrated during the testing included host ICs with VSR SerDes capability, host PCB

traces, optical module connectors, high-speed electrical I/O and backplane connectors, module re-timers, heat sinks and optical transceivers all operating with 28G electrical interfaces. Agilent Technologies Inc and Tektronix Inc supplied test equipment used in the demonstration.

OIF leadership speaking at ECOC
OIF leadership was invited to speak to ECOC attendees on OIF activities and work efforts:

- ‘Evolution of System Electrical Interfaces Towards 400G Transport’ – Semtech’s Ed Frlan (OIF PLL Interoperability Working Group chair) and TE Connectivity’s Nathan Tracy (OIF Technical Committee vice chair);
- ‘Requirements and Technologies for Transport SDN’ – Verizon’s Vishnu Shukla (OIF president) and Deutsche Telekom’s Hans-Martin Foisel (OIF Carrier Working Group chair and board member).

www.ecoc2013.org

www.oiforum.com

Molex showcases data transmission technologies at ECOC

At ECOC 2013, fiber-optic interconnect firm Molex Inc of Lisle, IL, USA exhibited high-speed, high-density solutions, including fiber optics, active optical cables (AOCs), connectors and patch cord, switches, photonic and all-optical switches.

Also, during the conference session on ‘Data Centre Networks’, new product development manager Adit Narasimha presented ‘Engines of the Cloud: Silicon Photonics In An Age of Changing Data Center Architectures’.

Three OIF-hosted demonstrations showcased Molex technologies:

- ‘Thermal Resistant Pluggable Modules, zCD Connectors, Heat Sinks’ Using eight zCD connectors, cages, modules and heat-sinks mounted in a side-to-side airflow line-card emulator, the demonstration (blending thermal technologies developed by

Molex) investigates heat-sink materials and the effects of heat-sink pin geometry and interface surface roughness on thermal dissipation.

- ‘CEI-28G-VSR - Molex zQSFP+ Connector’

Having what is claimed to be one of the fastest data channels of IO interconnect systems on the market, Molex’s zQSFP+ connector system addresses high-speed, high-density requirements for telecoms and data networking. The demonstration featured zQSFP+ connectors in a VSR-compliant, high-speed connectivity application. The zQSFP+ (one of the world’s first IO interconnects to achieve data rates in excess of 100Gbps) was operated at up to 25.78 Gbps per lane.

- ‘CEI-25G-LR Backplane Channel Connector — Molex Impel 25G LR Backplane System and

Daughter Cards’

Illustrating the OIF CEI 25G LR Implementation Agreement (IA) with 4-lane 100G operation across a backplane link with end-to-end loss of >25dB at 12.9GHz, each lane carried a PRBS-31 pattern running at 25.78Gbps. The system used a MoSys 100G Quad Retimer (a single-chip low-power CMOS IC designed to support full duplex 100 Gigabit links for optical transceivers, active and passive copper cable, extended line-card or backplane applications). Consisting of two daughter cards, a backplane, and two mated connectors, a Molex Impel backplane system provides a scalable price-for-performance, high-speed 25Gbps–40Gbps connector to enable more users to migrate to faster data rates.

www.molex.com

TriQuint expands SMT optical modulator driver portfolio with new 100–200Gb/s solutions

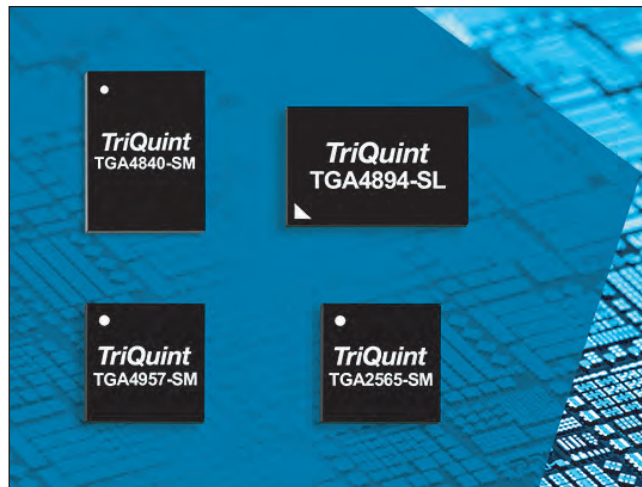
RF front-end component maker and foundry services provider TriQuint Semiconductor Inc of Hillsboro, OR, USA has introduced four new optical network products that expand its portfolio with miniaturized and integrated modules.

● **TGA4894-SL:** TriQuint's new lead-less SMT dual-channel linear driver reduces part counts by half compared to single-channel devices while meeting the higher-order 16 QAM (quadrature amplitude modulation) requirements for 200/400G systems; it is based on TriQuint's single-channel solutions. The new TGA4894-SL exhibits high gain, low total harmonic distortion (THD) and high channel-to-channel isolation. The TGA4894-SL's high gain (33dB) is a key benefit. When paired with commonly utilized/low-power DACs, it provides sufficient gain to deliver more than $7V_{pp}$ to industry-standard modulators; this results in low THD (<3%), a key requirement for 200/400G systems.

● **TGA4957-SM:** Designed for 40/100G long-haul and regional markets as well as ultra-long-haul (1000-4000+km) systems employing DP-BPSK modulation. The TGA4957-SM reduces the device footprint by 50% compared to prior generations.

● **TGA4840-SM:** This new modulator driver provides world-class power dissipation not exceeding 165mW for 32G baud rates in a miniaturized form factor. This enables TriQuint to grow its portfolio into short-reach/access network applications including those connecting smartphones and tablets. TGA4840-SM is ideal for 'hot pluggable' modules supporting the CFP2/CFP4 standards that are one-half to one-quarter the size of standard CFP modules.

● **TGA2565-SM:** Covering three key frequencies (11.3, 14.5 and 16.5GHz), TriQuint's new SMT wideband clock driver integrates analog gain control (AGC) that eliminates an off-chip component



TriQuint's newest optical modulator drivers expand its portfolio with solutions for 100/200Gb/s and beyond including dual-channel linear drivers, integrated clock drivers and modulator drivers for CFP2/CFP4 modules.

and utilizes industry-standard plastic-encapsulated SMT packaging. This solution reduces part counts while covering three frequencies with one product.

"As we expand our optical product portfolio, we remain committed to improving the performance and lowering system costs for our customers," remarks James L. Klein, VP & general manager for Infrastructure and Defense Products. "TriQuint solutions continue to set RF performance and reliability standards for current 100G and next-generation high-capacity networks required to support the exponential growth in video and data

and utilizes industry-standard plastic-encapsulated SMT packaging. This solution reduces part counts while covering three frequencies with one product.

Lower-cost 100G networks will accelerate adoption of the technology into higher-volume parts of the market, such as the metro

In a market once dominated by connectorized modules four or five times the size of TriQuint's surface-mount technology (SMT) modulator drivers, it's easy to see why smaller, more economical solutions continue to win market share, says TriQuint. While legacy 'gold brick' modules once met needs, they were complex to assemble, burdened by high cost and power dissipation, while also demanding substantial PCB real-estate.

TriQuint introduced

the first SMT modulator drivers for high-capacity optical networks, and has since built the industry's largest product portfolio. The firm claims that its solutions offer higher performance, ease of manufacturing, greater efficiency and integrated functionality. Its unique semiconductor passivation technology enables modulator drivers and other products to endure harsh conditions, lowering maintenance and extends operational lifetimes, it is claimed.

Infonetics Research forecasts continued growth for 100G networks and components, particularly for lower-cost formats such as CFP2. "Operators no longer view 100G as an exotic technology and the market is entering a new stage of growth where lower equipment cost is a critical catalyst to wider adoption," says Infonetics' Andrew Schmitt, principal analyst, Optical. "Lower-cost 100G networks will accelerate adoption of the technology into higher-volume parts of the market, such as the metro. High-performance, surface-mount solutions like TriQuint's continue to play key roles in the transition to 100G systems and beyond."

www.triquint.com

MACOM and GigOptix announce final settlement of all pending lawsuits between them

MACOM to make \$7.25m one-time payment to GigOptix

M/A-COM Technology Solutions Holdings Inc of Lowell, MA, USA, which makes semiconductors, components and subassemblies for RF, microwave and millimeter-wave applications, and GigOptix Inc of San Jose, CA, USA (a fabless supplier of analog semiconductor and optical components for optical fiber and wireless networks) have agreed to a global settlement of all pending lawsuits between them.

These include: (1) the state court case filed in Santa Clara County in

April 2011 by GigOptix against MACOM subsidiary Optomai Inc, three former employees of GigOptix who founded Optomai (Vivek Rajgarhia, Vikas Manan and Stefano D'Agostino) and MACOM for alleged misappropriation of trade secrets and breach of contract; and (2) the federal court case filed in the Northern District of California this August by MACOM against GigOptix for alleged patent infringement.

The parties have agreed to file joint requests with the relevant

courts to fully and finally dismiss both cases, with prejudice.

MACOM has agreed to make a one-time settlement payment of \$7.25m to GigOptix concurrently with the filing of the dismissals, which were expected to take place before October.

Neither party admits liability to the other, and each side is satisfied with the confidential settlement between them, the firms say.

www.gigoptix.com

www.macomtech.com

GigOptix showcasing drivers, TIAs and E-and products at ECOC

GigOptix Inc of San Jose, CA, USA (a fabless supplier of analog semiconductor and optical communications components enabling high-speed end-to-end information streaming over optical fiber and wireless networks) showcased drivers, transimpedance amplifiers (TIAs) and E-band products at the 39th European Conference and

Exhibition on Optical Communication (ECOC 2013), in London, UK (23–26 September).

GigOptix showcased a broad portfolio of products that enable:

- long-haul, metro, and short-reach fiber-optic telecommunications;
- ER/LR/SR data-center applications, servers and high-perform-

ance computing (HPC); and

- applications for the consumer market such as 4K/8K TV and gesture recognition.

Also at ECOC, GigOptix presented its latest product roadmap for drivers, TIAs and wireless point-to-point E-band products, as well as its short-form catalog.

www.gigoptix.com

MACOM launches lowest-power-dissipation quad-channel differential modulator driver in 14mm x 8mm SMT

M/A-COM Technology Solutions Inc of Lowell, MA, USA, which makes semiconductors, components and subassemblies for RF, microwave and millimeter-wave applications, has launched the MAOM-003404, a quad-channel 32Gbps differential modulator driver IC for 100G coherent transponders in CFP and CFP2 form factors.

The device's low power dissipation and extremely small size are key features that enable 100G coherent solutions in the size- and power-constrained pluggable form factors.

The MAOM-003404 meets CFP2 input voltage requirements, while the output voltage can drive the majority of available optical modulators requiring differential drive.



The four channels are packaged in a 14mm x8mm SMT optimized for maximum isolation and minimum crosstalk between channels.

The high-performance driver boasts market-leading power consumption, low RMS jitter, and typical rise/fall times of 12ps, says the firm. The four channels are pack-

aged in a single 14mm x 8mm surface-mount package that is optimized for maximum isolation and minimum crosstalk between channels. The MAOM-003404 hence suits real-estate-constrained users looking for a high-performance, low-power 100G modulator driver.

"Pluggable form factors are critical to the economics of 100G for metro applications, and MACOM has worked closely with its customers and partners to provide a driver solution which meets the stringent power and size requirements," says Optoelectronics product line manager Ray Moroney.

Samples of MAOM-003404 are available now.

www.macomtech.com

TeraXion and Canadian Photonic Fabrication Center form strategic partnership

NRC center to fabricate TeraXion's InP modulators for 100Gb/s coherent transmission systems

TeraXion Inc of Quebec, Canada (which designs and manufactures optical components and modules for high-speed fiber-optic transmission networks, fiber lasers and optical sensing applications) and the National Research Council of Canada (NRC) have announced a strategic partnership that should lead to the development and fabrication of TeraXion's new modulator products family and covers its next-generation indium phosphide (InP) high-speed modulators for coherent transmission systems at 100Gb/s and beyond. Work will take place at NRC's Canadian Photonics Fabrication Centre in Ottawa, which provides engineering and manufacturing services, commercial-grade prototyping and pilot-run

production facilities for III-V semiconductors.

The announcement is "another important milestone supporting our strategy for rapidly delivering state-of-the-art high-speed modulators," says TeraXion's president & CEO Alain-Jacques Simard. "The Canadian Photonics Fabrication Centre's proven track record for bringing products to a commercialization level has been a key factor in our decision to rely on this partner," he adds.

"The new modulator concept will use a proprietary design to achieve world-record low power consumption as well as reaching very high modulation speeds necessary for 100Gb/s and above transmission," says Ian Woods, vice-president

InP Platform at TeraXion. "In addition, the form factor of this modulator will be ten times smaller than the competing technologies available today," he adds.

"The new modulator design takes advantage of the unique process capabilities existing at the Canadian Photonics Fabrication Centre," explains Frank Shepherd, the Centre's technical manager.

TeraXion's team has previously demonstrated qualified modulator products. Among the catalysts for the TeraXion-NRC partnership are the close geographical location of both partners and the strong photonic eco-system present in the Ottawa region.

www.teraxion.com
www.nrc-cnrc.gc.ca

NeoPhotonics adds reduced-size NLW laser & ICR to suite of PIC-based components for 100G coherent transport

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, exhibited its suite of small-form-factor PIC-based optical components for 100G coherent transport at the European Conference on Optical Communications (ECOC 2013) in London, UK (23–25 September).

The small form factor products are designed to meet the requirements of high-port-density 100G coherent systems and to scale to 200G and 400G applications using higher-order modulation schemes.

NeoPhotonics supplies narrow-linewidth tunable lasers (NLW-TL) and intradyne coherent receivers (ICR), which are key components

in the 100G coherent transport systems currently being deployed in growing numbers worldwide, says the firm. NeoPhotonics is now adding new small-form-factor versions to its existing optical components for coherent systems.

The first new product is a narrow-linewidth, micro-integrable tunable laser assembly (micro-ITLA), designed to reduce the footprint by more than a factor of three and to reduce power consumption compared to current-generation ITLAs. NeoPhotonics' micro-ITLA is also designed to support the high optical output power and the narrow linewidth required for next-generation coherent network architectures.

The second new product is a small-form-factor intradyne coherent receiver (SFF-ICR) that is less than half of the size of

ICRs that are shipping currently. It has the option of an integrated variable optical attenuator (VOA) on the signal path and a monitor photodiode (MPD) to simplify board-level integration. The versatile device is suited to both single incoming channel and multiple incoming channel applications, says NeoPhotonics.

"Photonic integration has played a major role in enabling the current generation of coherent systems which are now transforming the optical communications landscape," says chairman & CEO Tim Jenks. "As exemplified by these new products, we are utilizing our photonic integration technology to bring our customers the benefits of reduced size, reduced power consumption and higher levels of integration and performance," he adds.

www.neophotonics.com

BinOptics offers optical engine to keep Moore's Law intact for computing and datacom industries

Patented etched facet technology overcomes cost, yield and performance barriers associated with sources for silicon photonics

BinOptics Corp of Ithaca, NY, USA (which makes semiconductor lasers and monolithically integrated optoelectronic components) has incorporated its patented Etched Facet Technology (EFT) into a variety of silicon photonic applications. The firm says that creating indium phosphide (InP)-based lasers and other photonic components using EFT, instead of by the conventional cleaving process, improves performance, reproducibility, reliability and quality while maintaining affordable manufacturing costs.

The firm believes that silicon photonics is a key technology for "keeping Moore's Law intact" for computing applications as the industry moves towards exaflop computing (10^{18} operations per second). Similarly, recent advances in datacom infrastructure have further necessitated cost-effective, yet highly reliable lasers to support next-gen, high-speed information exchange.

An efficient, reliable, and non-hermetic photonic source is required to provide infrared radiation to silicon photonics circuits. BinOptics has fabricated semiconductor lasers and other photonic elements on InP that meet these specific requirements.

EFT was first conceived and co-invented by BinOptics' CEO Alex Behfar, while pursuing a PhD at Cornell's School of Electrical and Computer Engineering. Since Behfar co-founded BinOptics in 2000, EFT has been utilized in the manufacturing of more than 40 million lasers shipped worldwide.

"Customers have long experienced the benefits of our EFT produced lasers, but only recently have they been exploring the potential of our EFT offerings in silicon photonics," says CEO Alex Behfar. "EFT is solving a new set of unique challenges as

organizations look for solutions to enable the next generation of computing," he adds. "Many industry experts expect

chip-to-chip and on-chip photonics to be the most significant technology impacting the future of computing."

Challenges with reproduction, flexibility, integration, and performance using conventional cleaving processes drive up cost and threaten the sustainability of continuous improvement, says Behfar. But the BinOptics EFT approach can eliminate these barriers.

EFT solutions

● *Reproducibility and Flexibility:* EFT allows facets to be defined via high-precision photolithography rather than "imprecise" cleaving, leading to greater uniformity and yield, and structures that are impossible to achieve by conventional techniques. Anti-reflection geometries can be used in place of expensive coatings.

● *High Yield:* Facet cleaving and bar testing is often one of the most costly operations in other factories. BinOptics says its lasers are fully fabricated with EFT and automatically tested on the wafer before separation into individual chips. As a result, BinOptics is able to fully evaluate all the lasers on the wafer in an automated, high-throughput test operation, in addition to dramatically reducing the cost of chip handling.

● *Surface Emission:* BinOptics' technology platform enables etching of angled facets that allow the light

from a laser to emerge perpendicular, or at an angle off from perpendicular, to the surface of the InP chip — helpful with coupling to grating couplers on silicon photonic chips, for example.

● *Performance and Reliability:* Facet cleaving operation and subsequent coating operations can cause failures and performance issues due to the disruptive nature of the process. EFT eliminates both these sources of failure. Devices made using EFT with proprietary passivation technology are exceptionally robust with respect to temperature and humidity, eliminating the need for costly hermetic packages.

● *Precision Facet Location:* Device facets are formed with extreme precision, enabling low-cost passive alignment with silicon photonics.

"Active alignment of a light source to the silicon photonics chip is a costly process, requiring extremely expensive equipment," says professor Jonathan Klamkin, director of the Integrated Photonics Laboratory at Boston University, MA, USA.

"With EFT, BinOptics has found a way to reap the cost and efficiency benefits of passive alignment without sacrificing the accuracy associated with real-time active alignment. This should be a critical factor for companies seeking economical, large-scale rollout of silicon photonics applications," he adds.

"We needed an experienced but innovative InP partner who could provide a reliable, easy-to-integrate, non-hermetic light source for our silicon photonics platform," says Kotura's chief technology officer Dr Mehdi Asghari. "BinOptics provided us with the fastest path to market for our new 100Gbps optical engine."

www.binoptics.com

Matthew Peach, Contributing Editor

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IN BRIEF

Infinera wins 'Best Optical Component Beyond 100G' award

Infinera Corp of Sunnyvale, CA, USA, a vertically integrated manufacturer of digital optical network systems incorporating its own indium phosphide-based photonic integrated circuits (PICs), says that its 500Gb/s PIC was named Best Optical Component Product Beyond 100G at the Next Generation Optical Networking Awards 2013 in Monaco.

Embedded in the DTN-X packet optical transport networking platform, PICs enable the industry's only commercially available 500Gb/s long-haul super-channels, says the firm. Super-channels reduce complexity in carrier networks by simplifying the process of provisioning transmission capacity.

The award follows a similar award last year for Infinera's 100Gb/s PIC, named Best 100G Optical Component at the Next Generation Optical Networking Awards ceremony in 2012.

The award was established to celebrate and recognize achievements made by service providers and solutions providers in the optical networking industry.

"The InP technology based PICs Infinera delivers is far and away the most innovative component available today. In a land of me-too products this company has dared to build something different," said the judges for the Next Generation Optical Networking Awards.

"When first introduced, Infinera's 100Gb/s PICs changed the dynamics of the optical networking industry," says Mark Showalter, senior director corporate communications at Infinera.

"Today 500Gb/s PICs are a key ingredient of the Intelligent Transport Network as operators advance into the Terabit Era."

www.infinera.com/go/intelligent

JDSU reports quarterly revenue of \$421.3m & 2013 revenue of \$1.677bn

For its fiscal fourth-quarter 2013 (ended 19 June), optical networking and associated semiconductor technology firm JDSU of Milpitas, CA, USA has reported net revenue of \$421.3m, up 4% on \$405.3m last quarter but down 3% on \$434m a year ago. Revenue for full-year fiscal 2013 was \$1676.9m, up 0.9% on fiscal 2012's \$1662.4m.

On a non-GAAP basis, net income was \$30.4m, up from \$24.1m last quarter and \$35.4m a year ago. During the quarter, JDSU generated over \$57m of cash from operations and exited the quarter with net cash of \$516m.

For its full-year fiscal 2013, JDSU's net income was \$131.8m, down on fiscal 2012's \$137.5m.

"Bookings were strong across all three segments, particularly in CommTest and CCOP, resulting in an overall book-to-bill above 1," says president & CEO Tom Waechter.

"We saw improved demand in a number of areas such as gesture and datacom, which partially offset lower than expected customer demand for optical components in the telecom space. We look ahead to fiscal 2014 with a strategically differentiated and market-leading product portfolio, improved operating leverage and a solid balance sheet."

"During the quarter, we navigated through market challenges and performed to plan in Communications Test & Measurement and OS&P.

We grew revenue significantly in newer markets, such as gesture recognition and cloud data comm products. Softer demand for telecom products led to less than our expected sequential growth in CCOP. In Q4, we generated \$57.1m of cash from operations, bringing the total for fiscal 2013 to \$187.8m. This is nearly \$70m more than the \$119.1m generated in fiscal 2012 on comparable revenue.

"At the same time, our continuing investments in innovation led to a record 65% of combined CommTest

and Optical Communications revenue derived from products less than two years old. Fiscal Q4 was the ninth consecutive quarter of new product revenue over our target of 50%.

In Optical Communications, our focus on growing our business in Datacom and cloud is paying dividends. In addition to receiving our largest customer booking in this space this quarter, we have shipped samples of our industry-leading CFP2 100G product and expect to begin production in our fiscal Q2."

"JDSU's consolidated fourth quarter revenue of \$421.3m was sequentially up 3.9% from March, at the low end of our guidance due to less-than-expected telecom revenue from CCOP," says CFO Rex Jackson. Year-on-year, revenue was down 2.9%. The Americas accounted for \$204.5m (48% of total revenue). EMEA contributed \$86.8m (21%) and Asia-Pacific \$130m (31%). Asia-Pacific results benefited from gesture recognition, while EMEA slipped due to sequentially lower demand for CommTest and OSP products in the quarter.

"Considering our CCOP division, which consists of our Optical Communications and lasers businesses. In Q4, CCOP delivered revenue of \$182.3m, a sequential improvement but below the expected range due primarily to lower-than-expected telecom revenue and a 1.5% decline from the year ago period. Q4 gross margin was 30.9% compared to 31.8% in the prior quarter and 27.8% in the prior year. Likewise, operating margin of 10% was down from 10.7% sequentially but up from 8.5% year-on-year due to operational improvements and the shift to new products. The book-to-bill ration for Optical Communications and Lasers was above 1."

For its fiscal first-quarter 2014 (ending 28 September 2013), JDSU expects revenue of \$410–430m.

www.jdsu.com

Finisar's quarterly revenue grows by 9% to record \$266m

Fiber-optic communications component and subsystem maker Finisar, of Sunnyvale, CA, USA, has reported financial results for Q1 2014, which ended July 28, 2013, including "all-time record sales for a quarter", according to executive Chairman of the Board Jerry Rawls.

Quarter revenues increased to \$266.1m, up \$22.7m, or 9.3%, from \$243.4m in the preceding quarter and up \$45.5m (20.7%) on those of Q1 2013, primarily driven by strong sales of datacom products. Sales of products for datacom applications increased by \$20.5m (12.5%) on the preceding quarter while sales of products for telecoms rose by \$2.2m (2.7%) on Q4 2013.

Overall quarter revenues were approximately 12% greater than those of the preceding quarter, after adjustment to reflect the elimination of recently-divested businesses. Non-GAAP gross margin increased to 35.1% from 32.2% in Q4, 2013; non-GAAP operating income increased \$12.4m to \$32.4m, or 12.2% of revenues, compared to \$20.0m, or 8.2% of revenues, in the preceding quarter.

Rawls commented, "I am pleased to report that our first quarter revenues of \$266.1m exceeded the guidance of \$245m to \$260m that we provided in the first quarter. Furthermore they have grown for the fourth consecutive quarter. Growth in revenues in the first quarter came primarily from increased sales of 10G, 40G and 100G Ethernet transceivers for datacom applications. As a result of these higher than expected revenues, a favorable product mix and operating leverage, we also were able to achieve gross margin and earnings per diluted share that exceeded our original guidance range."

Eitan Gertel, Finisar's Chief Executive Officer, added, "During the latest quarter, we continued to invest

significantly in technology and product development. Our new products for 100 gigabit parallel and serial applications for either single mode and multi mode fiber applications continue to have strong customer demand. We also expect our new platform of high density dual and single WSS will extend our leadership in the WSS market in both the component and ROADM linecard form."

Kurt Adzema, Finisar's CFO, gave an update on the company's performance, product mix and expenses: "Our non-GAAP gross margin was 35.1% up from 32.2% in the preceding quarter, primarily as a result of higher revenues, a favorable product mix and operating leverage. Non-GAAP operating expenses for the quarter were \$60.9m, an increase of \$2.6m over the prior quarter. This increase was primarily driven by higher compensations, expenses, including annual seller increases associated with the beginning of our new fiscal year.

"Our first quarter (2014) capital expenditures totaled \$27.9m, below our guidance of \$32m. This drop is the result of a slight delay in the timing of payments related to the new manufacturing facility we are building in Wuxi, China. Capital expenditures are expected to be approximately \$32m in the second quarter of fiscal 2014, primarily driven by the remaining expenses for the new building. Cash and cash equivalents totaled \$288.4m at the end of the first quarter compared to \$289.1m in the preceding quarter."

Considering the next quarter's outlook, Finisar said it expects revenues for the second quarter of fiscal 2014 to be in the range of \$277–292m; non-GAAP operating margin to be in the range of 13.7–14.7% and non-GAAP earnings per diluted share to be in the range of approximately \$0.37–0.41.

www.finisar.com

IN BRIEF

Record provisioning of long-haul optical transmission capacity

Infinera and DANTE (Delivery of Advanced Network Technology to Europe) have achieved a Guinness World Record for the fastest rate of multi-Terabit optical capacity across the GÉANT Network, activating 8Tb/s of long-haul super-channel optical capacity across the GÉANT production network in 19 minutes and 1 second after plugging in the first line-card (provisioning 26.02Tb/s per hour).

The record was set using an Infinera Intelligent Transport Network, featuring the DTN-X packet optical transport networking platform, deployed on the GÉANT backbone across a long-distance link from Vancis Amsterdam, The Netherlands to GlobalConnect Hamburg, Germany.

"Infinera provides the easy-to-deploy multi-Terabit capacity we need to rapidly scale GÉANT, Europe's largest research and education network," says DANTE's chief technology officer Michael Enrico.

The DTN-X platform provides transmission capacity using 500Gb/s super-channel line-cards which require only two fiber connectors each. 16 such cards and 32 fiber connections were deployed at each end of the link and a 100 Gigabit Ethernet (GbE) service was provisioned over it.

The DTN-X delivers the only production-ready long-haul 500Gb/s FlexCoherent super-channels based on 500Gb/s PICs, engineered to be upgradeable to 1 Terabit super-channels in the future. The DTN-X converges 5 Terabits of non-blocking OTN switching into the same platform, resulting in much more efficient network utilization when compared to conventional WDM architectures, says the firm.

www.infinera.com/go/gwr

Fraunhofer ISE, Soitec, CEA-Leti and Helmholtz Center achieve record 44.7% solar cell efficiency

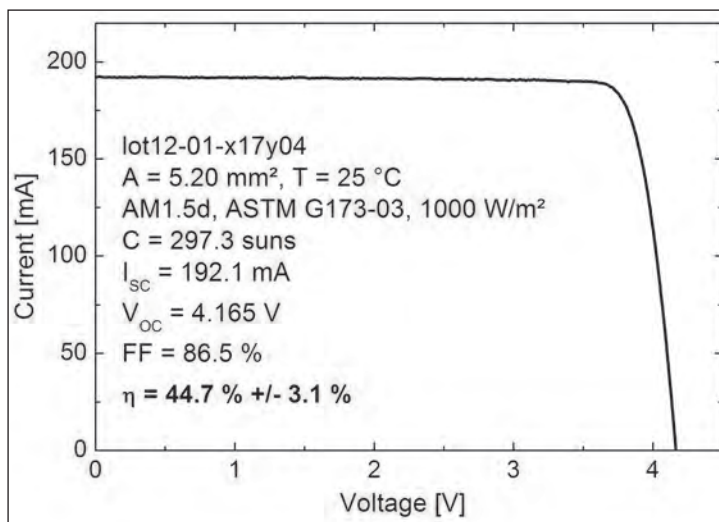
Four-junction cell efficiency rises 1 percentage point in just 4 months

The Fraunhofer Institute for Solar Energy Systems ISE in Freiburg, Germany, concentrated photovoltaic (CPV) system maker Soitec of Bernin, France, micro/nanotechnology R&D center CEA-Leti in Grenoble, France and the Helmholtz Zentrum Berlin have jointly achieved a new record for solar energy conversion efficiency by using a new cell structure with four subcells.

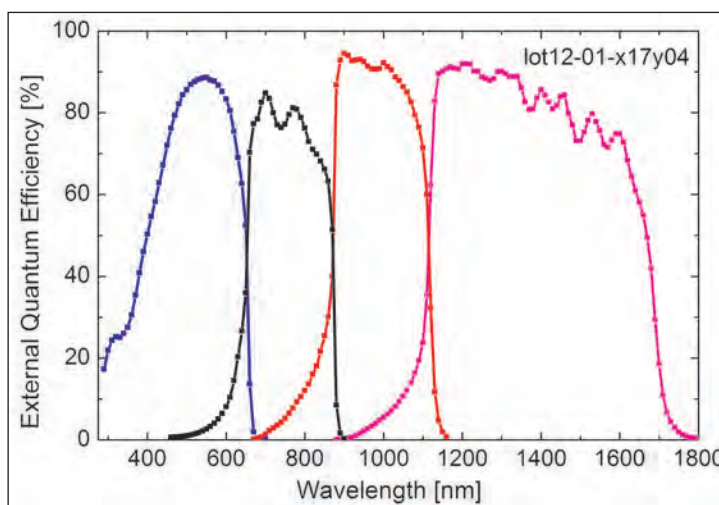
Previously, in May, the German-French team reported a four-junction solar cell with 43.6% efficiency, while Solar Junction Corp of San Jose, CA, USA reported a 44.1%-efficient production-ready cell in August following Sharp in June reporting a 44.4%-efficient triple-junction cell in research. After just over three years of research on the four-junction solar cell, the German-French team's new record of 44.7% was measured at a concentration of 297 suns. The latest figure is cited as a major step on the roadmap towards 50% efficiency.

The solar cells are for use in CPV, which can achieve more than twice the efficiency of conventional PV power plants in sun-rich locations. Originating from space technology, the terrestrial use of III-V multi-junction solar cells has prevailed to realize the highest solar energy conversion efficiencies. In the latest multi-junction solar cell, several cells made out of different III-V semiconductor materials are stacked on top of each other, with each single subcell absorbing different wavelength ranges of the solar spectrum.

"Besides improved materials and optimization of the structure, a new procedure called wafer bonding plays a central role," says Frank Dimroth, department head & project leader in charge of the development work at Fraunhofer ISE. "With this technology, we are



I-V characteristic for record four-junction solar cell under AM1.5d ASTM G173-03 spectrum at a concentration of 297 suns. Measurements were carried out at Fraunhofer ISE CalLab. ©Fraunhofer ISE



External quantum efficiency of four-junction solar cell. Measurement was performed at the Fraunhofer ISE CalLab. ©Fraunhofer ISE

able to connect two semiconductor crystals, which otherwise cannot be grown on top of each other with high crystal quality. In this way we can produce the optimal semiconductor combination to create the highest efficiency solar cells," he adds.

"This world record, increasing our efficiency level by more than 1 point in less than 4 months, demonstrates the extreme potential of our four-junction solar cell

design, which relies on Soitec bonding techniques and expertise," notes Soitec's chairman & CEO André-Jacques Auberton-Hervé. "It confirms the acceleration of the roadmap towards higher efficiencies, which represents a key contributor to competitiveness of our own CPV systems," he adds.

"This new record value reinforces the credibility of the direct semiconductor bonding approaches that is developed in the frame of our collaboration with Soitec and Fraunhofer ISE," believes Leti CEO Laurent Malier.

Concentrator modules are produced by Soitec (beginning in 2005 under the name Concentrix

Solar, a spin-off of Fraunhofer ISE). The technology is employed in solar power plants located in sun-rich regions with a high percentage of direct radiation. Currently Soitec has CPV installations in 18 different countries, including Italy, France, South Africa and the USA (California).

www.ise.fraunhofer.de

www.leti.fr

www.soitec.com

www.helmholtz-berlin.de

Soitec launches CPV module with 31.8% efficiency

Concentrating photovoltaic (CPV) solar system maker Soitec of Bernin, France has announced its newest concentrated photovoltaic (CPV) module featuring a record power-generating efficiency of 31.8%. The new module, which is already in industrial volume production, is claimed to have the highest efficiency of any commercial product available for multi-megawatt installations.

Using an optimized anti-reflective coating, Soitec's CX-M500 module increases nominal peak power output over previous generations from 2335Wp to 2450Wp. The new module has been certified according to the International Electrotechnical Commission's (IEC) and Underwriters Laboratories' (UL) standards (IEC 62108, IEC 62688, UL 62108 and UL SU 8703), confirming that it meets product safety, performance and reliability requirements in both the US and European markets.

"Looking ahead, the potential for

further improvement is significant," says Gaetan Borgers, executive VP of Soitec's Solar Energy Division. "Based on our current work in solar cell development, we are well positioned to achieve even higher module efficiencies in the near future," he adds. "With our newest commercial modules and their higher efficiencies, we are delivering on our cost-competitiveness roadmap."

Also, the new module complies with the California Solar Initiative, so power-plant installations using it can qualify for performance-based incentives from the California Energy Commission (CEC). The module also bears the CE mark, indicating its compliance with the relevant European Union directives, regulations and standards.

Using Soitec's proven Concentrix technology, each CPV module comprises a Fresnel lens plate and a bottom plate on which solar cells are mounted. The Fresnel lenses focus sunlight concentrated by a

factor of 500 on the cells beneath. The cells are precisely mounted on the bottom plate, enabling the focused sunbeam to align with the cells. In constructing its modules, Soitec uses elements from the circuit board and dual pane window industries, which are both cost effective and have been proven to be reliable over many years, says the firm.

The modules are used in assembling Soitec's CPV systems. The firm's tracker-based systems are designed to build high-capacity solar-power plants with low construction and maintenance costs, and can significantly improve the levelized cost of electricity (LCoE) for mid-sized to very large solar-power plants.

Soitec also recently announced the signature of a performance-warranty insurance contract with Munich Re, which should ease financing of solar projects using the firm's CPV modules.

www.soitec.com

Soitec Solar Division signs performance-warranty insurance contract with Munich Re

Soitec has signed a performance-warranty insurance contract with Munich Re, covering all CPV modules manufactured by Soitec. Soitec says that its customers should hence benefit from a greater degree of business certainty, helping them to secure financing for projects based on Soitec's CPV technology.

Soitec already provides its customers with a module power output warranty that guarantees its products' performance for 25 years. However, from now on, in the unexpected event of an excessive loss of output from the CPV modules, Munich Re (through its subsidiary Great Lakes Reinsurances) will indemnify Soitec for its warranty obligations. This performance-warranty insurance contract covers the long-term warranty risk and therefore gives

the CPV modules manufacturer additional financial protection. In addition, Soitec's customers will have the option of directly taking out insurance policies for specific projects with Munich Re, allowing the projects to become direct beneficiaries of the insurance. Since this insurance contract provides additional risk protection, it may also allow banks and financing institutions to provide project financing at more attractive conditions, Soitec reckons.

Before signing the contract with Soitec, Munich Re conducted an in-depth review of Soitec's modules as well as its manufacturing and quality control processes.

"Our CPV modules have proven to be extremely durable and reliable. We have already installed our products in 18 countries worldwide and have yet to receive any warranty

claims due to module degradation," says Gaetan Borgers, executive VP of Soitec's Solar Energy Division. "The contract with Munich Re, following their due diligence, is another element supporting our high confidence level with regards to the robustness of our product."

Combined with the high reliability and durability of Soitec's CPV modules, the new warranty-protection insurance will further facilitate photovoltaic projects. "We are not only protecting our balance sheet, but also giving additional protection to our customers," Borgers explains. "As the performance of our modules is reinsured, the economic security of CPV projects is reinforced," he adds. "Our customers will therefore have one more argument to put to banks and investors to negotiate favorable financing conditions for their solar power plants."

Sol Voltaics adds \$9.4m in equity funding

Sol Voltaics AB of Lund, Sweden has completed a total of \$15.6m (SEK102m) in new funding by adding \$9.4m in an equity round to the \$6.2m (SEK41m) loan (announced in June) from the Swedish Energy Agency (SEA), Sweden's national authority for energy policy issues. The development-stage firm has now reached its 2013 funding goals set earlier this year, which will enable it to enter pilot production with its Solink nanomaterial for increasing the performance and energy output of solar panels.

The latest funding round was led by Norway-based investment firm Umoe, which had previously made an incubation-level investment in Sol Voltaics. Umoe now joins Industrifonden, Nano Future Invest and Foundation Asset Management as major shareholders. Kent Janér, cleantech investor and CEO of Nektar Asset Management, also became an investor, joining veteran solar industry technologist and executive Erik Sauar as a private investor. Founded in 2008,

Sol Voltaics' other existing investors include Teknoinvest AS, Provider Venture of Sweden, and Scatec Energy of Norway. The firm has also previously received public funding from the European Union, Vinnova, and Nordic Innovation Center.

Along with this latest funding round, chairman Magnus Ryde welcomes two new members of the board: Thomas Moe Borseth of Umoe and independent director Kang Sun, former CEO of JA Solar and CEO of Amprius.

"The technology that Sol Voltaics is developing promises to be disruptive in the solar market," comments Jens Ullveit-Moe, CEO of Umoe and former chairman of REC Solar. Sol Voltaics produces Solink, a gallium arsenide (GaAs) additive for crystalline silicon or thin-film that enables solar modules to convert more of the sun's light into electricity. The firm says that, to date, the challenge of advanced materials is that they have been expensive to produce and difficult to implement. Sol Voltaics says that Solink can increase module efficiency

by up to 25% from existing levels using miniscule amounts of the nano-material. Solink's Aerotaxy process for producing nano-materials also reduces the cost of producing the materials while increasing uniformity and volume of production, the firm adds.

Solink is applied to conventional solar panels toward the end of the existing module production process using relatively inexpensive standard equipment. Sol Voltaics expects to produce functional solar cells made from GaAs nanowires for demonstration by the end of 2013. Commercial production of Solink-enhanced modules should begin in 2015 and move into volume production in 2016.

"With this closing we now have the resources to take the company to pilot production," says Sol Voltaics' CEO David Epstein. "Together with strategic partners, we plan to demonstrate Wave Concentrated Photovoltaics using large quantities of nanowires on commercially viable solar cells."

www.solvoltaics.com

Soitec to supply US DoD with 1MW demonstration project

Concentrating photovoltaic (CPV) solar system maker Soitec of Bernin, France has signed a contract with the US Department of Defense's Environmental Security Technology Certification Program (ESTCP) for a 1MWAC solar project at Fort Irwin, CA. According to the Department of Defense (DoD), 22 projects were competitively selected from the 468 proposals submitted to demonstrate emerging energy and water technologies on military installations through its Installation Energy Test Bed initiative. This initiative tests and evaluates innovative energy technologies that improve the Department's energy security and reduce its facility costs while meeting its renewable energy goals.

The demonstration power plant

will provide onsite distributed generation for the Fort Irwin military facility, which is home to the National Training Center and has a daily population of nearly 25,000. The CPV power plant will offset the emission of almost 1850 tons of carbon dioxide annually. Project planning is underway and construction is scheduled to be completed in 2014. "This project will not only prove an efficient CPV renewable energy technology but also pave a path forward towards energy surety and security at Fort Irwin," says Fort Irwin's director Public Works, Muhammad Bari.

"This project will allow the Department of Defense to showcase Soitec's CPV technology, demonstrating future government applications consistent with the

goals of improving energy security and expanding the development of renewable energy," comments Clark Crawford, Soitec's VP of sales & business development USA. "Our technology is perfectly suited for desert locations as it shows almost no degradation, even under very harsh environmental conditions," he adds.

The energy will be produced using Soitec's Concentrix fifth-generation CPV dual-axis tracking technology with 480 CPV solar modules manufactured in the firm's new North American manufacturing headquarters in San Diego, CA. The CX-S530 system is designed to improve the levelized cost of electricity (LCOE) for utility-scale solar power plants in the sunniest regions of the world.

www.soitec.com

Alferov and Andreev honored for work on III-V-based photovoltaics

In a ceremony that was held on 20 September at the University of Delaware's Interdisciplinary Science and Engineering Laboratory (ISE Lab) in Newark, MD, USA, Zhores Alferov (Nobel Laureate, professor and president of the St. Petersburg Academic University of the Russian Academy of Sciences) and Viacheslav M. Andreev (who is professor and head of the laboratory of the A.F. Ioffe Physico-Technical Institute in St. Petersburg) received the 2013 Karl Böer Solar Energy Medal of Merit.

The medal and a cash award of \$60,000 (funded by the Karl W Böer Solar Energy Medal of Merit Trust) is presented every two years to individuals who have made significant pioneering contributions to the promotion of solar energy as an alternate source of energy through research, development or economic enterprise or otherwise promoted solar energy.

The award is given in honor of longtime University of Delaware faculty member Karl Wolfgang Böer, founder of the university's Institute of Energy Conversion and a distinguished scientist in the field of solar cells.

George C. Hadjipanayis, executive director of the Karl Böer Trust and the Richard B. Murray professor of Physics and Astronomy, explained that the award is being given to Alferov and Andreev "for their pioneering work in the design of new solar cells and concentrator modules based on III-V semiconductor compounds with superior efficiencies and increased lifetime."

The recipient of the award is chosen by a panel of commissioners composed of scientists and presidents of several solar energy-related professional societies, a representative from the US Department of Energy, a past recipient of the award, and a member of the Böer family.

Track record

The scientific activity of this year's winners has focused for over 40 years on R&D of III-V semiconductor heterostructures; combining group III elements such as aluminium, gallium and indium with group V elements such as nitrogen, phosphorus and arsenic, specifically to improve solar cells. In the late 1960s and early 1970s, the pair carried out multi-faceted investigations in device technology and physics, based on heterojunctions.

They developed what are considered ideal aluminium gallium arsenide/gallium arsenide (AlGaAs/GaAs) lattice-matched heterojunctions, allowing for the proposal and realization of a number of semiconductor devices, including high-voltage and high-temperature rectifiers for power electronics; heterolasers; powerful LEDs in the visible and infrared spectrum regions; radiation detectors; and solar cells for space and terrestrial application.

"While the majority of solar cells are made from silicon, Alferov and Andreev were ahead of their time in working with the III-V semiconductor compounds, which demonstrated greater performance and opened the door to increased efficiency in solar cells and arrays," says Hadjipanayis.

The improvements were put into practice in the 1970s as the cells were used to equip the Soviet Mir space station. Subsequent years saw further modifications, with the researchers improving the radiation tolerance and almost doubling the lifetime of space solar cells.

Their developments in solar energy systems resulted in wide international cooperation with organizations such as the Instituto de Energia Solar in Madrid, the Fraunhofer Institute for Solar Energy Systems in Freiburg, NASA's Glenn Research Center and the Toyota Technological Institute.

www.udel.edu

Matthew Peach, Contributing Editor

IN BRIEF

Atwater presents technology to push PV efficiency to 50%

At July's Intersolar North America conference in San Francisco, in 'Alta Devices and Spectrum-splitting III-V Multijunction Cells' Dr Harry A. Atwater discussed innovative photonic concepts for photovoltaic technology that have the potential to enable solar efficiencies of over 50%.

Atwater is the Howard Hughes professor of Physics at Caltech (California Institute of Technology) and director of the Resnick Sustainability Institute at Caltech. He is also a founder of Alta Devices, which is focused on delivering the most efficient, thin and flexible mobile power technology.

The most commonly available solar technologies currently have reached 20% efficiency or less. The new technology has the potential to enable the use of solar technology in many ways that have not been considered practical to date, says Atwater.

Atwater's talk covered how he and his team are using solar cells like those designed by Alta along with new 'spectrum-splitting' techniques to increase conversion efficiency of around 30% to over 50%. This is being accomplished by using single-junction solar cells as components of multi-junction cells using spectrum splitting. Atwater explained that the Alta technology is critical because it has uniquely been able to accomplish very high efficiency and commercializable manufacturing by applying two important methods: photon recycling and epitaxial lift-off.

The work covered in the presentation was supported by the Resnick Sustainability Institute, ARPA-E and the Dow Chemical Company.

www.altadevices.com

<http://resnick.caltech.edu>

First Solar sells 50MW Canadian power plants

First Solar Inc of Tempe, AZ, USA, which makes thin-film photovoltaic modules based on cadmium telluride (CdTe) as well as providing engineering, procurement & construction (EPC) services, has sold a collection of solar projects in Ontario, Canada, totaling 50MW_{AC} to an investment partnership led by GE unit GE Energy Financial Services of Stamford, CT, USA. Terms were not disclosed. It is the first project transaction between First Solar and GE (General Electric) since it was announced on 6 August that First Solar had acquired GE's solar technology intellectual property and that the two companies had entered into a collaborative commercial partnership.

The ABW Partnership (announced originally in 2011) consists of majority owner GE Energy Financial Services and Alterra Power Corp, which made an equity contribution and will serve as the projects' managing partner. The ABW Partnership raised debt for the acquisition, with The Manufacturers Life Insurance Company serving as agent and lead arranger. The debt syndicate consists of The Great-West Life Assurance Company, Sun Life Assurance Company of Canada, and Caisse de dépôt et placement du Québec.



The 20MW_{AC} Walpole Solar Power Plant.

First Solar has completed construction of the power plants — Amherstburg (10MW_{AC}), Belmont (20MW_{AC}) and Walpole (20MW_{AC}) — and has commissioned and energized them so they are providing power to the grid. First Solar will provide operations and maintenance services under long-term contracts. Output of the power plants will be sold to Ontario Power Authority under its Renewable Energy Standard Offer Program (RESOP), with 20-year power purchase agreements.

"In addition to providing clean electricity, the projects have provided meaningful employment and local economic benefits, as well as contributing to the safe and efficient operation of the local utility system," says Tim Rebhorn, First Solar's senior VP of business development — Americas.

GE Energy Financial Services said the Ontario projects contribute to its cumulative 1 gigawatt, \$1.5bn solar investment portfolio, which consists of 50 installations, including several with First Solar in

North America and Australia.

"Our Ontario investments deepen our longstanding relationship with First Solar and illustrate our interest in acquiring solar power projects at various stages of development and construction," says Mark Tonner, managing director & Canada business leader at GE Energy Financial Services.

"Through a variety of equity and lease arrangements, we help developers monetize their own investments."

Combined, the Ontario facilities are expected to produce enough electricity to power about 6300 local homes and avoid 14,600 tons of carbon dioxide emissions annually (equivalent to taking 3700 cars off the road).

www.ge-energy.com

www.firstsolar.com

Power purchase agreement signed with Roseville for Lost Hills plant

First Solar and the City of Roseville, California, have signed a power purchase agreement (PPA) for 32MW_{AC} of solar electricity to be generated at the Lost Hills photovoltaic power plant that First Solar is developing and will construct in Kern County, California. Construction could start in early 2014 and create up to 200 jobs at its peak.

Approved by the Roseville City Council on 17 July, the 10-year PPA is First Solar's first such agreement with a municipal utility, and is effective in 2015.

Roseville Electric purchased 325,000MW-hr of renewable energy

for \$24m for 10 years. The contract cost \$6.5m less than similar renewable energy purchase offers in 2012.

"It will help the city reach its state renewable energy goals," says Brian Kunz, First Solar's VP of project development. "We are pleased to acquire renewable electricity to help us reach the state's requirement for 33% by 2020," says Roseville Electric utility director Michelle Bertolino. "As a community-owned utility, contracts such as this help minimize the cost impact on our customers while maintaining highly reliable service."

Under the agreement, Roseville will receive 100% of the Lost Hills power plant's output for the first four years of the agreement; it will then decline to a smaller percentage of the output. First Solar has an additional PPA for Lost Hills' output with Pacific Gas and Electric, which goes into effect in 2019.

In its first year, Lost Hills will produce enough energy to power more than 11,000 homes, offsetting over 20,000 metric tons of CO₂ annually (equivalent to taking about 4000 cars off the road each year) and displacing over 18,000 metric tons of water consumption annually.

VDE Americas and First Solar implement new standards for bankability and quality assurance

First Solar has established a strategic relationship with VDE Americas (a subsidiary of Germany's VDE Testing and Certification Institute) that aims to boost technical bankability and risk reduction for PV power plant operators, investors and financial entities.

First Solar says that, for years, it has relied on module-level testing and manufacturing processes that went beyond currently established international standards. Working with third-party independent certification body VDE, First Solar reckons that it has now set a benchmark for quality and reliability for entire PV solar power systems.

"This expanded relationship with

VDE documents rigorous quality assurance requirements at the PV plant/system level," says Azmat Siddiqi, First Solar's senior VP of quality and reliability.

The 'VDE Quality Tested' mark for PV power plants was designed by VDE together with its partner, Fraunhofer Institute for Solar Energy Systems (ISE) in Freiburg, Germany. The testing portfolio is said to deliver advantages in four key areas: electrical and mechanical safety of the system; system performance (through a highly accurate energy yield report); appropriate system operation; and independent verification for investors, lenders, insurance companies and other

stakeholders by highly competent and reputable independent experts.

"VDE has been engaged with First Solar for many years in the certification of modules and manufacturing processes. We're pleased that First Solar will be leading the industry by implementing our new VDE Quality Tested mark for their PV solar power systems," says VDE Americas' president John Sedgwick. "VDE and our partner Fraunhofer ISE are committed to reducing the technical risk often associated with PV power plant investments. We will continue to work closely with industry players to help raise the standard for the solar sector."

www.ise.fraunhofer.de

First Solar appoints chief commercial officer

First Solar has named Joe Kishkill as chief commercial officer.

Kishkill will have comprehensive leadership responsibility for Global Business Development, Sales and International Public Affairs, with a primary focus on sustainable growth in emerging markets. Reporting to Kishkill will be regional business development and global public affairs teams.

"Joe brings unparalleled expertise to this extremely critical role," says CEO Jim Hughes. "I am confident that he can craft and lead a business development organization that will deliver on our near-term objectives and build a solid foundation for growth."

Most recently, Kishkill was president – Eastern Hemisphere for Exterran, a global provider of

natural gas, petroleum and water treatment production services. Prior to that, he led Exterran's business in the Latin America region. He also served as Enron's CEO for South America.

Kishkill earned an MBA from the Harvard Graduate School of Business Administration, and holds a BS in electrical engineering from Brown University.

First Solar breaks ground on 150MW Solar Gen 2 project

Construction has started on First Solar's 150MW_{AC} Solar Gen 2 project, which will be the largest solar power plant it has constructed in Imperial County (and its third project in California's Imperial Valley).

Solar Gen 2 will provide about 800 jobs during construction (which should be completed by July 2014) and generate about \$150,000 in property taxes annually and \$4.6m under the Public Benefits Agreement.

"With the support of county officials, IID [Imperial Irrigation District] and SDG&E, we are helping to deliver thousands of green jobs, millions of dollars in economic benefits, and

clean, renewable energy for Southern California homes," says construction director Anthony Perrino.

Under a 25-year power purchase agreement (PPA) between SDG&E (San Diego Gas & Electric Company) and First Solar, the 150MW project will generate enough energy to power more than 60,000 average California homes, displacing more than 115,000 metric tons of CO₂ (equivalent to taking 22,000 cars off the road) and saving 93,000 metric tons of water annually.

Purchased by First Solar from Energy Power Partners in April, Solar Gen 2 consists of three neigh-

boring sites: Sonora, Arkansas, and Alhambra. The modules used on the project will be installed on a tracking system, which will follow the sun throughout the day to maximize the amount of power generated.

First Solar also developed and is constructing the 139MW Campo Verde Project in El Centro, which should be complete by the end of October. Additionally, the firm is completing construction of the 130MW Tenaska Imperial Solar Energy Center South project in Calexico for project owner and developer Tenaska.

www.firstsolar.com

First Solar creates Germany-based PV Projects joint venture with BELECTRIC

First Solar Inc of Tempe, AZ, USA, which manufactures thin-film photovoltaic modules based on cadmium telluride (CdTe) as well as providing engineering, procurement & construction (EPC) services, and BELECTRIC Holding GmbH are to undertake a joint venture (JV).

The joint venture PV Projects GmbH & Co KG will be based in Germany and will develop selected photovoltaic (PV) power projects independently acquired or developed by either First Solar or BELECTRIC in Europe, North Africa, and projects of less than 20MW in the USA.

Under the terms of the JV, First Solar will supply its thin-film modules, selected components such as the First Solar Tracker and value-added services, while BELECTRIC will provide its Balance of Systems (BoS) and a

range of service capabilities. Both firms' EPC contributions will vary by project and geography. The JV's emphasis on the sub-20MW segment in the USA will include BELECTRIC's existing 280MWp pipeline in the country, along with other opportunities. The non-exclusive agreement will also allow both firms to independently and competitively pursue development prospects and corresponding EPC work.

Recently, the two firms marked the inauguration of the 128MWp Templin solar power plant in Germany, the largest deployment of First Solar modules in Europe. An estimated 80% of the 1400MWp of solar electricity generation capacity installed by BELECTRIC is powered by First Solar modules.

"First Solar and BELECTRIC share a long history of excellence and we are confident about the future of

this initiative, which is based on a firm foundation of mutual trust, expertise and a track record that is unrivalled in the solar energy industry," says Jim Hughes, First Solar's chief executive officer.

"We are happy to celebrate this important new milestone in our long-term partnership with First Solar," says Bernhard Beck, chief executive officer of BELECTRIC Holding. "By joining forces to create a world-class project delivery platform, we hope to strengthen both companies' relationships with key stakeholders including project developers and investors at a time when prices of electricity from solar power plants can already compete with the prices for conventionally generated electricity in a growing number of regions," he adds.

www.firstsolar.com

Calyxo welcomes EU decision to support fair competition between solar module makers in Europe

Calyxo GmbH of Bitterfeld/Wolfen-Thalheim, Germany, which is the largest manufacturer of cadmium telluride (CdTe) thin-film solar panels in Europe (with a current annual capacity of 85MW), says it welcomes the agreements between European Union and China over imports of Chinese solar panels (for Chinese modules to be offered at a minimum price of €0.56/Wp in the Europe in the near future).

For customers of Chinese firms buying at lower prices, punitive tariffs ranging from 37.2% to 67.9% will apply, EU Trade Commissioner Karel De Gucht has declared.

As one of few firms in Germany, Calyxo says it has been able to survive the years of alleged Chinese dumping in Germany. The firm says that it provides modules based on an atmospheric production process and also offers suitable mounting



Calyxo's production line.



CEO Dr Florian Holzapfel.

systems, complete design and installation of PV systems.

"Module prices below €0.56/Wp can be realized without any problem by Calyxo today, and marginal higher BOS [balance of system] costs can be compensated by our customers based on a price advantage of the modules and additional

yield of thin-film modules," says CEO Dr Florian Holzapfel. "As a consequence, our customers not only have lower investment costs, but also a better return on their investment," he claims. "Our capacity expansion at Thalheim comes online exactly at the right point in time."

www.calyxo.com

Smit Ovens and SoLayTec to co-develop large-area spatial ALD tool for Solliance CIGS/CZTS program

Applications to include buffer and barrier layers for thin-film photovoltaics

Smit Ovens of Eindhoven, The Netherlands, which supplies customized thermal equipment and processes for the photovoltaic, glass and display industries, and Eindhoven-based SoLayTec, a spin-off from Dutch research organization TNO founded in 2010 to make atomic-layer deposition (ALD) equipment, are joining forces for large-area applications of spatial ALD. The collaboration aims to leverage the experience of both firms to allow rapid market introduction. Expected applications include buffer and barrier layers for thin-film photovoltaics (PVs) and layers for improved thin-film transistor (TFT) structures required for organic light-emitting (OLED) displays.

The process development tool that will be integrated in the existing copper indium gallium diselenide (CIGS) development line is part of

the CIGS/CZTS program of Solliance, the European R&D consortium that focuses on thin-film photovoltaic solar energy in the ELAT (Eindhoven-Leuven-Aachen) region. The system will be used for developing alternative buffer layers as well as other layers that can improve device structure and performance.

Smit Ovens and SoLayTec have agreed that both parties will contribute to technical aspects that best match their experience. SoLayTec will focus on injector head development in order to make use of experience from its InPassion ALD product for the crystalline silicon (c-Si) PV market. Smit Ovens will take the role of machine integrator and act as contract partner to customers.

"The cooperation since it allows us to achieve two strategic targets at the same time," says Smit Ovens'

CEO Wiro Zijlmans. "We are able to offer an advanced process solution for the buffer layer to our existing customers for CIGS crystallization. On top of that we are able to expand our market penetration in the display market, which we were already addressing with drying & sintering solutions," he adds.

"After having successfully launched our first products in the market for crystalline PV, we now are able to use the proven deposition technology for the next market opportunity," says SoLayTec's managing director Huib Heezen. "Also, we are very enthusiastic about our cooperation with an experience player as Smit Ovens, as this enables us to market both our combined areas of expertise within a short time frame."

www.solaytec.com

www.solliance.eu

Ascent Solar appoints CFO

Ascent Solar Technologies Inc of Thornton, CO, USA, which makes lightweight copper indium gallium diselenide (CIGS) thin-film photovoltaic modules that it integrates into its EnerPlex series of consumer products, has appointed Bill Gregorak as chief financial officer.

"He brings extensive experience in both technology and consumer products businesses with highly respected companies," says CEO Victor Lee.

Gregorak has a background in public company financial reporting, internal controls as well as mergers and acquisitions. Prior to joining Ascent, Gregorak served as VP & CFO of Thule Organized Solutions, a consumer products manufacturer of personal electronics cases sold under both the Case Logic and Thule brands, from 2008–2013, overseeing organizations in the

USA, Europe and Hong Kong.

Before Thule, Gregorak was VP & corporate controller for Advanced Energy and Xilinx, both of which trade on NASDAQ. Advanced Energy is a manufacturer of semiconductor equipment with operations in both the USA and China, while Xilinx is a manufacturer of semiconductors with operations spanning the USA, Ireland and Singapore. Prior to 2000, Gregorak spent 17 years with Hewlett-Packard in various financial and operational capacities. He has a Bachelor's degree in Economics from the University of Washington.

"His background in larger organizations, especially in the consumer-oriented businesses, will be invaluable as Ascent Solar executes its B2C expansion strategy," says Lee.

IN BRIEF

Ascent Solar debuts EnerPlexKickr I & II

Ascent Solar has debuted the latest additions to its EnerPlexKickr line of personal solar chargers.

The 1.5W Kickr I is suitable for charging batteries and power banks. The 3W Kickr II can charge most smartphones in under 5 hours. Both are lightweight, flexible and compact, allowing for easy attachment to bike, backpacks etc.

"Expansion of the Kickr line represents another step forward for Ascent's consumer brand, EnerPlex, as we continue to deliver rugged and innovative solutions to consumers," says VP of product development Robert Meck.

www.AscentSolar.com

Competing for solar energy records and applications

Until recently compound semiconductor photovoltaic energy conversion has been restricted by cost to space vehicles, where the higher efficiencies lead to lighter panels. **Mike Cooke** reports on new developments that may lead to terrestrial applications.

Although compound semiconductors have since the 1980s produced the most efficient photovoltaic (PV) conversion of solar energy, their application has tended to be restricted to space applications due to their high production cost, which can be up to 100 times that of alternatives.

In the single-junction cell, gallium arsenide (GaAs) PV cells and modules offer the highest conversion rates with the minimum weight and area/size penalties. These devices also operate over a wider range of temperatures, allowing deployment in extreme conditions.

Further performance improvement can be made by adding multi-junction layers sensitive to different wavelength ranges that match the device more closely to the relevant solar spectrum. Multi-junction cells have been deployed in space for about two decades.

However, companies and researchers would like to find ways to make compound semiconductor PV more attractive in terrestrial applications.

One method that has come to the fore is for

compound semiconductor PV cells to be put under the magnifying glass with the development of concentrator photovoltaic (CPV) systems. By focusing and tracking sunlight on small compound semiconductor PV cells, systems are being developed that, it is hoped, will be competitive with lower cost silicon-based modules.

Another way forward is to package compound semiconductor PV in thin and light-weight formats that allow deployment into a wider variety of applications.

At the same time, researchers and companies are keen to develop PV cells and modules with the very highest performance that will enable these hopes to come to fruition. Here we look at some of the leaders in these technical developments and their vision of how these technologies can be used.

To aid us in our search for the current leadership, we consulted the rather helpful 'Research Cell Efficiency Records' chart on the US National Renewable Energy Lab (NREL) National Center for Photovoltaics (NCPV) website (www.nrel.gov/ncpv/).

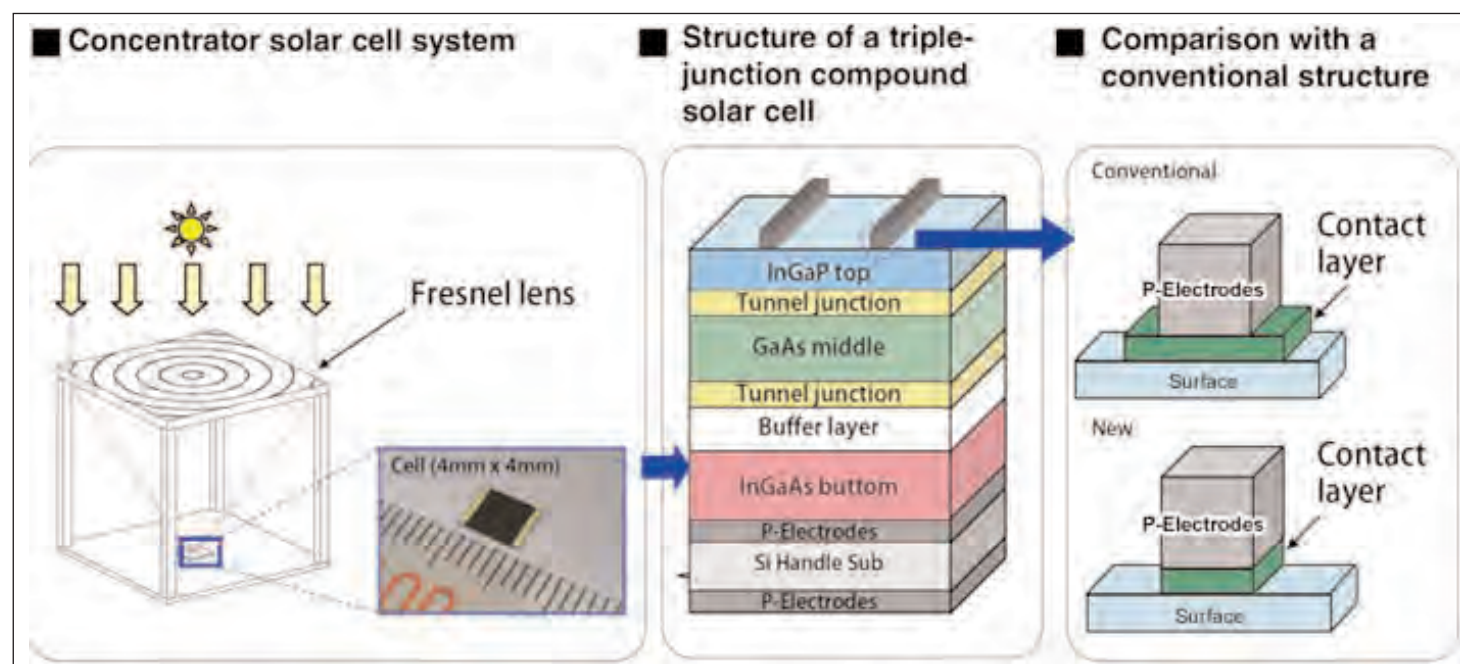


Figure 1. Structure of Sharp concentrator system and compound semiconductor solar cell, compared with conventional structure.

Power of concentration

As of writing, the leading cell technology is from Sharp. The Japanese company announced in June 2013 the achievement of 44.4% conversion efficiency for a concentrator triple-junction compound semiconductor solar cell (Figure 1). The research leading to this achievement was part of the 'R&D on Innovative Solar Cells' project promoted by Japan's New Energy and Industrial Technology Development Organization (NEDO).

The efficiency figure was validated by Germany's Fraunhofer Institute for Solar Energy Systems (ISE) in April under 302-suns concentration and with a cell surface area of 0.165cm^2 . Sharp and Fraunhofer are also part of an EU-Japanese project 'New Generation CPV' (www.ngcpv.org/) set up in June 2011 that is due to last 42 months up to the end of 2014. NGCPV has "the objective of approaching the 50% efficiency goal at cell level and 35% at module level".

Sharp's cell uses three photo-absorption layers: indium gallium arsenide (InGaAs), gallium arsenide (GaAs), and indium gallium phosphide (InGaP) in an inverted metamorphic multi-junction (IMM) configuration. In the research, Sharp worked to expand the effective concentrator cell surface area and on improving the interface between concentrator cell and electrodes. The plan (Figures 1 and 2) is to use such cells in modules that combine many cells with Fresnel lens concentrators in fields of modules.

Sharp began its development of solar cells for space applications in 1967, using single crystal silicon. The development of triple-junction compound semiconductor devices for the same purpose but with improved efficiency and durability, and reduced weight, began in 2000. Application of these cells began in 2005 with the small Rimei scientific satellite. The company has also developed triple-junction compound solar cells with 37.9% conversion efficiency under 1-sun illumination for use in space, particularly in its work with the JAXA Japanese space agency.

Preparing for high volume

Solar Junction is a US company that is developing cells for CPV and has held the record cell efficiency until recently. In October 2012, the company beat its own April 2011 record of 43.5% conversion efficiency (418 suns) with a 44% NREL-validated measurement under 947 suns.

This has apparently been edged up to 44.1%, according to an August 2013 announcement from Solar Junction's epitaxial wafer supplier and strategic partner IQE. The wafers were produced on IQE's high-volume molecular beam epitaxy (MBE) equipment. IQE claims that "the standard three-junction solar cells are believed to set a new world record for production-scale CPV wafer technology." The cell uses a lattice-matched

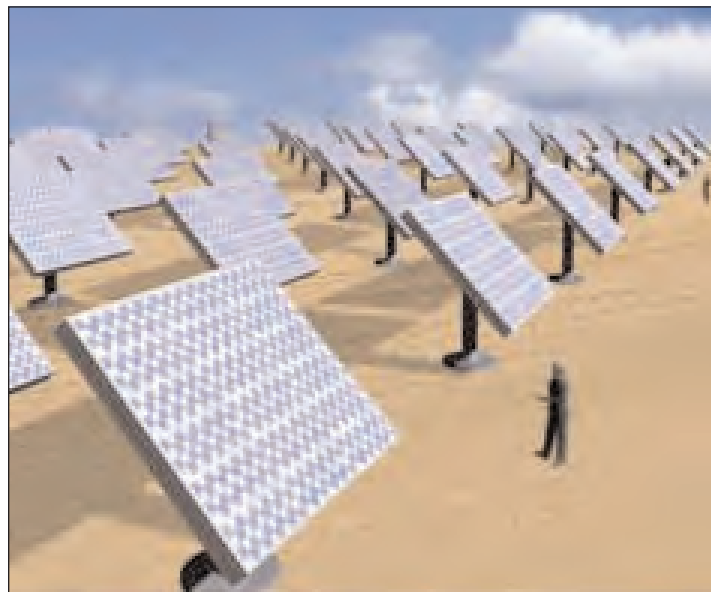


Figure 2. Sharp's vision of solar power generation using concentrator triple-junction solar cells in fields of modules.

InGaP/GaAs/GaInNAs(Sb) structure on GaAs substrate [for further details: Mike Cooke, *Semiconductor Today*, p72, March 2013].

Vijit Sabnis, CEO at Solar Junction, comments: "Breaking a world record is a major achievement, but improving on our most recent record using high-volume production equipment produced in conjunction with our manufacturing partner IQE, and Solar Junction's fabrication line in Sunnyvale, CA, is dramatically more significant."

Amonix, a CPV module manufacturer that uses Solar Junction cells, announced an NREL-validated record module efficiency rating of 35.9% in August. The test was carried out under the recently adopted IEC Concentrator Standard Test Condition (CSTC) of 1000W/m^2 at 25°C cell temperature, rather than the older Concentrator Standard Operating Condition (CSOC) of 900W/m^2 at 20°C ambient. The data for the rating were generated in an outdoor test at NREL from late February to April 2013.

Junction pile-up

SOITEC in Europe is another firm with multi-junction cells. The NREL chart gives SOITEC the record for 4-junction devices, at 43.6% conversion efficiency under 319 suns. At the time of writing, SOITEC's device is the only one listed on the chart under the "four junction or more (concentrator)" category, suggesting that the technology has plenty of room to improve.

For more traditional three-junction devices based on GaInP/GaInAs/Ge technology, SOITEC has achieved efficiencies of more than 41%.

SOITEC's CPV solar module work is marketed under the trade-name Concentrix, after acquiring the



Figure 3. Schematic diagram of SOITEC's concentrated photovoltaic module.

Fraunhofer spin-off Concentrix Solar in 2009. The base technology was developed for more than a decade at Fraunhofer's ISE solar energy laboratory. SOITEC uses its Smart Cut and Smart Stacking layer transfer and wafer bonding techniques to produce high-quality semiconductor materials for solar cells.

SOITEC works also with France's CEA-Leti organization, along with Fraunhofer ISE. The research collaboration hopes to use these technologies to create high-quality III-V compounds materials to deliver significantly higher efficiency than conventional multi-junction cells grown by epitaxy.

Like Sharp, SOITEC's modules use Fresnel lenses to concentrate the sunlight (Figure 3). The module efficiency has reached 30%. SOITEC has developed an automated production process and, from its first demonstration systems in 2005, now has an installed module base of more than 10MWp in 14 countries. SOITEC's production capability is 70MWp (Figure 4). The company also inaugurated a US manufacturing facility in December 2012 (Figure 5).

Boeing's Spectrolab subsidiary was another solar cell record holder, achieving 37.8% efficiency for a "new class of high-efficiency multi-junction solar cell, created from two or more materials" without concentration. The device is labeled on the NREL chart as '5-J', presumably meaning that it involves five junctions



Figure 4. Installation of SOITEC CPV technology at Wadi El Natrun, Egypt.

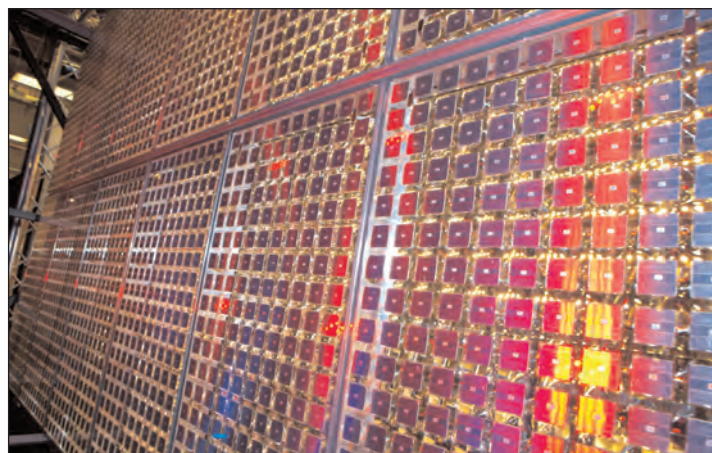


Figure 5. Picture from grand opening of SOITEC's San Diego facility.

(Figure 6). The Boeing announcement on 9 April was pipped on 24 April by Sharp with its 37.9%-efficient 1-sun 3-J IMM device described above.

Spectrolab is part of Boeing's Defense, Space & Security unit. The Boeing corporation describes Spectrolab as "the world's leading merchant supplier of high-efficiency

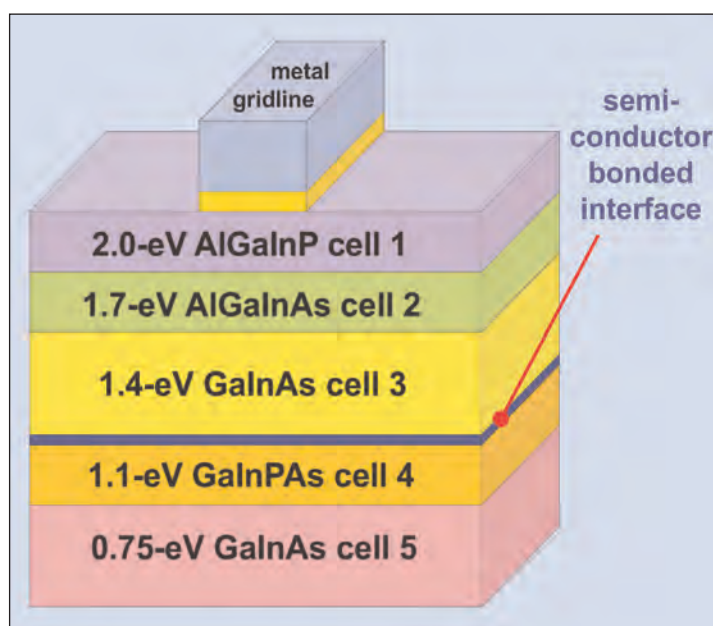


Figure 6. Schematic diagram of Boeing Spectrolab's five-junction cell.

multi-junction solar cells and panels for concentrated photovoltaic and spacecraft power systems”.

The cells and panels are based on GaInP/GaAs/Ge multi-junctions. “The greatest share of Spectrolab’s product deliveries are fully assembled space solar panels” the company says on its website. The firm provides arrays of panels for commercial, science, and military space program solar power. Spectrolab also works on cells and assemblies for CPV systems.

Widening the application net

Alta Devices of Santa Clara, CA, USA develops thin-film single-junction GaAs and two-junction non-concentrator cells. The single-junction devices hold that class’s record for efficiency at 28.8%. Alta also announced in March that its dual-junction GaAs/InGaP cells broke the record for two-junction devices at 30.8% efficiency. Since then, NREL announced in June that one of its own two-junction (GaAs/GaInP) IMM devices had achieved 31.1% efficiency. Alta has an efficiency target of 38% for its two-junction device. Alta modules containing single-junction cells have reached 24.1% efficiency,

In collaboration with NREL, Alta has also shown that its solar technology runs at temperatures up to 10°C lower than silicon under full solar illumination. The Alta module was five times less sensitive to increased temperature. In fact, rather than performance being degraded, the Alta module showed higher efficiency at high temperature due to the different spectral profile of the sun on hot days.

Alta’s application strategy is somewhat different from the companies above in that its devices are designed for single-sun illumination. The aim is to extend battery life in unmanned, consumer device, remote power, and automotive systems. In particular, the company wants to apply the technology to mobile, portable or wearable objects. In some cases, Alta hopes that its power delivery systems will eliminate the need to plug into the grid.

One recent achievement enabled by Alta’s solar power was a 9 hour flight by AeroVironment’s Puma AE



Figure 7. Launch of AeroVironment’s Puma AE small unmanned aircraft that has achieved 9 hours flight using Alta solar power.

small unmanned aircraft that is being developed for military, public safety and commercial applications (Figure 7). Alta also sees uses for solar-powered unmanned aerial vehicles (UAVs) in agriculture, wild-fire mapping, search and rescue, law enforcement, and industry. The solar panels are integrated into the wings of the UAVs.

Alta has developed an efficient growth process to deliver thin films of active material that consume small amounts of raw material, while maintaining high conversion efficiency, reducing costs and manufacturing time. The company has also developed ways to package the cells in lightweight, robust, and flexible form factors, allowing integration into curved surfaces such as the wings of UAVs or the roofs of cars. Alta Devices claims that its technology produces between 2x and 4x more electricity per unit area and per unit weight than all competing technologies. ■

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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Quantum dot lasers on silicon with stable operation at high temperature

Devices emitting at 1.3μm show infinite characteristic temperature around room temperature and 150K around 100°C.

University of Tokyo has improved the temperature performance of 1.3μm quantum dot (QD) laser diodes bonded to silicon [Katsuaki Tanabe et al, Appl. Phys. Express, vol6, p082703, 2013]. Photonic circuits are commonly created in silicon, but the light sources presently need to be produced using compound semiconductor technology.

In particular, researchers are seeking devices that are more stable over wide temperature ranges and that can operate at higher temperatures. The Tokyo devices used silicon-doping to provide partial p-type conduction in the gallium arsenide (GaAs) barriers around the self-assembled indium arsenide (InAs) QD that formed the active light-emitting regions of the laser diode devices. These devices were bonded onto silicon substrates.

The InAs/GaAs QDs were grown using molecular beam epitaxy (MBE) on GaAs substrate (Figure 1). The active region consisted of 8 layers of self-assembled InAs QDs in p-GaAs barriers. The dots had a per-layer density of $6 \times 10^{10}/\text{cm}^2$.

The AlGaAs n- and p-type cladding layers were 40% aluminium and 60% gallium. The 1μm AlGaAs etch stop on the GaAs substrate consisted of material with 70%-Al and 30%-Ga.

The QD material was flipped and bonded onto epi-ready p-Si (100) substrate. The QD material and substrate were first coated with photoresist and diced into 1cm² dies. The purpose of the photoresist was to protect the interface between the QD structure and silicon substrate from particles that could weaken the bond.

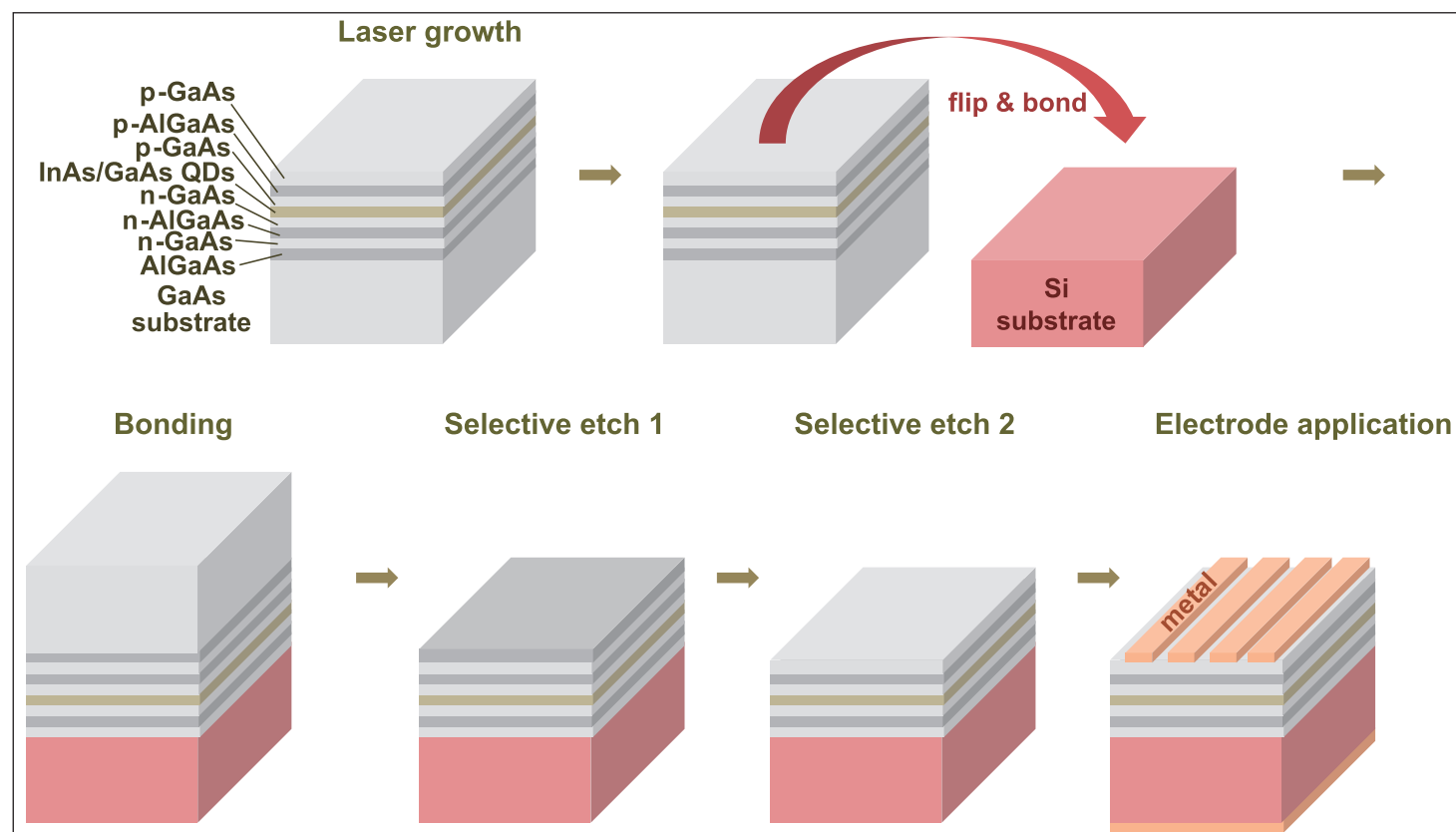


Figure 1. Schematic of fabrication of InAs/GaAs QD lasers on Si substrates.

Two types of bonding process were tested: direct and metal-mediated. The direct wafer bonding was prepared for using a hydrofluoric acid dip to remove native oxide from the surfaces of the laser and substrate materials. The metal-mediated bonding consisted of coating the surfaces with 100nm of gold germanium nickel alloy applied using evaporation. The dies were bonded with their (110) edges aligned to facilitate cleavage of the laser facets. The bonded assembly was annealed at 300°C for 3 hours in air.

The removal of the GaAs substrate material was achieved by a two-stage wet etch in phosphoric acid-hydrogen peroxide and then citric acid-hydrogen peroxide. The edges of the wafer were coated with photoresist to avoid undercutting into the QD layers. The AlGaAs etch stop was removed with a hydrofluoric acid etch.

The material was used to create 2mm-cavity-length broad-area Fabry–Perot lasers with cleaved facets.

The 100µm-wide laser stripes were coated top and bottom with gold/gold-germanium-nickel electrodes. The cleaved facets were not coated.

Both devices operate at more than 100°C with an emitted wavelength of 1.3µm (the O-band of optical communications). The researchers comment: “No significant difference in the temperature-dependent light–current characteristics is observed between the direct-bonded and metal-mediated-bonded QD lasers on Si substrates.”

The researchers compared the temperature performance of the new InAs/p-GaN QD lasers with that of devices without p-doping in the GaN barriers around the dots (Figure 2). The new p-doped devices had a higher characteristic T₀ temperature (less variation of the threshold with temperature) due, it is thought, to “suppression of thermal excitation of holes in the lasing mode at higher temperatures”.

The comparison devices were produced in previous work by the research team, and included a coating

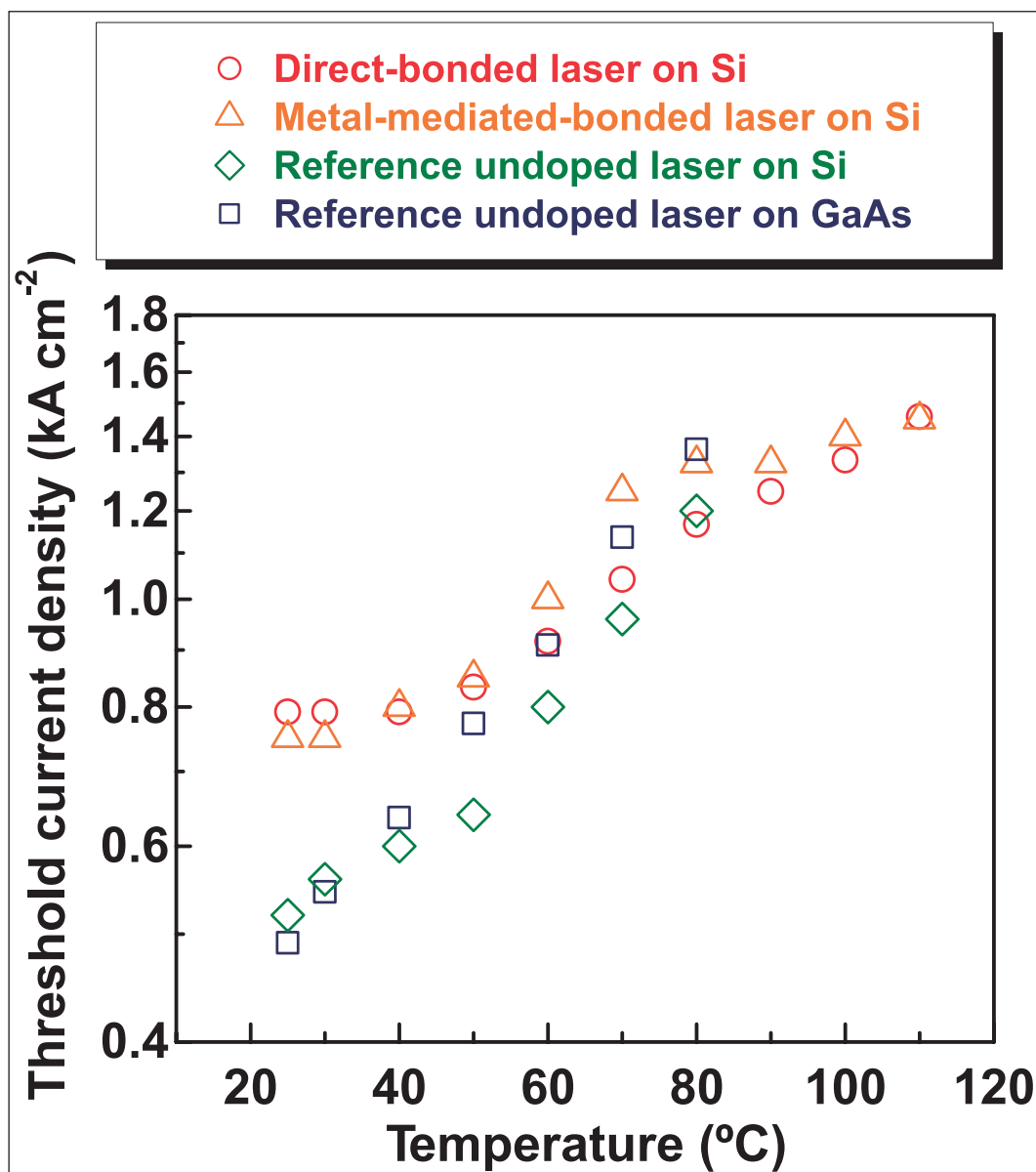


Figure 2. Temperature dependence of threshold current densities for p-doped and undoped 1.3µm InAs/GaAs QD lasers on Si and GaAs substrates.

layer on the facets.

Around room temperature the T₀ value for the p-doped LDs was effectively infinite (no change in threshold). One might note, however, that the room-temperature threshold was somewhat higher than for the undoped samples. Around 100°C, the T₀ value was in the range 150–180K. The T₀ for the comparison devices was around 60K across the whole temperature range.

“These lasing temperatures and T₀ of our p-doped lasers are significantly higher than the cases of the previous works for telecommunication-band QW [quantum well] and QD lasers on silicon,” the researchers write, adding: “These results verify that III–V QD lasers on silicon fabricated by wafer bonding are promising for temperature-stable light sources in high-density photonic integrated circuits.” ■

<http://apex.jsap.jp/link?APEX/6/082703>

Author: Mike Cooke

Pre-straining for reduced quantum-confined Stark effect in blue laser diode material

Peking University has reduced the blue-shift over the 5–50mA range from 23meV to 1meV by using pre-strained material.

Peking University has found that using a pre-strain layer in nitride semiconductor epitaxial structures designed for blue laser diodes (LDs) can reduce the efficiency-sapping quantum-confined Stark effect (QCSE) [Cao Wen-Yu et al, Chin. Phys. B, vol. 22, p076803, 2013].

The QCSE arises from the strongly polar nature of the III-nitride bond that leads to piezoelectric (strain-dependent) and spontaneous polarization fields. In multiple quantum well (MQW) structures used for generating light, the contrasts in polarization of the different layers lead to strong electric fields that tilt the potential wells and tend to pull apart the electrons and holes that should be combining into photons.

The LD epitaxial structures (Figure 1) were grown on c-plane sapphire using metal-organic chemical vapor deposition (MOCVD). The material was subjected to a series of measurements.

Electroluminescence spectral peak measurements showed that LDs with a pre-strain layer were blue-shifted to 3.05eV at 20mA, in comparison to control devices without such a layer that had a 2.89eV peak. This was attributed to the reduced QCSE from the tensile strain introduced into the GaN barriers from the pre-strain layer.

The spectrum measurement also showed a narrower linewidth for the pre-strained LDs due, it is thought, to reduced InGaN composition/potential fluctuations.

In the current range 5-50mA, the control material's peak photon energy 23meV varied from 2.879eV to 2.902eV, respectively. The blue-shift of the pre-strained sample was much less at 1meV, varying from 3.055eV

Contact	p-GaN	60nm
Multiple quantum well	In _{0.11} Ga _{0.89} N/GaN	5x(2.5nm/8nm)
Prestraining	In _{0.03} Ga _{0.97} N	10nm
Waveguide	n-GaN	0.1μm
Superlattice cladding	n-Al _{0.2} Ga _{0.8} N/n-GaN	160x(3nm/3nm)
Contact	n-GaN	3μm
Buffer	GaN	1μm
Substrate	Sapphire	

Figure 1. Epitaxial structure of material designed for blue LDs with pre-strain layer of InGaN. Control devices without this layer were also produced for comparison.

to 3.056eV for the same injection current range.

Again, blue-shifts with increasing current injection are often attributed to QCSE, and the smaller blue-shift in the pre-strained LD suggests a weaker QCSE.

The light intensity is also increased in the pre-strained devices: a 65% increase in the case of 20mA injection. Temperature-dependent photoluminescence measurements suggest internal quantum efficiencies (IQEs) of ~14% for the control material and ~24% for the pre-strained sample.

The researchers used simulations to help understand the effect of the pre-strain layer. It was found that one effect was to reduce the piezoelectric field in the wells from the range 780–874kV/cm in the control structure to 579–619kV/cm with the pre-straining. Also, the overlap of the electron and hole wavefunctions was increased from 43–50% to 60–64%, respectively.

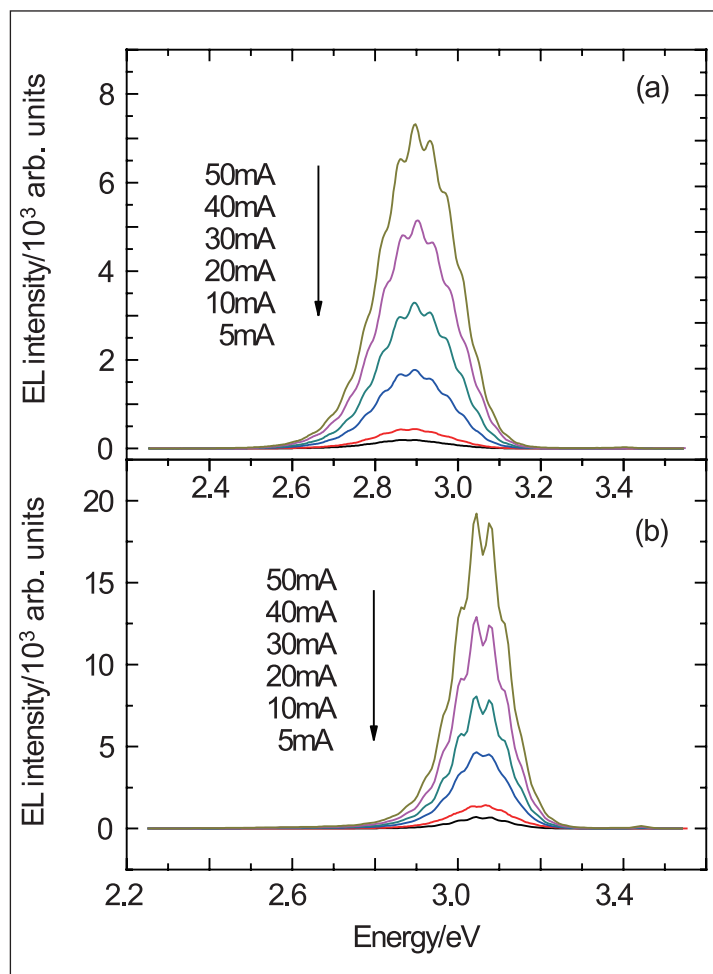


Figure 2. Electroluminescence spectra of (a) control sample and (b) pre-strained sample at various injection current levels.

Increased wavefunction overlap should result in increased radiation output. QCSE tends to pull the electrons and holes apart, reducing overlap. ■

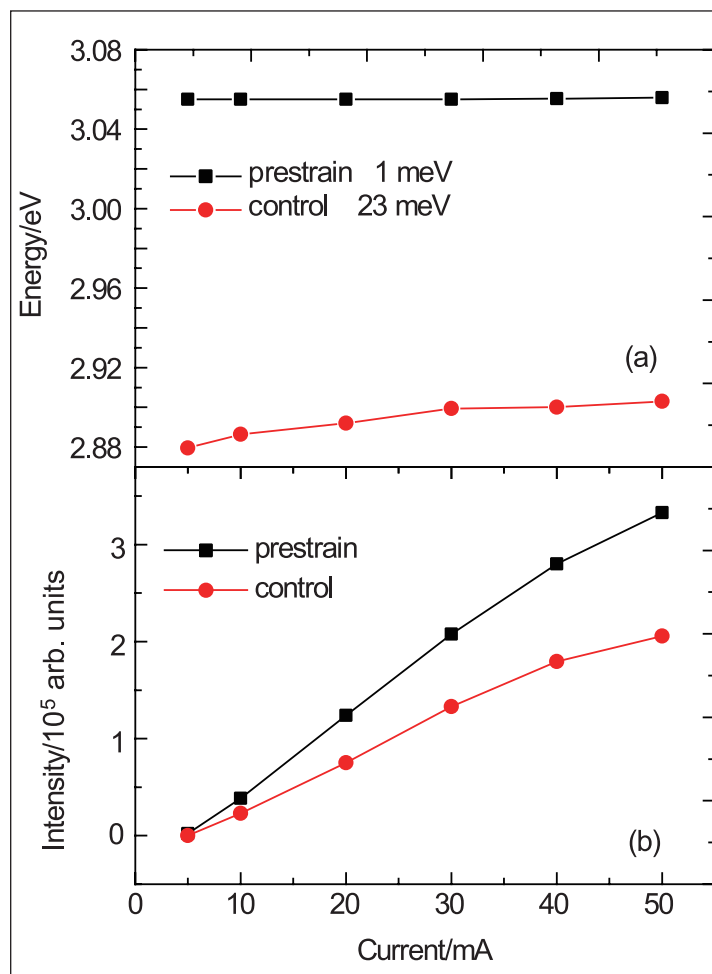


Figure 3. (a) Electroluminescence spectral peak shift and (b) integrated electroluminescence intensity as function of injection current in control and pre-strained samples.

<http://iopscience.iop.org/1674-1056/22/7/076803>

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Grading barriers for improved hole distribution in nitride LEDs

A structure with varying-thickness GaN barriers between InGaN MQWs outperforms equal-thickness barriers at high injection current.

Researchers in China and Turkey have been using varying-thickness gallium nitride (GaN) barriers between indium gallium nitride (InGaN) multiple quantum wells (MQWs) to improve hole distributions and thus to reduce efficiency droop effects in blue light-emitting diodes (LEDs) [Z. G. Ju, et al, Appl. Phys. Lett., vol102, p243504, 2013]. The idea for such a structure has been proposed before on the basis of simulations at Taiwan's National Changhua University of Education.

The new work at Nanyang Technological University, South University of Science and Technology of China, and Bilkent University, includes the growth and characterization of actual

LEDs. The researchers conclude that the proposed graded-thickness quantum barrier (GTQB) structure only outperforms equal-thickness quantum barriers (ETQBs) at high current beyond 22A/cm².

The epitaxial material was prepared on c-plane sapphire using metal-organic chemical vapor deposition (MOCVD). The substrate was patterned with cones of 2.4μm diameter and 1.5μm height at 3μm pitch. Growth began with 30nm of low-temperature GaN buffer and a 150nm GaN interlayer. A further 5μm of GaN and 3μm of silicon-doped n-type GaN were grown at high temperature.

The active MQW light-emitting region consisted of five 3nm InGaN wells grown at 750°C. The wells were separated by GaN barriers grown at 800°C. Material with equal-thickness 12nm barriers was used to represent

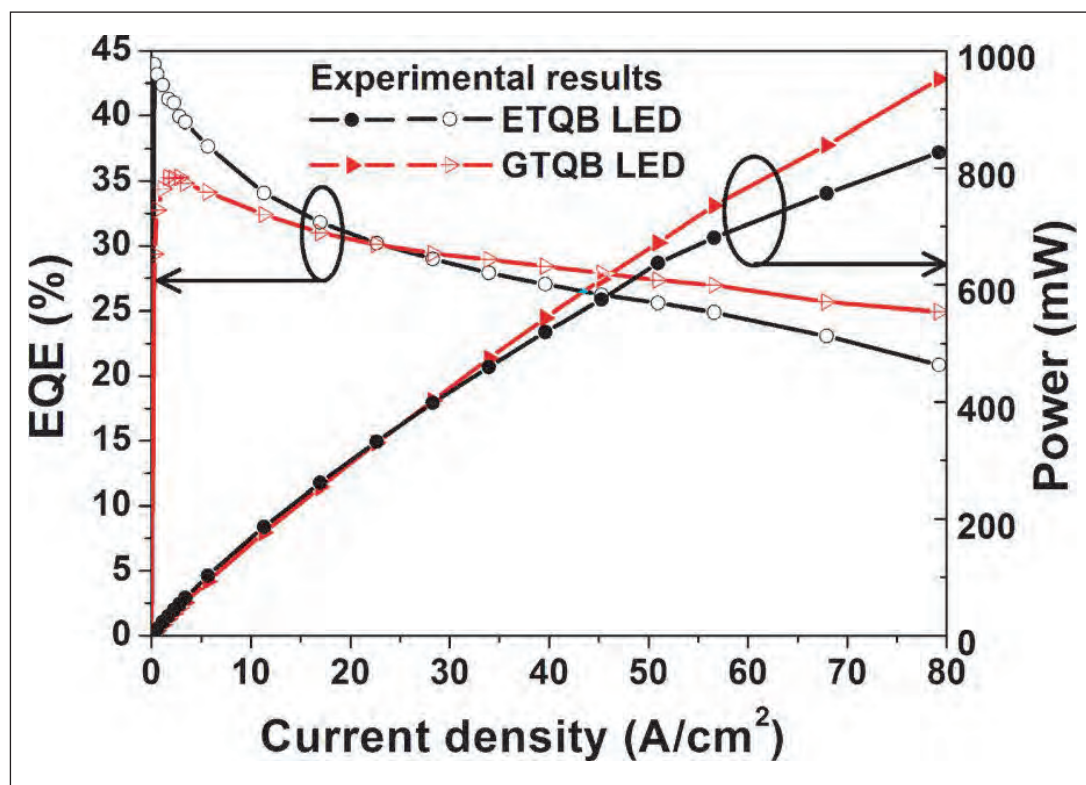


Figure 1. Experimentally measured EQE and light output power with increasing current density for ETQB and GTQB LEDs.

conventional structures. Material with graded-thickness quantum barriers consisted of layers of 12nm, 7.2nm, 6.6nm, and 6.0nm thickness, which become gradually thinner towards the p-GaN contact.

The nitride semiconductor layers were completed with 30nm of Al_{0.2}Ga_{0.8}N as electron-blocking layers and 200nm p-GaN contact layers.

Electroluminescence was excited using indium contacts (Figure 1). The GTQB devices showed higher external quantum efficiency (EQE) and light output power above ~22A/cm². The poorer performance below this current injection is attributed to the "weaker quantum confinement of the electrons within the QWs of the GTQB LED due to the thinner QB thickness."

At 70A/cm², the light output power was 870mW, which is 13% higher than the comparison ETQB device

(770mW). The droops from the maximum EQE were 28.4% for the GTQB LEDs and 48.3% for the ETQB devices. The researchers attribute improved optical power and EQE at high current density to better hole transport in the GTQB LED. As is often the case, improved droop performance comes at the cost of degraded peak EQE.

Spectral measurements show blue-shifts and broadening of the linewidth at increased current for both devices (Figure 2). However, the shift and line broadening are smaller for the GTQB LEDs.

The blue-shift effect is often attributed to screening of the quantum-confined Stark effect (QCSE) caused by the electric fields resulting from strong piezoelectric (strain-dependent) polarization fields in the nitride semiconductors. With the thinner barriers in the GTQB material, one expects smaller strain fields in the MQW structure, reducing the QCSE.

The linewidth broadening is commonly associated with band-filling effects, which can be reduced by distributing the holes more evenly across the MQW region.

The researchers used numerical simulations of the LED structures under bias to help in interpreting the experimental results. In particular, the model can be used to explore electron-hole densities and recombination rates in the structure.

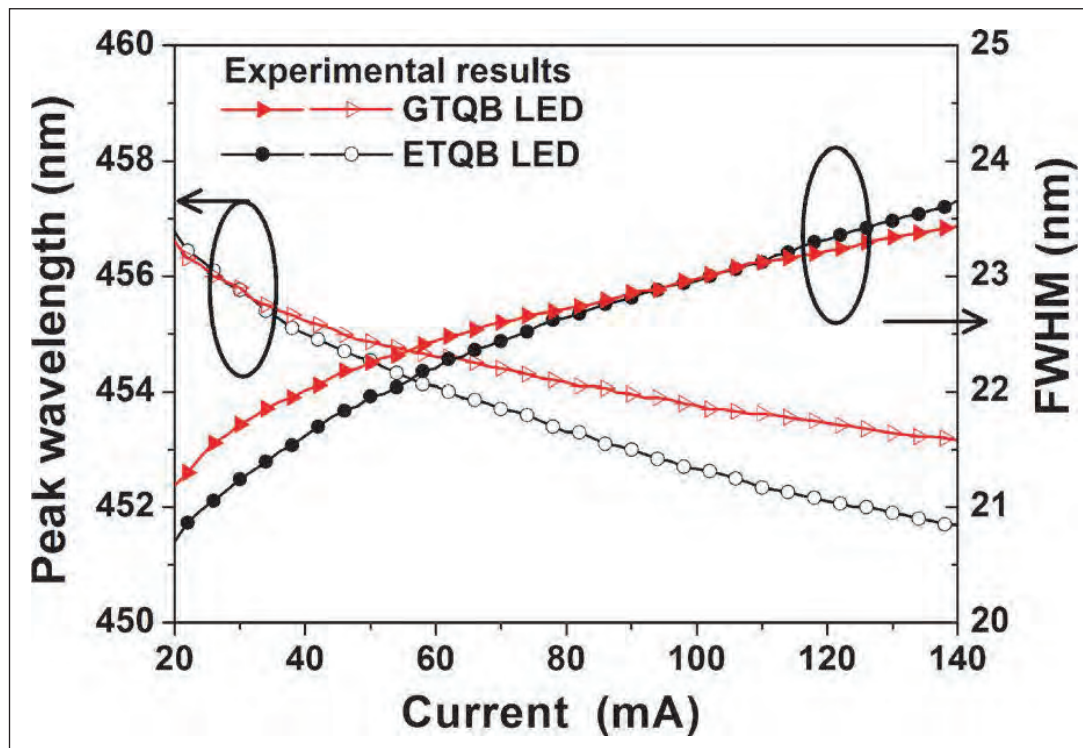


Figure 2. Experimentally measured peak wavelength and full-width at half maximum (FWHM) as a function of current for ETQB and GTQB LEDs.

The thinner barriers near the p-GaN end were found to encourage a more uniform distribution of holes through the structure. Often, MQWs emit predominantly near the p-GaN end due to scarcity of holes reaching the deeper wells. Hole uniformity improved with the increase in injection current, according to the model.

In terms of the electron-hole recombination rate that determines light output, this was greatest near the p-GaN end in both ETQB and GTQB devices at low current ($10\text{A}/\text{cm}^2$). At high current ($70\text{A}/\text{cm}^2$), recombination increases in the deeper wells more significantly in the GTQB LED, compared with the ETQB structure. ■

<http://link.aip.org/link/doi/10.1063/1.4811698>

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Exploring graded electron-blocking layers for nitride LEDs

Efficiency droop at 100mA reduced to 7.8%, compared with 9.7% for bulk electron-blocking layers.

Researchers in South Korea and USA have been developing graded-composition superlattice electron-blocking layers (GSL-EBLs) for nitride semiconductor light-emitting diodes (LEDs) [Jun Hyuk Park et al, Appl. Phys. Lett., vol103, p061104 2013]. The team consisted of scientists/engineers from Pohang University of Science and Technology (POSTECH), Rensselaer Polytechnic Institute (RPI), Seoul Opto-device Co, and Chonbuk National University.

Electron-blocking layers are used to confine electrons to gallium indium nitride (GaInN) multiple quantum well (MQW) active regions in attempts to improve efficiency. Electrons in nitride semiconductor LEDs can overshoot the light-emitting region, ending up in the p-contact and recombining non-radiatively with holes, reducing efficiency and hole injection into the MQW. Up to now, using EBLs to reduce these effects has had mixed results. Such structures often do not reduce overshoot as expected. At the same time, the EBL also tends to create a barrier to the injection of holes into the MQW.

The researchers designed their test EBL structures by performing a series of Advance Physical Model of Semiconductor Devices (APSYS) simulations (Figure 1). They found that using a superlattice structure with graded aluminium gallium nitride (AlGaIn) layers and gallium nitride

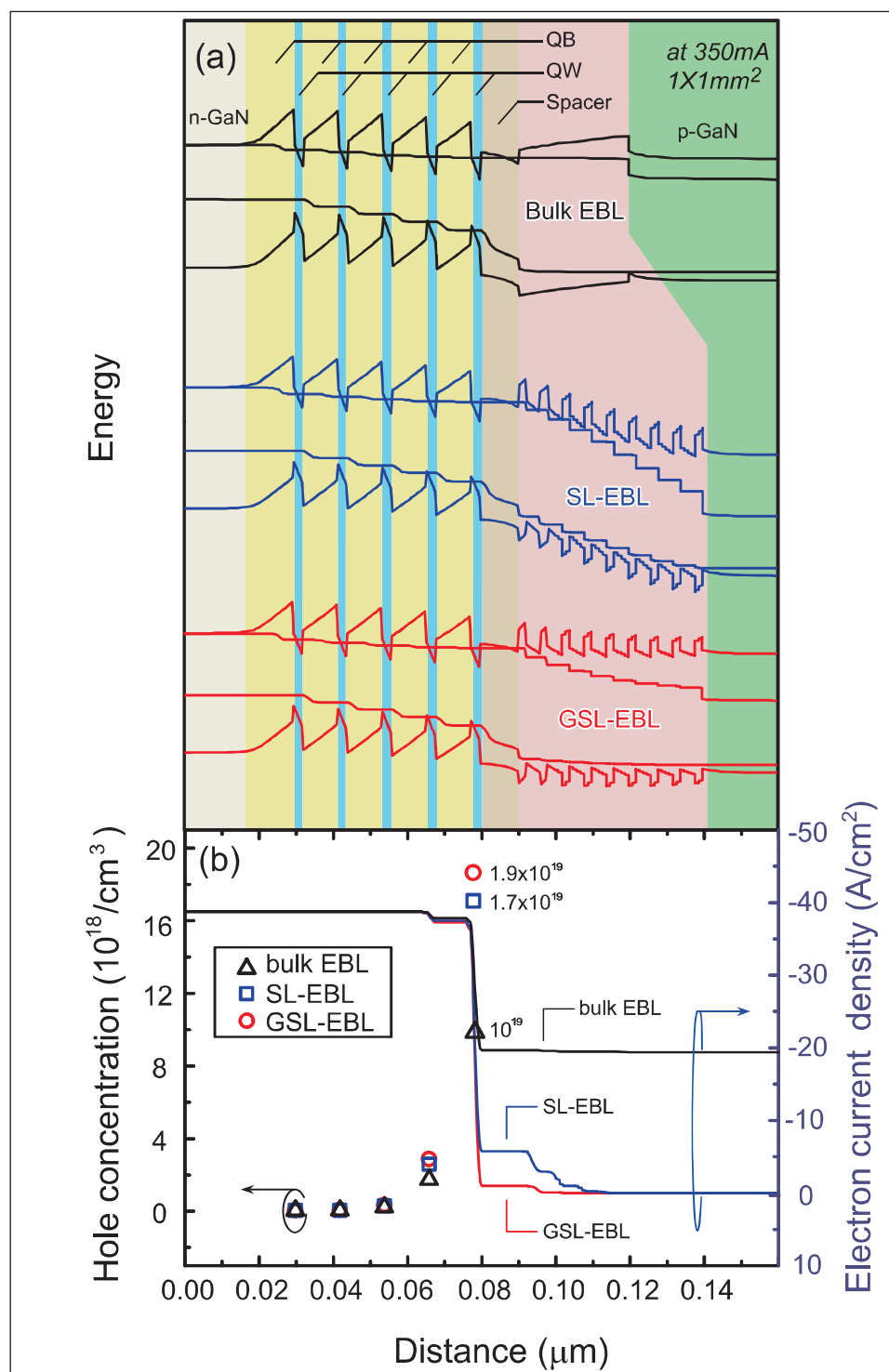


Figure 1. (a) Energy band diagrams and (b) hole concentration and electron leakage current of GaInN/GaN MQW LEDs with three different EBL structures at 350mA injection current, as calculated by APSYS simulator.

(GaN) bilayers reduced electron overshoot and improved hole injection. The grading of the AlGaIn was also designed to avoid a penalty in operating voltage that arises in ungraded SL structures.

Actual LED structures were grown on c-plane sapphire substrates by metal-organic vapor phase epitaxy (MOVPE). The buffer was 2 μm of GaN. This was followed by a short-period GaInN/GaN superlattice with 20 periods, 3 μm of n-GaN, a quantum well (MQW) active region, the EBL, and a 100nm p-GaN contact. The MQW was a five-period structure with 9nm GaN barriers separating 3nm Ga_{0.8}In_{0.2}N wells.

Three types of EBL were implemented: an 18nm p-Al_{0.2}Ga_{0.8}N bulk material; a five-period GSL-EBL with p-Al_xGa_{1-x}N/p-GaN 2nm/3.6nm bilayers graded from x values of 0.23 to 0.07 from the MQW to the p-GaN contact; and a nine-period GSL-EBL with 2nm/2nm bilayers where the x values grade over the same range as in the five-period structure.

The LED wafers were processed into 600 μm x 600 μm mesa-type devices. The n-contact was annealed titanium/aluminium and the p-contact was annealed indium tin oxide transparent conductor with chromium/gold metal pads.

The light output power (L), current (I) and voltage (V) performance of the devices was measured and the external quantum efficiency (EQE) was extracted (Figure 2). The nine-period GSL-EBL showed slightly improved peak efficiency and reduced droop effect

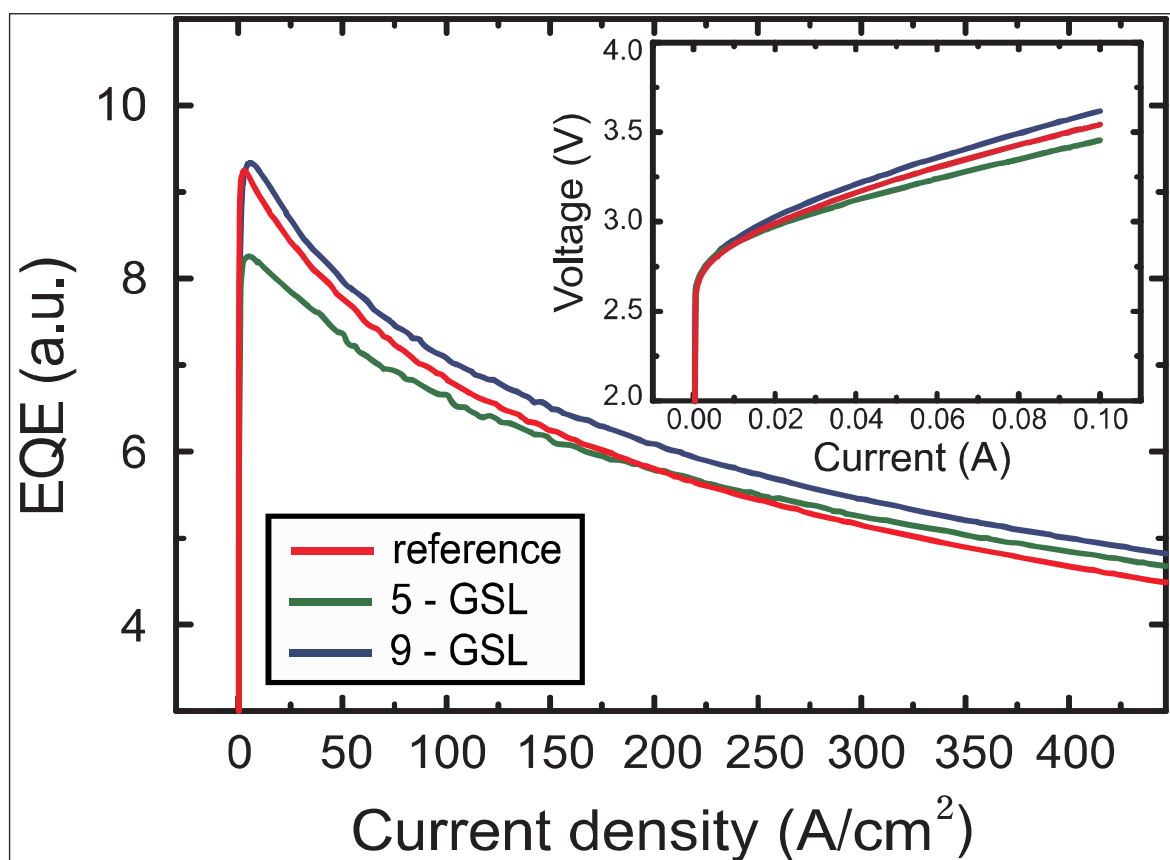


Figure 2. EQE as a function of injection current for GaInN LEDs with three different EBL structures. Inset: I–V characteristics.

Graded-composition superlattice electron-blocking layer LEDs optimized in terms of crystal quality and structure will show not only a higher efficiency with reduced droop but also an even lower operating voltage than LEDs with conventional bulk EBL

over the bulk EBL. The droop at 100mA was 7.8% for the nine-period GSL-EBL compared with 9.7% for the bulk EBL. The efficiency droop was even less apparent in the five-period GSL-EBL at 5.6%, but at the cost of lower peak efficiency.

The 20mA forward voltages for the devices were 3.00V for the bulk EBL, 3.05V for the nine-period GSL-EBL, and 2.95V for the five-period GSL-EBL. It is thought that the increased voltage for the nine-period GSL-EBL is due to its increased thickness, leading to increased resistance to current flow. Higher forward voltages indicate a source of power loss.

Temperature-dependent measurements suggested that the problem with the 5-period EBL was related to “somewhat inferior” crystal quality compared with the other devices. The poor quality increased Shockley–Read–Hall recombination through defect levels at low current, reducing the peak efficiency. At current densities above 200A/cm², where SRH recombination becomes less significant, the five-period EBL performed better than the bulk EBL in terms of EQE.

The researchers comment: “We anticipate that GSL-EBL LEDs optimized in terms of crystal quality and structure will show not only a higher efficiency with reduced droop but also an even lower operating voltage than LEDs with conventional bulk EBL.” ■

<http://link.aip.org/link/doi/10.1063/1.4817800>

Author: Mike Cooke

Explaining high electron leakage over electron-blocking layers in nitride LEDs

Researchers see unequivocal correlation between onset of high injection and efficiency droop.

Researchers based in the USA and Korea have found “an unequivocal correlation between the onset of high injection and the onset of the efficiency droop” of gallium indium nitride (GaInN) light-emitting diodes (LEDs) [David S. Meyaard et al, Appl. Phys. Lett., vol102, p251114, 2013].

The researchers from Rensselaer Polytechnic Institute, Chonbuk National University, and Samsung Electronics, use their observations to suggest that an electric field develops in the p-type region of the device that sweeps electrons out of the active light-emitting region despite high barriers provided by aluminium gallium nitride (AlGaIn) layers that are supposed to act as ‘electron-blocking layers’ (EBLs). The electron leakage from the active region results in degradation of efficiency.

The 440nm blue LED material was grown using metal-organic chemical vapor deposition (MOCVD). The active region consisted of five indium gallium nitride (InGaIn) wells separated by GaN barriers. The structure includes an $\text{Al}_{0.15}\text{Ga}_{0.85}\text{N}$ EBL deposited on a 6nm GaN spacer from the last InGaIn well. The LEDs were bonded to a silicon wafer and the sapphire growth

substrate removed by laser lift-off. The exposed N-face of the nitride structure was roughened to improve light extraction. The LED wafer was diced into unpackaged 1cm x 1cm chips.

Low-level injection describes the condition where conduction by the majority carrier dominates in the quasi-neutral region of a doped semiconductor. In nitride semiconductor LEDs, violation of low-level injection is accompanied by a significant voltage drop across the electron-blocking layer and the p-GaN contact quasi-neutral region.

The researchers determined the onset of high-level injection in the diode as being when the low-level exponential dependence of current on voltage transitions to a linear behavior. This point was found by considering the slope of the logarithm of current with voltage, which takes an abrupt downward path at the transition.

The researchers correlated the onset of high-level injection with the peak efficiency current of the light output over the temperature range 200–450K.

The reason for studying temperature dependence is that the various efficiency-sapping mechanisms have

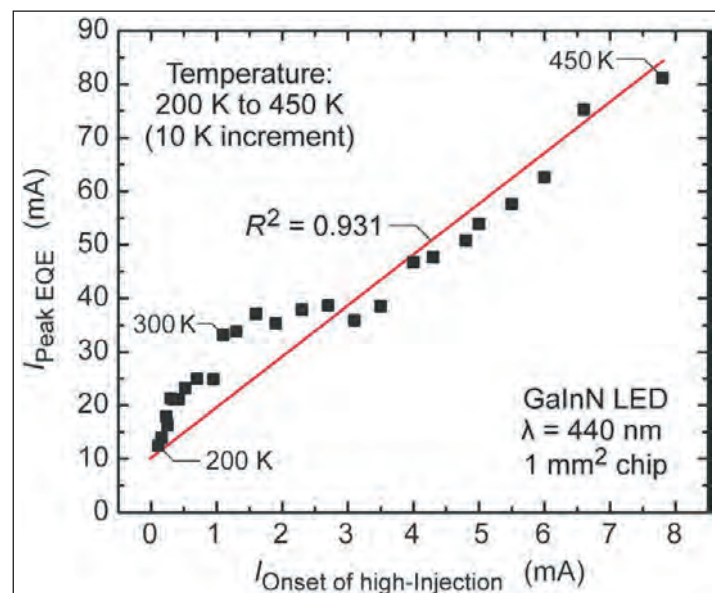


Figure 1. Current at the onset of high injection, correlated with current of peak efficiency for GaInN LED in temperature range 200–400K.

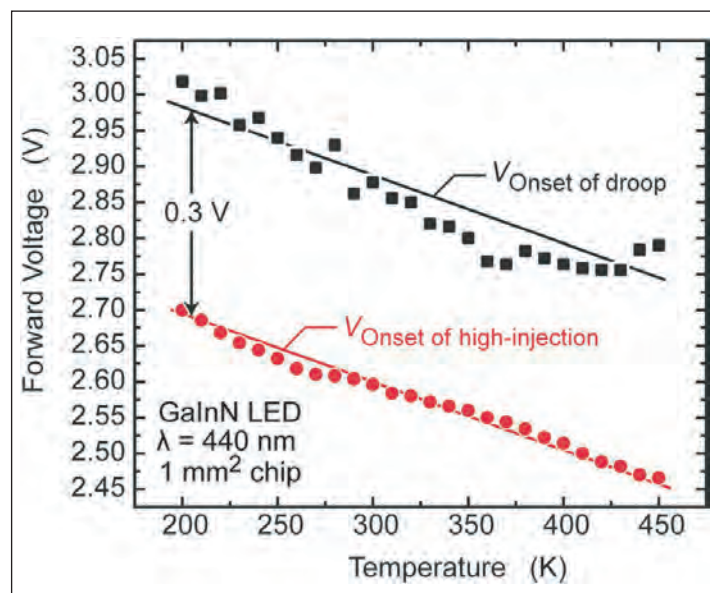


Figure 2. Voltage at the onset of high injection and voltage at onset of efficiency droop (peak-efficiency point) as function of temperature.

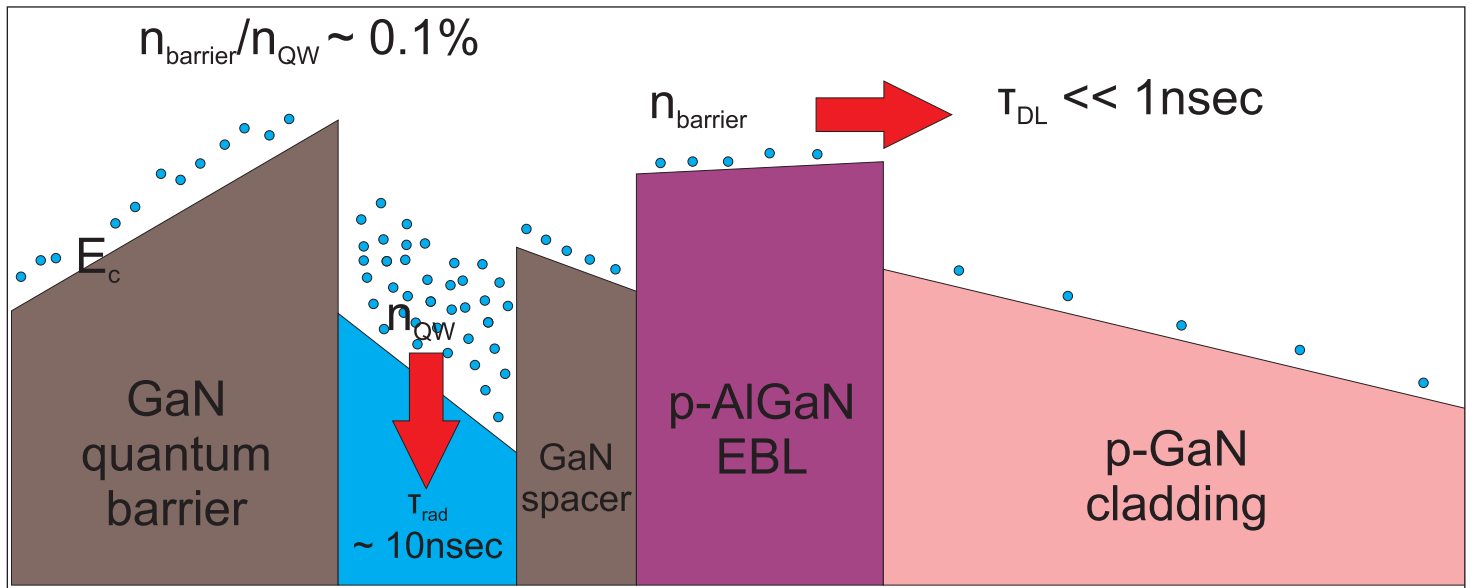


Figure 3. Conduction band of GaInN LED in high-level injection, leading to electron escape from active region.

different behaviors. For example, Shockley–Read–Hall recombination of electrons through mid-gap impurity levels to the valence band is less of a problem at low temperature. By contrast, the desired radiative recombination of electrons and holes into photons is enhanced at cryogenic temperatures. Electron leakage into the p-GaN region is found to be greater at 200K than at room temperature ($\sim 300\text{K}$).

The factors combine to reduce the peak efficiency at high temperature. It is also found that position of the peak shifts up in current as the temperature increases. A further observation is that the droop after the peak is sharper near 200K. Such an increase in the droop effect at cryogenic temperatures has been reported by others.

Plotting the onset currents of external quantum efficiency (EQE) droop against high-level injection (Figure 1), a linear trend is found with strong correlation (R^2 of 0.931). Peak EQE comes at currents about an order of magnitude ($\sim 10\times$) higher than the high-level injection point.

The researchers write: “We propose that the voltage associated with the current difference is required to build up an electric field in the EBL and p-type GaN region. That is, at the onset of high injection, the electric field in the p-type region is negligible; it takes an additional incremental voltage drop over this region to generate an electric field that will initiate the transport of electrons by drift (rather than diffusion).”

Looking at the forward voltage at peak EQE and the onset of high-level injection over the temperature range (Figure 2), the researchers find a roughly constant difference of 0.3V. The researchers believe that a portion of this voltage drop is made over the EBL and p-GaN contact materials.

The researchers comment: “The parallel nature of the two lines constitutes evidence that the efficiency droop is directly linked to the onset of high-injection. As an electric field builds up in the EBL and p-type GaN, electrons are extracted out of the active region, thereby

causing the efficiency droop.”

Although the electron concentration in the EBL is of the order of 0.1% ($\sim 1/1000$) of that in the last QW, the researchers believe that the electric field reduces the lifetime for the sweeping out of electrons from the p-type EBL and GaN regions (τ_{DL}) to values significantly smaller than the radiative lifetime in the quantum well ($\tau_{\text{rad}} \sim 10\text{nsecs}$). This can enhance the fraction of electrons that leak out of the QW to replace those swept from the p-type regions by the electric field (Figure 3).

APSYS simulations suggested that τ_{DL} could be of the order of tens of picoseconds at the onset of droop, where the average electric field across the p-type regions has increased by about 3kV/cm above that of the point of high-level injection. The simulations included an Auger recombination coefficient of $10^{-34}\text{cm}^6/\text{sec}$ that is much smaller than the $10^{-29}\text{cm}^6/\text{sec}$ needed to explain droop effects in nitride semiconductors.

The $10^{-34}\text{cm}^6/\text{sec}$ coefficient is that expected from first-principles calculations of direct Auger recombination, where energy from electron-hole recombination is converted to kinetic energy of a conduction-band electron or valence-band hole. Some theorists have found ways to enhance the Auger coefficient through resonance or excited-state contributions to give values closer to that needed to explain droop.

The US/Korean researchers believe that, apart from the expected smallness of the Auger coefficient, the mechanism also offers a poor explanation because it cannot describe the larger droop at cryogenic temperatures, and the appearance of droop in other material systems such as AlGaInP LEDs, among other features.

By contrast, “these key characteristics can be explained, qualitatively as well as quantitatively, by the drift-leakage model”, they write. ■

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Author: Mike Cooke

Gold-free CMOS-compatible nitride semiconductor Schottky barrier diodes

Gate-edge termination and recessing used to reduce reverse leakage by more than three orders of magnitude.

Researchers based in Belgium have developed gold-free nitride semiconductor Schottky barrier diodes (SBDs) on 200mm-diameter silicon to complement metal-insulator-semiconductor high-electron-mobility transistors (MISHEMTs) previously reported [Silvia Lenci et al, IEEE Electron Device Letters, published online 3 July 2013; MISHEMTs reported at www.semiconductor-today.com/news_items/2011/MAY/IMEC_260511.html]. The research team was based at imec, KULeuven and Ghent University.

Most nitride semiconductor devices use gold in the fabrication of Schottky and ohmic contacts. However, one would like to integrate such devices produced on silicon substrates with CMOS to benefit from the respective strengths, such as high breakdown in the nitride semiconductor section and unsurpassed CMOS logic performance. Gold is a killer of CMOS performance through its drastic reduction of carrier lifetimes in silicon.

The epitaxial structure of the SBD and MISHEMT devices (Figure 1) was obtained through metal-organic

chemical vapor deposition (MOCVD) on 8-inch (200mm) <111> silicon. The aluminium gallium nitride (AlGaN) buffer was grown on a 200nm AlN nucleation layer. The buffer consisted of a series of steps down in Al-concentration: 400nm $\text{Al}_{0.74}\text{Ga}_{0.26}\text{N}$, 400nm $\text{Al}_{0.44}\text{Ga}_{0.56}\text{N}$ and 1800nm $\text{Al}_{0.21}\text{Ga}_{0.79}\text{N}$. This structure was then used as a template for the 150nm GaN channel and

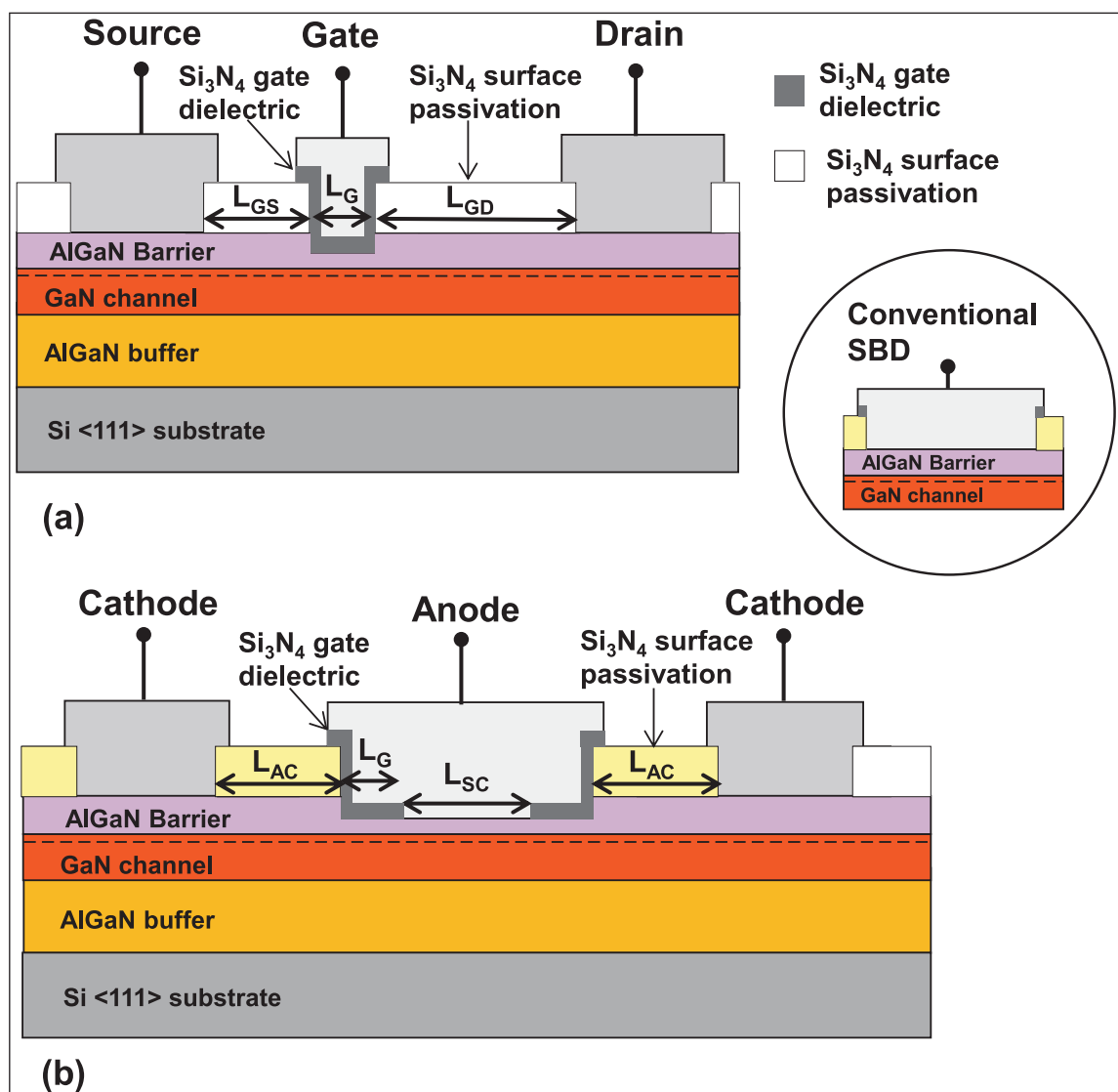


Figure 1. Schematic representation of (a) AlGaN-on-Si MISHEMT and (b) GET-SBD. Reference SBD is shown in circle.

15nm $\text{Al}_{0.21}\text{Ga}_{0.79}\text{N}$ barrier. The wafer was capped with 2nm of GaN, and 140nm silicon nitride (SiN) passivation, applied using rapid thermal chemical vapor deposition (RTCVD).

Device isolation was achieved by nitrogen implantation. The anode and cathode regions of the Schottky barrier diode were opened using sulfur hexafluoride plasma etch of the passivation layer. The anode was further recessed by atomic layer etching of the barrier, leaving ~5nm AlGaIn above the GaN channel.

The anode recess was lined with 15nm of RTCVD silicon nitride, which was also used as gate dielectric in the MISHEMT process. The silicon nitride was then etched to give an anode region with gate dielectric edge termination (GET).

This was the only extra lithography step over the MISHEMT process. The use of GET aims to allow forward current flow across the

Schottky contact length (LSC) while blocking reverse-bias flow leakage across the lateral shielding areas (LG).

The gold-free metal stack used for the Schottky anode contact and MISHEMT gate electrode consisted of 20nm of titanium nitride, 20nm of titanium, 250nm of aluminium, 20nm of titanium, and 60nm of titanium nitride. The gold-free cathode/source/drain ohmic metals were 20nm of titanium, 200nm of aluminium, 20nm of titanium and 60nm of titanium nitride. Metals were annealed at 550°C.

Small diodes with single anode fingers of width 100µm were produced, along with multiple-finger diodes with a total width of 10mm. The anode-cathode distance was 10µm. The GET length (LG) was 1.5µm with the Schottky contact 6µm. The Schottky contact length for comparison conventional SBDs without GET was 9µm (1.5+6+1.5µm).

The forward current-voltage characteristic for the small GET-SBD was similar to the conventional SBD with the GET-SBD turning on a little faster. However, the reverse-bias current leakage was more than three orders of magnitude lower in the GET-SBD.

The researchers also studied breakdown of GET-SBDs with different anode-cathode distances (Figure 2): with

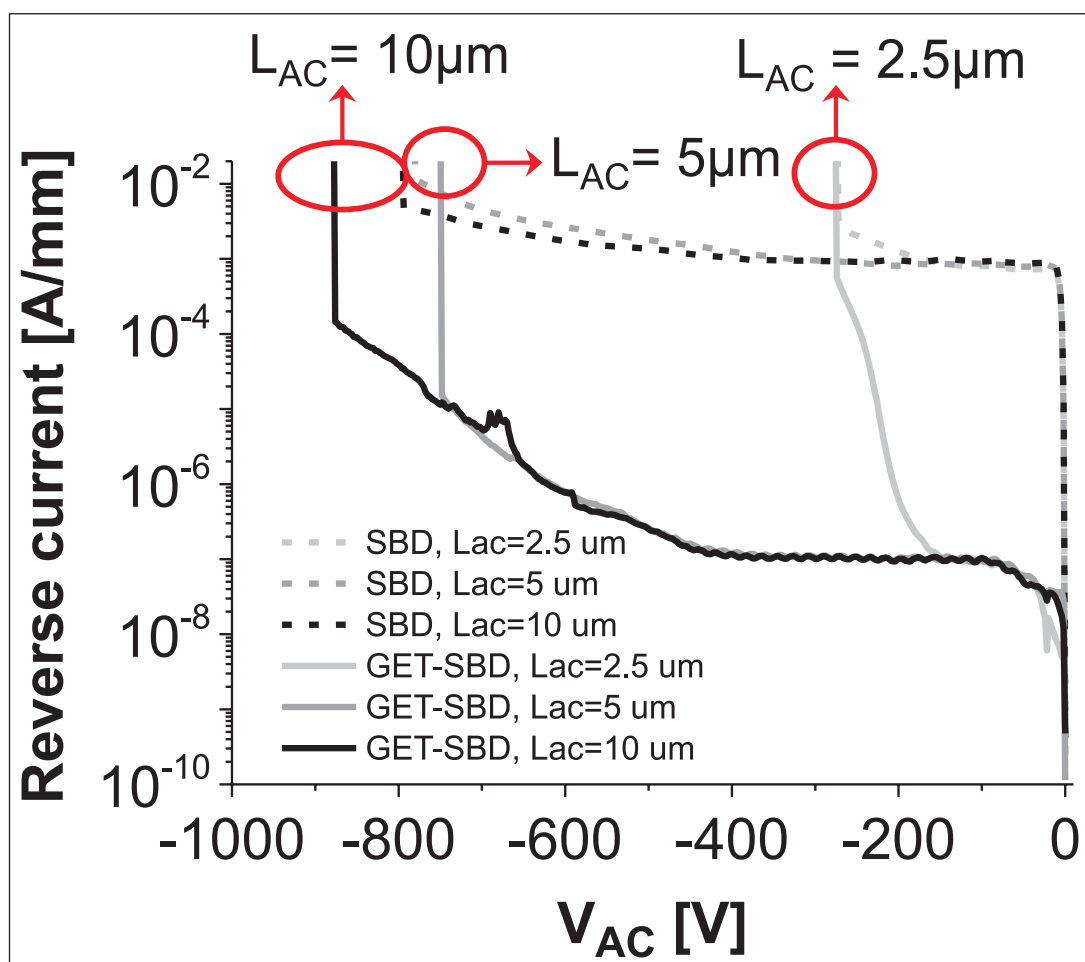


Figure 2. Reverse leakage current, measured until hard breakdown, of 100µm-wide rectifiers with varying anode-to-cathode spacing. Light gray, dark gray, and black curves: L_{AC} = 2.5µm, 5µm, and 10µm, respectively. Solid lines: GET-SBDs. Dashed lines: conventional SBDs.

L_{AC} of 5µm and 10µm, 1µA/mm breakdown occurred at -600V. Hard breakdown came at -800V for L_{AC} of 10µm.

Although the reverse current leakage of the GET-SBD increases with temperature in the range 25–150°C, the researchers comment that the leakage is smaller at 150°C than in SBDs with gold-based electrodes at 130°C.

The larger multi-finger devices showed hard breakdown at -600V, "a symptom of possible epi-related defects across the wafer". In the forward direction, the devices are capable of handling up to 2A current at 2V bias.

MISHEMTs produced on the same wafer demonstrated functionality with a negative (depletion-mode/ normally-on) threshold voltage of -1V with a 10V drain bias. The hard breakdown voltages of these devices were higher than 600V.

The researchers comment: "When compared with Au-based AlGaIn/GaN rectifiers, our Au-free devices had state-of-the-art turn-on and on-state voltages (0.41V and 1.14V, respectively), together with low reverse leakage current (within 1µA/mm at V_{AC} = -600V)." ■

<http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=6553126>

Author: Mike Cooke

GaN-based HEMT improvement using advanced structures

Giuseppe Vacca gives an overview of the benefits obtainable from innovative gallium nitride transistor architectures.

In order to overcome silicon's performance limitations, the general trend in research has changed to the use of wide-bandgap semiconductors and devices made with innovative structures; in fact, devices built with silicon cannot be improved significantly due to the material's intrinsic limitations.

In recent years, high-electron-mobility transistor (HEMT) devices fabricated from group III-V compound semiconductor materials have been growing rapidly in terms of utilization and proliferation.

This trend applies to both well-established gallium arsenide materials technology (AlGaAs/GaAs) and especially to newer gallium nitride materials technology (AlGaN/GaN).

Indeed, AlGaN/GaN devices seem to be the most promising technology, considering that it can potentially be used to cover a vast array of applications, such as RF and microwave amplifiers with operating frequencies up to the S-band and in many cases working at frequencies of 4GHz and above.

The devices can also be used in the power supply and power management environments, where typical applications are products such as switched-mode power supplies (SMPS), electronic welding units, home appliances, inverter equipment and, in general, AC-to-DC and DC-to-DC converters.

The advantages of GaN are well known: the wide energy bandgap permits a large breakdown voltage, and the higher charges provide higher current; the power density is hence more than 10 times that in GaAs and silicon devices.

In every application GaN shows performance that is at least an order of magnitude greater than that of silicon. It has hence been considered the reference semiconductor for the whole electronics industry over the last few years.

To improve electrical performance together with the reliability that is currently available between the compound semiconductors present on the market, many researchers are studying new transistor structures that enable an increased power level to be managed in these kinds of new devices.

Over the last few years experiments have been performed on new technology consisting of introducing a novel electrode (the field plate) in power HEMT structures designed for radio-frequency, microwave and power applications: this technique has been developed especially for the new AlGaN/GaN heterojunction transistor types.

Due to the integration described, this type of device has already achieved significant improvements and important results regarding electrical performance. Also, very good reliability — of more than 20 years mean time between failure (MTTF) — has been reached.

Additional field-plate integration foresees placement in the median position, between the gate and drain electrodes, in order to enable electric field modulation. In particular, the main function performed by this new electrode is reshaping the electric field distribution profile, spreading it along the device's channel; this is because the maximum electric field is a dominant factor for reliability in high-voltage GaN HEMT transistors.

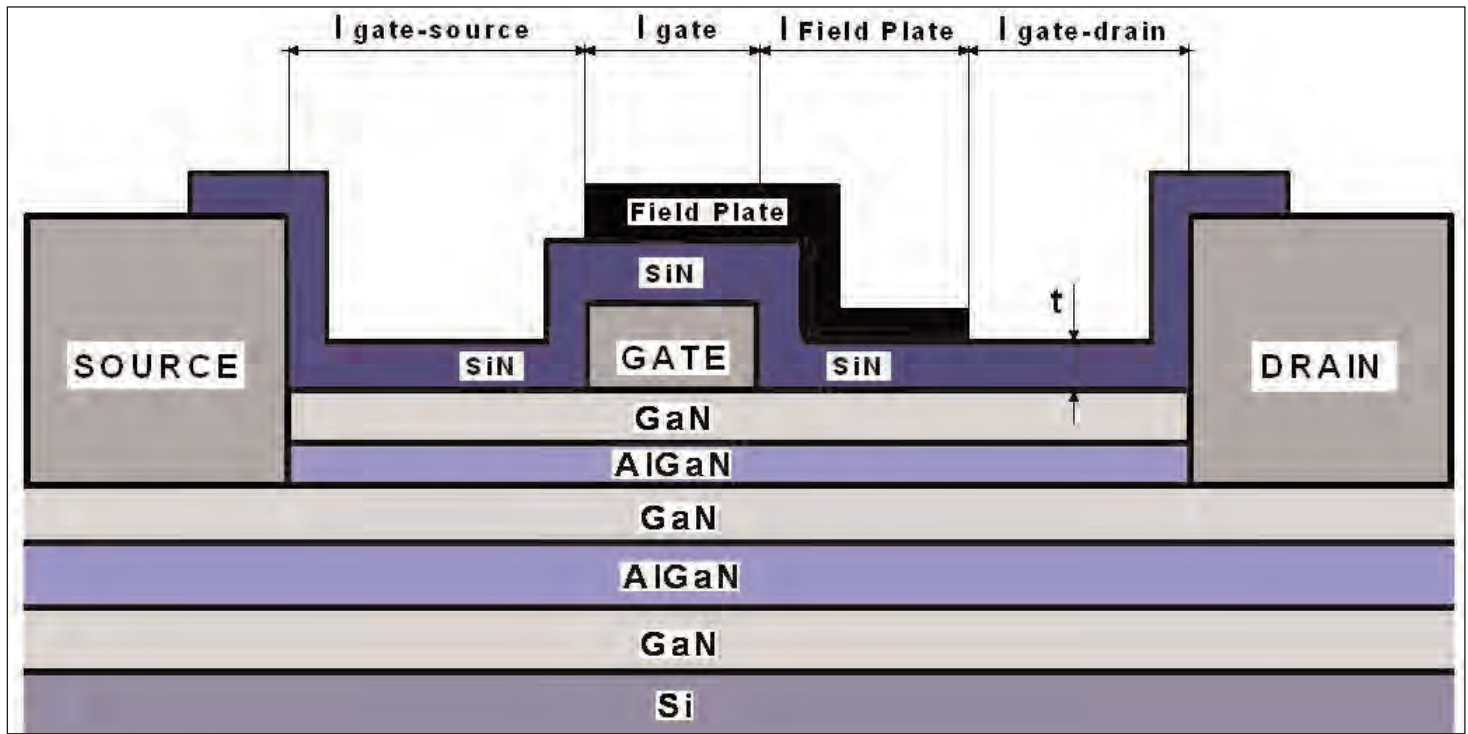
By using a field plate it is possible to achieve a reduction in the maximum peak value of electric field concentration at the drain side of the gate edge. This happens due to the depletion zone formed under the field plate.

The main benefits are a large increase in the breakdown voltage and a reduction in high-field trapping effects in the surface, enhancing current-voltage swings at high frequencies.

Overall, the power density can increase greatly: due to the higher breakdown voltage, in some cases it can grow from 10W/mm to about 40W/mm.

Moreover, the addition of a field plate allows a reduction in the parasitic effect of DC-to-RF dispersion (otherwise termed drain-current collapse). In fact, if the device is affected by this phenomenon, the drain current reached during RF operation is lower than the value obtained in DC mode, so the output power achievable during RF operation is lower and device performance is less than expected.

Experiments have shown a reduction in current collapse, especially for high-voltage applications (compared to the expected value) in devices with field-plate structures, since these help to improve large-signal RF performance compared to devices without a field plate.



AlGaIn/GaN HEMT cross section with introduction of field-plate electrode.

Field plates also allow a reduction in the high-frequency dispersion effect in high-power applications.

This new electrode can be fabricated by covering part of a silicon nitride (SiN) passivated layer through an extension of the metallization gate, starting from the gate edge, towards the drain contact.

Field-plate geometry is the key factor to increasing device performance, but correct optimization regarding the plate extension area and the passivated layer is also needed.

A comparison between devices without a field plate versus those equipped with a field-plate electrode can be explained by looking at the electric field distribution. The profile shows the presence of a high single peak placed at the drain edge of the gate contact side; this happens in the case of devices without any field-plate electrode.

If this field plate is present, the shape of the electric field is modified in a novel profile that shows two lower peaks: the first one is located close to the gate (like the previous case); the second one is placed at the edge of the field plate.

Using the field-plate structure it is possible to increase the device breakdown voltage because the new electrode splits the peak of the electric field, relaxing its concentration, and distributes it across the region among the gate and drain: in this way the maximum value of the breakdown voltage rises.

There is a relation between field-plate structure dimensions and breakdown voltage; in particular, the electric field distribution in the channel can be optimized by changing the field-plate electrode geometry because two parameters could be modified: they are the length of the field plate ('Field Plate') and the thickness 't' of the silicon nitride (SiN) dielectric layer.

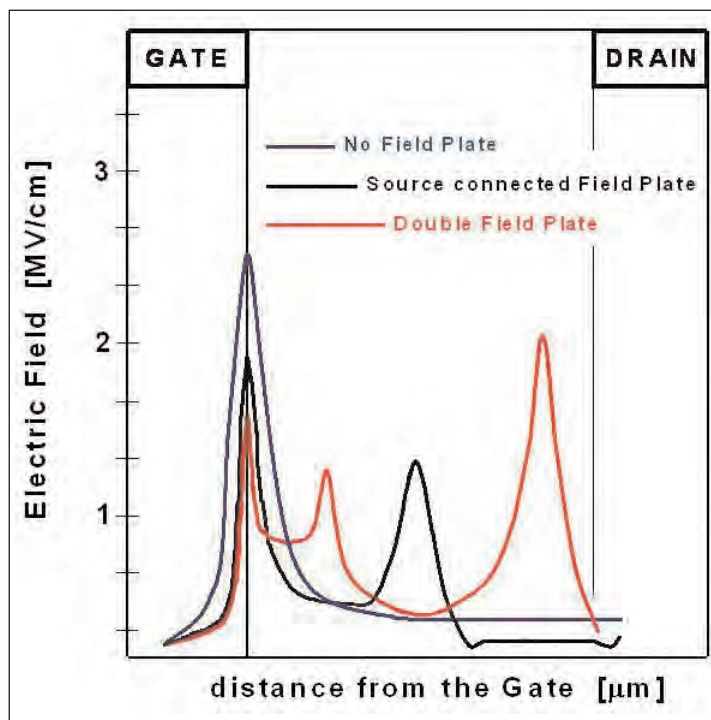
The gate length 'l gate' establishes the transit time under this electrode and the field-plate length determines the size of the reshaping region.

In particular the device's breakdown voltage is enhanced if the field-plate length is increased; this trend is followed up to the saturation point, which changes for different voltage levels. This occurs for different SiN layer thickness 't', and also the breakdown voltage increases with the thickness of this layer up to a defined point. However, above a certain value, there is no further increase in breakdown voltage. So, there is an optimum thickness of the SiN passivated layer that maximizes the device's breakdown voltage.

By performing a transient time gate assessment, it can be seen that FP structures help to recover the drain current and will consequently improve device reliability. A field plate reduces the maximum electric field, and this fact leads to lower electron temperature. In devices without a field plate, hot electrons diffuse into the bulk and are trapped, but if a field plate is used, the electron temperature can be reduced.

The addition of the FP electrode represents an insertion of parasitic capacitance that decreases and limits the behaviour in small-signal conditions.

In order to obtain improvements in the device performance in terms of small-signal conditions together with the breakdown voltage characteristic, other advanced structures have been studied in experiments. One of these consists of the insertion of a double field plate. This kind of structure is built by using essentially two distinct field plates. The first electrode is placed in the gate-drain access region and the second one is connected to the gate terminal.



Electric field profiles from gate to drain.

► This technique is quite easy to apply because it is based on standard planar transistor fabrication, and this is an attraction for GaN transistors specifically designed for power-switching applications.

Another kind of advanced structure foresees connection of the field plate to the source. This connection with the FP electrode generally remains joined to the ground.

A double field-plate structure exhibits three peaks in the electric field profile, while devices with the source connected to the field plate have only two peaks. These two peaks in many cases are lower than the three peaks present in devices with two field plates.

Some other types of experimental and non-conventional FP structures have been proposed. One is called 'fingered field plate', and in the simplest case consists of a double FP where small fingers of the FP metal structure (connected with the gate) penetrate into the SiN passivation.

In conventional FP structures, the RF delay propagation time due to gate fingers introduces a phase difference between the gate and the field plate. This can reduce the breakdown voltage and increase the high field trapping; it occurs in particular if the gate finger dimension is comparable to the signal wavelength.

It is possible to solve this issue by using a new, simpler structure obtainable by shorting the FP electrode to the gate at the end of the gate fingers: the metal FP and an exposed metal gate area have to be connected together (using a metal evaporation process) at their ends.

Due to this fix the breakdown voltage still increases. Also, the minimum noise figure and gain are both improved.

The impact caused by the new structure is small since no additional processing is needed to achieve it; it needs just a small change in one photolithography mask.

The dimension, depth and spacing between fingers can be changed in order to optimize the distribution of the electric field. Generally, it is necessary to have 4–5 fingers placed at 1–2 μm distance with an extension of 0.2–0.4 μm into the passivated layer.

Using a multi-field-plate structure, it is possible to obtain complete control of the shape of the electric field, but with this kind of structure the engineering device processing is quite difficult because multiple connections are required.

A further complication is present in the multi-fingered modulated depth FP: in this case it is very important to optimize the distance downwards of every single finger.

Regarding this structure, a particular biasing level is required for every finger. The first one is drain connected while the last one is generally grounded. The voltage difference between adjacent fingers can be about 100V.

Another non-conventional structure is termed 'Inner Field Plate' because the FP is incorporated between the gate and drain electrodes, at the drain side. Due to this structure it is possible to reduce the gate–drain leakage current, maintaining high-frequency performance. In particular, with this kind of FP the leakage current characteristics depends on the biasing of the inner electrode, V_{IFP} . If the voltage is a negative value (e.g. –15V), the leakage current can be 10–20% smaller than in the case of no biasing ($V_{IFP}=0V$). The inner FP is promising for high-power microwave applications.

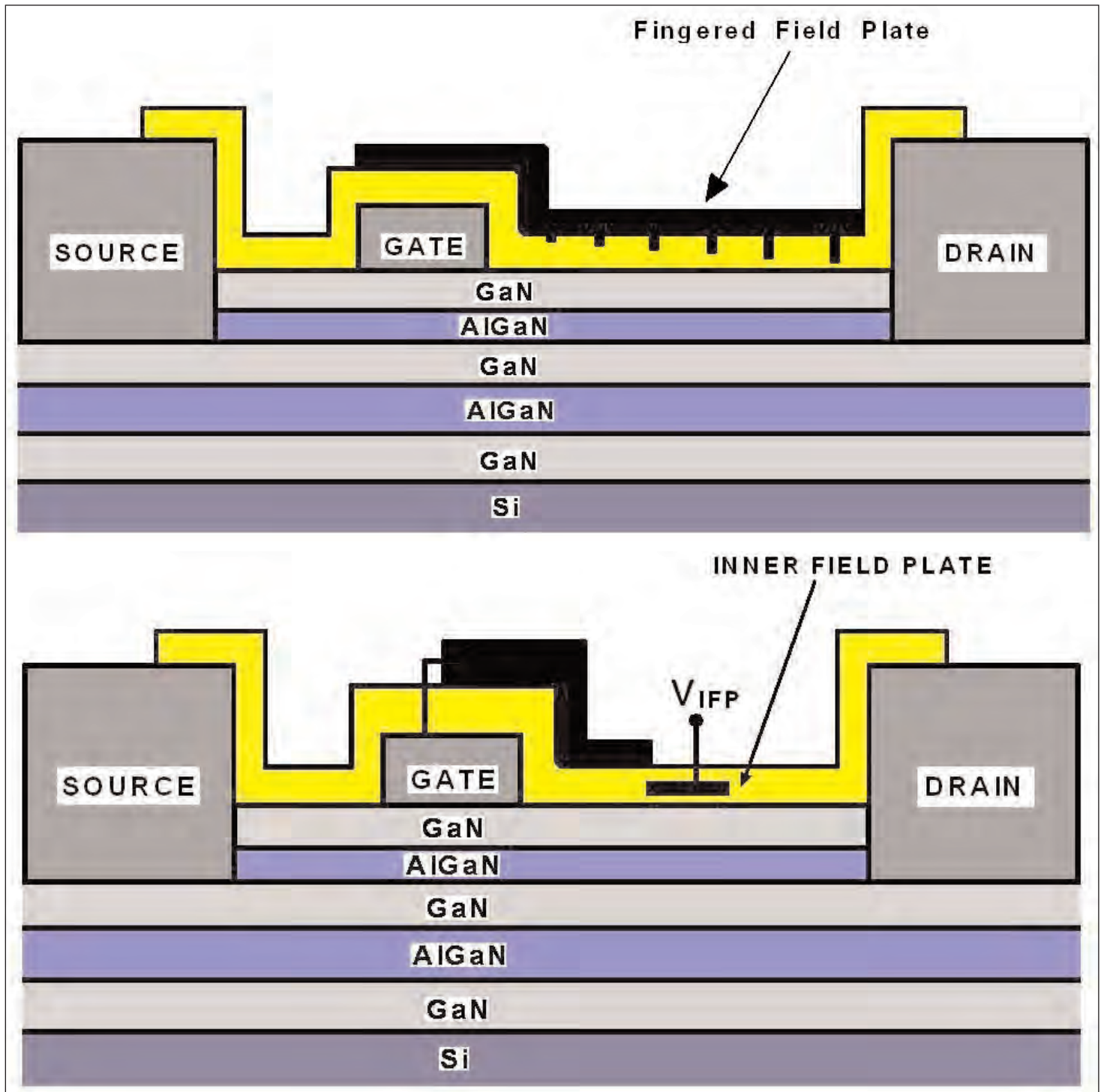
Overall, due to the adoption of field-plate structures, besides reducing the maximum value of electric field, it is possible to improve the control of surface traps that have a bad collateral effect of decreasing the drain current. The impact is particularly marked in situations where the trap concentration is quite high.

Surface traps represent the main cause of GaN HEMT performance degradation when operating at high frequency. Here, field-plate structures reduce trap occupation by limiting the tunnelling injection of electrons into surface traps of the gate-drain region and improve the transient operation of the device.

Also, the leakage current is reduced significantly, by more or less an order of magnitude, assuming the additional field plate. Devices with such a structure show a lower 1/f spectral noise level compared to standard devices.

Although promising good performance, there are some limitations due to parasitic effects and reliability problems (such as superficial and volume traps) that cause a limiting effect on the drain current, particularly related to pulsed conditions.

Defects affecting the gate junction introduce an important reverse leakage current and soft-breakdown problems. A specific study must be dedicated to kinks effects, the consequence of which is the insertion of micro-hysteretic behaviour along the current–voltage characteristic.



AlGaIn/GaN HEMT cross sections with (top) fingered modulated-depth field plate and (bottom) inner field plate.

The degradation due to hot electrons under different bias conditions of the device produces stress effects that occur during operation conditions with current collapse.

At the moment the identification of breakdown mechanisms is not clear because there are some scientifically controversial points regarding the determination of the events that occur during the breakdown phenomenon; this factor is quite strong for short-channel devices.

It is necessary to pay attention to studying the correlation between the degradation of GaN HEMT device performances for events related to stress in the continuous regime and at radio-frequency conditions.

In general, technical immaturity will leave space, in future years, for improvements to be achieved, with efforts focused on the geometry of the materials and an in-depth study of the parasitic elements, since the technology has great potential for improvement. ■

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Digital etch recess achieves highest current for e-mode GaN MISHFET on silicon

Maximum drain current of 1.35A/mm in transistor with 2.1nm barrier.

Germany-based researchers claim a record on-current for an enhancement-mode (e-mode) gallium nitride (GaN) metal insulator semiconductor heterostructure field-effect transistor (MISHFET) on silicon (Si) substrate [Herwig Hahn et al, Jpn. J. Appl. Phys., vol52, p090204, 2013].

Nitride semiconductor transistors are being developed for high-power and high-frequency applications. Producing such devices on silicon would reduce material costs and introduce economies of scale from the larger substrates available (up to 300mm).

Another desirable characteristic is enhancement-mode operation rather than the depletion-mode operation that is usual with nitride semiconductor transistors. Enhancement-mode transistors are in the off-state at zero gate potential, reducing power consumption. Further, e-mode operation is important for fail-safe power circuits.

There are a number of techniques to shift the threshold voltage of nitride semiconductor transistors to positive e-mode values. The team from RWTH Aachen University, Fraunhofer IAF and Aixtron used gate recessing, reducing the thickness of the aluminium gallium nitride (AlGaN) barrier, to achieve this. In addition, a gate insulator material, aluminium oxide (Al_2O_3), was applied to reduce gate leakage currents through the barrier.

The epitaxial structure for the transistors (Figure 1) was produced up to the GaN cap on 6-inch (150mm) silicon using metal-organic chemical vapor deposition (MOCVD). A thin 1.5nm AlN layer above the GaN buffer has been found to enhance mobility in the two-dimensional electron gas (2DEG) used as the transistor channel.

The material was diced into 15mm x 15mm pieces. The first fabrication steps consisted of dry etch mesa isolation and the application and annealing of titanium/aluminium/nickel/gold ohmic source-drain contacts. After a 120nm silicon nitride (SiN) passivation, the pieces had a sheet resistance of 280 Ω /square and a two-dimensional electron gas mobility of 2100cm²/V-s.

Gate recessing was achieved by opening a trench with a soft fluorine-based dry etch and continuing into the AlGaN barrier with a chlorine-based digital dry etch. Digital etching refers to a precise layer-by-layer

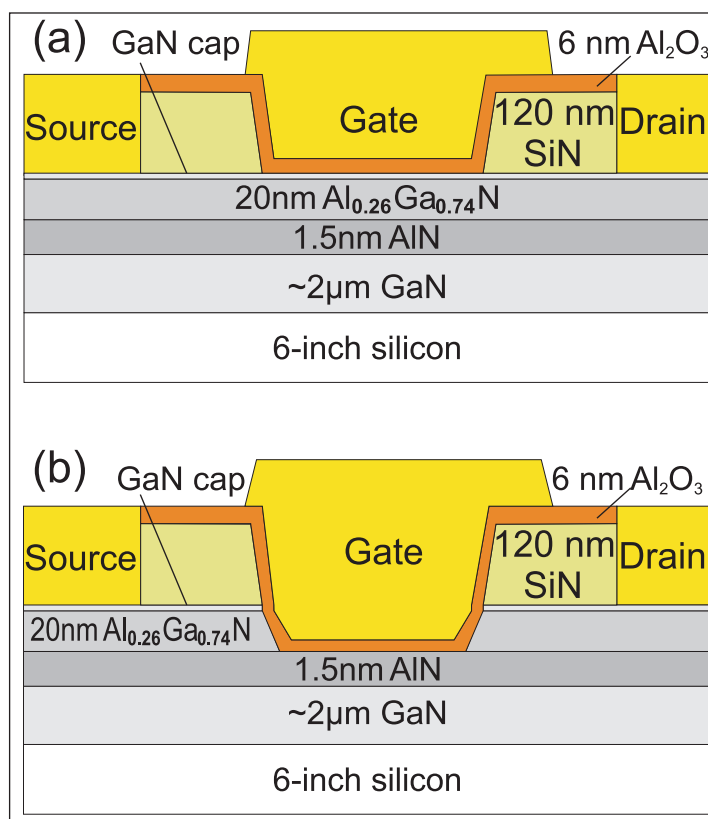


Figure 1. Schematic cross sections of unrecessed (a) and deepest recessed (b) devices.

removal that is rather similar to atomic layer deposition (ALD) in reverse. The depth of the digital etch was varied, leaving differing thicknesses of AlGaN barrier under the gate.

Gate stack formation was completed with atomic layer deposition of Al_2O_3 insulation, and electron-beam evaporation of platinum/gold electrodes.

Capacitance-voltage (C-V) measurements allowed estimation of the barrier thicknesses for the four samples produced: 22nm (no digital etch), 8.8nm, 5.1nm, and 2.1nm. The last sample barrier thickness suggests that the majority is made up of the 1.5nm AlN layer. The C-V analysis also suggests a positive threshold and near zero hysteresis for the 2.1nm barrier. However, stressing the sample to more negative voltages of -6V does give a hysteresis effect of 100mV, comparable to that found with the other samples.

Direct current measurements (Table 1) were made to determine threshold voltage (V_{th}), maximum drain current ($I_{d,max}$), maximum transconductance ($g_{m,max}$), source resistance (R_s), and intrinsic maximum transconductance ($g_{m,max}^i$) for devices with $1\mu\text{m}$ gate length.

The enhancement-mode device with positive threshold voltage (2.1nm barrier) has maximum drain current of 1.35A/mm: “the highest value reported so far when a silicon substrate is used”, according to the

research team. Although shorter gates should theoretically lead to higher drain currents, the researchers warn that the threshold voltage would also be expected to shift.

The transconductance measurement was affected by the relatively high contact resistance, as shown by the intrinsic transconductance being up to a factor of four higher. The researchers believe that optimizing the contacts to give a contact resistance of $0.3\Omega\text{-mm}$ could boost transconductance to 0.75S/mm (700mS/mm). The contact resistance of the measured devices was estimated at $1.75\Omega\text{-mm}$.

The subthreshold swing values were in the range $80\text{--}100\text{mV/dec}$. With 8V drain bias, the gate leakage current under negative gate potential was as low as 10nA/mm . This would enable devices with on-off ratios of the order of 10^8 . However, setting the off condition to that of 0V gate for enhancement-mode operation gives a ‘real’ on-off ratio of 10^4 .

The gate leakage increases with positive gate potentials, with the thinner barriers naturally offering less resistance to current flow. Even so, the leakage is less than 1mA/mm for the on-current of 1.3A/mm in the 2.1nm barrier device.

The researchers comment: “The values are below the ones reported in literature for e-mode metal insulator semiconductor heterostructure field effect transistors (MISHFETs) and much better than those for Schottky-gated e-mode devices.” The maximum applicable extrinsic gate potential of $+7\text{V}$ is limited by dielectric breakdown.

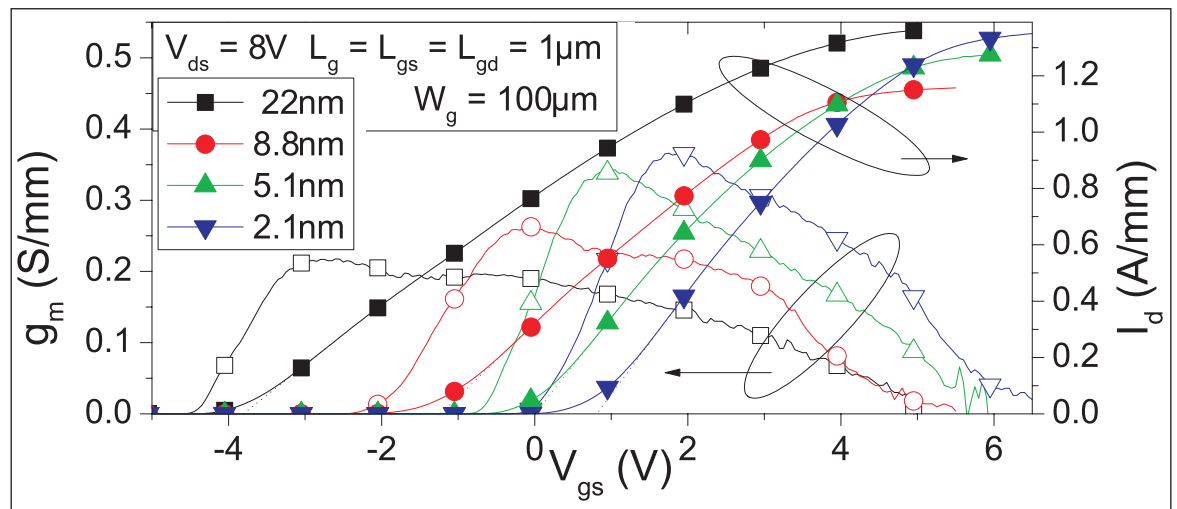


Figure 2. Drain current (I_d) and transconductance (g_m) characteristics for all four samples.

Table 1. Extracted DC values for all samples.

Barrier thickness	V_{th}	$I_{d,max}$	$g_{m,max}$	R_s	$g_{m,max}^i$
22nm	-3.83V	1.36A/mm	215mS/mm	$2.14\Omega\text{-mm}$	400mS/mm
8.8nm	-1.22V	1.16A/mm	260mS/mm	$2.08\Omega\text{-mm}$	566mS/mm
5.1nm	$+0.00\text{V}$	1.27A/mm	342mS/mm	$1.97\Omega\text{-mm}$	1050mS/mm
2.1nm	$+0.82\text{V}$	1.35A/mm	366mS/mm	$1.95\Omega\text{-mm}$	1280mS/mm

Three-terminal measurements at 0V gate gave a breakdown voltage of around 65V drain for the 2.1nm barrier device with $2\mu\text{m}$ gate length and a gate-drain spacing of $2.5\mu\text{m}$. The “rather early breakdown” is blamed on the aluminium oxide in the absence of an exponential behaviour that would indicate buffer problems.

Pulsed measurements to assess current collapse effects were also carried out on devices with a 2.1nm barrier. The researchers compared the specific on-resistance ($R_{on}\times A$) at 65% maximum current for a pulsed unbiased state that eliminates thermal effects and for a 50V drain bias to reveal current collapse. In the thin 2.1nm barrier device ($1.5\mu\text{m}$ gate-source, $1\mu\text{m}$ gate, $2.5\mu\text{m}$ gate-drain, $100\mu\text{m}$ width), the unbiased specific on-resistance was $0.24\Omega\text{-cm}^2$, which increased by 20% to the biased/current collapse value of $0.29\Omega\text{-cm}^2$. By contrast, the non-recessed/ 22nm barrier device showed a 70% increase in on-resistance in the bias/current collapse mode.

The researchers comment: “We believe that the suppression of the current collapse (even if not as good as for a comparable HFET) is related to the slanted gate shape in combination with a barrier recess which reduces trapping phenomena by the passivation/barrier interface.”

In the future, it is believed that the threshold voltage could be shifted to even more positive values by fluorine implantation or by adding a back-barrier. ■

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Author: Mike Cooke

Increased maximum oscillation for ETH double-heterostructure transistor

ETH-Zurich has reported a record maximum oscillation frequency f_{MAX} of 621GHz for any InP/GaAsSb device.

Researchers at ETH-Zurich have reported increased maximum oscillation frequency for its indium phosphide/gallium arsenide antimonide (InP/GaAsSb) double-heterostructure bipolar transistors (DHBTs) [Rickard Löbblom et al, IEEE Electron Device Letters, published online 12 July 2013].

Based on radio-frequency measurements between 0.2GHz and 40.2GHz, the researchers extrapolated a cut-off frequency (f_T) of 428GHz and a maximum oscillation (f_{MAX}) of 621GHz. "To the best of our knowledge, this represents the highest f_{MAX} reported for any InP/GaAsSb DHBT," the researchers write. The performance beats ETH's previous device by 100GHz for f_{MAX} [reported at www.semiconductor-today.com/news_items/2011/MAY/ETH_020511.html].

The epitaxial material (Figure 1) was grown on 2-inch semi-insulating indium phosphide (InP) substrate using metal-organic chemical vapor phase epitaxy. The InP and GaAsSb have a staggered 'type-II' band alignment where the conduction and valence band offsets are in the same direction at interfaces. The material design had a zero conduction band offset at the base-emitter junction and 150meV offset at the base-collector junction.

The devices were built using a triple mesa process. The emitter contact was 0.3 μm wide and the base was 0.5 μm . The emitter-base junction width was 0.2 μm , giving an emitter area of 0.2 μm x 4.4 μm . The structure was achieved using electron-beam lithography and a hybrid dry/wet etch.

Emitter	n-Ga _{0.25} In _{0.75} As	Si 3.8x10 ¹⁹ /cm ²	5nm
Grading	n-Ga _{0.25} In _{0.75} As ↑ n-Ga _{0.47} In _{0.53} As	Si 3.8x10 ¹⁹ /cm ²	10nm
Emitter	n-Ga _{0.47} In _{0.53} As	Si 3.8x10 ¹⁹ /cm ²	
Emitter	n-InP	S 3.0x10 ¹⁹ /cm ²	130nm
Emitter	n-InP	Si 2.5x10 ¹⁶ /cm ²	5nm
Grading	n-InP ↑ n-Ga _{0.22} In _{0.78} P	Si 2.5x10 ¹⁶ /cm ²	10nm
Emitter	n-Ga _{0.22} In _{0.78} P	Si 2.5x10 ¹⁶ /cm ²	5nm
Graded base	p-GaAs _{0.59} Sb _{0.41} ↑ p-GaAs _{0.41} Sb _{0.59}	C 8.4x10 ¹⁹ /cm ²	20nm
Collector	n-InP	S 1.3x10 ¹⁷ /cm ²	125nm
Collector pedestal	n-InP	S 2.2x10 ¹⁹ /cm ²	50nm
Etch stop	n-Ga _{0.40} In _{0.60} As	Si 3.0x10 ¹⁹ /cm ²	20nm
Sub-collector	n-InP	S 2.2x10 ¹⁹ /cm ²	300nm
Substrate	InP	Semi-insulating	350 μm

Figure 1. Epitaxial layer structure.

The emitter electrode metals were titanium/platinum/gold. The base electrode consisted of platinum/nickel/platinum/gold.

The emitter sidewall and base extrinsic surface were passivated with silicon nitride. Undercut etching was used to reduce the length of the collector mesa with the aim of decreasing the extrinsic base–collector capacitance.

Application of the final metal interconnects was preceded by a low-temperature (less than 190°C) Teflon-based etch-back planarization developed at ETH [see www.semiconductor-today.com/news_items/2012/JULY/ETH_120712.html].

The high f_{MAX} performance was attributed to the small emitter width of 0.2µm and the reduced extrinsic base–collector capacitance. Improvement in f_T over other devices produced by ETH was attributed to “a higher Kirk current density achieved by raising the collector doping level.”

The Kirk effect in bipolar transistors is a significant increase at high current densities of the transit time across the base region, degrading device performance. A higher Kirk current density means a delay in the onset of the effect.

Bias conditions for the quoted frequency cut-offs were 7.6mA collector current and 1.2V between collector and emitter. Varying these conditions (Figure 2) decreased

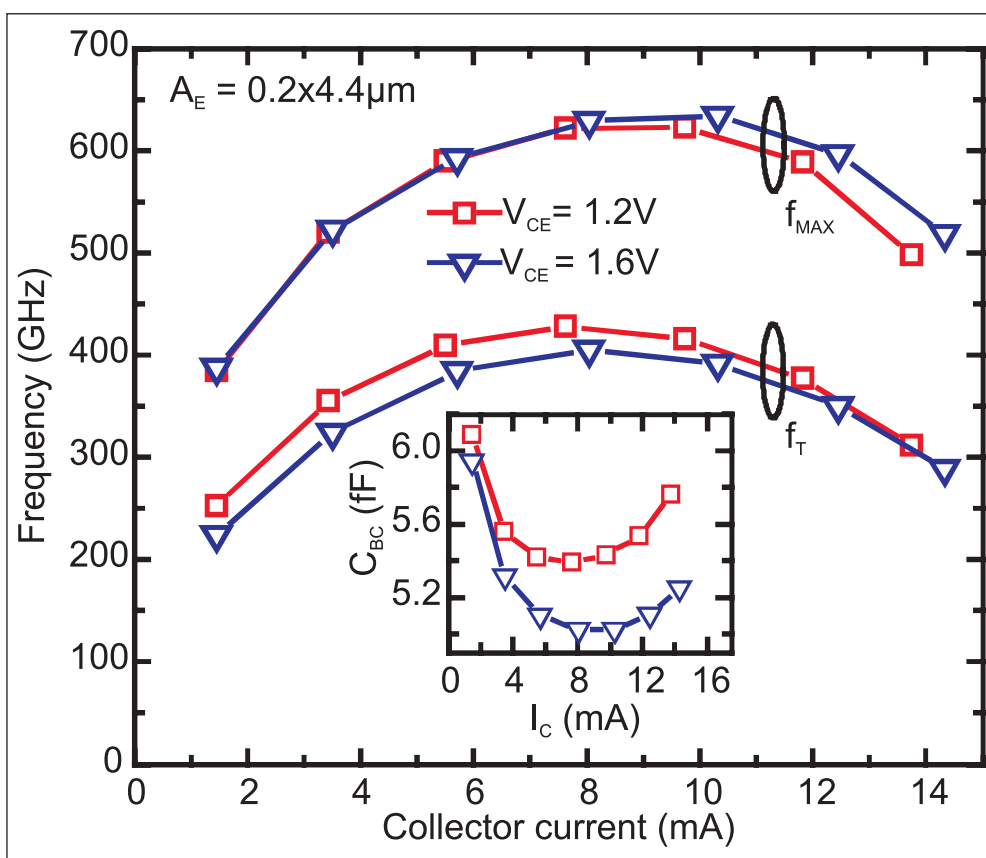


Figure 2. Dependence of f_T and f_{MAX} on collector current at 1.2V and 1.6V collector–emitter biases. Inset: total base–collector capacitance as a function of collector current.

the cut-off frequency but increased f_{MAX} to 634GHz (1.6V collector–emitter). The device’s DC peak current gain was 19 and the common–emitter breakdown voltage (BV_{CEO}) was 5V at 1kA/cm² collector current density. ■

<http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=6558475>

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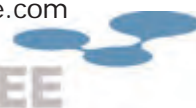
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k-Space Associates Inc specializes in in-situ, real-time thin-film process monitoring tools for MBE, MOCVD, PVD, and thermal evaporation. Applications and materials include the research and production line monitoring of compound semiconductor-based electronic, optoelectronic, and photovoltaic devices.

KLATencor

One Technology Dr,
1-22211, 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 with particular focus on compound semiconductor and photovoltaic applications. Its know-how is based on optical techniques: reflectometry, emissivity corrected pyrometry, curvature measurements and reflectance anisotropy spectroscopy.

Optical Reference Systems Ltd

OpTIC Technium,
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St Asaph, LL17 0JD,
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

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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
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Fax: +1 402 477 8214
www.jawoollam.com

Lake Shore Cryotronics Inc

575 McCorkle Boulevard,
Westerville, OH 43082,
USA
Tel: +1 614 891 2244
Fax: +1 614 818 1600
www.lakeshore.com

14 Chip test equipment

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: +1 858 674 4681
www.quikicpak.com

18 Chip foundry**Compound Semiconductor Technologies Ltd**

Block 7, Kelvin Campus,
West of Scotland, Glasgow,
Scotland G20 0TH,
UK
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Fax: +44 141 579 3040
www.compoundsemi.co.uk

United Monolithic Semiconductors

Route departementale 128,
BP46, Orsay, 91401,
France
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Fax: +33 1 69 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**

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Fax: +43 5672 600 500
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21 Computer hardware & software**Ansoft Corp**

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Fax: +1 804 740 3814
www.semitech.us

22 Used equipment**Class One Equipment Inc**

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Fax: +1 770 808 8308

www.ClassOneEquipment.com

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Fax: +44 (0)20 7405 9772
www.henrybutcher.com

M+W Zander Holding AG

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Germany
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Fax: +49 711 8804 1950
www.mw-zander.com

24 Consulting**Fishbone Consulting SARL**

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78460 Choisel,
France
Tel: + 33 (0)1 30 47 29 03
E-mail: jean-luc.ledys@neuf.fr

25 Resources**SEMI Global Headquarters**

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European Microwave Week (EuMW 2013)

NCC Nuremburg, Germany

E-mail: eumwreg@itn-international.com

www.eumweek.com/2013

7–10 October 2013

SEMICON Europa 2013

Dresden, Germany

E-mail: ktorres@semi.org

www.semiconeuropa.org

13–16 October 2013

2013 IEEE Compound Semiconductor IC Symposium

Portola Hotel and Spa, Monterey, CA, USA

E-mail: customer.service@ieee.org

www.csics.org

16–17 October 2013

PHOTONEX

Ricoh Arena, Coventry, UK

E-mail: info@xmarkmedia.com

www.photonex.org

16–17 October 2013

SEMI Strategic Materials Conference (SMC 2013)

Santa Clara Marriott, CA, USA

E-mail: acobar@semi.org

www.semi.org/smc

27–29 October 2013

1st IEEE Workshop on Wide Bandgap Power Devices and Applications (WiPDA 2013)

Columbus, OH, USA

E-mail: program@wipda2013.org

www.wipda2013.org

27 October – 1 November 2013

224th Electrochemical Society (ECS) Meeting

San Francisco, CA, USA

E-mail: meetings@electrochem.org

www.electrochem.org/meetings/biannual/fut_mtgs.htm

28–29 October 2013

3rd Berkeley Symposium on Energy Efficient Electronic Systems

Berkeley, CA, USA

E-mail: info@e3s-center.org

www.e3s-center.org/symposium

28–29 October 2013

LEDs & the SSL Ecosystem 2013: Phase 2, the Path to Profit

Omni Parker House, Boston, MA, USA

E-mail: bsantos@smithers.com

www.ledsconference.com

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28–29 October 2013

SolarTech Expo Japan 2013

Tokyo, Japan

E-mail: ds@greenworldconferences.com

www.greenworldconferences.com

11–14 November 2013

Intersolar India 2013

Bombay Exhibition Centre (BEC), Mumbai, India

E-mail: steffen@intersolar.in

www.intersolar.in

12–14 November 2013

LASER World of Photonics India

Bombay Exhibition Centre (BEC), Mumbai, India

E-mail: bhupinder.singh@mmi-india.in

www.world-of-photonics.net/en/laser-india/start

9–11 December 2013

IEEE International Electron Devices Meeting (IEDM 2013)

Hilton Washington and Towers, Washington DC, USA

E-mail: iedm@his.com

www.ieee.org/conference/iedm

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

<http://spie.org/opto.xml>

10–11 February 2014

SolarTech Germany 2014

Berlin, Germany

E-mail: pl@greenworldconferences.com

www.greenworldconferences.com

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 San Jose Marriott, 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

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

Laser World of Photonics China

SNIEC – Shanghai New International Expo 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

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