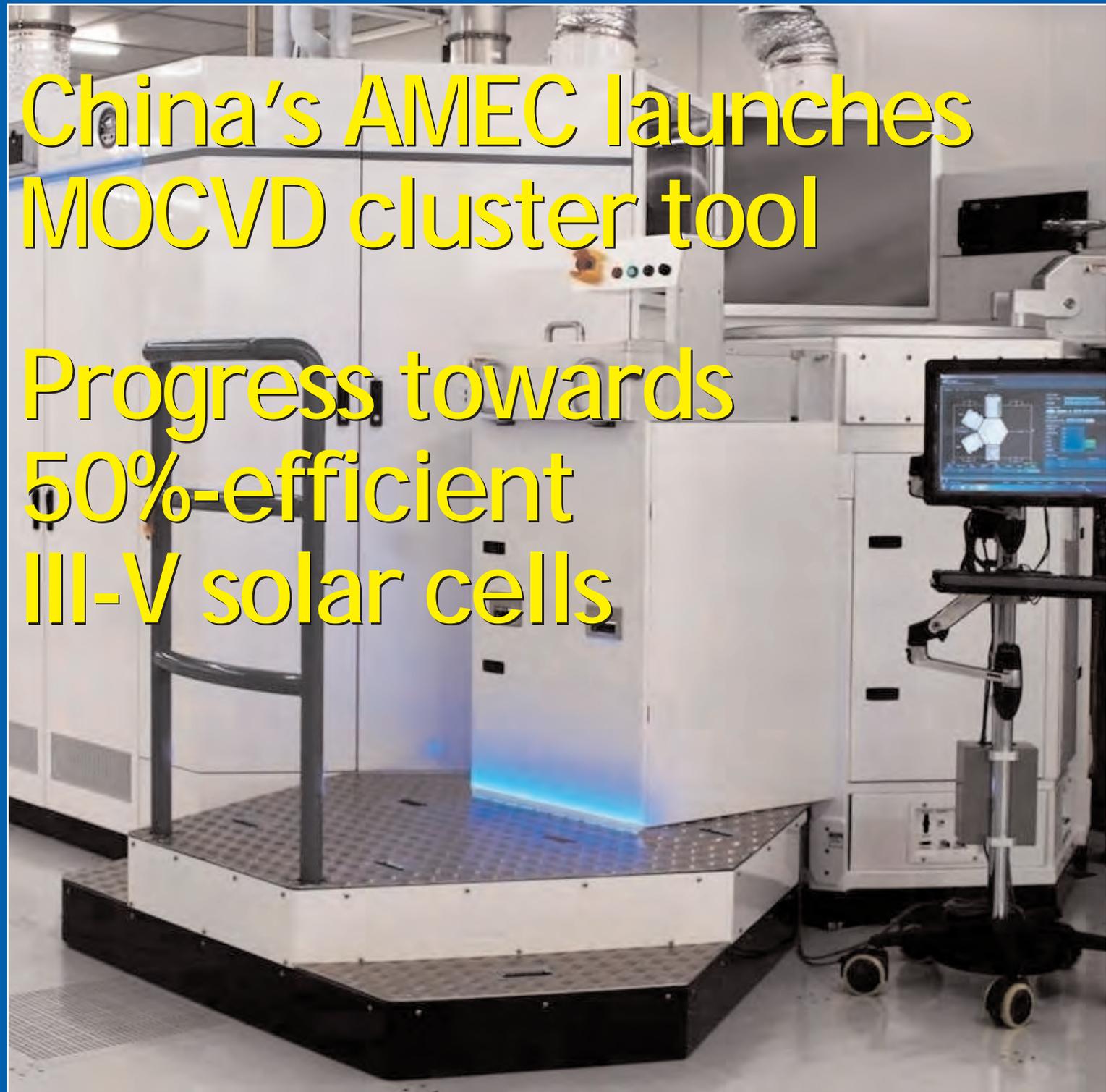


semiconductor TODAY

COMPOUNDS & ADVANCED SILICON

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China's AMEC launches MOCVD cluster tool

Progress towards 50%-efficient III-V solar cells

RFMD divesting UK fab • 5N shifting ex-Firebird InSb operation
OneChip forms foundry relationships with IQE and GCS

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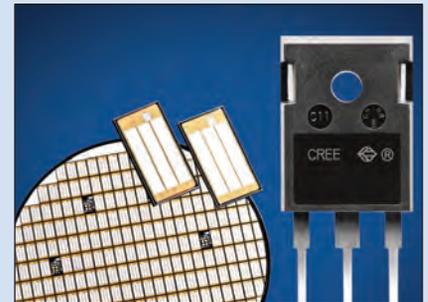
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p23 Cree has begun volume production of its second generation of SiC MOSFETs, which extends to include a much larger 25mW die.



p40 OIPT's new PlasmaPro1000 Astrea system is a large batch etch tool for PSS, GaN and AlGaInP applications in HB-LED production.



p54 Osram's new SFH 4232A Golden Dragon IR LED boosts output by 20% for applications such as surveillance.



Cover: At SEMICON China, Shanghai-based AMEC launched its Prismo D-Blue multi-reactor MOCVD cluster tool for high-volume manufacturing of

GaN, InGaIn and AlGaIn epilayer structures required in high-brightness LED production (with extendibility to GaN-on-silicon). **p38**

Foundries providing flexibility

This issue's cover photo shows part of the new multi-reactor metal-organic chemical vapor deposition cluster platform — launched by Shanghai-based dielectric and through-silicon via (TSV) etch tool supplier Advanced Micro-Fabrication Equipment Inc (AMEC) at March's Semicon China event — targeted at high-volume production of high-brightness LEDs (see page 38).

As a new entrant into the MOCVD equipment market — which has been dominated for many years by two incumbents (Germany's Aixtron and the USA's Veeco) — the firm's first MOCVD system targets the high-volume, high-flexibility end of the market (clustering up to four independent reactors).

Aixtron and Veeco have previously fended off both existing competitors and potential new entrants in the past. Most notably, the world's largest semiconductor equipment maker Applied Materials pulled back from its plans to make inroads into the MOCVD market. However, the latter was perhaps partly due to the overcapacity in the MOCVD market for HB-LED manufacturing applications in 2011/2012.

By comparison, AMEC is launching its MOCVD tool at a more favorable phase in the market cycle (with Aixtron expecting a market recovery this year, after the firm's loss-making 2012 — see page 36). Secondly, AMEC is based in the country that has been, in recent years, the main market for MOCVD systems. Even considering the more recent overcapacity and the drying up of Chinese government subsidies for MOCVD system purchases, a local supplier in the main market (together perhaps with the other Chinese firms that have developed MOCVD systems) may make inroads, provided that they prove to be competitive on quality.

Another theme prevalent in this issue's news pages is the development of foundry relationships — with either fabless design houses or integrated device manufacturers seeking more flexible manufacturing capacity or process technologies, especially as emerging technologies find commercial applications and device designs become increasingly complex. Regarding indium phosphide-based photonic integrated circuits (PICs), Ottawa firm OneChip Photonics is working with epiwafer foundry IQE and chip foundry Global Communication Semiconductors, enabling production of its PICs for the data-center interconnect and passive optical network markets (page 66).

Meanwhile, Avago Technologies has expanded its strategic collaboration with specialty foundry TowerJazz, focusing on its next-generation fiber-optics products using TowerJazz's SiGe BiCMOS technology (page 65).

In addition, Belgium's Imec has launched its fully integrated silicon photonics platform through a cost-sharing multi-project wafer service via the EU-funded silicon photonics foundry consortium ePIXfab (page 62). California-based silicon photonics firm Kotura has announced an agreement with a "large Japanese foundry" to complement its in-house fab (page 63). Silicon Valley-based fiber-optic communications component maker Finisar, reporting its latest quarterly results (page 64), said it will "likely eventually use [silicon photonics] in our product... technologies are available to us through foundries" (page 64). N.B. News from March's Optical Fiber Communication conference (OFC) in Anaheim will be reported in the next issue.

Foundries are also involved in the latest RFIC production news, where RF Micro Devices is divesting its GaAs HEMT fab in the UK and planning to outsource some of its GaAs HBT manufacturing to foundries (see page 8),

Mark Telford, Editor

mark@semiconductor-today.com



semiconductorTODAY
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Editor

Mark Telford
Tel: +44 (0)1869 811 577
Cell: +44 (0)7944 455 602
Fax: +44 (0)1242 291 482
E-mail: mark@semiconductor-today.com

Commercial Director/Assistant Editor

Darren Cummings
Tel: +44 (0)121 288 0779
Cell: +44 (0)7990 623 395
Fax: +44 (0)1242 291 482
E-mail: darren@semiconductor-today.com

Advertisement Manager

Jon Craxford
Tel: +44 (0)207 193 9749
Cell: +44 (0)7989 558 168
Fax: +44 (0)1242 291 482
E-mail: jon@semiconductor-today.com

Original design Paul Johnson
www.higgs-boson.com

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

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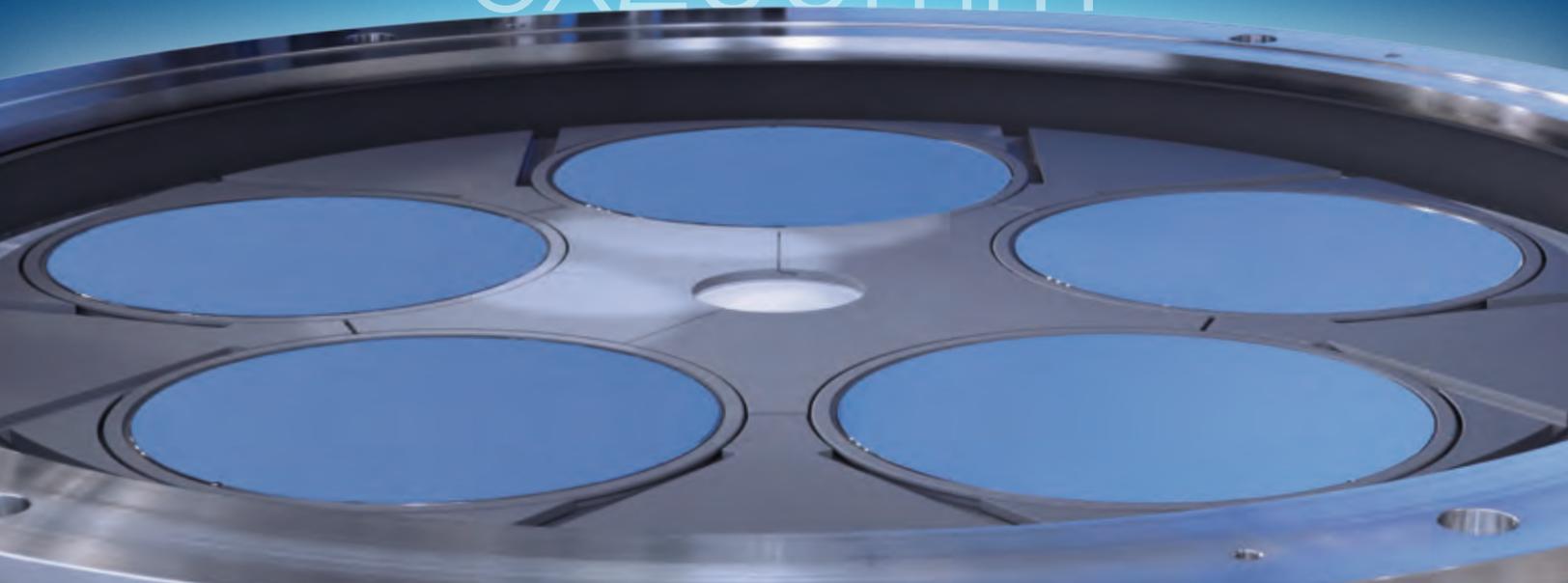
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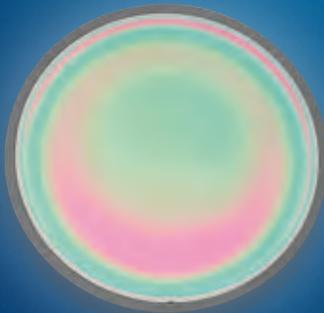
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5x200mm



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AIX G5+ for GaN-on-Si

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Smartphones to outship feature phones for first time in 2013

The global mobile phone market in 2013 will see the first time that annual vendor shipments of feature phones are outnumbered by smartphones (918.6 million, or 50.1% of the market), forecasts the International Data Corporation (IDC) Worldwide Quarterly Mobile Phone Tracker.

Smartphone prices have fallen globally, the smartphone strata are wider than ever, and the roll-out of data-centric fourth-generation (4G) wireless networks are three factors that have made these 'do-it-all' devices an increasingly attractive option for users, says IDC. The firm hence forecasts that, by the end of 2017, 1.5 billion smartphones will be shipped worldwide - just over two-thirds of the total mobile phone forecast.

To date, much of the world's smartphone shipments were a direct result of demand in mature economies such as the USA. However, the balance of smartphone demand is gradually shifting to emerging markets, where smartphone user bases are still relatively small and economic prospects are considerably higher, notes IDC. Smartphone shipments to China, Brazil and India will comprise a growing percentage of the device type's volume in each forecast year, it adds. Smartphone demand is burgeoning in these large, populous nations as their respective economies have grown; this has created a larger middle class that is prepared to buy smartphones. China, which supplanted the USA last year as the global leader in smartphone shipments, is at the forefront of this shift.

"While we don't expect China's smartphone growth to maintain the pace of a runaway train as it has

Top five countries smartphone shipments and market share, 2013 and 2017 (in millions).

Country*	2013 unit shipments	2013 market share	2017 unit shipments	2017 market share	2017/2013 growth
1. China	301.2	32.8%	457.9	30.2%	52.0%
2. USA	137.5	15.0%	183.0	12.1%	33.1%
3. UK	35.5	3.9%	47.5	3.1%	33.8%
4. Japan	35.2	3.8%	37.7	2.5%	7.1%
5. Brazil	28.9	3.1%	66.3	4.4%	129.4%
6. India	27.8	3.0%	155.6	10.3%	459.7%
Others	352.5	38.4%	568.1	37.5%	61.2%
Total	918.6	100.0%	1516.1	100.0%	65.0%

Source: IDC Worldwide Mobile Phone Tracker, 4 March.

* Note: Countries are listed by 2013 rank, based on unit shipments. The 2017 ranking is forecast to be:

1. China, 2. USA, 3. India, 4. Brazil, 5. UK, 6. Japan.

over the last two years, there continue to be big drivers to keep the market growing as it leads the way to ever-lower smartphone prices and the country's transition to 4G networks is only just beginning," says Melissa Chau, senior research manager, IDC Asia/Pacific. "Even as China starts to mature, there remains enormous untapped potential in other emerging markets like India, where we expect less than half of all phones shipped there to be smartphones by 2017, and yet it will weigh in as the world's third largest market," she adds.

Brazil is another market where smartphone growth will remain high over the course of the forecast as its economic fortunes improve.

Even as China starts to mature, there remains enormous untapped potential in other emerging markets like India

"Brazilians have yet to turn in their feature phones for smartphones on a wholesale basis," says Bruno Freitas, consumer devices research manager, IDC Brazil. "The smartphone tide is turning in Brazil though, as wireless service providers and the government have laid the groundwork for a strong smartphone foundation that mobile phone manufacturers can build upon."

Top five markets for smartphone shipments

China will easily remain the world's largest market for smartphones, specifically low-cost handsets based on the Android operating system and to a lesser degree iOS, says IDC. While shipment volume to the country will remain at the top, growth will slow towards the end of the forecast period. Also, smartphone prices are expected to fall amid increased competition. Consequently, China's share of the global smartphone market will be diluted as more smartphones are shipped to India, Brazil, and other

▶ emerging markets.

Now that smartphone users constitute the majority of all mobile phone users in the USA, IDC expects slower growth in the years ahead. Underpinning its growth is the constantly shifting operating system landscape, in which resurgent BlackBerry and Windows Phone aim to gain salience against incumbents Android and Apple iOS.

India's year-on-year smartphone shipment growth will be the highest among the top countries by a wide margin as the vast majority of the country's wireless subscriber base currently use feature phones. The smartphone market will grow due to

a variety of factors, including greater availability of low-cost devices and additional sales emphasis by top-flight vendors on less populous parts of the country. In addition, 3G network coverage will continue to expand while 4G networks are expected to stimulate smartphone growth from 2015 onwards.

Brazil's smartphone market rise is driven by a confluence of circumstances, such as tax breaks for vendors that create jobs via local mobile phone production. Wireless service providers are offering greater subsidies to drive smartphone sales, with an eye on higher data revenue streams in the future.

The successful rollout of long-term evolution (LTE) networks in Brazil is key to the country's smartphone market growth, says IDC.

Growth of the UK smartphone market has slowed considerably in recent quarters as penetration has risen and economic growth remains minimal, which has led to consumer trepidation, notes IDC. However, the size of the market and its wealth relative to much of Western Europe will make it a smartphone volume leader over the forecast, given the ongoing transition to LTE networks and continued high carrier subsidies.

www.idc.com

Smartphone shipment growth slows from 64% in 2011 to 43% in 2012, as Q4 grows 38% year-on-year Samsung takes 30% and Apple 19% share of 700 million unit market in 2012, as Nokia slumps from 16% to 5%

Global smartphone shipments grew 43% annually from 490.5 million units in 2011 to a record 700.1 million units in 2012, according to a report from Strategy Analytics. Samsung was the star performer, capturing 30% marketshare worldwide and extending its lead over Apple and Nokia.

"Shipment growth slowed from 64% in 2011 to 43% in 2012 as penetration of smartphones began to mature in developed regions such as North America and Western Europe," says senior analyst Neil Shah. Quarterly shipments were 217 million units in Q4/2012, up 38% year-on-year from 157 million in Q4/2011.

Samsung shipped a record 213 million smartphones worldwide and captured 30% marketshare in 2012. "This was the largest number of units ever shipped by a smartphone vendor in a single year, beating Nokia's previous all-time record when it shipped 100.1 million units during 2010," notes executive director Neil Mawston. "Despite tough competition in stores and courtrooms, Samsung continued to deliver numerous hit models, from the

Smartphone vendor shipments (million units) and market share in Q4/2012.

Vendor	Q4/11	2011	Q4/12	2012
Samsung	36.5	97.4	63.0	213.0
Apple	37.0	93.0	47.8	135.8
Nokia	19.6	77.3	6.6	35.0
Others	63.9	222.8	99.6	316.3
Total	157.0	490.5	217.0	700.1
Share	Q4/11	2011	Q4/12	2012
Samsung	23.2%	19.9%	29.0%	30.4%
Apple	23.6%	19.0%	22.0%	19.4%
Nokia	12.5%	15.8%	3.0%	5.0%
Others	40.7%	45.4%	45.9%	45.2%
Growth y-o-y	55.9%	63.8%	38.2%	42.7%

high-end Galaxy Note2 phablet to the mass-market Galaxy Y," Mawston adds. Apple grew a healthy 46% annually and shipped 135.8 million smartphones worldwide for 19% marketshare in 2012, broadly flat from the 19% recorded in 2011.

"Apple had a strong year in developed regions like North America, but this was offset partly by its limited presence in high-growth emerging markets such as Africa."

Samsung and Apple together accounted for half of all smartphones

shipped worldwide in 2012. "Large marketing budgets, extensive distribution channels and attractive product portfolios have enabled Samsung and Apple to tighten their grip on the smartphone industry," says analyst Linda Sui. The growth of Samsung and Apple has contin-

ued to impact Nokia. Nokia retained its position as the world's third largest smartphone vendor for full-year 2012, but its global marketshare has dropped sharply from 16% to 5% during the past year. "Nokia's Windows Phone portfolio has improved significantly in recent months, with new models like the Lumia 920, but we believe the vendor still lacks a true hero model in its range that can be considered an Apple iPhone or Samsung S3 killer," Sui concludes.

www.strategyanalytics.com

RFMD announces flexible GaAs sourcing strategy Newton Aycliffe pHEMT fab to be divested and manufacturing shifted to Greensboro; HBT foundries to be used for extra capacity

Radio-frequency component and compound semiconductor company RF Micro Devices Inc of Greensboro, NC, USA has announced a new gallium arsenide (GaAs) sourcing strategy intended to increase manufacturing flexibility, expand gross margin, and support aggressive growth.

RFMD will phase out manufacturing in its GaAs pseudomorphic high-electron-mobility transistor (pHEMT) facility in Newton Aycliffe, UK and transition most GaAs manufacturing to its GaAs HBT manufacturing facility in Greensboro. RFMD will also partner with GaAs HBT foundries for additional capacity.

The Newton Aycliffe GaAs pHEMT

facility had been RFMD's primary source for cellular switches, which RFMD has transitioned to higher-performance, lower-cost silicon-on-insulator (SOI). The transition will occur over the next 9–12 months to support existing millimeter-wave customer contracts. Once implemented, RFMD expects annual cost savings of about \$20m (\$5m per quarter).

"RFMD is enjoying increasing demand for our GaAs- and silicon-based RF solutions... including power amplifiers, switches, antenna tuners, and envelope tracking solutions," says president & CEO Bob Bruggeworth. "The combination of our industry-leading internal

GaAs manufacturing capabilities and our external GaAs and silicon foundry partnerships support our long-standing commitment to 'Optimum Technology Matching', satisfy the full breadth of our customers' performance, size, and cost requirements, and give RFMD unlimited growth potential," he adds. "We expect these structural changes to have a lasting positive effect on the company's cost structure, resulting in meaningful gross margin expansion."

RFMD is actively seeking a buyer for the Newton Aycliffe facility. If a buyer cannot be found, the facility will be closed once contractual obligations are met.

Share repurchase program extended to \$200m

RF Micro Devices' board of directors has authorized an extension of RFMD's 2011 share repurchase program to repurchase up to \$200m of the firm's common stock through 31 January 2015.

Since January 2011, RFMD has repurchased \$49.9m of its common

stock under this program, leaving it with additional authorization of up to \$150.1m under the program as a result of this extension.

RFMD's share repurchase program authorizes the firm to repurchase shares from time to time through solicited or unsolicited transactions

in the open market or in privately negotiated transactions. The number of shares to be purchased and the timing of the purchases will be based on market conditions and other factors. The program may be discontinued at any time.

www.rfmd.com

RFMD launches GaAs- and Si-based power amplifiers and transmit modules for entry smartphones

At the 2013 Mobile World Congress in Barcelona, Spain, RF Micro Devices Inc of Greensboro, NC, USA announced it is expanding its entry solutions product portfolio to include multiple new RF solutions for 2G and 3G entry smartphones, designed to solve the increasingly complex RF requirements of entry-level 2G and 3G smartphones related to cost, band count, and thermal dissipation.

The firm's entry solutions product portfolio is compatible with all leading baseband chipset providers, including Qualcomm, Intel, Broadcom, Mediatek, Spreadtrum

and others.

RFMD offers a complete portfolio of GaAs- and silicon-based RF solutions for the entry smartphone segment. The firm's newest entry solutions include GaAs- and silicon-based power amplifiers (PAs) and transmit modules for 2G and 3G entry smartphones, enabling RFMD to deliver complete RF reference designs, from the transceiver to the antenna.

RFMD aims to expand its entry solution product portfolio in calendar 2013 to include fully integrated silicon-based multimode PAs and multimode transmit modules.

Industry analysts estimate quarterly shipments of entry smartphones will reach record levels, as new smartphone models proliferate across all tiers and as entry smartphone prices drop below \$100.

Leading manufacturers of entry smartphones are leveraging RFMD's entry solutions product portfolio to achieve the optimum balance of cost, performance and flexibility while satisfying critical requirements for quality and reliability in high-volume manufacturing.

www.rfmd.com

RFMD ships production volumes of power amplification solution based on Broadcom 5G WiFi technology

RF Micro Devices Inc of Greensboro, NC, USA is shipping production volumes of its power amplification solutions compatible with Broadcom's 5G WiFi chips.

RFMD developed the RFFM82x5 (2.4GHz) and RFFM85x5 (5GHz) front-end modules (FEMs) with Broadcom's 5G WiFi chips, which are based on the IEEE 802.11ac standard. The combined solution delivers faster throughput and expanded range, it is reckoned. RFMD's portfolio of WiFi FEMs support Broadcom's BCM4335 5G WiFi reference design for mobile platforms and Broadcom's BCM4360 5G WiFi reference design for customer premise equipment

(CPE) solutions.

"5G WiFi provides faster, more reliable coverage so that consumers can watch video and connect multiple devices to the network simultaneously without issue, all while also preserving battery life," says Rahul Patel, Broadcom's VP, Mobile Wireless Connectivity Combos Group. "By partnering with RFMD, Broadcom is continuing to drive the adoption of 5G WiFi into a broad range of products and leading the industry transition to this next-generation wireless breakthrough."

Key attributes of the RFFM82x5 and RFFM85x5 include:

- highly integrated solutions with power amplifier (PA), low-noise

amplifier (LNA) with bypass, switch, filtering and power detection functions;

- foremost linear power capability at 1.8% EVM and 256QAM modulation;

- 5GHz meeting 18dBm over 80MHz bandwidth nominal and 2.4GHz meeting 18.5dBm over 40MHz bandwidth nominal;

- industry-required footprint of 2.5mm x 2.5mm with 0.4mm maximum height, enabling both system-in-package (SIP) and chip-on-board designs; and

- optimized ESD capabilities meeting industry mobile 1kV HBM requirements.

www.rfmd.com

RFMD's 3G/4G LTE components selected by leading smartphone maker to support 4th-generation flagship

RF Micro Devices has been selected by a leading smartphone maker to supply multiple 3G/4G LTE components into a recently announced fourth-generation flagship smartphone platform. The smartphones will feature RFMD's RF7388 multi-mode multi-band (MMMB) 3G/4G power amplifier (PA), which was launched in late February, plus multiple variants of the RF73xx family of ultra-high-efficiency LTE PAs, and the firm's antenna control solutions.

"RFMD is rapidly increasing our exposure to the world's leading smartphone manufacturers and extending our position in the high-growth LTE category," says Eric Creviston, president of RFMD's Cellular Products Group. "We expect to grow our content in the world's leading LTE devices as major new programs are introduced and ramp throughout calendar 2013."

RFMD's highly integrated RF7388 PA covers bands 1, 2, 3, 4, 5, 6, 8, 9, 10, 15, 18, 19, 20, 26, 27, 33, 35, 37 and 39, and delivers what is claimed to be best-in-class effi-

ciency in a multi-mode multi-band package. It is mated with RFMD's RF7307, RF7320 and RF7321 ultra-high-efficiency satellite single-band 4G LTE PAs to provide additional coverage for LTE bands 7, 20 and 11/21, respectively.

In addition to the RF7388, RF7307, RF7320 and RF7321, RFMD will supply its RF1119 antenna control solution to optimize and miniaturize the antenna function across this global smartphone

RFMD is rapidly increasing our exposure to the world's leading smartphone manufacturers and extending our position in the high-growth LTE category. We expect to grow our content in the world's leading LTE devices as major new programs are introduced and ramp throughout calendar 2013

platform. The RF1119 is compatible with the leading 4G LTE basebands and is designed to deliver optimal RF performance in high-data-rate, high-band-count multi-mode applications. RFMD says that its antenna control solutions enable thinner handsets and help to extend network coverage by reducing dropped calls and increasing data throughput rates.

The RF7388 MMMB PA is compatible with the leading 4G LTE basebands and supports advanced power management functionality, enabling improved system-level efficiency in high-data-rate applications, RFMD says. The firm's broad range of 3G/4G LTE solutions is available in single-mode, multi-mode, and converged architectures and covers all 3G, 4G LTE and TD-LTE bands.

RFMD says that it is supporting this top customer across all product tiers with a broad range of products, including PowerSmart power platforms, ultra-high-efficiency 3G/4G power amplifiers, and multiple switch-based components.

IN BRIEF

TriQuint researcher honored by IEEE

RF front-end component maker and foundry services provider TriQuint Semiconductor Inc of Hillsboro, OR, USA says that TriQuint design engineering fellow Charles (Chuck) Campbell, a member of the firm's Infrastructure & Defense Products (IDP) Research Group, has been named a Fellow of the Institute of Electrical and Electronic Engineers (IEEE) Microwave Theory and Techniques Society (MTT-S). He was recognized for contributions to the development of microwave and millimeter-wave integrated circuits. Specifically, Campbell focuses on advancing compact, high-power MMIC design and device modeling.

Campbell joined TriQuint in 1998.

He has held positions as a design team leader and design engineering director.

He is also **TriQuint Fellow** the firm's **Chuck Campbell**, ambassador to University of Colorado Boulder (UC-Boulder).

TriQuint says that Campbell has been active in the IEEE throughout his career (serving on technical program committees, editorial boards and delivering presentations) and has authored numerous technical papers on GaAs and GaN technologies.

www.triquint.com



RF Micro Devices expands portfolio of envelope tracking power management and power amplifier solutions

At the 2013 Mobile World Congress in Barcelona, Spain (25–28 February), RF Micro Devices Inc of Greensboro, NC, USA announced the addition of multiple new products to its portfolio of envelope tracking (ET) power management and power amplifier (PA) solutions.

RFMD's ET-based solutions leverage the company's leadership in RF power management and cellular PAs to improve system-level efficiency in high-data rate applications.

The new RF solutions — the RF7389, RF7390, RF7459, RF8081, and RF8085 — comprise ET PMICs, ET multimode multi-band (MMMB) PAs, and ET ultra-high efficiency

PAs. RFMD's expanding ET product portfolio is compatible with the leading LTE chipsets and provides full ET compatible coverage of all FD-LTE and TD-LTE bands (1–14, 17–21, 25–28, 38, 40, 41, and 44).

"The importance of power management technologies such as average power tracking (APT) and envelope tracking will continue to expand in smartphones, enabling RFMD to leverage our combined leadership in power amplifiers and RF power management and increase our RF content opportunity," believes Eric Creviston, president of RF Micro Device's Cellular Products Group.

www.rfmd.com

RFMD expands family of multi-mode multi-band power amplifiers, achieving compatibility with all leading basebands

At the 2013 Mobile World Congress in Barcelona, Spain (25–28 February), RF Micro Devices Inc of Greensboro, NC, USA announced the expansion of its family of multi-mode multi-band (MMMB) power amplifiers (PAs) to include the highly integrated RF7388 3G/4G MMMB PA.

RFMD says that its PowerSmart PAs are at the forefront of the technology shift to multimode-based architectures for smartphones, tablets, and other data-centric mobile broadband devices.

The firm's MMMB PA portfolio is compatible with all leading chipset providers and includes multiple derivatives accommodating a variety of band counts, air-interface standards, interfaces (both GPIO and RFFE), and power management schemes, including average power tracking (APT) and envelope tracking (ET). RFMD also

Our newest products expand RF Micro Device's multi-mode multi-band product portfolio to include ultra-high efficiency and average power tracking capability

offers a complete family of discrete single-mode PAs that are available optionally with any RFMD MMMB solution to achieve

additional band or mode coverage.

"RFMD offers the industry's only converged solution with single-die multi-mode performance," claims Eric Creviston, president of RFMD's Cellular Products Group, "Our newest products expand RFMD's MMMB product portfolio to include ultra-high efficiency and APT capability," he adds.



Compound Semiconductor Mantech

May 13 - May 16, 2013
Hilton New Orleans Riverside
New Orleans, LA, USA

www.csmantech.org



IN BRIEF

M/A-COM Tech Solutions launches power amplifiers for 13 and 15GHz point-to-point applications

M/A-COM Technology Solutions Inc of Lowell, MA, USA (which makes analog semiconductors, components and subassemblies for RF, microwave and millimeter-wave applications) has launched two power amplifiers (PAs) for point-to-point (PtP) radios for cellular backhaul applications.

Packaged in a fully molded 5mm x 5mm plastic QFN, the 12.75–13.25GHz MAAP-010516 and 14.5–15.35GHz MAAP-010517 amplifiers include on-chip ESD protection structures with DC by-pass capacitors, allowing customers easy implementation and volume assembly of the packaged parts.

The MAAP-010516 and MAAP-010517 provide small-signal gain of 23dB and 24dB respectively, with a third-order intercept point (OIP3) of 42dBm. The devices consist of a three-stage PA with an integrated, temperature-compensated on-chip power detector, which omits the customer's need for a complex and costly discrete or printed detector.

"The QFN packaging makes these devices compatible with standard SMD assembly lines," says David Richardson, market director, Wireless Infrastructure. "In addition, the devices are package, pin-out, biasing, and performance compatible with each other, allowing for easy board layouts and common supporting circuitry," he adds.

Production quantities and samples of both PAs are available from stock.

www.macomtech.com

Hittite's chairman, president & CEO Stephen Daly steps down

Hittite Microwave Corp of Chelmsford, MA, USA (which designs and supplies analog, digital and mixed-signal RF, microwave and millimeter-wave ICs, modules and subsystems as well as instrumentation) says that Stephen G. Daly is stepping down as chairman, president & CEO at the end of March.

Daly joined Hittite in 1996 and held leadership positions in sales, marketing and product development. In 2004, he was promoted to president & CEO, and took the firm public in July 2005. In 2006, he was appointed chairman. Since its IPO, Hittite has increased its market capitalization to about \$2bn.

"The decision to step down was initiated by me, as I am ready to set new goals for myself outside of Hittite," says Daly. "Hittite's business and financial conditions are strong, and I feel this is an opportune time to make this transition."

The board has named Rick D. Hess as the next president & CEO, and Franklin Weigold as non-executive chairman of the board, effective from 1 April. Daly will support the transition in an advisory role to the new CEO as needed, and will remain a director until the 2013 annual shareholders meeting in May.

"Rick has been an outstanding Hittite board director since 2005, and is familiar with our strategies, culture, technology and industry, and as a director he already has strong relationships with our entire management team," comments Daly. Franklin has been a member of the board since 2003 and the lead independent director since 2009.

"In 2012, I began discussing with the board of directors my desire to initiate a succession plan," says Daly. "The board retained an internationally recognized executive recruiting firm, to advise on potential candidates and support the succession planning process," he adds.

"Rick has experience creating shareholder value and leading

semiconductor companies to more than \$500m in revenue," notes Weigold.

Hess has served in executive roles in the microwave, semiconductor, energy and manufacturing industries for more than 30 years. From 2011 to 2013, he was vice president at American Superconductor Corp, a provider of technologies and solutions for the electrical power infrastructure industry. From 2006 to 2010, Hess was president & CEO of Konarka Technologies Inc, a developer of photovoltaic cells on flexible plastic. From 2004 to 2006, he was president & CEO of Integrated Fuel Cell Technologies Inc. From 1989 to 2004, Hess held several positions at M/A-COM (a semiconductor provider of high-frequency components and systems for the wireless, defense, public safety and automotive markets), including president from 1999 to 2004. Hess had previously founded Stable Energy Sources, a manufacturer of microwave subsystems and components serving military and industrial markets. He began his career as an engineer at Westinghouse Electric. Hess received a B.S. in Electrical Engineering from Purdue University and an M.S. in Electrical Engineering from Johns Hopkins University.

Weigold has served as VP & general manager of Analog Devices Inc's Micromachined Products Division and from 1992 to 1999 was VP & general manager of the firm's Transportation and Industrial Products Division. Prior to joining Analog, Weigold was president & chief operating officer of Unitrode Corp. Previously, he was president of Silicon General Inc. Weigold also serves on the board of directors of privately held Enpirion Inc. He received a B.S. in Electrical Engineering from Michigan Technological University and an M.B.A. from the University of Pittsburgh.

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Anadigics expands dual-band ProEfficient-Plus PA family

Anadigics has expanded its dual-band ProEfficient-Plus power amplifier (PA) family with the introduction of the AWT6765, optimized for LTE bands 25 and 26.

"The rapid increase in 3G and 4G mobile device use continues to place tremendous pressure on battery life," says VP of Cellular Products Jerry Miller. "Our ProEfficient-Plus power amplifiers are optimized to address this challenge by delivering the industry's highest combined efficiency for longer talk-time and data use. By offering this power-saving performance in compact, highly integrated dual-band packages, we are providing manufacturers with compelling solutions for ultra-thin, feature-rich mobile devices."

ProEfficient-Plus solutions leverage Anadigics' exclusive InGaP-Plus

technology and patented design architectures to provide efficiency in low- and high-power modes, as well as low quiescent currents without the use of DC/DC converter. ProEfficient-Plus PAs are also optimized for use with average power tracking (APT) to further increase efficiency and reduce current consumption at medium and low operating powers. The firm's dual-band ProEfficient-Plus solutions offer frequently used band combinations with an internal voltage regulator in 3mm by 4mm packages to save PCB space.

Rapid increase in 3G and 4G mobile device use continues to place tremendous pressure on battery life

Anadigics' Dual-Band ProEfficient-Plus features:

- industry-leading efficiency across all power levels and exceptionally low quiescent current to extend battery life, including longer talk-time and data use;
- two independent amplification chains to provide industry-leading performance for each band;
- compact 3mm x 4mm x 0.9mm package with internal voltage regulation and integrated DC blocks on the RF ports to reduce PCB space requirements;
- best-in-class linearity to maintain stable, high-throughput 3G/4G connections; and
- RF matching optimized for output power, efficiency, and linearity in a 50Ω system

www.anadigics.com

Japanese device maker selects Anadigics' 802.11ac 5GHz WiFi front-end IC for Gigabit WiFi router

Anadigics is shipping production volumes of its AWL9581 front-end integrated circuit (FEIC) for a Japan-based WiFi device maker's new 802.11ac gigabit WiFi router, which is optimized for home networks and is expected to launch in Q1/2013.

The emerging IEEE 802.11ac standard supports high-throughput multi-station connectivity with speeds of up to 1Gb/s.

"Our devices provide the industry's best combination of linearity and noise figure performance to achieve gigabit transmission at greater ranges," claims Dave Cresci, VP of

WiFi products at Anadigics. "As the adoption of 802.11ac accelerates, OEMs and ODMs are increasingly selecting our FEICs to power next-generation WiFi solutions that offer users real-world performance advantages," he adds.

Anadigics' 802.11ac FEICs leverage the firm's exclusive InGaP-Plus technology and patented design architectures to combine a 5GHz power amplifier (PA), low-noise amplifier (LNA), and Tx/Rx switch on a single die. The 2.5mm x 2.5mm x 0.4mm QFN package also incorporates a high-accuracy, integrated power detector, and RF

ports internally matched to 50Ω. This level of integration reduces PCB space requirements and simplifies RF front-end design, as well as reducing reduce time-to-market, says the firm.

The FEICs also deliver what is claimed to be exceptional error vector magnitude (EVM) and noise figure performance (to maintain high modulation accuracy for error-free transmission), enabling ultra-high data throughput at extended range. What is claimed to be best-in-class power efficiency also provides optimal thermal performance, the firm adds.

Anadigics' raises \$20m in public offering of stock

Anadigics Inc of Warren, NJ, USA priced an underwritten public offering of 10,000,000 shares of its common stock (announced on 13 March) at \$2.00 per share.

The firm granted underwriters a 30-day option to purchase, at the same price per share as the underwriters paid for the initial shares,

an additional 1,500,000 shares in connection with the offering. After deducting the underwriting discount and estimated offering expenses, the firm receives net proceeds of about \$18.4m, assuming no exercise of the option.

The offering was due to close on 19 March, subject to customary

closing conditions.

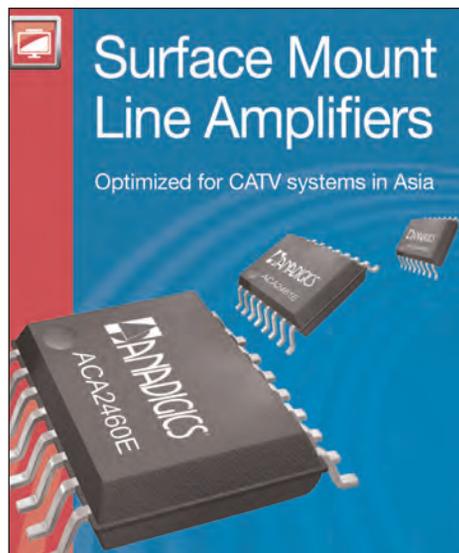
Needham & Company LLC acted as the sole book-running manager. Craig-Hallum Capital Group LLC acted as co-manager.

Anadigics intends to use the net proceeds from the offering for working capital and general corporate purposes.

Anadigics adds 1GHz surface-mount line amplifiers optimized for CATV systems in Asia

Anadigics Inc of Warren, NJ, USA has launched three new surface-mount line amplifiers. The ACA2460E, ACA2461E and ACA2462E 1GHz line amplifiers are optimized for cable television (CATV) systems in Asia by combining low power consumption and enhanced thermal performance with a wide gain range. They also provide high linearity to ensure optimal performance in a fully loaded spectrum.

"As emerging CATV markets aggressively build out new infrastructure, equipment manufacturers are seeking RF components that meet the unique specifications required by these applications," says Tim Laverick, VP of Infrastructure Products. Anadigics' line amplifiers ensure distortion-free video and audio, while minimizing costly field failures, he adds. "Our new surface-mount line amplifiers expand our MMIC product family with a wider range of gain and sig-



Anadigics' new 1GHz surface-mount line amplifiers for Asian CATV systems.

nificantly reduced power consumption targeted for CATV systems in Asia."

Anadigics says that its new 24V MMIC line amplifier 'eco' power doublers leverage the firm's proven MESFET process technology to

deliver high linearity and reliability, with a high mean-time-to-failure (MTTF). The ACA2460E, ACA2461E and ACA2462E line amplifiers provide 22dB, 25dB and 28dB of gain, respectively, to provide the performance and flexibility required to design systems up to 1GHz. With lower power consumption and the proven thermal characteristics of Anadigics' standard SOIC (small-outline integrated circuit) package platform, the new MMIC line amplifiers help to reduce heat sink requirements.

Anadigics is also demonstrating an innovative system-level manufacturing solution for these MMICs during the China Content Broadcasting Networking (CCBN 2013) conference at the China International Exhibition Center (CIEC) in Beijing (21–23 March).

Samples of the ACA2460E, ACA2461E and ACA2462E are available for qualified customers.

www.ccbn.tv

Anadigics's president & CEO Michels appointed chairman

GaAs-based broadband wireless and wireline communications component maker Anadigics Inc of Warren, NJ, USA says that president & CEO Ron Michels has been appointed chairman of the board of directors. In conjunction, the firm has also appointed Lew Solomon as lead independent director of the board.

Michels, 59, joined Anadigics in 1987 and has been president & CEO since March 2011. He was executive VP & chief technology officer from 2009 to 2011, and was senior VP/general manager of broadband products from 2005 to 2009. Prior to that, he served in several other management and executive positions. Before joining Anadigics, he held various engineering and management positions in Lockheed Electronics, New

Jersey Public Broadcasting, and K & M Broadcasting.

Michels earned his Bachelors degree in Electrical Engineering from the New Jersey Institute of Technology. He holds several US patents, has authored a number of publications in the area of RF communications, and serves on the Lehigh University Electrical & Computer Engineering Advisory Board.

Solomon has been a director of Anadigics since September 1994 and was chairman from September 2009 until 20 March 2013 and, previously, from 1985 to 1989. He has been chairman of SCC Company (a consulting firm specializing in technology) since 1990, in addition to serving as chairman of the board of Harmonic Inc. Prior to founding SCC, Solomon was an executive VP with Alan Patricof

Associates from 1983 to 1986, and a senior VP of General Instruments from 1967 to 1983.

"The Anadigics board is extremely pleased with the steps that Ron and his team have taken to turn around our new product development performance and position the company for much improved financial performance," says Solomon, on behalf of Anadigics' board. "Naming Ron as chairman will bring added strategic vision and perspective as well as operating experience to the position, will fully leverage his skill and expertise, will enable an effective process for board and leadership succession at Anadigics, and will best serve the interests of the company and its shareholders," he concludes.

www.anadigics.com

Skyworks expands suite of 802.11ac front-end modules

Skyworks Solutions Inc of Woburn, MA, USA has introduced highly integrated front-end modules enabling 802.11ac connectivity in smartphones and tablets. IEEE 802.11ac technology allows consumers to download content much faster than equivalent 802.11n solutions and improve the wireless range. With download speeds of more than 1Gb/s, the devices offer consumers the fastest, most reliable wireless coverage and help address the growing need for a more robust and efficient wireless network, says the firm.

The SKY85302-11 is a complete 802.11 wireless local-area network (WLAN), RF front-end module (FEM) with a Bluetooth port. It provides all the functionality of a fully matched power amplifier (PA), power detector, harmonic filter, low-noise amplifier (LNA) and single-pole, triple-throw switch. This functionality provides a complete 2.4GHz, 256 quadrature amplitude modulation WLAN RF solution from

the output of the transceiver to the antenna, and from the antenna to the input of the transceiver. The LNA increases the receive (Rx) sensitivity of embedded solutions to improve range. SKY85302-11 also includes a transmit (Tx) power detector with 20dB of dynamic range, and a digital enable control for Tx on/off control.

The SKY85702-11 is a highly integrated 5GHz, 802.11ac FEM incorporating a single-pole, double-throw (Tx/Rx) switch, and a PA intended for mobile 802.11ac applications and systems. It operates from a single supply voltage of 3.6V. An integrated power detector with 20dB of dynamic range is included to provide closed-loop power control within the system.

Both FEMs are provided in an ultra compact, 16-pin, 2.5mm x 2.5mm x 0.45mm, quad-flat-no-lead (QFN) package. Also, both feature direct-from-battery operation, removing the need for a low drop-out regulator and associated components.

"Skyworks is gaining early momentum in meeting the demand for 802.11ac solutions, particularly in the high growth smartphone and tablet markets," said Peter Gammel, VP & general manager of mobile connectivity. Several key reference design wins are in place.

ABI Research says that all major smartphone makers are planning to include WiFi functionality in their platforms, with many carriers adding the standard for its ability to support large files for movies and songs. The number of smartphones with WiFi capability is expected to rise from 44% now to 90% by 2014. ABI also says the number of WiFi-enabled traditional mobile phones shipped will rise from 141 million units in 2009 to 520 million by 2014.

Skyworks says its precision analog semiconductors are already used in many of the first commercially available 802.11ac notebooks, ultrabooks, LED TVs, routers, USB data-cards and Blu-Ray players.

www.skyworksinc.com

TriQuint launches duplexer bank for 3G/4G smartphones

TriQuint Semiconductor Inc of Hillsboro, OR, USA has harnessed its filter product expertise and technology portfolio to introduce a new high-performance duplexer bank. The new filter module serves two of the most challenging RF bands for smartphones and mobile devices.

TriQuint's bulk acoustic wave (BAW) and temperature-compensated surface acoustic wave (TC-SAW) technologies enable simultaneous voice and data for next-generation 3G/4G smartphones, particularly in RF bands with the most demanding performance requirements. The new TQQ2526 duplexer bank leverages both technologies, using BAW to support Band 25 and TC-SAW for Band 26 in North American markets. The module integrates two duplexers into a single, compact package that provides extended frequency range and requires less board space.

"TriQuint has built the most advanced portfolio of filter technologies to help our customers solve interference issues in the toughest 3G/4G smartphone bands," said Tim Dunn, VP of Mobile Devices.

"We've made significant investments in capacity and hired more engineers to deliver a growing line of high-performance filters, with more to come."

As LTE rolls out, demand is surging for high-performance filters in multi-band smartphones. High-end smartphones house a rapidly growing number of cellular and Wi-Fi bands to support 2G/3G/4G voice and data services, as well as global roaming. Amid a global spectrum crunch, new 4G bands are being squeezed next to pre-existing bands, often with minimal guard bands. Advanced filter technology is needed to mitigate the resulting interference issues, says the firm.

TriQuint has recorded several recent design wins for its high-performance filters in sought-after 4G smartphones from manufacturers including Blackberry, HTC, LG, Motorola Mobility and Samsung.

TriQuint claims its new TQQ2526 duplexer bank provides outstanding filter performance, with high isolation over the full bandwidth and very low variation over temperate ranges. The highly integrated, ultra-small 2.8mm x 4.7mm x 1mm module features a single antenna connection, eliminating the need for antenna switching. Its low transmit insertion loss reduces total current consumption, extending battery life and usage time. The TQQ2526 enhances receiver sensitivity and dynamic range with low Rx insertion loss and high rejection of Tx signals at the Rx ports, the firm adds.

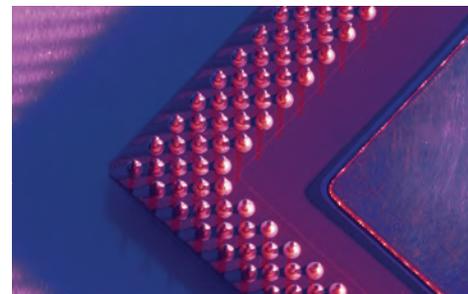
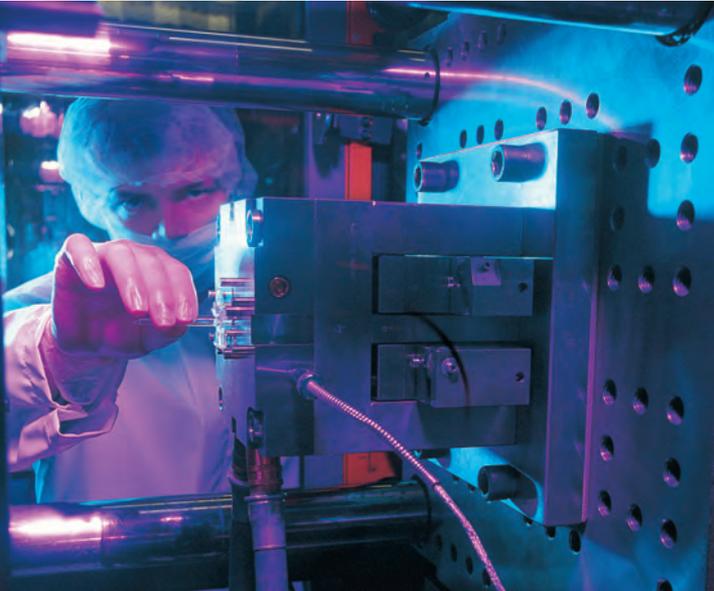
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IN BRIEF

Skyworks ramps antenna tuning devices

Skyworks Solutions Inc of Woburn, MA, USA is ramping several antenna tuning products with smartphone manufacturers. The devices are meeting the market demand for tunable antennas that improve performance by increasing data throughput, reducing dropped calls and minimizing the antenna footprint needed for multi-band LTE smartphones, says the firm.

With the proliferation of world-wide mobile spectrum, smartphone manufacturers are seeking new analog semiconductor solutions that can efficiently handle more than 20 cellular frequency bands in addition to WiFi and Bluetooth. Antenna tuning and antenna diversity are both key elements to solving these challenges. Antenna tuning enhances cellular operators' available spectrum while antenna diversity is an effective means for improving RF transmission performance. Together they provide a highly efficient platform to optimize today's demanding radiated requirements.

"Skyworks is enabling higher data rates while reducing the number of antennas required to support global roaming in data-intensive smartphones," says David Stasey, general manager of analog solutions. "We are pleased with the design-win traction of our antenna tuning solutions and excited to be further expanding our portfolio. With customers facing unprecedented analog and RF complexity and placing greater value on system performance, Skyworks is uniquely positioned to capitalize on this front-end opportunity while capturing increasing dollar content per platform."

www.skyworksinc.com

Skyworks captures initial SkyOne front-end design wins

Skyworks Solutions Inc of Woburn, MA, USA says that several OEMs and smartphone providers are leveraging its highly customizable, fully optimized SkyOne front-end solution.

The SkyOne platform — which integrates all RF and analog content between transceiver and antenna — reduces complexity, size and time-to-market for customers with demanding architectures for advanced mobile applications, says the firm.

Utilizing Skyworks' full technology portfolio and multichip module capabilities including proprietary shielding and packaging, SkyOne is claimed to be the first semiconductor device to condense multiband power amplifiers and high-throw switches along with all associated filtering, duplexing and control functionality into a single, ultra-compact package. Furthermore, claims the firm, the solution provides the world's best linearity and power-added efficiency for smart RF integration.

"Consumer demand for increasingly thinner mobile platforms with increased talk and data access time is creating unprecedented analog and RF complexity as well as harmonic coexistence issues," says Liam K. Griffin, executive VP & corporate general manager at Skyworks. "SkyOne is a proven architecture that optimizes performance beyond what is possible with existing approaches and incorporates all 2G, 3G and 4G/LTE protocols enabling seamless global roaming and extended battery life," he claims. "Incorporating Skyworks' arsenal of tested and patented technologies and leveraging GaAs, SOI, SiGe and CMOS processes, SkyOne can be modulated and customized depending upon the system requirements and roadmaps of each OEM."

SkyOne solutions incorporate the field-proven SKY77619, Skyworks' high-efficiency, multimode power amplifier module already in volume production with multiple customers.

Also, the highly flexible solution contains a common footprint that can be implemented by all of the world's carriers and in various regions.

Sampling now, these second-generation, hybrid, multi-mode, multi-band, patented front-end modules with low insertion loss support 2.5/3G/4G handsets and operate in quad-band GSM, GPRS, EDGE, WCDMA, HSPA and LTE modes. The compact 7mm x 9.8mm x 1.05mm packaged FEMs consist of a GSM800/EGSM900 power amplifier block (PA), a DCS1800/PCS1900 PA block, separate WCDMA blocks operating in the low and high bands, logic control block for multiple power control levels as well as band-enable functions in cellular and universal mobile telecommunications system. RF I/O ports are

Increasingly thinner mobile platforms with increased talk and data access time is creating unprecedented analog and RF complexity as well as harmonic coexistence issues

internally matched to minimize external components while extremely low leakage current maximizes handset standby time. The InGaP/GaAs die and passive components

are mounted on a multi-layer laminate substrate and the assembly encapsulated in plastic overmold.

The new products comprise the SKY78010 (for Bands I, II, IV, V, VIII) and the SKY78011 (for Bands I, II, III, V, VIII). Skyworks showcased its product portfolio at the 2013 Mobile World Congress in Barcelona, Spain (25–28 February).

Skyworks will be sampling third-generation solutions in March and is already developing fifth-generation architectures with multiple OEMs.

www.skyworksinc.com

Skyworks' SOI switching technology supports automotive infotainment systems

Analog and mixed-signal semiconductor maker Skyworks Solutions Inc of Woburn, MA, USA says that its silicon-on-insulator (SOI) switching technology is now being used by European, Japanese, Korean and North American car manufacturers for advanced infotainment systems.

The firm's solid-state technology is enabling seamless low-noise and broadband switching between

audio, Blu-ray/DVD, navigation, cell-phone and vehicle security display inputs as well as a variety of other high-bandwidth media sources in automobiles. Skyworks' ultra-broadband RF switches, the first targeted for AEC-Q100 automotive qualification, offer increased reliability at a lower cost structure than electromechanical switches, claims Skyworks.

RF semiconductor integration is one of the fastest-growing trends in automotive-interior electronics. Globally, automotive semiconductor revenues are estimated at over \$25bn, according to IHS iSuppli. Automotive and transportation user interface solutions are being driven to the next level by interior and exterior human-to-machine interfaces.

www.isuppli.com

Skyworks launches SOI-based LTE Tx/Rx switches

Skyworks has unveiled five new LTE Tx/Rx switches for smartphones and tablets.

The SKY13414-485LF, SKY13415-485LF, SKY13416-485LF, SKY13417-485LF and SKY13418-485LF main/diversity antenna switches cover single-pole 4-throw (SP4T) through 8-throw (SP8T), and allow up to eight bands of WCDMA/LTE.

The high linearity and low insertion loss achieved by the suite of devices suit switching applications commonly used in LTE-based handsets, data-cards and tablets. Their symmetric design and higher power handling also provide flexibility in signal routing for higher-power TD-SCDMA/TDD-LTE, WCDMA/FDD and LTE transmit/receive functions, says Skyworks. In addition, their good isolation and pin-to-pin compatibility, along with their high linearity, help with co-existence issues in smartphones and tablets, reckons the firm.

Because the devices are designed with a silicon-on-insulator (SOI) process featuring an integrated general-purpose input/output (GPIO) logic controller, no external blocking caps are required, notes Skyworks.

www.skyworksin.com

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TowerJazz claims rising share of front-end module market Silicon radio platform challenging GaAs as design wins exceed 50

Specialty foundry TowerJazz (which has fabrication plants at Tower Semiconductor Ltd in Migdal Haemek, Israel, and at its subsidiaries Jazz Semiconductor Inc in Newport Beach, CA, USA and TowerJazz Japan Ltd) has announced significant customer engagements and market share gain in the front-end module (FEM) market.

TowerJazz says that its Silicon Radio Platform (SRP) for smartphones and other mobile systems allows integration of the radio in mobile devices including components such as antenna switches, antenna tuners, diversity switches, controllers, low-noise amplifiers (LNAs) and power amplifiers (PAs), eliminating the need for more costly discrete GaAs devices, it is claimed. The SRP uses RF silicon-on-insulator (SOI) technology and a SiGe PA technology together with 0.18µm RF CMOS for the integration of control and MIPI (Mobile Industry Processor Interface) interface functions.

TowerJazz claims that its latest RF SOI technology offers the industry's best figure of merit for antenna switch and antenna tuning applications, with Ron-Coff of only 217fs. The technology has already been adopted by multiple customers

worldwide, with more than 50 separate designs taped-in with initial designs ramping to production.

The firm's silicon germanium (SiGe) PA process is fabricated in 0.18µm technology to enable the efficient integration of power amplifier, controller and MIPI interface, and also includes through-silicon via (TSV) technology to deliver performance comparable to that of GaAs at just 40% of the cost while enabling new tunable features and affording levels of integration not otherwise possible, it is reckoned.

TowerJazz reckons that the economic- and performance-driven move from GaAs technologies to Si and SiGe technologies is expected to more than triple the portion of the FEM market available to it over the next several years, and that it is well poised to manufacture a major portion of the devices that will serve this fast-growing, multi-billion dollar market. According to a 2012 report by market research firm Mobile Experts LLC, the handset front-end market is expected to double to \$10bn and the number of RF paths is expected to grow to 20 billion by 2017. The report further indicates that multi-mode, multi-band handsets and MIMO

(multiple-input and multiple-output) will drive staggering growth in the number of RF components shipped for mobile devices.

Drivers contributing to the growth in the FEM market include: connectivity everywhere (802.11a/b/g/n/ac, NFC, GPS, Bluetooth, ZigBee, HSPA+ and LTE); the expanding footprint/content in mobile platforms; and the emergence of other analog markets (e.g. smart energy, power management, and emerging automotive).

TowerJazz says it is addressing these markets and further recognizes three megatrends — (1) 'Green Everything', (2) 'Wireless Everywhere', and (3) 'Smart Everything' — which are transforming the consumer electronics industry.

"These megatrends, coupled with the slowing of Moore's law, will create even more opportunities for specialty technologies such as those provided by TowerJazz: analog, RF, SiGe, power, MEMS, and CMOS image sensors to offer even more differentiation and create opportunities for system-level optimization of performance," reckons CEO Russell Ellwanger.

www.towerjazz.com

TowerJazz receives fourth Foundry Supplier of the Year award

TowerJazz has received the 2012 Foundry Supplier of the Year award and the Quality Iron Man award from analog and mixed-signal semiconductor maker Skyworks Solutions Inc of Woburn, MA, USA. TowerJazz has been recognized as Foundry Supplier of the Year for the fourth time, providing "excellent quality, performance and solid alignment with Skyworks' supply chain requirements".

TowerJazz has received supplier awards from Skyworks for the past five years — including Foundry Supplier of the Year, Innovation Partner of the Year, Overall Sup-

plier of the Year, and now Quality Iron Man Partner of the Year.

Skyworks uses TowerJazz's specialty processes including mixed-signal CMOS, RFCMOS, silicon germanium (SiGe) BiCMOS, SOI (silicon-on-insulator) and BCD (bipolar-CMOS-DMOS) to develop differentiated products across their target market segments.

"Skyworks is a diversified, fast-growing company, and a top five customer of TowerJazz... their product direction is increasingly using specialty silicon based technologies — effectively more than tripling our served market over the

next several years," says David Postula, VP of North American sales.

"The Iron Man award clearly demonstrates our commitment to quality and manufacturing excellence," notes Don Cerney, VP of worldwide quality and reliability.

"We continue to align our roadmaps toward the next-generation needs of all of our key customers, particularly in the fast-growth area of wireless front-end-modules with our RF SOI and SiGe technologies," says Dr Marco Racanelli, senior VP & general manager of RF/High Performance Analog and Power business groups at TowerJazz.

Peregrine to license UltraCMOS IP to Murata for RF switches

Peregrine Semiconductor Corp of San Diego, CA, USA, a fabless supplier of silicon-on-sapphire (SOS)-based RFICs, is to collaborate with Murata Manufacturing Company (a supplier of RF front-end modules for the mobile wireless market) on a multi-source arrangement for RF switches and other components based on proprietary UltraCMOS technology.

Murata will be granted a license to design and manufacture RF switches and switch-related components using Peregrine's technology and intellectual property. The parties expect the deal to yield an expanded source of supply for such RF components, and to assure global OEMs broad access to RF CMOS products.

Peregrine pioneered CMOS RFs with its UltraCMOS silicon-on-insulator (SOI) process, and over 20 years of R&D have resulted in 140 patents issued and pending.

"OEM customers of both Peregrine and Murata have for some time requested that the companies implement an independent source of supply for the critical switching elements that are widely utilized in today's smart phones and other wireless-communications products," says president & CEO Jim Cable.

"This agreement marks the first license of Peregrine's core switch-based IP to a third party," he adds.

"Peregrine has fundamental IP in CMOS-based switches and tuning products," says Norio Nakajima, Murata's VP, Communication business unit. "This IP licensing arrangement solidifies our existing relationship and future collaboration with Peregrine... the combination of Murata's filter and packaging technology with Peregrine's UltraCMOS switch and tuning technology is a formidable RF front-end solution."

www.psemi.com

IN BRIEF

San Diego Business Journal honours CFO

Peregrine's chief financial officer Jay Biskupski has been named San Diego's 'CFO of the Year', in the category of public company, an honor presented annually by the San Diego Business Journal.

"We are grateful to the Business Journal for the opportunity to be recognized alongside San Diego's most exceptional business leaders, first for the 'Most Admired CEO' award last December and now for the 'CFO of the Year' award," said Biskupski. "None of the accomplishments Peregrine has achieved in recent years — including the shipment of our billionth device in 2011 and the completion of our initial public offering in 2012 — would have been possible without a dedicated, hard-working team to make it happen."

<http://sdbj.com>

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IN BRIEF

SemiSouth's SiC manufacturing and test equipment being auctioned via webcast

Asset advisory and auction services firm Heritage Global Partners (HGP, a subsidiary of Counsel RB Capital) and equipment auction and valuation firm The Branford Group have announced a global webcast auction of late-model silicon carbide (SiC) semiconductor manufacturing assets and testing equipment of SemiSouth Laboratories Inc of Starkville, MS, USA, which made SiC devices for high-power, high-efficiency, harsh-environment power management and conversion applications.

The auction is scheduled to begin at 10am CT (US central time) on 4 April. Assets being sold include: semiconductor fabrication equipment, electronic test equipment, dicing equipment and final assembly equipment. Interested bidders can attend the on-site preview on 3 April (9am–4pm CT) at 201 Research Boulevard on the campus of Mississippi State University in Starkville.

"The SiC materials and electrical components being sold via our global webcast are ideal for high-power, high-efficiency, harsh-environment power management and conversion applications," says Branford Group's president William Gardner.

"Typical applications range from power conversion to variable-speed drives to high-power, harsh-environment military and aerospace applications," he adds.

A full listing of the items for sale can be found on the web-sites of HGP and The Branford Group below.

www.hgpauction.com
www.thebranfordgroup.com
<http://semisouth.com>

First mass-produced SiC MOS module without Schottky diode

Reduced power loss makes Rohm's module suitable for 1200V/180A inverters

Rohm Co Ltd of Kyoto, Japan has started mass-production of the BSM180D12P2C101 1200V/180A-rated silicon carbide (SiC) metal-oxide-semiconductor (MOS) module for inverters/converters used in industrial equipment, photovoltaic power conditioners etc.

The new module is reckoned to be the first to incorporate a power semiconductor consisting of just an SiC metal-oxide-semiconductor field-effect transistor (MOSFET) — without a Schottky barrier diode (SBD) — increasing the rated current to 180A for broader applicability while contributing to lower power consumption and greater compactness. Next-generation SiC MOSFET technology is used to minimize conduction degradation of the body diode, eliminating the need for diode rectification, says Rohm. This makes it possible to increase the mounting area for higher current-handling capability while maintaining the same compact form factor.

In addition, by improving processes and device structures related to crystal defects, Rohm says that it was able to overcome all problems related to reliability, including that of the body diode. With no tail current, the result is 50% less loss compared with conventional silicon insulated-gate bipolar transistors (Si IGBTs) used in general-purpose inverters. This, along with an operating frequency greater than 50kHz, ensures compatibility with smaller, lighter peripheral components for greater end-product miniaturization, says Rohm.



Rohm's new 1200V/180A SiC MOS module.

Features of the new module also include:

- *Reverse conduction possible for high efficiency synchronous rectification* — General-purpose Si IGBT devices are not capable of conduction in the reverse direction. In contrast, the body diode in Rohm's SiC MOSFET always conducts in reverse. Also, depending on the gate signal input, the MOSFET can operate in either direction for lower ON resistance compared with using just the diode. These reverse direction conduction characteristics allow high-efficiency synchronous rectification in the 1000V range — higher than diode rectification.

- *Body diode conduction degradation eliminated, enabling conduction over 1000 hours with no performance loss* — Clarifying the mechanism by which defects are spread based on body diode conduction makes it possible to minimize the primary factors through process and device construction. With general-purpose products, the ON resistance rises significantly after 20 hours. In contrast, Rohm's new module ensures no ON resistance increases, even after more than 1000 hours.

www.rohm.com

Cree begins volume production of second-generation SiC MOSFET

Cree Inc of Durham, NC, USA has released its second-generation SiC MOSFET, enabling systems to have higher efficiency and smaller size at cost parity with silicon-based solutions, it is claimed. According to the firm, the new 1200V MOSFETs deliver leading power density and switching efficiency at half the cost per amp of Cree's previous-generation MOSFETs.

At this price-performance point, they enable lower system costs for OEMs and provide additional savings to end-users through increased efficiency and lower installation costs due to the lower size and weight of SiC-based systems, Cree adds.

"We have evaluated Cree's second-generation SiC MOSFET in our advanced solar circuits," says professor Dr Bruno Burger of the Fraunhofer-Institute in Freiburg, Germany. "They have state-of-the-art efficiency and enable system operation at higher switching frequencies that result in smaller passive components, especially smaller inductors," he adds. "This substantially improves the cost-performance trade-off in solar inverters in favor of smaller, lighter and more efficient systems."

The performance of the new SiC MOSFETs enables a reduction in required current rating by 50–70% in some high-power applications, says Cree. For solar inverters and uninterruptible power supply (UPS) systems, the efficiency improvement is accompanied by size and weight reductions. In motor drive applications the

power density can be more than doubled while increasing efficiency and providing up to twice the maximum torque of similarly rated silicon solutions.

The product offering range has been extended to include a much larger 25mΩ die aimed at the higher-power module market for power levels above 30kW. The 80mΩ device is intended as a lower-cost, higher-performance upgrade to the first-generation MOSFET.

"With our new MOSFET platform, we already have design wins in multiple segments," says Cengiz Balkas, VP & general manager, Cree Power and RF. "Due to the rapid acceptance of this second generation of SiC MOSFETs, we are shipping pre-production volumes to several customers ahead of schedule and we are ramping volume production in-line with customer demand."

Die are available with ratings of 25mΩ, intended as a 50A building block for high-power modules, and 80mΩ. The 80mΩ MOSFET in a TO-247 package is intended as a higher-performance, lower-cost replacement for Cree's first-generation CMF20120D.

Packaged parts are available from DigiKey, Mouser and Farnell.

www.cree.com/power



Cree's second-generation SiC MOSFET.

IN BRIEF

Richardson RFPD launches website resource focused on SiC technology

Richardson RFPD Inc (an Arrow Electronics Company) of LaFox, IL, USA has launched a new website resource focused exclusively on silicon carbide (SiC) technology for energy and power applications.

Several Richardson RFPD suppliers are driving innovation in the development of SiC discrete devices and modules, and the new SiC technology section of the website offers a range of Schottky diodes and MOSFETs, as well as SiC and hybrid modules from manufacturers such as Cree, Microsemi, Powerex and Vincotech.

In addition to product and supplier information, the new SiC website section offers links to an extensive list of technical resources, from applications notes to brochures, presentations, selector guides, videos, Spice models, and supplier documentation.

The market research firm MarketsandMarkets estimates that the global SiC semiconductor devices market will grow from roughly \$218m, as of 2012, to \$5.34bn by the end of 2022.

● This new web resource follows Richardson RFPD's launch in late February of a website resource focused exclusively on gallium nitride (GaN).

The GaN technology section of the website offers power transistors, power amplifiers and switches from manufacturers Empower RF Systems, M/A-COM Technology Solutions, Microsemi, Nitronex, TriQuint, and United Monolithic Semiconductors (UMS).

www.richardsonrfpd.com/sicpower

GeneSiC's low-inductance second-generation hybrid SiC Schottky rectifier/Si IGBT modules enable 175°C operation

Silicon carbide (SiC) power semiconductor supplier GeneSiC Semiconductor Inc of Dulles, VA, USA has announced the immediate availability of its GB100XCP12-227 second-generation hybrid mini-modules using 1200V/100A SiC Schottky rectifiers with rugged silicon IGBTs.

The performance-price point at which the product is being released allows many power conversion applications to benefit from the reduction in cost/size/weight/volume that neither silicon IGBT/silicon rectifier solutions nor a pure SiC module can offer, claims the firm. The devices are targeted at applications including industrial motors, solar inverters, specialized equipment and power grid applications.

GeneSiC says that its SiC Schottky/Si IGBT mini-modules (co-packs) are made with silicon insulated-gate bipolar transistors (IGBTs) that exhibit a positive temperature coefficient of on-state drop (1.9V at 100A), a robust



GeneSiC Semiconductor's new 1200V/100A SiC rectifier/Si IGBT co-packaged mini-modules.

punchthrough design, high-temperature operation (maximum junction temperature of 175°C) and fast switching characteristics that can be driven by commonly available commercial 15V IGBT gate drivers. Turn-on energy losses are 23μJ (typical).

The SiC rectifiers used in the co-pack modules allow extremely low-inductance packages, low on-state voltage drop and no reverse recovery, notes the firm. The SOT-227 package offers an isolated-baseplate, 12mm low-

profile design that can be used flexibly as a standalone circuit element, high-current paralleled configuration, a phase leg (two modules), or as a chopper circuit element.

"We listened to our key customers since the initial offering of this product almost 2 years back," says president Dr Ranbir Singh. "This second-generation 1200V/100A co-pack product has a low-inductance design that is suitable for high-frequency, high-temperature applications," he adds. "The poor high-temperature and reverse-recovery characteristics of silicon diodes critically limits the use of IGBTs at higher temperatures. GeneSiC's low- V_F , low-capacitance SiC Schottky diodes enable this breakthrough product," Singh continues.

All devices are 100% tested to full voltage/current ratings and housed in halogen-free, RoHS-compliant industry-standard SOT-227 packages.

www.genesicsemi.com

GeneSiC launches 1700V and 1200V SiC junction transistors

GeneSiC has announced the availability of a family of 1700V and 1200V SiC junction transistors: three 1700V devices (the 110mΩ GA04JT17-247, 250mΩ GA08JT17-247 and 500mΩ GA16JT17-247) and two 1200V devices (the 220mΩ GA06JT12-247 and 460mΩ GA03JT12-247).

GeneSiC says that its junction transistors exhibit ultra-fast switching capability (with typical turn-on/off rise/fall times of less than 50ns), a square reverse-biased safe operation area (RBSOA), and temperature-independent transient energy losses and switching times (with a maximum junction temperature T_{jmax} of 175°C). The switches are gate-oxide free, normally-off,

exhibit a positive temperature coefficient of on-resistance, and - unlike other SiC switches — are capable of being driven by commercial, commonly available 15V insulated-gate bipolar transistor (IGBT) gate drivers. While offering compatibility with SiC JFET drivers, junction transistors can be easily paralleled due to their matching transient characteristics.

Incorporating high-voltage, high-frequency and high-temperature-capable SiC junction transistors can increase conversion efficiency and reduce the size/weight/volume of power electronics, says GeneSiC. The new devices are hence targeted at a variety of applications including server, telecom and networking power

supplies, uninterruptable power supplies (UPS), solar inverters, industrial motor control systems, and downhole applications.

"As power system designers continue to push the limits of operating frequency while still demanding high circuit efficiencies, they need SiC switches that can offer a standard of performance and production uniformity," says president Dr Ranbir Singh. "Utilizing unique device and fabrication innovations, GeneSiC's transistor products help designers achieve all that in a more robust solution," he claims.

All devices are 100% tested to full voltage/current ratings and housed in halogen-free, RoHS-compliant TO-247 packages.

AKHAN licenses Argonne's low-temperature diamond deposition technology

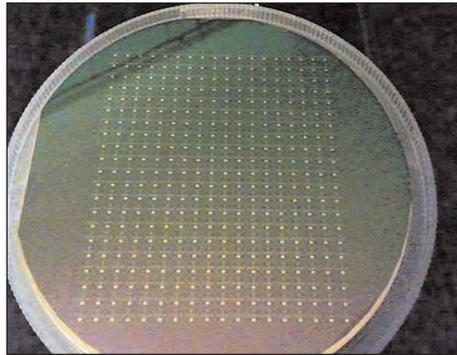
Plan to fabricate n-type devices on 4" fused silica wafers at CMOS-compatible thermal budget

Diamond-based electronic device design firm AKHAN Technologies Inc of Hoffman Estates, IL, USA has been granted exclusive diamond semiconductor application licensing rights to low-temperature diamond deposition technology developed by the Center for Nanoscale Materials (CNM) at the US Department of Energy's Argonne National Laboratory.

AKHAN was founded by CEO Adam Khan in 2007 to commercialize Diamond Lattice Technology, with the main aim being to introduce diamond device technology for the commercial realization of diamond-based electron devices for both the digital and discrete semiconductor markets.

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

AKHAN says that, with the acquisition of Argonne's low-temperature diamond technology, it plans to fabricate thin-film n-type NCD devices on 4" fused silica (glass) wafers at a CMOS-compatible thermal budget. "The vertically integrated development capability now afforded through the combination of IP will allow for both next-generation-performance devices and lower per-unit costs more conducive to present global industry demands," comments Khan.

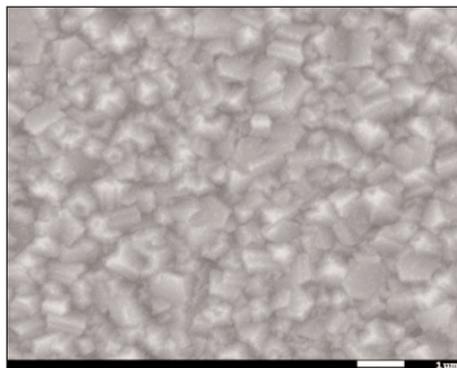


A wafer of nanocrystalline diamond. (Photo courtesy of Ani Sumant.)

"This licensing agreement gives us the impact of a one-two punch, in which we combine AKHAN's novel process to achieve efficient n-type doping in diamond with Argonne's low-temperature diamond deposition technology,"

says Argonne nanoscientist Anirudha Sumant, co-inventor of the Argonne IP. "This will break barriers that restricted the use of diamond thin films in the semiconductor industry limited to only p-type doping," he adds. "The AKHAN process will allow us to fabricate efficient p-n junction devices

The vertically integrated development capability will allow for both next-generation-performance devices and lower per-unit costs



Surface of nanocrystalline diamond.

based on diamond, which was not possible before, and Argonne's technology will allow integration with the existing CMOS platform."

"It is always wonderful to see when basic materials research leads to promising new technology developments," comments Andreas Roelofs, Argonne's CNM deputy division director and industrial relations liaison. "Having a company license your technology is the best proof of showing that you are working on relevant questions."

AKHAN and Argonne are planning to develop this further through a Cooperative Research and Development Agreement (CRADA) initiative. "We are looking forward to the further developments in diamond technology and hope to continue our successful collaboration with AKHAN in the future," adds Roelofs.

As part of a recent collaborative project, AKHAN and Argonne researchers were able to demonstrate working diamond devices with improved performance using the Miraj Diamond process based on conventional high-temperature nanocrystalline diamond. AKHAN also announced the availability of published characterization data of its Miraj Diamond technology in the Materials Research Society (MRS) Online Proceedings Library. In the paper 'On Enabling Nanocrystalline Diamond For Device Use: Novel Ion Beam Methodology and The Realization Of Shallow N-Type Diamond', AKHAN and Argonne researchers confirm what is claimed to be breakthrough morphological, phase, and electrical characterization data for both n-type NCD wafer material and NCD PIN diode devices. The full paper is available through Cambridge Journals Online.

www.akhantech.com

<http://journals.cambridge.org/action/login>

EPC introduces development board featuring 100V enhancement-mode gallium nitride FETs

Efficient Power Conversion Corp (EPC) of El Segundo, CA, USA has introduced the EPC9010 development board to make it easier for engineers to start designing with a 100V enhancement-mode gallium nitride (eGaN) field-effect transistor (FET) in applications such as high-speed DC-DC power supplies, point-of-load converters, class D audio amplifiers, hard-switched and high-frequency circuits.

The EPC9010 development board is a 100V maximum device voltage,

7A maximum output current, half-bridge with onboard gate drives, featuring the EPC2016 eGaN FET. The purpose of the development board is to simplify the evaluation process of eGaN FETs by including all the critical components on a single board that can be easily connected into any existing converter.

The EPC9010 development board is 2" x 1.5" and contains two EPC2016 eGaN FET in a half-bridge configuration using the LM5113 gate driver from Texas Instruments,

as well as supply and bypass capacitors. The board contains all critical components and layout for optimal switching performance. There are also various probe points to facilitate simple waveform measurement and efficiency calculation.

EPC9010 development boards are priced at \$99 each and are available from Digi-Key. A Quick Start Guide is included for reference and ease of use.

http://epc-co.com/epc/documents/guides/EPC9010_qsg.pdf

EPC presents GaN technology at APEC 2013

EPC presented an educational seminar and application-focused technical presentations at the Applied Power Electronics Conference (APEC 2013) in Long Beach, CA, USA (17–21 March).

"Selection supports our belief that the superior performance of GaN technology has gained the interest and acceptance of power system design engineers," said co-founder & CEO Alex Lidow.

The Educational Seminar 'GaN Transistors for Efficient Power Conversion' explained how GaN high-electron-mobility transistors (HEMT) work. It discussed how to

use the devices, including showing the drivers, layout and thermal considerations for high-performance and high-frequency power conversion. To showcase the real-world value of GaN technology, several applications including high-frequency envelope tracking (ET), intermediate bus converters (IBC), and wireless power transmission were presented.

Technical presentations featuring EPC included:

Roundtable Discussion:

'Wide band-gap semiconductors — Prime time or promises?', presented by Alex Lidow;

Technical Sessions:

- 'Design of a High Frequency, Low Loss eGaN Converter with Reduced Parasitic Inductances', presented by David Reusch and Johan Strydom;
- 'Using eGaN FETs for Envelope Tracking', presented by Johan Strydom;
- 'eGaN FETs Enable Low Power High Frequency Wireless Energy', presented by Michael de Rooij; and
- 'eGaN FET based HF Resonant Converter', presented by David Reusch.

www.apec-conf.org
www.epc-co.com

Richardson RFPD launches Avionics & Radar Tech Hub

Richardson RFPD Inc (an Arrow Electronics Company) of LaFox, IL, USA has launched its Avionics & Radar Tech Hub, a micro-website featuring the latest news, innovations and new products related to avionics and radar applications.

The hub brings together all of Richardson RFPD's avionics & radar suppliers, including Microsemi, which has released the highest-power GaN-on-SiC RF transistors for avionics and radar available on the market today, it is reckoned.

The site also features products from Richardson RFPD suppliers

Freescale Semiconductor, M/A-COM Technology Solutions, Nitronex, Skyworks, TriQuint, and United Monolithic Semiconductors (UMS). The hub also offers links to transistor line-ups, associated products, and technical resources including block diagrams, technical articles, white papers, and selector guides.

"Both Richardson RFPD and Microsemi have heritages of supporting the highly specialized avionics & radar applications," says Mark Vitellaro, Richardson RFPD's director of strategic marketing. "There is a lot of excitement around

GaN technology and its potential to enable next-generation avionics and radar systems. Microsemi has demonstrated their commitment to the technology with their high-power GaN devices; it seemed a natural extension to develop this Tech Hub to feature every GaN part we offer from many of the world's leading manufacturers."

Visitors to the hub can also sign-up for emailed product updates, links to technical presentation videos, and other resources like white papers and technical articles.

www.richardsonrfpd.com

First JEDEC-qualified 600V GaN-on-Si power devices

Transphorm Inc of Goleta, near Santa Barbara, CA, USA (which designs and delivers power conversion devices and modules) has launched the Total GaN family of gallium nitride on silicon transistors and diodes, establishing what is claimed to be the first JEDEC-qualified 600V GaN device platform. The firm reckons that this marks a significant milestone in the broad adoption of GaN-based power electronics in power supplies and adapters, photovoltaic (PV) inverters for solar panels, motor drives, and power conversion for electric vehicles.

Based on Transphorm's patented EZ-GaN technology, the TPH3006PS GaN high-electron-mobility transistor (HEMT) combines low switching and conduction losses to reduce energy loss by 50% compared to conventional silicon-based power conversion designs. The TO-220-packaged GaN transistor features low on-state resistance ($R_{DS(on)}$) of 150m Ω , low

reverse-recovery charge (Q_{rr}) of 54nC and high-frequency switching capability, resulting in more compact, lower-cost systems.

Also available in industry-standard TO-220 packages, the TPS3410PK and TPS3411PK GaN diodes offer 6A and 4A operating currents, respectively, with a forward voltage (V_f) of 1.3V.

In addition, three application kits — the PFC (TDPS400E1A7), the Daughter Board (TDPS500E0A) and the Motor Drive (TDMC4000E0I) — are available for rapidly benchmarking the in-circuit performance of Transphorm's products.

"Transphorm has accomplished the first qualification of 600V GaN devices on silicon substrates," claims president Primit Parikh. "This is critically important because it allows manufacturers to access the energy savings from our GaN transistor and diode products with the cost benefits of silicon," he

adds. "The introduction of the Total GaN family dispels the myth that qualification of high-voltage GaN on silicon is not possible, and enables the introduction of new power products in the marketplace that are dramatically more efficient compared to silicon-based products."

Transphorm says that its proprietary EZ-GaN platform can reduce power system size, increase energy density and deliver high efficiencies across the grid. For a low-risk roadmap to the next generation of power conversion technology, EZ-GaN provides a cost-effective, customizable and easy-to-use solution ready for commercial scale, the firm claims.

For approved customers, the TPH3006PS HEMT device is available at \$5.89, while the TPS3410PK and TPS3411PK diodes are \$2.06 and \$1.38, respectively, all in 1000-unit quantities.

www.transphormusa.com

CEO presents at CERAWEEK as Energy Innovation Pioneer

Transphorm's co-founder & CEO Umesh Mishra presented as an Energy Innovation Pioneer at IHS CERAWEEK in Houston (4–8 March). CERAWEEK is a conference drawing senior energy decision-makers, industry executives, government officials and thought leaders from around the world. CERAWEEK 2013's 20 Energy Innovation Pioneers

were selected as forward-looking companies and entrepreneurs who are developing technologies and business plans that are transforming the energy future.

At the event, Mishra presented Transphorm's latest developments, including how its GaN technology is increasing energy efficiency in electric power applications.

Mishra also co-founded Nitres Inc (acquired by Cree in 2000). He was elected to the National Academy of Engineering in 2010 and received the IEEE David Sarnoff Award for 'The Development of Gallium Nitride Electronics'. Mishra is also a professor in the Electrical and Computer Engineering (ECE) department at University of California, Santa Barbara.

Transphorm enables first GaN high-power converter

At the 4th annual ARPA-E Energy Innovation Summit in late February, Transphorm announced that its 600V gallium nitride module has enabled the first GaN-based high-power converter. Transphorm also demonstrated the product, built with its customer-partner Yaskawa Electric of Japan, at March's APEC 2013 industry conference.

Yaskawa's product, a 4.5kW PV power conditioner, is powered by Transphorm's 600V GaN half-bridge

modules, which have enabled it to achieve several firsts:

- the first high-power converter product using GaN technology;
- the first efficient PV power conditioner to operate at 50kHz; and
- simultaneous achievement of a 40% reduction in inverter size and 98% efficiency operation, enabled by Transphorm's EZ-GaN module technology.

Transphorm's EZ-GaN module technology combines low switching

and conduction losses, offering reduced energy loss of more than 50% compared with conventional silicon-based power conversion designs while simultaneously operating at higher frequency, says the firm.

"This is a disruptive first step which signals the broad adoption of GaN-based power conversion solutions," says CEO Umesh Mishra.

www.arpae-summit.com
www.transphormusa.com

GaN Systems expands with UK support centre Manufacturing and automotive industries targeted

GaN Systems Inc of Ottawa, Ontario, Canada, which is a fabless provider of gallium nitride (GaN)-based power switching semiconductors for power conversion and control applications, has opened a new office in Reading, UK.

The firm reckons that its expansion of European operations will help it in continuing to impact key industries, such as manufacturing

and automotive, where the need for clean-tech power conversion applications is continuing to grow.

"GaN Systems new office facility comes in response to a strong pull from our growing base of European customer partners," says Geoff Haynes, the firm's UK-based VP of business development.

"The company has a strong focus on collaborating across the manu-

facturing value chains for global power electronics markets to accelerate the adoption and drive the cost of manufacture of GaN components. That can only be achieved through a strong local technical presence," he adds.

In addition to sales offices, the new location will include technical support and seminar facilities.

www.gansystems.com

IR presents power management solutions at APEC

Power semiconductor device maker International Rectifier Corp (IR) of El Segundo, CA, USA showcased its latest power management solutions at the Applied Power Electronics Conference and Exposition (APEC 2013) in Long Beach (17–21 March).

IR gave demonstrations of its GaNpowIR power device technology platform, which is based on proprietary gallium nitride-on-silicon (GaN-on-Si) epitaxy.

In addition, IR's power manage-

ment experts participated in the following conference events:

- Plenary session: 'PSMA Power Technology Roadmap 2013 Summary', presenter: Eric Persson (executive director, field applications engineering);
- Industry Session: IS1.1.1. 'GaN Based Power Conversion: Moving On', presented by Tim McDonald (VP, emerging technologies);
- Exhibitor Session: 3. 'The Status of GaNpowIR Device Developments

at IR', presented by Dr Michael Briere of ACOO Enterprises LLC (on behalf of International Rectifier);

- Rap Session: 2. 'Wide band-gap semiconductors — Primetime or Promises?', presented by Tim McDonald;

- Technical Session: T15. 'Wide Gap/Hi Freq/Hi Density DC–DC Converters', co-chaired by Amir Rahimi (senior systems/applications engineer).

www.irf.com

DOE awards Structured Materials \$150,000 SBIR grant CVD firm to develop ZnO processes for high-current, low-cost, efficient power transistors for household appliances

Structured Materials Industries Inc (SMI) of Piscataway, NJ, USA, which provides chemical vapor deposition (CVD) systems, components, materials, and process development services, has been awarded a \$150,000 Small Business Innovation Research (SBIR) 2013 Phase 1 grant by the US Department of Energy (DOE) for the project 'High-Current Low-Cost Efficient Power Transistors for Household Appliances'.

The aim is to develop processing methods to produce high-quality metal-organic chemical vapor deposition (MOCVD)-grown zinc oxide (ZnO) material for low-cost power applications, particularly for appliances.

SMI says that wide-bandgap ZnO material offers an inexpensive and environmentally friendly material for use in smaller-scale power converters, increasing efficiency by increasing speeds and reducing power losses in switching power supplies. The target is to demonstrate a high-performance (high-current) power MOSFET with operation up to 240V, with increased performance over equivalent silicon-based devices at comparable production costs.

"ZnO provides an excellent material for significant performance increases in everyday power electronics while also maintaining low-cost production and minimal environmental impact," says the

project's principal investigator Dr Eric Gallo.

"ZnO power electronics for appliances is a very exciting emerging field where we have a history of fundamental expertise," comments SMI's president Dr Gary S. Tompa. "SMI has a strong history in the design and production of ZnO growth systems, ZnO processes and applications of ZnO," he adds. "We expect to achieve a highly economical device design that will be marketed as a high-performance alternative to presently used and inefficient Si-based devices."

www.structuredmaterials.com
<http://science.energy.gov/~media/sbir/pdf/awards%20abstracts/fy13/FY13-Phase-1-Release-1Final.pdf>

APEI and GaN Systems demo high-efficiency DC–DC boost converter with high-speed GaN switch at APEC

Arkansas Power Electronics International Inc (APEI) of Fayetteville, AR, USA, a developer of technology for power electronics systems, electronic motor drives and power electronics packaging, and GaN Systems Inc of Ottawa, Ontario, Canada, which is a fabless provider of gallium nitride (GaN)-based power switching semiconductors for power conversion and control applications, have announced test results for a gallium nitride power switch based DC–DC boost converter.

The converter demonstrated at APEI exploited the ultra-high switching capability of GaN Systems' high-power switch to achieve a 1MHz switching capability. In addition, the boost converter was able to demonstrate efficiency of more than 98.5% at 5kW output power. Testing demonstrated turn-on and turn-off transitions of only 8.25ns and 3.72ns, respectively.

The converter was displayed at the Applied Power Electronics Conference and Exposition (APEC 2013) in Long Beach, CA (17–21 March),

where both APEI and GaN Systems had booths showcasing the power package and converter technologies. Co-development of the GaN power switch and boost converter was funded partly by Sustainable Development Technology Canada (a foundation created by the Government of Canada that operates a \$550m fund to support development of clean technologies

The ultra-high switching frequency that gallium nitride enables is one key to reducing the size and weight of power electronic systems

addressing issues of clean air, climate change, clean water, and clean soil), with the goal of demonstrating the efficiency, performance and reliability of GaN power devices for hybrid and electric vehicles (HEVs and EVs). Other key applications include high-efficiency power supplies, solar inverters and industrial motor drives.

GaN power switches offer increased system performance advantages over traditional power semiconductor devices when used in power conversion systems, note the firms. "Wide-bandgap semiconductor technology, such as gallium nitride, enables increased power density for modern power electronic systems," says APEI's director of business development Dr Ty McNutt. "We are developing novel power packages and high-performance systems around these ultra-high-speed devices."

As new GaN devices become available at increasing power levels, demonstration in high-power systems is paramount to customer acceptance, reckons GaN Systems. "The ultra-high switching frequency that gallium nitride enables is one key to reducing the size and weight of power electronic systems," says CEO Girvan Patterson. "These test results demonstrate first-hand the system-level benefits enabled by this."

www.gansystems.com

www.apei.net

www.sdte.ca

TriQuint launches GaN Ku-band power amplifier and broadband integrated limiter/low-noise amplifier

In conjunction with the 2013 Government Microcircuit Applications and Critical Technology conference (GOMACTech 13) in Las Vegas (11–14 March), RF front-end component maker and foundry services provider TriQuint Semiconductor Inc of Hillsboro, OR, USA launched a 25W Ku-band gallium nitride (GaN) RF power amplifier for satellite communications, as well as a broadband integrated packaged solution that combines a limiter with a low-noise amplifier (LNA) for use in radar and electronic warfare. Both solutions deliver unique advantages for commercial and defense systems, the firm claims.

Operating from a 25V/1A DC bias, the new 13.75–15.35GHz (Ku-band) TGA2579-FL GaN RF power amplifier provides 25W (+44dBm) of output power, +48dBm output third-order intercept point (OIP3), 32dB of small-signal gain, and 30% of power-added efficiency (PAE). The device is supplied in a ground-signal ground (GSG) 14-pin SMT package so it can be mounted on the top or underside of multi-layer circuit boards, giving designers maximum flexibility.

TriQuint says that the TGA2543-SM's high gain (+17dBm mid-band) and wide operating bandwidth (4–20GHz) provides broad versatility in a

single package. Operating from a 5V/100mA DC bias, the integrated limiter/LNA has RF input limiting of 4W CW (+36dBm), +28dBm (OIP3) and adjustable gain control. Robust protection of sensitive receiver circuits and low-noise amplification (with a noise figure of 2dB) are achieved in less space with fewer devices, says the firm. The device's hermetically sealed, 22-lead 7mm x 7mm ceramic QFN surface-mount package meets MIL-STD 883H TM 1014.13 condition A1/C1, it adds.

The TGA2579-FL and TGM2543-SM are in production. Samples and evaluation boards are available.

www.triquint.com

IN BRIEF

AXT launches \$6m stock repurchase program

AXT has announced a program authorizing the repurchase of up to \$6m of the firm's common stock through 27 February 2014.

The timing, number and value of shares repurchased will depend on market conditions and corporate considerations including price, corporate and regulatory requirements and alternative investment opportunities. The program is expected to be funded from existing cash balances and cash generated from operations.

Repurchased shares will become authorized but unissued shares. As of 25 February, the firm had about 32.8m shares of common stock outstanding.

www.axt.com

AXT certified to ISO/TS 16949 automotive standard

AXT Inc of Fremont, CA, USA, which makes gallium arsenide, indium phosphide and germanium substrates and raw materials, has been certified as having met the international standards of ISO 16949:2009, a global standard developed by the International Automotive Task Force (IATF, a group of the world's leading manufacturers and trade organizations). This certification defines the quality management system requirements for the design, development, production and, when relevant, installation and service of automotive-related products.

ISO/TS 16949 is currently the world's most stringent quality management system standard for manufacturing and provides for strict adherence to the requirements of the worldwide automotive industry. The standard is a

technical specification defining quality system requirements for manufacturing operations. It encourages the use of a process approach that is aimed at improving process efficiency and is designed to achieve the highest levels of product quality, productivity, competitiveness, and continual improvement.

Certification is "a demonstration of AXT's commitment to serving our automotive customers," says CEO Morris Young. "I am very proud of the work, led by our operations team in Beijing, that resulted in a successful certification to an internationally recognized quality standard as it underscores our ongoing mission to provide superior product quality and customer satisfaction," he adds.

www.ts16949.com

www.axt.com

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AXT enters loss as revenue falls a further 9% in Q4

Signs of market improvement entering 2013 spur cautious optimism

For fourth-quarter 2012, AXT Inc of Fremont, CA, USA has reported sales of \$18.9m, down 9% on \$20.8m last quarter and 10.8% on \$21.2m a year ago. Full-year revenue was \$88.4m, down 15% on 2011's \$104.1m.

Q4 gallium arsenide substrate revenue was \$11.3m, up slightly from \$11.1m a year ago but down 12.4% on \$12.9m last quarter. Germanium substrate revenue was \$1.7m, down 15% on \$2m last quarter and almost halving from \$3m a year ago. Raw materials sales were \$4.3m, level with last quarter, but down on \$6.4m a year ago. In contrast, indium phosphide substrate revenue was \$1.6m, level with last quarter but more than doubling from \$724,000 a year ago.

Gross margin has fallen further, from 36.9% a year ago and 26.3% last quarter to 19.5%. Full-year gross margin was 28.1%, down

Table. AXT's revenue over the last five quarters.

Revenue	Q4/11	Q1/12	Q2/12	Q3/12	Q4/12
GaAs	\$11.1m	\$12.2m	\$14.9m	\$12.9m	\$11.3m
InP	\$0.72m	\$1.5m	\$1.3m	\$1.6m	\$1.6m
Ge	\$3m	\$2.6m	\$2.4m	\$2m	\$1.7m
Materials	\$6.4m	\$7.2m	\$6.5m	\$4.3m	\$4.3m
Total	\$21.2m	\$23.5m	\$25.2m	\$20.8m	\$18.9m

loss of \$0.8m, compared with net income of \$0.9m last quarter and \$2.6m a year ago. During

the quarter, cash and cash equivalents rose from \$35.5m to \$30.6m.

“As we enter 2013, we are seeing signs of market improvement in several of our product categories and believe that the current customer landscape holds interesting opportunity for AXT,” Young says. “We are approaching the year with cautious optimism and will continue to exercise tight expense control and careful financial planning,” he adds.

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www.axt.com

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[Download the Wafer World Presentation](#)

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IQE's CEO Drew Nelson joins EU high-level industry group on key enabling technologies

Epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK says that CEO & president Dr Drew Nelson has joined a high-level industry group to advise the European Commission (EC) on the implementation of key enabling technologies (KETs).

The formation of the group was announced by EC vice commissioner Antonio Tajani last week, together with the signing of a memorandum of understanding (MOU) between the European Investment Bank and the EC to support KETs. Nelson is the only UK representative among the group of 35 industrial leaders from across Europe.

The EC has identified nanotechnology, micro/nanoelectronics, industrial biotechnology, advanced materials, photonics and advanced

manufacturing technologies as KETs that are essential for Europe to regain and maintain global leadership in the face of intense competition from Asia and North America.

The impact of KETs cuts across world-leading industries including the automotive, chemicals, aeronautics, space, health and energy sectors, and will form a significant focus for European-funded programs in the coming years. The aim is to enable the European Union (EU) to translate its research and development (R&D) base into the production of goods and services needed to stimulate growth and employment.

"It is highly encouraging that the EC has recognized the global importance of key enabling technologies in shaping the future of Europe in the face of stiff global

competition," says Nelson. "EC initiatives included in 'Horizon 2020' aim to bridge the funding gap — often referred to as the 'valley of death' — that has held back EU countries from translating excellent R&D expertise into world-leading products and services," he adds. "I look forward to helping Europe regain a global leading technology position."

The formation of the high-level industry group follows the formation of a previous high-level expert group on KETs, which ran for a year until end-June 2011 and developed a long-term strategy on how to improve the deployment of KETs at the European level.

www.iqep.com

http://ec.europa.eu/enterprise/sectors/ict/key_technologies/kets_high_level_group_en.htm

EVG extends wafer bonding equipment and process solutions for covalent bonding technology

EV Group (EVG) of St Florian, Austria, a supplier of wafer bonding and lithography equipment for the MEMS (micro-electro-mechanical system), nanotechnology and semiconductor markets, says that it is developing equipment and process technology to enable covalent bonds at room temperature.

The technology will be available on a new equipment platform, EVG580 ComBond, which will include process modules that are designed to perform surface preparation processes on both semiconductor materials and metals. EVG says that it has built on its decades of experience with plasma-activated wafer bonding to create a process through which the treated surfaces form strong bonds at room temperature instantaneously without the need for annealing.

"In response to market needs for more sophisticated integration

processes for combining materials with different coefficients of thermal expansion, we have developed a revolutionary process technology that enables the formation of bond interfaces between

heterogeneous materials at room temperature," says Markus Wimplinger, corporate technology development & IP

The new process solutions will enable covalent combinations of compound semiconductors, other engineered substrates and heterogeneous materials integration

director. "Our unparalleled expertise in wafer bonding process technology will allow us to provide different variants of the new process according to the require-

ments of different substrate materials and applications," he adds.

EVG says that the new process solutions will enable covalent combinations of compound semiconductors, other engineered substrates and heterogeneous materials integration for applications such as silicon photonics, high-mobility transistors, high-performance/low-power logic devices and novel RF devices. The process technology and equipment that enables this room-temperature covalent wafer bonding will be applied to EVG's wafer bonding solutions for MEMS wafer-level packaging as well as to the integration of MEMS and CMOS devices.

Equipment systems based on a 200mm modular platform, tailored for the specific needs of the new processes, will be available this year.

www.EVGroup.com

Quebec-based 5N Plus closing ex-Firebird InSb operations in Trail, British Columbia

Activities to be consolidated into US subsidiary Sylarus and Montreal

Specialty metal and chemical product producer 5N Plus Inc of Montreal, Quebec, Canada has decided to close its indium antimonide (InSb) manufacturing operations in Trail, British Columbia over the next few months, laying off the 75 staff and aiming to then sell the building, according to a report in the Trail Daily Times in February.

The operation in Trail was founded as Firebird Semiconductors Ltd in 1991 to resurrect the compound semiconductor technology developed at Cominco Electronic Materials Group after Cominco sold the division in 1989 to Johnson Matthey Electronics (which then closed the plant in 1990, moving its operations to Spokane, WA, USA, where an employee buyout subsequently formed antimony-based substrates maker Galaxy Compound Semiconductors Inc — bought by IQE in 2010).

Trail-based Firebird's products included indium antimonide (InSb) wafers (scaling up from 3" in 1993 to 4" in 2002 then 5") joined later by the pure metals antimony, tin and indium (the latter for in-house use, from 2006). Firebird also developed epi-ready gallium antimonide (GaSb) substrates in 2004 and started germanium development in 2005. Applications for antimony include III-V compound semiconductors used in the production of diodes, infrared detectors and Hall-effect devices.

After changing name to Firebird Technologies Inc in 2004, in late 2009 the firm was acquired by 5N Plus. 5N focuses on specialty high-purity metals such as tellurium, cadmium, selenium, germanium, indium and antimony and also produces related semiconducting compounds such as cadmium telluride (CdTe), cadmium sulphide (CdS)

and indium antimonide (InSb) as precursors for the growth of crystals for electronic applications, including solar photovoltaic, radiation detector and infrared markets.

In a \$10m investment, in May 2011 the Trail operation re-located from its 14,000ft² facility into a new 40,000ft² facility near Trail airport, aiming to double staffing and increase productivity 20-fold, focusing on expanding its commercial product lines to germanium and GaSb.

"The biggest challenge we had there was to attract and retain competent personnel," said Jean Mayer, 5N's director of legal and corporate affairs, in the Trail Daily Times. "It's an isolated area, and we found it was difficult to retain personnel compared with the bigger player in the area, Teck." Even though 5N Plus offered competitive employment conditions, the plant could not attract the people it needed to sustain it, Mayer added.

Trail-based Teck Metals Ltd (a subsidiary of Vancouver-based mining firm Teck Resources Ltd) has a contract to supply germanium and indium feedstock to 5N's Trail operation. Teck Metals' plant includes one of the world's largest fully integrated zinc and lead smelting and refining complexes, producing germanium, indium and cadmium as co-products.

Most of 5N's Trail activities will be consolidated into 5N Plus' US subsidiary Sylarus Technologies in Utah (which produces germanium substrates for solar cells). "Part of the activities will be moved to our head office in Montreal, the rest will be transferred to the US," Mayer said. Some staff at Trail will be offered jobs within the firm, he added, but nothing is finalized yet.

www.5nplus.com



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www.EVGroup.com

Solar Junction's CPV cell efficiency record achieved using Veeco GEN200 MBE system

Epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA says that the record for energy conversion efficiency of a commercial-ready production solar cell reported in October by Solar Junction was achieved using its Dual GEN200 molecular beam epitaxy system.

Solar Junction of San Jose, CA, USA, which manufactures III-V multi-junction solar cells for concentrated photovoltaics (CPV), reported that the power conversion efficiency of their CPV cells was measured as 44% at 947 suns, as verified by the US National Renewable Energy Laboratory (NREL).

Founded in 2007, Solar Junction says that its cells, which incorpo-

rate proprietary adjustable-spectrum lattice-matched (A-SLAM) materials technology, enable it to more optimally partition the solar spectrum for maximum efficiency and greater reliability.

"Veeco's MBE system enables us to reach critical milestones in solar cell efficiency," comments Homan Yuen Ph.D., Solar Junction's VP of research & development. "Their system is instrumental in pushing the boundaries of technology to make CPV a more competitive option for solar power," he adds.

"We wholeheartedly congratulate Solar Junction on their world record, and are committed to supporting their new facility's production ramp," says Veeco's VP &

general manager Jim Northup. "The GEN200 is the ideal pilot-production tool," he reckons.

The GEN200 MBE cluster-tool design provides the material source and wafer configuration flexibility for R&D or for multi-wafer production applications, says Veeco. The flexibility enables the system to deliver higher throughput and lower cost per wafer, in a footprint up to 60% smaller than comparable MBE systems, it is reckoned. It can also support dual growth modules, allowing facilities to either greatly increase production or grow different materials within a single, integrated system.

www.sj-solar.com

www.veeco.com/GEN200

Fraunhofer IAF buys Veeco GEN200 MBE system for antimonide- and arsenide-based optoelectronic devices

Veeco says that the Fraunhofer Institute for Applied Solid State Physics (Fraunhofer-IAF) of Freiburg, Germany, which develops electrical and optical devices based on compound semiconductors, has purchased a GEN200 MBE system. The new system will be used for R&D on antimonide- and arsenide-based III-V optoelectronic devices.

"We have been working with

Veeco for more than a decade, and have had very good experiences with the existing Veeco MBE systems in our facility," comments Dr Martin Walther, head of Fraunhofer IAF's Infrared Detectors business unit. "Thus we decided in favor of Veeco's fully automated production MBE systems as demand for epitaxial layers for antimonide-based III-V optoelectronics has increased," he adds.

"This new purchase extends our long-standing collaborative relationship with Fraunhofer IAF, one of the world's top research facilities in the field of III-V s," says Jim Northup, VP & general manager of Veeco's MBE Operations. "Our GEN200 is known for its lowest-cost 4x4" epiwafer growth and it is the ideal tool to support Fraunhofer IAF's expansion in growth services."

www.iaf.fraunhofer.de/en.html

Riber sells research MBE system to Russia's Institute of Automation and Control Processes in Vladivostok

Riber S.A. of Bezons, France, which makes molecular beam epitaxy (MBE) systems as well as evaporation sources and effusion cells, has sold a SIVA 21 research system to the Institute of Automation and Control Processes (IACP), part of the Russian Academy of Sciences in Vladivostok. The Russian Academy of Sciences is the umbrella organization for scientific institutes in the Russian Fed-

eration, and is very active in semiconductor physics.

The reactor will be set up in the optoelectronics and electronics physics research center, which is headed by professor Nicolay Galkin. It will enable the laboratory to ramp up its semiconductor research capabilities, focusing on the preparation of silicon- and germanium-based thin nanostructured layers.

Riber claims its 21 Series is the world's top-selling research MBE system, with the flexibility to meet the most demanding expectations for applied research on compound semiconductor materials. The order will affirm its position in the Russian market, where the semiconductor industry is developing strongly.

www.iacp.dvo.ru

www.riber.com

Qingshan Li appointed director of Process Support at Aixtron China

Germany-based Aixtron says its Training and Demonstration Center in Suzhou, China, has reached the next planning stage. Qingshan Li has taken over as director of Process Support at Aixtron China Ltd from Dr Nicolas Muesgens, who has built up and led the center since its opening one year ago.

"Customers benefit immensely from seeing and evaluating real process runs in Suzhou without having to interrupt their own production line," says Muesgens.

"Most of Aixtron's key customers attended a training session during this first year of operation," says Aixtron China's general manager Tim Wang. "Feedback confirms it is very helpful and effective to have real process demos with training capabilities locally."

Qingshan Li has a Ph.D. in material science from East China University of Science and Technology (ECUST)

in Shanghai. Before joining Aixtron, he had roles in process engineering at Novellus Systems, most recently as director Process & Technology.

"My goal is to continue accelerating the drive to increased tool stability and productivity under mass production at our customers' sites in China with high-quality training in Suzhou," says Li. "Customer process demos with major Chinese customers on the CRIUS II-XL are scheduled," he adds. "For training purposes a new CRIUS II-XL system trolley reactor will be added and made available to bring the technology even closer to our customers, significantly intensifying our hands-on hardware training. Both of our latest MOCVD systems will have been equipped with advanced features in the first half of 2013, e.g. the AIX G5 system with GaN-on-Si capability."

www.aixtron.com

Transphorm scales up to 200mm wafers with Aixtron AIX G5+ GaN-on-Si system

Transphorm Inc of Goleta, near Santa Barbara, CA, USA (which makes power conversion devices and modules) is stepping up production of gallium nitride on silicon (GaN-on-Si) with its latest order (placed in fourth-quarter 2012) of an Aixtron G5+ MOCVD system, capable of handling five 200mm wafers, for delivery in second-quarter 2013.

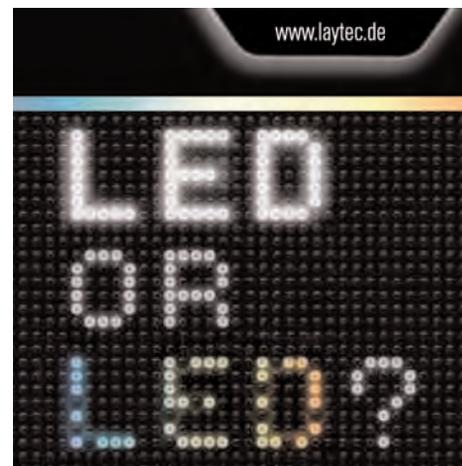
"We are not just increasing our capacity with this order," says Transphorm's president Primit Parikh. "This new system also expands our capability from 150mm to 200mm diameter wafers, providing economies of scale. We are projecting lower costs of ownership with larger wafer diameters, allowing us to bring this transformative technology into much wider use," he adds.

"When we developed the Aixtron G5+ system [based on the proven

AIX G5 HT reactor platform] we had customers like Transphorm in mind," notes Dr Frank Wischmeyer, VP & program manager Power Electronics at Aixtron. "GaN-on-Si is rapidly developing, and the industry expects commercial products in the near future," he adds. "To be successful, GaN-on-Si needs to deliver the highest quality at the lowest cost of ownership. We have developed the G5+ to deliver extremely stable, uniform processing on multiple large-diameter wafer runs."

Transphorm ordered its first Aixtron system (an AIX 2800G4 HT system in a 6x150mm-wafer configuration) in 2010. "Due to the performance of our existing system, we expect to be able to scale up to the larger-diameter wafers smoothly and quickly," Parikh says.

www.transphormusa.com



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Knowledge is key

Aixtron reports loss of €132m for 2012 as sales fall 63%

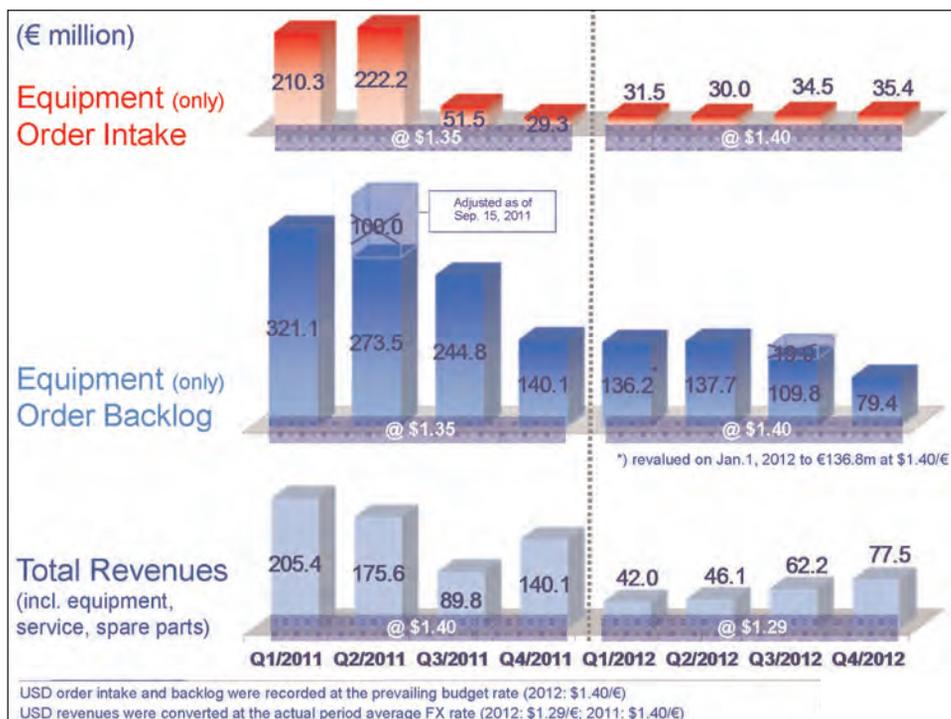
Firm sees signs of market stabilization; quarterly sales rise 25%, but only vague hints of a bounce

For full-year 2012, deposition equipment maker Aixtron SE of Herzogenrath, Germany has reported revenue down by 63% to €227.8m (from €611m in 2011). But despite the dramatic fall in full-year sales, fourth-quarter revenue of €77.5m was up 25% on Q3/2012's €62.2m.

Throughout 2012, customers "remained hesitant to add significant LED manufacturing capacity, despite increasingly high utilization rates at some mainline Asian manufacturers," the firm says. Aixtron describes a "slow recovery of revenues but a virtually flat order intake throughout the year, reflecting a reluctant investment attitude by customers and a continuation of macroeconomic uncertainty. Total order intake in full-year 2012 was €131.4m, down 74% on 2011's €513.4m. However, orders in second-half 2012 were about 14% higher than first-half 2012. Year-end order backlog stood at €79.4m, 44% lower than the €141m at end-2011 (although a third of this reduction was due to the €19m order backlog adjustment made in Q3/2012).

The second-half order intake development that became clearer in Q3/2012 did not constitute the expected second-half market recovery, and became a catalyst for "a thorough internal review into the company's immediate outlook", said the firm. The conclusion of Aixtron's management, announced in October, was that the objective at the start of the year of remaining EBIT profitable in 2012 was not achievable.

The accompanying risk assessment that was conducted as part of this business review also concluded that the likelihood of "ongoing subdued demand" necessitated the reduction in value of certain work-in-progress assemblies, components and spare parts. The firm had hence executed



Aixtron's 24-month business development, showing recovery in revenue from Q1 to Q4/2012.

a significant write-down of €51.5m in inventories in Q3/2012.

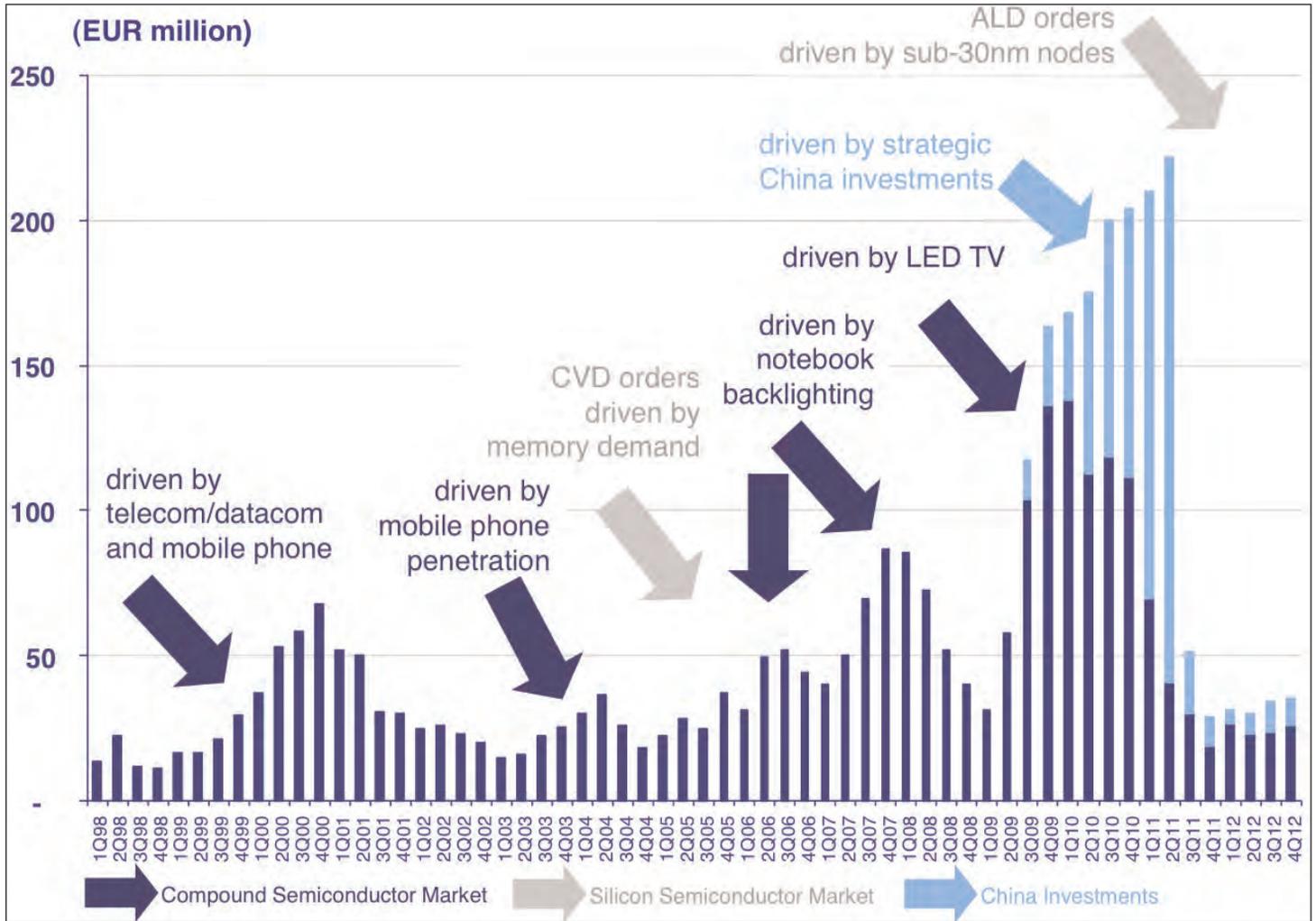
The subdued business environment, evident throughout 2012, had a consequent effect on Aixtron's overall 2012 earnings. Gross profit declined to €0.4m (contrasting sharply with 2011's €231.4m) and earnings before interest and taxes (EBIT) dived to –€132.3m (compared with a profit of €112.9m in 2011, and worse than the –€125m forecast at the end of October). The firm continues to implement cost-reduction measures, which include both efficiency improvements and cost-reduction measures throughout the organization.

The 2012 net loss of –€145.4m was down considerably on the profit of €79.5m achieved in 2011. Aixtron says that its executive and supervisory boards will propose to its shareholders' meeting that the 2012 loss should be carried forward, and consequently no dividend for 2012 will be distributed.

Management review

Looking ahead, Aixtron's management expects demand for MOCVD production equipment to "potentially improve" as demand for LEDs increases later in the current year. Looking at the same time frame, the firm stated cautiously that it "envisages incremental equipment demand arising from non-LED emerging MOCVD applications and other technology markets, including silicon and organic semiconductor applications. Nevertheless, the exact timing of that order intake pickup is difficult to predict whilst order visibility remains so low."

"2012 proved to be an exceptionally challenging year for Aixtron, largely due to the severe and extended macroeconomic headwinds that the whole world has been suffering from," said president & CEO Paul Hyland. "Our original expectation that 2012 would develop into a transitory year with the prospect of a significantly better second half has evidently not materialized. ➤



Aixtron's quarterly equipment orders, showing a recovery since Q2/2012.

► “However, the ongoing, albeit low level of demand we have seen in the second half of 2012 and into 2013, encourages us to reiterate our view that we have reached the bottom of the current cycle and that we might reasonably expect to see further market recovery at some point during 2013, driven by increasing demand for LED manu-

facturing equipment,” he added.

“We also remain confident that we will see increased demand for our manufacturing equipment for non-LED appli-

There remains “a high degree of uncertainty” about the timing of a significant order recovery

cations such as power electronics, silicon or organic applications going forward,” Hyland continued.

“Despite the current short-term challenges, we will continue to invest into the development of manufacturing technologies for these and other emerging markets to secure our technological leadership and stay fit for the future.”

Outlook

Despite the generally more positive outlook for 2013, Aixtron said that there remains “a high degree of uncertainty” about the timing of a significant order recovery. Hence, despite an improving market consensus on the potential outlook for the back end of 2013, Aixtron’s management is “unable at this stage [the end of February 2013] to offer precise revenue and EBIT margin guidance for the year, due to the prevailing low visibility.”

www.aixtron.com

New shares from Aixtron stock option program to be traded under separate ISIN

Aixtron has a number of stock option programs in place that grant employees the right to purchase shares under certain conditions.

Under the terms of the stock option plan 2007, stock options can currently be exercised. New shares resulting from exercised options are not entitled to a dividend for fiscal 2012 and will there-

fore be traded on the Frankfurt Stock Exchange under the separate ISIN DE000A1TNVU3 until and including the day of the annual general meeting (AGM) on 23 May.

Aixtron adds that its Executive and Supervisory Boards will propose to the shareholders’ meeting that the 2012 loss of –€33.2m should be carried forward to new account.

AMEC debuts MOCVD platform for high-volume HB-LED manufacturing, with extendibility to GaN-on-Si

Four reactors can be controlled independently for process flexibility

At the SEMICON China show in Shanghai (19–21 March), Shanghai-based dielectric and through-silicon via (TSV) etch tool supplier Advanced Micro-Fabrication Equipment Inc (AMEC) made its solid-state lighting (SSL) market debut by launching a multi-reactor metal-organic chemical vapor deposition (MOCVD) cluster tool.

The firm says that its Prismo D-Blue MOCVD platform enables high-volume manufacturing of gallium nitride (GaN), indium gallium nitride (InGaN) and aluminium gallium nitride (AlGaN) ultrathin-layered structures required for high-brightness LEDs. With precise parameter control, full automation and a compact design, the new MOCVD tool for LED manufacturing targets high productivity, high yields and low cost-of-ownership. A Prismo tool has already been shipped to a customer's LED production line in China.

The patented architecture can accommodate up to four reactors. Each reactor can be controlled independently, enabling manufacturing flexibility (claimed to be the only tool of its kind with this capability). The system can hence process in parallel or sequential mode, reducing cross-contamination and ensuring the high crystalline quality required for advanced LED applications, the firm adds. Also, the tool's footprint efficiency is claimed to be nearly 30% smaller than competing single-reactor systems.

AMEC reckons that solid-state lighting is a natural market move for it. Currently, more than 200 AMEC etch stations are operating in production at 16 semiconductor fabs across Asia. The firm says that the silicon technology experience, process knowledge, R&D protocols and materials engineering that produced its front-end semiconductor equipment have been applied to develop the Prismo D-Blue platform,



AMEC's new Prismo D-Blue MOCVD platform.

while new LED customers can benefit from its stringent supplier-management protocols.

The firm reckons that the timing is good for a new MOCVD supplier, especially one with an R&D and manufacturing hub in Shanghai. Between now and 2017, the market for MOCVD tools will be \$4.3bn, estimates market research firm Yole Developpement, and China will continue to dominate global manufacturing. With bulb prices dropping, LEDs are becoming the de-facto alternative to traditional incandescent lights for retrofits and new builds, AMEC says. Cheaper bulbs mean tighter margins for LED makers, making production efficiencies (and high-productivity tools such as AMEC's) more essential than ever.

"The SSL market is an essential element of our growth strategy," says Dr Zhiyou Du, senior VP & general manager of AMEC's MOCVD Product Business Division. "Our expert MOCVD technology team has created a differentiated, thoroughly flexible MOCVD platform with innovations to solve complex technical and production challenges," he adds.

The Prismo platform can process up to 216 2-inch wafers simultaneously. Processing capability will extend to 4-, 6- and 8-inch wafer production, says AMEC. In marathon runs, the

tool has demonstrated good repeatability and within-wafer and wafer-to-wafer uniformity with no recipe adjustments throughout the epitaxial process, the firm adds, despite the

inherent sensitivity of the process to chamber surface conditions, chemical environments, temperature shifts, and other variables.

In the same marathon runs the system encountered zero process interruptions, the firm adds. Reliability is enabled by in-situ, real-time monitoring of growth process parameters, as well as the software, transfer modules, and process automation and control technologies (as per the field-proven technologies of AMEC's front-end processing tools).

AMEC also says that the Prismo is optimized for easy maintenance (imperative in fast-moving, cost-conscious LED production). The process performance and uptime extends the interval between services, it is claimed, while novel design features aim to make servicing easier. Also, automated and programmable maintenance routines aim to make reactor open/close operations safer, faster, predictable and less prone to error, the firm adds.

The Prismo D-Blue MOCVD platform is protected by a portfolio of over 100 patents (granted and pending), says AMEC, while the tool also follows semiconductor manufacturing disciplines and complies fully with SEMI standards.

www.amec-inc.com

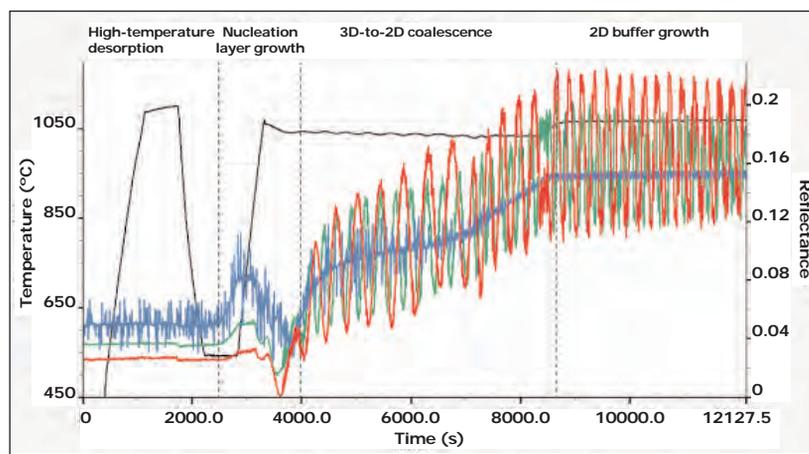
LayTec's EpiNet 2 software tailored for growth analysis on patterned sapphire substrates

LayTec AG of Berlin, Germany (which makes in-situ metrology systems for thin-film processes, focusing on compound semiconductor and photovoltaic applications) says that, in the next few years, the use of patterned sapphire substrates (PSS) will increase due to the high light extraction efficiency. Following this trend, the firm says that its EpiNet 2 in-situ metrology software can be individually customized for various kinds of PSS, with users able to expand the substrate database by themselves.

LayTec's Calibration Manual explains how to measure PSS reflectance in different pockets in one single calibration run. If required, LayTec also offers related customer training.

Once the initial reflectance values of the PSS substrates are uploaded, the operator can choose the required substrate in the RunType's Material Spec window. As a result, all PSS wafers can be monitored with the same accuracy as standard sapphire substrates.

The figure shows GaN growth on



Reflectance at 405nm (blue), 633nm (green), 950nm (red); True Temperature (black), measured by EpiCurveTT at FBH, Berlin.

PSS. The initial 405nm reflectance on the bare PSS substrate is noisy because it senses the local non-uniformity of the PSS structure. As soon as the GaN buffer layer is thick enough, this noise reduces because the 405nm light no longer reaches the PSS pattern through the UV-absorbing GaN.

The increasing reflectance of all three wavelengths after about 4000s shows the coalescence process of GaN. After about 8050s,

the 405nm reflectance remains stable at 15.5%, which is an indication of improvement in the GaN surface quality.

However, the interference patterns of the 633/950nm reflectance look noisy during two-dimensional buffer growth. Clearly, the initial non-uniformity of the PSS structure causes a certain non-uniformity in GaN thickness.

Along with the customized database, EpiNet 2 also provides fitting of thin layers, wafer bow calculation, and many other features that are indispensable for growth on PSS, says LayTec.

www.laytec.de

LayTec launches version of EpiCurve TT with both blue laser and 405nm reflectance measurement

A major challenge of in-situ metrology on single-port reactors with small viewport geometries is the combination of curvature measurements (by blue laser) with reflectance measurement at a wavelength of 405nm, says LayTec.

Curvature measurement by blue laser is a must for patterned sapphire substrates (PSS) and double-side polished substrates, says the firm. Meanwhile, reflectance measurement at 405nm is indispensable for monitoring indium gallium nitride (InGaN) multi-quantum well (MQW) growth. Until now, it was impossible to have both features for reactors with only one small optical access

because of the cross-talk effect, but the new optical and electronic design of EpiCurve TT eliminates this problem, says LayTec.

The latest version of the tool has been installed on an Aixtron 200-4 RF/S MOCVD reactor with just a 5mm hole in the ceiling at Otto-von-Guericke University in Magdeburg.

The team of professor Alois Krost and professor Armin Dadgar is using the tool in development projects for in-situ monitoring of various GaN-based optoelectronic and power electronic device structures on both silicon and sapphire substrates. The EpiCurve TT is equipped with a blue laser (emitting at 405nm) for wafer bow control

and with triple-wavelength reflectance (405, 633, 950nm) for precise monitoring of MQW layers, aluminium nitride (AlN) interlayers, aluminium gallium nitride (AlGaIn) buffers, and further features.

After several years of experience with LayTec systems, Krost is convinced that "EpiCurve TT is the best in-situ tool available on the market to control strain, temperature uniformity, MQW formation and surface morphology during III-N device growth". LayTec's chief technology officer Dr Kolja Haberland thanks the team in Magdeburg for the year-long research cooperation and for testing the new product in the field.

www.laytec.de

OIPT launches PlasmaPro1000 Astrea system to maximize batch etch for HB-LED production

UK-based etch and deposition system maker Oxford Instruments Plasma Technology (OIPT) has launched the PlasmaPro1000 Astrea system, a large batch etch solution for patterned sapphire substrate (PSS), gallium nitride (GaN) and aluminium gallium indium phosphide (AlGaInP) to offer high-brightness (HB) LED production manufacturers high throughput coupled with what is claimed to be industry-leading cost of ownership (CoO). The launch was made at the LED China exhibition in Shanghai, where HB-LED product manager Dr Mark Dineen presented the system to conference delegates.

"PlasmaPro1000 Astrea is our ultimate batch etch tool, building on over 15 years experience as a major supplier to the HB-LED industry," says Dineen. "HB-LED manufacturers justifiably demand high yield, high throughput, optimum device quality

and low cost of ownership," he adds. "Our PlasmaPro1000 Astrea large batch etch system offers solutions for all of these."

With wafer batch sizes from 55x2" to 3x8", the system is designed specifically for the harsh chemistries required for HB-LED materials. It delivers low-damage, high-yield processes, ensuring the maximum light output from customers' chips, it is claimed. The system is highly configurable, with process chambers available as standalone modules or in cluster configurations, on a four-sided cluster tool capable of supporting up to three process modules.

Designed to ensure high system availability and ease of serviceability, key system features include:

- >690mm large-area source for highly uniform plasma;
- a 490mm electrode, giving what is reckoned to be unparalleled throughput from batch sizes of

55x2", 14x4", 7x6" and 3x8";

- a high-conductance pumping system;
- a dual-entry gas inlet for ease of process tuning;
- maximized clamping for wafer cooling;
- a Z-movement electrode for ultimate uniformity; and
- reliable hardware and ease of serviceability to boost uptime.

The system has been developed to address the exacting needs of HB-LED production users who demand not only technical innovation but also superb customer support, says managing director Dan Ayres, adding that Oxford Instruments strives to evolve its systems. With access to an exclusive library of over 6000 process recipes, built up over 25 years as a plasma tool manufacturer, users receive comprehensive backup, he adds.

www.oxford-instruments.com

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Laird acquires Nextreme to expand its thermal management portfolio

Laird Technologies Inc of Earth City, MO, USA, which designs and supplies customized performance-critical components and systems for electronics and wireless products, has acquired Nextreme Thermal Solutions of Durham, NC, USA, which designs and makes microscale thin-film thermal management and power generation modules and subsystems.

Laird reckons that Nextreme's thermoelectric technology, which delivers high-precision cooling in an ultra-small form factor, will advance its thermal management business (particularly beneficial as devices become more compact).

Nextreme and Laird have a strategic design and distribution partnership, but the acquisition aims to enable wider market access to serve current and potential new customers in

applications such as sensors, solar power and LEDs.

"Nextreme is the next generation in technology for thermoelectric. It can fundamentally change the way we cool electronics at the most integrated levels while being produced in large volumes," reckons chief executive David Lockwood.

"This significant shift in technology will also enable new applications such as energy harvesting," he adds.

"Nextreme is an excellent fit with our business growth strategy," Lockwood reckons. "We will combine the most innovative technology with our market presence and ability to scale operations, to deliver added value to our customers and enable us to move into new segments."

www.nextreme.com

www.lairdtech.com

IN BRIEF

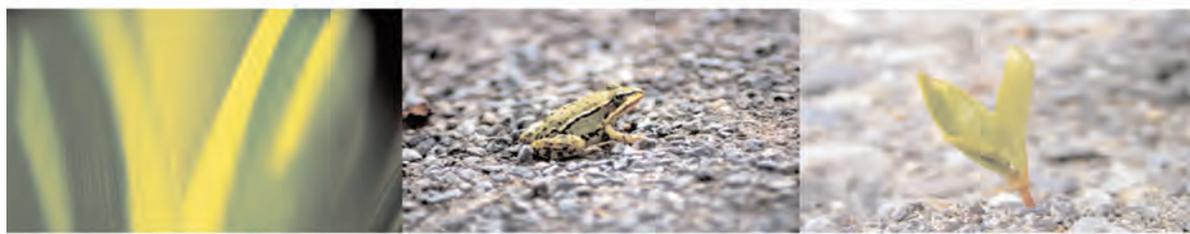
S3 to distribute for Trion in Europe

Plasma etch, strip and deposition system maker Trion Technology of Clearwater, FL, USA has formed a strategic alliance for S3 Alliance GmbH to distribute and support its products in Europe.

S3 provides Trion penetration into Europe with an installed service and support network.

Trion's products expand S3's offerings to the European customer base. "They have a strong product range for production descum and photoresist removal and have extensive experience with RIE etching, ICP and microwave plasma generation as well as for PECVD," says S3's managing director Thomas Riedel.

www.triontech.com



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IN BRIEF

LED package singulation blades

At SEMICON China, Kulicke & Soffa Industries Inc of Fort Washington, PA, USA launched its Opto_{C_{eramic}} and Opto_{PCB} package singulation blades for the LED market.

Opto blades boost LED package singulation quality, precision and productivity by providing improved stability and longer blade life, says the firm. Features of Opto blades include: low cost of ownership via consistently longer blade life; 100% pre-dressed to shorten on-site dressing steps; and an optional kerf control feature to meet special application demands. Significant UPH improvement has been seen in some applications by enabling higher feed speeds.

Opto_{C_{eramic}} blade uses unique electroplating technology to achieve up to 3 times the blade life of traditional resin/metal bonded blades, with minimal kerf change and blade wear. The new design minimizes machine downtime for blade changes, achieves the highest cut quality, and allows higher feed speeds, increasing productivity.

Opto_{PCB} blade for PCB and composite material substrates has an optimized design that provides uniform vertical wear, maintaining cutting power and consistent sawn package dimensions, eliminating in-process dressing steps. The optional 'slits' feature improves blade cooling, achieving high singulation quality without typical whisker issues.

"Opto blades provide a significant CoO improvement and a 'plug and play' solution for most dicer spindle configurations," says Nelson Wong, VP – Wire Bonding Solutions business unit. "Hub-type design provides flexibility to various dicer configurations for package singulation and enhances machine utilization and factory productivity."

www.kns.com

Pall launches Gaskleen long-life gas purifiers for HB-LED makers

Pall Corp of Port Washington, NY, USA has introduced its Gaskleen High-Bright purifiers to remove molecular contaminants from ammonia used in the manufacture of high-brightness light-emitting diodes (HB-LEDs). According to the firm, the purifiers have a service life that is twice that of other commercially available technologies.

"With this new purifier, Pall has addressed the industry demand for the brightest LEDs at the lowest operating cost," says Jan-Paul van Maaren, VP of strategic marketing, Pall Microelectronics. "The cost of LEDs needs to drop and the performance has to rise to accelerate

the adoption of LED lamps as replacements for incandescent and CFL bulbs. This new technology will give our customers both a performance and cost advantage."

Gaskleen purifier assemblies combine Pall's proprietary purification materials and Ultramet-L stainless-steel filter media. The purifiers remove moisture and other oxygenated compounds from process gases to sub ppb levels while providing 3nm or 0.4µm filtration. Furthermore, they do not release aluminum or other metal ions into the process stream, says the firm.

www.pall.com

Brewer Science launches Cee X-PRO workstation mini-environment

Brewer Science Inc of Rolla, MO, USA, which provides specialty materials, integrated processes, and laboratory-scale wafer processing equipment, has announced the commercial release of the Cee X-PRO workstation with exhaust enclosure, complementing the firm's line of cost-effective equipment products including Cee precision spin coaters, bake plates, developers, and megasonic cleaners, as well as ZoneBOND separation tools.

The virtual cleanroom environment features a stand-alone design, enabling complete process integration for pilot-scale production and commercial R&D prototyping

The new stand-alone workstation is a bridge for low- to medium-volume applications and delivers ultra-clean performance and chemical containment, says the firm.

"Mini-environments provide the precision-controlled laboratory conditions that are critical for conducting cutting-edge research within the microelectronics, biomedical,



The Cee X-Pro workstation.

and pharmaceutical industries," says equipment technology strategist Justin Furse. "The Cee X-PRO workstation gives customers a turnkey solution with exceptional particle control in a compact footprint design."

www.brewerscience.com/brewer-science-cee-x-pro

SEMI-GAS mini gas enclosure provides safe, continuous gas delivery for small process and purge gas cylinders

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 the Xturion MGE-X, a mini gas enclosure that provides safe and continuous gas delivery from small process and purge gas cylinders.

The MGE-X suits low-volume applications or where space is limited. But, despite its size of just 69" high by 32" wide by 27" deep, the MGE-X includes all of the operational and safety features required for two complete source systems, with four process and purge cylinders.



The Xturion MGE-X.

The MGE-X includes two separate compartments, each designed for a process cylinder and a purge cylinder. The system is also available in a single-source design, with one empty compartment that is expandable for future applications. To provide a flexible, custom tailored fit-up, each unit comes equipped with adjustable steel shelves and cylinder straps as well as adjustable back mounted exhaust ducts.

The system features a SEMI-GAS GigaGuard GSM controller, which continuously checks system conditions for alarms and performs an automatic shutdown in the event of a risk. The 4.3" color touch-screen includes intuitive operating prompts, making cylinder changes and status monitoring easy and seamless.

All MGE-X systems meet SEMI S2 and uniform fire-code requirements and are equipped with UL-approved fire sprinklers and ¼" safety glass windows.

The MGE-X enclosure is constructed of welded 11 Ga steel and includes reinforced rear mounting holes for wall installations. A welded steel rack option is also available for free-standing applications. Self-closing and lockable doors and windows, as well as a steel cylinder divider plate, are standard MGE-X safety containment features for hazardous production materials. The system's internal manifold components are orbitally welded, helium leak tested and certified to the highest purity standards.

"Our MGE-X system was designed to give customers a miniature option for gas delivery," says Jim Murphy, division manager of SEMI-GAS Systems. "People are accustomed to compact technologies and place a high value on space. MGE-X is our solution for ultra-high-purity, safe delivery of hazardous gases within high-value, compact spaces."

www.semi-gas.com

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The Business of Science®

IN BRIEF

GT adds VP, new business development & product management

GT Advanced Technologies Inc of Nashua, NH, USA (a provider of polysilicon production technology as well as sapphire and silicon crystalline growth systems and materials for the solar, LED and other specialty markets) has appointed Linda Reinhard as VP, new business development and product management for its sapphire, DSS and HiCz products, reporting to chief operating officer Dan Squiller. Reinhard will be responsible for leading GT's growth into new market segments and driving the product roadmap to capitalize on these new opportunities.

"Linda brings deep experience and a proven track record in both product management and new business development," Squiller says. "Linda's initial focus will be on growing our sapphire material and ASF [Advanced Sapphire Furnace] equipment business, particularly new opportunities in the cover and touch screen markets," he adds. "She has extensive experience in Asia as well as in the mobile device segment, which we believe could be a significant area of opportunity... Linda will also drive our product management and new business development for HiCz and our traditional PV business."

Reinhard received her BSEE from University of Illinois and an MBA from The Kellogg Graduate School of Management. She has over 20 years of experience with technology firms including Motorola, Cisco, Nokia and H-P, holding senior positions in new business development, marketing, sales, and product management. She has lived in Asia and has extensive experience in China and Asia Pacific introducing new products to major OEMs.

www.gtat.com

BluGlass' low-temperature RPCVD-grown p-type GaN films match MOCVD-grown electrical properties

Following a proof-of-concept in late 2012, BluGlass Ltd of Silverwater, Australia says that it has produced p-type gallium nitride films with industry-equivalent electrical properties using its proprietary low-temperature remote-plasma chemical vapor deposition (RPCVD) technology when grown on top of metal-organic chemical vapor deposition (MOCVD) GaN templates.

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

BluGlass has now demonstrated p-GaN films grown at low temperature with electrical properties equivalent to films grown using the industry-standard MOCVD process. Specifically, compared with resistivity of under $3\Omega\text{-cm}$ for a carrier concentration of 10^{17}cm^{-3} for a typical MOCVD-grown p-GaN film, BluGlass' RPCVD p-GaN film (grown on a commercial GaN template) yielded $1\Omega\text{-cm}$ for a carrier concentration of $2 \times 10^{17}\text{cm}^{-3}$, according to room-temperature Hall measurements.

BluGlass contracted The Australian National University to independently measure and verify the electrical

properties of the samples. Metal contacts required for the measurement were prepared by the Australian National Fabrication Facility.

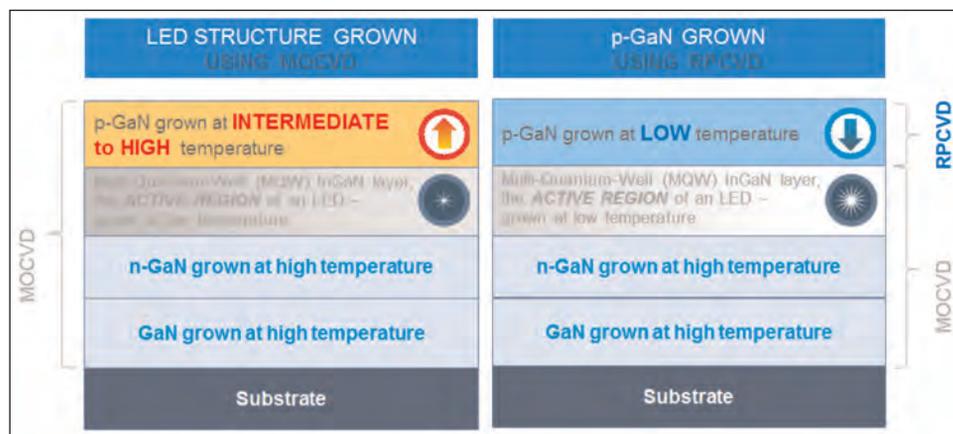
Having demonstrated these material specifications BluGlass says it can now begin experiments targeting improved LED device efficiency using RPCVD-grown p-GaN layers, to demonstrate the commercial value of a low-temperature technology.

With a lower growth temperature than MOCVD, BluGlass reckons its proprietary RPCVD technology has the potential to allow LED makers to create higher-performing devices by reducing the multi-quantum well or active region's exposure to high temperatures, which currently leads to performance loss (see Figure).

"The technology team is making increasingly rapid progress in the development of our platform technology and technical milestones to prove the competitive advantages of the low-temperature RPCVD technology," says CEO Giles Bourne.

"The next steps will see the technology focus on demonstrating that a low-temperature p-GaN layer can improve an LED's efficiency," says chief technology officer Dr Ian Mann. "We aim to do this by making a test LED device using RPCVD to grow p-GaN on top of an MOCVD-grown partial LED structure".

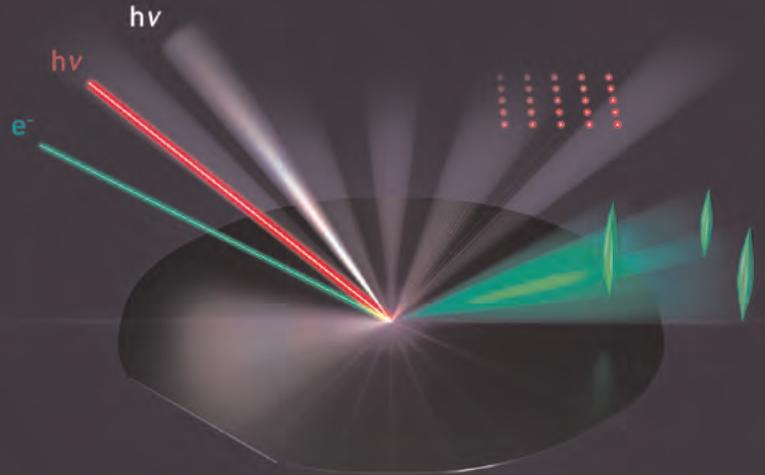
www.bluglass.com.au



Low-temperature p-GaN targeted as first commercial opportunity for RPCVD.



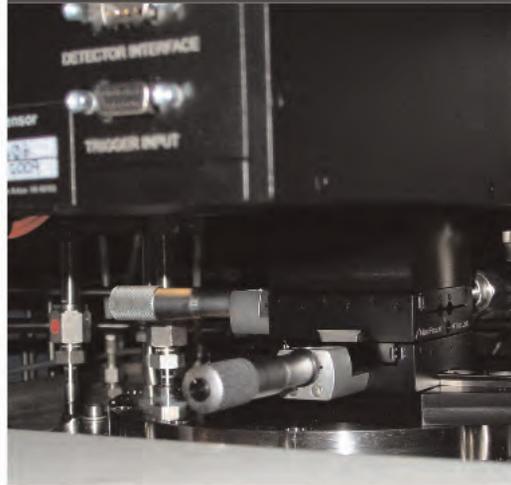
Control Your Process! Real-Time Process Monitoring for MOCVD, MBE, Sputtering, and Thin-Film PV Deposition



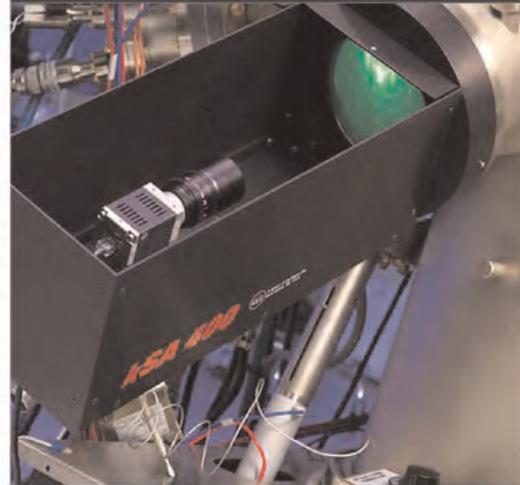
kSA BandiT Wafer Temperature



kSA MOS and kSA Mini-MOS
Thin-Film Stress



kSA 400 Analytical RHEED



kSA MOS Ultra-Scan and
Thermal-Scan Stress Mapping



kSA Rate Rat Pro Thickness &
Deposition Rate



kSA BandiT PV Process Tuning



Lemelson-MIT Collegiate Student Prize awarded to Rensselaer Polytechnic Institute student for GRIN LEDs

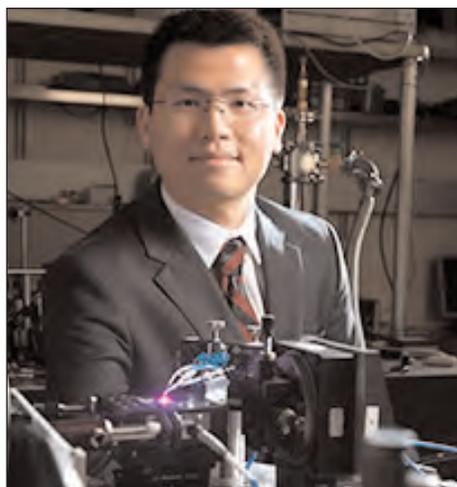
Ming Ma, a doctoral student in the Department of Materials Science and Engineering of the Rensselaer Polytechnic Institute (RPI), has been named the winner of the 2013 Lemelson-Rensselaer Student Prize which (along with prizes for students at the Massachusetts Institute of Technology and the University of Illinois at Urbana-Champaign) is one of three \$30,000 Lemelson-MIT Collegiate Student Prizes awarded annually.

The Lemelson-MIT Program was founded in 1994 by Jerome H. Lemelson (one of America's most prolific inventors) and his wife Dorothy. Funded by the private philanthropy The Lemelson Foundation, the program is administered by MIT's School of Engineering, and supports projects in the USA and developing countries that nurture innovators to advance economic, social and environmentally sustainable development.

Ma is the seventh recipient of the Lemelson-Rensselaer Student Prize. First given in 2007, it is awarded annually to a senior or graduate student at RPI who has created or improved a product or process, applied a technology in a new way, redesigned a system, or demonstrated remarkable inventiveness in other ways.

RPI says that Ma has developed a new method for manufacturing LEDs that are brighter, more energy efficient, and have superior technical properties than those currently on the market. His patent-pending invention of 'GRIN' (graded-refractive-index) LEDs could hasten adoption of LEDs and cut the overall cost and environmental impact of illumination, it adds.

Conventional incandescent and fluorescent light sources are increasingly being replaced by more energy-efficient, longer-lived, and environmentally friendlier LEDs, but LEDs still suffer from



RPI's Ming Ma.

challenges related to brightness, efficiency, and performance. With his project 'Graded-refractive-index (GRIN) Structures for Brighter and Smarter Light-Emitting Diodes', Ma has tackled a fundamental technical shortcoming of LED materials, it is claimed.

Currently, most unprocessed LEDs have a light-extraction efficiency of only 25%, so 75% of light produced gets trapped within the device. One solution that has emerged is to roughen the surface of LEDs, in order to create nanoscale gaps and valleys that enable more light to escape. While surface roughening leads to brighter and more efficient light emission, the roughening process creates random features on the LED's surface that do not allow complete control over other critical device properties such as surface structure and refractive index.

Ma's solution to this problem was to create an LED with well-structured features on the surface to minimize the amount of light that gets reflected back into the device, boosting the amount of light emitted. His process creates many star-shaped pillars on the surface. Each pillar consists of five nanolayers, engineered specifically to help guide the light out of the LED material and into the surrounding air.

Ma's patent-pending GRIN LED technology has demonstrated hugely improved light-extraction efficiency of 70%. GRIN LEDs also have controllable emission patterns, and enable more uniform illumination. Overall, it is reckoned that Ma's innovation could lead to new methods for manufacturing LEDs with increased light output, greater efficiency, and more controllable properties than both surface-roughened LEDs and the LEDs currently on the market.

Growing up in Jiangxi Province in southeast China, Ma became interested in advanced materials as an undergraduate student at Fudan University in Shanghai. Ma joined RPI in 2008 as a member of professor E. Fred Schubert's research team. He has since been the first author on five research papers, published in *Applied Physics Letters*, *Journal of Applied Physics*, and *Optics Express*, and co-author of several studies in other journals. He is also a reviewer for *Optics Letters* and *Optics Express*. Upon completing his doctoral degree later this year, Ma plans to continue researching materials and LEDs in academia or industry.

"Ming's technical accomplishments are innovative, and have had a significant impact on the LED materials research community," comments Schubert, the Wellfleet Senior Professor in the Future Chips Constellation at RPI and a faculty member of the Department of Electrical, Computer, and Systems Engineering and Department of Physics, Applied Physics, and Astronomy. "Ma's invention [GRIN LEDs] is the first viable approach for high-efficiency LEDs with a controllable far-field emission pattern," he adds. "This is an important development for LED lighting, and it is already capturing the attention of industry."

www.eng.rpi.edu/lemelson

www.mse.rpi.edu

Crystal IS extracts record 65mW cw at 260nm from single-chip UVC LED

Die thinning and encapsulation techniques boost photon extraction efficiency to over 15%

Working with the US Army Research Laboratory (ARL), Crystal IS Inc of Green Island, NY, USA, which makes ultraviolet light-emitting diodes (UVC LEDs) grown pseudomorphically (strained) on aluminum nitride (AlN) substrates, has achieved more than 65mW in optical output at 260nm from a single UVC LED operated in continuous-wave (cw) mode (Appl. Phys. Express 6 (2013) 032101).

"By employing die thinning and encapsulation techniques, we were able to increase the photon extraction efficiency to over 15%," says founder & chief technology officer Leo Schowalter. Furthermore, improved thermal management and a high characteristic temperature resulted in low thermal roll-off up to 300mA injection current with output power of 67mW, an external quantum efficiency (EQE) of 4.9%, and a wall plug efficiency (WPE) of 2.5% for a single-chip UVC LED emitting at 271nm. "By fabricating our LEDs on our home-grown aluminium nitride substrates, we continue to set the pace of what is possible for the combination of highest efficiencies and longest lifetimes in the 250–280nm wavelength range, far surpassing diodes fabricated on sapphire," Schowalter adds.

"This R&D accomplishment represents a more than six-fold increase in performance from just one year ago," says CEO Larry Felton. "Our progress in business operations continues on a like pace, readying us and our LEDs for commercial success."

Light in the UVC wavelength range (200–280nm) can be used for disinfecting water, sterilizing surfaces, destroying harmful micro-organisms



UVC LED engineering sample from Crystal IS.

in food products and in air, and for spectroscopy applications. Market analyst firm Yole Développement estimates that the UVC lamp market was nearly \$200m in 2012, with lamps being replaced increasingly by UV LEDs.

"Our products will address some of the most pressing health concerns of our time," says Therese Jordan, senior VP of business development. "We are seeing demand in both water and air for the disinfection and quality monitoring aspects of UVC. Similarly, spectroscopic instruments are also taking advantage of the high light output available in a UVC LED," she adds. "Unlike UV lamps, UVC LEDs are mercury-free, compact, rugged and robust, lending themselves to an array of designs and hold the promise of long life and environmentally friendly end-of-life disposal."

Engineering samples of UVC LEDs are available from Crystal IS.

www.crystal-is.com
<http://apex.jsap.jp/link?APEX/6/032101>

IN BRIEF

SETi launches new line of UVTOP UVC and UVB LEDs in surface-mount packages for high-volume cost-sensitive markets

At the 2013 SPIE Photonics West show, ultraviolet light-emitting diode (UV LED) maker Sensor Electronic Technology Inc (SETi) of Columbia, SC, USA launched a new line of UVTOP products in surface-mount packages. Initial devices added to this product line will operate with peak operating wavelengths at 275nm and 310nm, respectively. Additional wavelength specifications will be added to the product line in the near future.

SETi says that the SMD-based line of UVTOP LEDs has been developed to address high-volume markets that demand lower device and assembly costs. The ceramic package dimensions are 3.5mm x 3.5mm and are available with UV stable encapsulation, a flat glass window, or a hemispherical glass window. Windowless devices are also available.

The entire range of UVTOP LEDs will remain available in TO packages for lower-volume requirements, customized specifications, and for customers who prefer a through-hole package.

In 2012, SETi opened its high-volume manufacturing facility for UV LEDs, driving the cost of manufacture down. Now, by employing new high-volume packaging techniques and with the use of the cost-effective ceramic package, SETi aims to bring its UVTOP LEDs to new mass-volume markets where the TO package is not the most effective solution.

www.s-et.com

Lextar officially merges with Wellypower

More vertically integrated firm targets LED lighting

Lextar Electronics Corp says that its official merger with Wellypower Optronics Co Ltd - both of Hsinchu Science Park, Taiwan and LED subsidiaries of Taiwan-based display panel maker AU Optronics (AUO) - is set to take place on 1 February. The merger was agreed last September. Lextar chairman Dr David Su is chairman & CEO of the merged company, while Wellypower chairman Allen Huang becomes president.

Founded in May 2008, Lextar specializes in manufacturing high-brightness LED epiwafers, chips and packages, as well as energy-saving and smart lighting products. Applications include LCD backlighting, LED light modules, LED light sources and luminaires. After acquiring LightHouse Technology Inc in March 2010, boosting staffing to more than 2500 at manufacturing plants in the Hsinchu Science Park, Hukou

Industrial Park and Chunan Science Park in Taiwan, and an assembly plant in Suzhou, China. Revenue grew from US\$255m in 2010 to US\$309m in 2011 then US\$339.5m in 2012.

With a factory in Zhunan, Mao-Li County, Taiwan as well as Hsinchu, Wellypower has experience in LED packaging as well as in lighting product manufacturing and sales.

Upon the merger with Wellypower, Lextar will have nearly 4000 staff and capital valued at NT\$5bn (US\$169m), as well as a more vertically integrated business model. The firm says the merger also further expands its LED lighting and backlighting product lines and customer base.

Lextar says that in the past its backlighting products were used mostly for monitor and TV applications, but as a result of the merger they will now also be used in notebook and smartphone appli-

cations. In addition, apart from developing solid-state lighting products such as lamps and board lights, the merger gives Lextar a line of products that includes T5 tube and CCFL lighting applications along with LED bulbs and fixtures.

The expanded customer portfolio also gives Lextar OEM business in the USA and Japan. Lextar says it will continue to expand its reach in addition to supplying its own Industrial Design team to provide more value-added services. On the supply-chain side, Lextar says it is enlarging its economies of scale, increasing its access to materials and resources while improving cost competition.

Su notes that the product lines, system platforms and personnel of Lextar and Wellypower have already merged to form a team that is more well-versed in lighting operations.

www.Lextar.com

www.wellypower.com.tw

Finland's VTT and Lumichip invest in LED technology start-up LightTherm

Finland's VTT Ventures Ltd and LED lighting components provider Lumichip Ltd of Espoo, Finland have made a joint investment in LED technology start-up LightTherm Ltd.

A difficulty with LEDs, says LightTherm, is the heat sensitivity of components and materials. Overheating can shorten the lifespan and efficiency of LEDs, while light output falls as temperatures rise. LightTherm uses innovative materials and heat management solutions to introduce novel design and manufacturing capabilities that improve the lifespan, efficiency and light output of LEDs.

"The high thermal management efficiency of this technology enables significantly higher light output - for example from replacement spots - than is currently

available anywhere in the LED market," claims Lumichip's chairman Dr Juha Rantala. "LightTherm materials, device construction and manufacturing processes give flexibility in design, and will enable the manufacture of entirely new lighting applications for both consumer and industrial luminaires," he adds. "This will change completely the way in which LED products are manufactured in the future," he believes.

A VTT spin-off firm, LightTherm's technologies are based on development, characterization and lifetime tests carried out at VTT Technology Research Centre, which produces technology solutions and services. VTT Ventures Ltd supports companies exploiting new technology, from business plan through to

funding.

"We are pleased to co-operate with a partner such as Lumichip to take this very innovative and promising technology to the industrialization and commercialization phase," says VTT Ventures' CEO Antti Sinisalo.

LightTherm's founding team consists of Petri Nyman, Ville Moilanen and Kimmo Jokelainen. CEO & co-founder Petri Nyman has extensive experience in start-ups, as well as in the management of growth companies. Co-founders Ville Moilanen and Kimmo Jokelainen have a research background with VTT and have been instrumental in developing the core innovations behind this new technology.

www.ventures.fi

www.lumichip.com



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IN BRIEF

Plessey expands distribution network in Greater China via agreement with Alphatec

Plessey Semiconductors Ltd of Plymouth, UK has signed an agreement with electronics distributor Alphatec relating to the greater China region.

The cooperation will market Plessey's EPIC (Electronic Potential Integrated Circuit) sensors, together with Alphatec's system solutions for applications in the fields of e-health, automotive, sports, fitness and smart lighting. The latter links in with Plessey's high-brightness MAGIC (MANufactured on Gan ICs) LED technology, which is based on standard silicon wafers rather than the more costly sapphire. Also, by expanding Alphatec's portfolio with Plessey's RF solutions and power management products (LDOs) for applications in DVB (digital video broadcasting) and set-top box products, Alphatec will be able to offer more complete solutions.

EPIC technology enables the sensor to capture minimal changes of the electric field using a high-precision, non-contact voltmeter within the millivolt region to detect bio-electrical signals (ECG, EMG, EOG, EEG) and changes in electric fields.

"The Chinese market will be a critical one for the design of advanced healthcare applications," says Plessey's global sales director David Owen. "Added to that the huge growth in LED-based lighting applications in China, where Plessey's advanced GaN on silicon MAGIC LED technology will offer a significant cost saving, means we are very pleased to be working with Alphatec, who have a unique position in this region."

www.plesseysemiconductors.com

Lumileds launches LUXEON 3535L family of 165lm/W mid-power LEDs

LED maker Philips Lumileds of San Jose, CA, USA has launched the LUXEON 3535L family of mid-power LEDs, offering what is claimed to be the highest luminous efficacy available for the category on the market: 165 lumens per watt (165lm/W) at cool-white and 150lm/W at warm-white correlated color temperatures (CCTs).

The LUXEON 3535L line supports ENERGY STAR certification requirements for color quality and a lumen maintenance lifetime of 35,000 hours at test conditions as high as 105°C and 150mA.

"Our LUXEON 3535L mid-power LED offers luminaire and lamp manufacturers unique flexibility by combining industry-leading efficacy of 165lm/W with a wide range of CCTs and CRIs [color rendering

indexes] to help them achieve the right light quality for their application," claims Khim Lee, director of mid-power products. "With the industry's leading lumen maintenance, the LUXEON 3535L helps luminaire and lamp manufacturers bring a quality product to market that meets the application needs of their customers," he adds.

To provide lamp and luminaire manufacturers with maximum flexibility, LUXEON 3535L mid-power LEDs are available across a full range of CCT (2700–6500K) and CRI (70, 80 and 90 CRI) combinations. The 3535L is already being widely used in retrofit A19 bulbs, TLEDs, and several office, indoor area lighting and retail applications, the firm adds.

www.philipslumileds.com

Samsung launches mid-power LED package with 160lm/W efficacy

Samsung Electronics Co Ltd of Seoul, South Korea has begun producing a new lineup of mid-power LED packages, which the firm claims offer the industry's highest efficacy level.

Suiting LED lighting applications, including LED tubes, LED ambient lighting, downlighting and retrofit lamps, the LM561B features 160lm/W luminous efficacy, electric current rated at 65mA, 5000K CCT (correlated color temperature), and a rating of over 80 CRI (color rendering index).

The new LM561B achieves a 30% increase in efficiency compared to Samsung's previous mid-power LED (LM561A) package. The improved heat dissipation means that smaller heat sinks can be used, saving on material costs, while also providing customers with the ability to create more compact and flexibly innovative products, the firm claims.

"The Samsung LM561B will provide customers with the highest quality of light in the LED package market today, through its high efficacy and variety in color temperatures," says Jaap Schlejen, senior VP, LED lighting sales & marketing. "Samsung will continue to improve its product offerings with highly advanced LED package solutions that clearly meet customer needs."

Samsung's LM561B product lineup offers a wide range of color temperatures. It also comes in three brightness levels and provides quarter binning to allow customers to quickly maximize its use in LED lighting production.

Samsung Electronics will officially introduce its LM561B family at the LIGHTFAIR International 2013 event in Philadelphia (23–25 April), along with other LED packages, as well as new LED engines, lamps and L-Tubes.

www.samsung.com

Seoul Semi's new 0.6T LED boosts side-view output by 10% to 8.8lm

Seoul Semiconductor Co Ltd has launched a 0.6T side-view LED, optimized for the fast-growing smart-phone and tablet (phablet) market, which requires high brightness and high efficacy. The 0.6mm (tall) LED delivers 8.8 lumens, which is claimed to be the world's best light output performance, 10% brighter than a conventional side-view LED.

The firm says it has achieved this by improving the efficacy and design of its LED chip, package and phosphors. The added performance can improve the visibility of phablets in bright places and give the added benefit of energy savings, helping to extend battery life. The firm plans to apply the technology to other sizes of side-view

LEDs such as 0.8mm and 0.4mm.

Seoul Semiconductor has been in mass production of 1.0mm-type side-view white LEDs since 2002 and has also launched 0.8mm, 0.6mm and 0.5mm side-view LEDs. It says that the products have been adopted by the major players in the mobile phone and tablet PC market space. The firm adds that it will use this accumulated experience and side-view LED technology to continue to offer high-end products with a variety of specifications for the global phablet market. "Seoul Semiconductor maintains a leading position in the side-view LED market by continually introducing thinner and brighter products," says IT division leader Hyuk-won, Kwon.

www.seoulsemicon.com/en

New 64V, 140lm/W multi-junction Acrich LED targets outdoor and streetlight markets

South Korean LED maker Seoul Semiconductor has announced the new MJT 4040 package, which uses multi-junction technology to bring performance and size advantages to the LED outdoor and streetlight markets. The firm also announced that it recently won a retrofit project for streetlights using this new product in China.

The MJT 4040 uses multi-junction technology that allows multiple LED junctions to be combined in a single chip, increasing the operating voltage and concentrating more light output within a given area. Operating at a nominal 64V and 20mA, the device can reach output levels of 200 lumens and efficacies as high as 140lm/Watt (5000K CCT).

Streetlights using the MJT 4040 device, combined with the firm's Acrich2 technology, allows operation on AC current without a driver, which usually weighs 2–3kg, and allows Seoul Semiconductor's customers to make lightweight LED streetlights. This

allows the end-user to employ the existing streetlight pole infrastructure as well as its functionality (such as existing wiring), drastically reducing retrofitting cost. In addition, due to the reduced component count and the elimination of electrolytic condensers commonly found in traditional ballasts and drivers, reliability is increased, claims the firm.

"The new MJT 4040 extends the Acrich family of LEDs into higher-power applications," says global marketing VP Marten Williams, adding that it is suitable for not only streetlights but also parking-lot lights, security lights, low-bays, high-bays, and other outdoor lighting fixtures. "We are currently supplying this product to streetlight manufacturers in China, South America and other developing countries."

The MJT 4040 has been released to mass production and high-volume orders are now being accepted.

www.acrich.com

IN BRIEF

Soraa's VIVID LED MR16 lamp receives Red Dot award

Soraa Inc of Fremont, CA, USA, which develops solid-state lighting technology built on 'GaN on GaN' (gallium nitride on gallium nitride) substrates, has received the 'red dot award: product design 2013' for its full-visible-spectrum VIVID LED MR16 lamp.

Soraa says many LED lamps based on first-generation, foreign-substrate LEDs must overcome thermal management and optical hurdles, as they need multiple light sources that must be kept cool in order to generate enough light and last long. Their look hence often reflects less-than-optimal transitional design strategies, such as the 'shower head' face and optics or a mechanical fan.

Soraa's lamp design is based around a single, small, bright LED light source combined with a single optic and heat-sink.

The design is possible because the GaN-on-GaN LEDs emit up to ten times more light per unit area and tolerate much higher temperatures than first-generation LEDs, it is claimed. The organic fin geometry heat-sink has a tiny core and more fins at the edge, maximizing thermal transfer; the 'Origami' driver circuit, designed with electronic components used in automotive and other extreme temperature environments, enables highly efficient thermal dissipation; and the LED light source is directly attached to the heat-sink without intermediate circuit boards, increasing power density and lowering cost, the firm claims. The result is an MR16 lamp that produces 50W-halogen-equivalent light output and operates reliably at lamp temperatures of up to 120°C (for reliable operation in constrained fixtures).

www.red-dot.org

www.soraa.com

IN BRIEF

Cree adds AR Series LED architectural troffers to lighting product portfolio

Building on its CR Series LED troffer, Cree has introduced its 100 lumens per watt AR Series LED architectural troffers, with a flush-mount white housing that helps it to blend into any ceiling design and softly illuminate the space through highly diffused performance optics, says the firm.

Providing 33% energy savings versus standard T8 fluorescent solutions and a lifetime of up to 75,000 hours, the AR Series is covered by Cree's 10-year limited warranty.

"The AR Series provides an excellent option to the lighting specifier, designer or customer who is seeking aesthetic options to our standard CR Series LED troffer," says Greg Merritt, vice president, lighting at Cree. "We now have a fully luminous troffer, with a new architectural look suitable for applications such as corporate offices, up-market retail merchandising spaces and automotive retail applications."

AR Series troffers are available in two models, the AR22 and AR24, and a range of color temperatures to match existing fluorescent technologies (3500K and 4000K). The series supports dimming down to 5% with industry-standard 0–10V controls. Lutron EcoSystem-enabled AR Series troffers supporting dimming down to 5% are targeted to be available in mid-2013.

The AR Troffer provides increased architectural lighting options while delivering industry-leading light quality and energy savings using Cree TrueWhite Technology.

www.cree.com/lighting/ARseries

Cree raises March-quarter revenue and income forecast

Top end of guidance now indicating sequential growth, despite extra expenses from LED light bulb launch

Cree Inc of Durham, NC, USA has raised its revenue target for fiscal third-quarter 2013 (to end-March) from \$325–\$345m (forecast at the end of January) to \$335–\$350m. This compares with \$346.3m reported for fiscal Q2 last quarter.

Excluding stock-based compensation expense of about \$2.4m, non-GAAP gross margin is still targeted to rise slightly from 39.2% last quarter to 39.5%. However, rather than remaining similar to last quarter, operating expenses should be about \$2m higher than previously

announced, due to higher R&D and marketing costs to support the launch of Cree's new LED light bulb products (unveiled today).

Despite this, the non-GAAP net income target has been raised from \$35–\$41m (\$0.30–0.35 per diluted share) to \$36–\$42m (\$0.31–0.36 per diluted share, excluding expenses related to the amortization of acquired intangibles and stock-based compensation expense of \$0.15 per diluted share). This compares with \$36.9m (\$0.32 per diluted share) in fiscal Q2 last quarter.

Cree launches sub-\$10 LED light bulbs that save 84% energy compared to traditional bulbs

Cree has introduced new LED light bulbs that save 84% energy compared to traditional bulbs while shining as brightly as comparable incandescents, it claims.

"The Cree LED light bulb was designed to offer consumers a no-compromise lighting experience at a compelling price," says chairman & CEO Chuck Swoboda. "Over the last couple of years we recognized that the consumer is instrumental in the adoption of LED lighting, but we needed to give them a reason to switch. We believe this breakthrough LED bulb will, for the first time, give consumers a reason to upgrade the billions of energy-wasting light bulbs."

Designed to last 25,000 hours (25 times longer than typical incandescent light bulbs), the new bulbs are illuminated by Cree LED Filament Tower Technology. With a shape that looks like a traditional light bulb, Cree LED bulbs can be placed in most lighting fixtures in the home.

With a retail price of \$9.97 for the warm-white 40W replacement, \$12.97 for the 60W warm-white

replacement and \$13.97 for the 60W day-light, Cree LED bulbs can pay for themselves quickly. By replacing the incandescent bulbs with Cree LED bulbs in a home's five most frequently used light fixtures, users can save \$61 per year on electric bills (based on Cree LED bulb 60W replacements at 9.5W, \$0.11 per kilowatt-hour, 25,000 hour lifetime and average usage of 6 hours per day).

The new LED bulbs turn on instantly and are free of the mercury found in CFL bulbs. Also, Cree LED bulbs are dimmable with most standard incandescent dimmers.

The 60W-incandescent-replacement LED light bulb delivers 800lm, consumes only 9.5W and is available in warm-white (2700K) and day-light (5000K) color temperatures. The 40W-incandescent-replacement LED light bulb delivers 450lm and consumes only 6W and is available in 2700K color temperature.

The new bulbs are backed by a 10-year limited warranty and available exclusively at The Home Depot.

www.cree.com



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Osram boosts Golden Dragon infrared LED output by 20% via higher efficiency at currents up to 2A

Osram Opto Semiconductors GmbH of Regensburg, Germany claims that, with typical optical output power of 650mW, its new Golden Dragon SFH 4232A infrared LED (IRED) is currently the most efficient infrared power emitter on the market. Housed in a performance-proven 11mm x 6mm x 1.8mm SMT package, the luminous efficacy of the high-power component is more than 39% at a drive current of 1A. The IRED can hence provide the basis for reliable monitoring and surveillance systems and help to reduce system costs, says the firm, benefitting general applications in process and production control in industry and camera-based surveillance applications.

Road intersections, bus stations, parking lots and other public areas need high-performance surveillance systems, notes Osram Opto. Cost-effective systems can be provided based on the SFH 4232A, supplied in a tried-and-tested SMT



Golden Dragon SFH 4232A IRED.

(surface-mount technology) package design, it adds.

The SFH 4232A IRED contains the firm's latest-generation high-power thin-film chip, emitting infrared light with a wavelength of 850nm. The IRED has a beam angle of $\pm 60^\circ$ and achieves a typical optical output of 650mW from an operating current of 1A and voltage of 1.65V. This equates to an increase of over 20% compared with the 530mW of its predecessor model. The radiant intensity (i.e. light output within a solid angle) is 210mW/sr at 1A.

This higher optical output has been achieved due to improved light extraction from the chip.

The 1mm² chip is optimized for currents up to 2A, making the new Golden Dragon suitable for the infrared illumination required in security applications. Due to improved output efficiency, more light can be generated from the same chip surface and fewer components are needed to achieve a particular brightness, resulting in reduced system costs, says Osram Opto. Alternatively, if the same number of components is used as before, then the infrared lighting unit will be considerably brighter.

"Customers are provided with a tried-and-tested product of the same size but with higher output, and they also benefit from lower system costs in their particular applications," summarizes Dr Jörg Heerlein, head of product marketing for industrial infrared components.

www.osram-os.com

Bridgelux sponsors Bay Area Climate Collaborative to help equip local governments for streetlight upgrades

LED chip and lighting array maker Bridgelux Inc of Livermore, CA, USA and the Bay Area Climate Collaborative (BACC) are collaborating to accelerate the market for advanced streetlighting technologies through the Bay Area Next Generation Streetlight Initiative, a region-wide project to upgrade 200,000+ municipal streetlights to LED technology.

BACC is a public-private partnership initiative of the Silicon Valley Leadership Group, launched by regional civic and business leaders in 2009 to accelerate the Bay Area clean-energy economy through high-impact, market-oriented projects that can be replicated and scaled. Partners include Bank of America, Pacific Gas & Electric, the Environmental Defense Fund and local governments

representing over 70% of Bay Area people. Together with the UC Davis California Lighting Technology Center (CLTC), BACC is delivering education, tools and guidance via the Bay Area Next Generation Streetlight Initiative in order to accelerate the move to next-generation streetlighting.

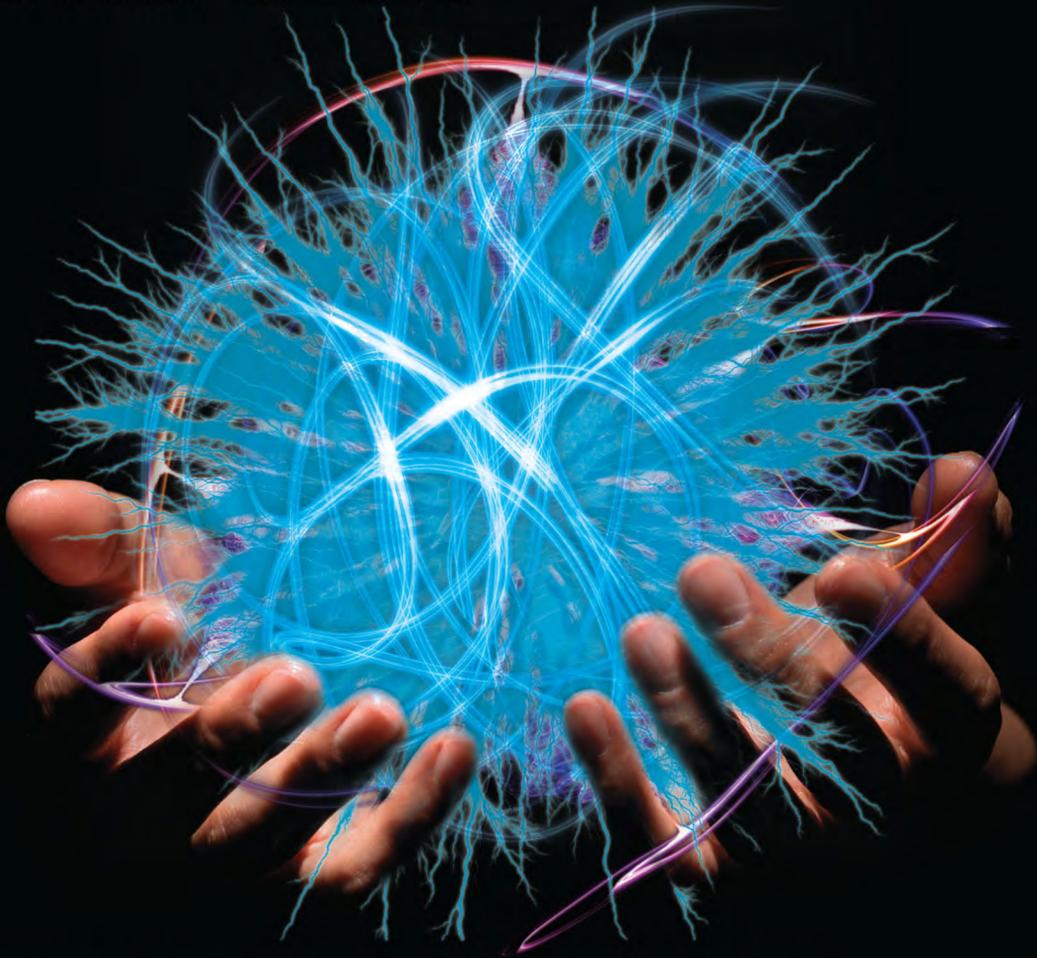
Bridgelux's sponsorship of the initiative will support outreach to municipalities on LED lighting, and the development of key resources (e.g. the recently published guide 'Next generation streetlights: LED technology and strategies for action') which deliver education and specific steps for streetlight conversions. With the ultimate goal of pooling regional interest in LED streetlight conversions to secure improved purchase and financing terms, the

initiative will act as a business model that local governments can replicate to upgrade streetlights at lower costs, relieving municipal budgets. Over five years, regional upgrades could deliver up to \$50m in reduced costs for local governments, over 100,000 metrics tons of CO₂ avoidance, and many jobs, it is reckoned.

"Initiatives that help scale the LED lighting market are critical to realizing savings and increasing adoption, but first the practical business case must be made," says Bridgelux's CEO Brad Bullington. "BACC is providing straightforward, up-to-the-minute information that equips local governments with the guidance they need to make informed decisions about streetlight upgrades."

www.bridgelux.com

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NIST tests raise potential hazards of green laser pointers

Nearly 90% of green pointers and 44% of red pointers out of compliance with safety regulations

Using a low-cost apparatus designed to quickly and accurately measure the properties of handheld laser devices, researchers at the National Institute of Standards and Technology (NIST, an agency of the US Department of Commerce) have tested 122 laser pointers and found that nearly 90% of green pointers and about 44% of red pointers were out of compliance with federal safety regulations. The NIST test apparatus was designed so that it can be replicated easily by other institutions.

As NIST reported on 20 March at the International Laser Safety Conference in Orlando, FL, USA, both red and green laser pointers often emitted more visible power than allowed under the Code of Federal Regulations (CFR), and green pointers often emitted unacceptable levels of infrared light as well (J. Hadler, E.L. Tobares and M. Dowell, 'Random testing reveals excessive power in commercial laser pointers. Random testing reveals excessive power in commercial laser pointers', *Journal of Laser Applications*, to be published).

Anecdotal reports of green laser hazards have previously appeared in scientific journals and the media, but the new NIST tests are claimed to be the first reported precision measurements of a large number of handheld laser devices. The NIST tests point out that many red laser pointers are also, unexpectedly, out of compliance with federal regulations. "Our results raise numerous safety questions regarding laser pointers and their use," say the researchers.

The tests were conducted on randomly selected commercial laser devices labeled as Class IIIa or 3R and sold as suitable for demonstration use in classrooms and other public spaces. Such lasers are limited under the CFR to 5mW



NIST laser safety officer Joshua Hadler and his apparatus for measuring the properties of handheld laser devices.

maximum emission in the visible portion of the spectrum and less than 2mW in the infrared portion of the spectrum. About half the devices tested emitted power levels at least twice the CFR limit at one or more wavelengths. The highest measured power output was 66.5mW, more than 10 times the legal limit. The power measurements were accurate to within 5%.

According to the American National Standards Institute (ANSI), laser devices that exceed 3R limits may be hazardous and should be subject to more rigorous controls, such as training, to prevent injury (American National Standard for the Safe Use of Lasers (ANSI Z136-2007) Section 1.2 and Table 1. Lasers that exceed 3R emissions limits are classified as 3B or 4).

NIST is a non-regulatory agency with decades of experience providing industry, research and military agencies with laser power measurements traceable to international standards. It also has a history of innovation in devices for making such measurements. Technical staff from NIST's Laser Radiometry Project built the laser pointer test bed

and collaborated with the NIST Office of Safety, Health and Environment on the tests. NIST has provided its data on laser pointer power measurements to the US Food and Drug Administration (FDA), which regulates laser product safety.

Green lasers generate green light from infrared light. Ideally, the device should be designed and manufactured to confine the

infrared light within the laser housing. However, according to the new NIST results, more than 75% of the devices tested emitted infrared light in excess of the CFR limit.

NIST's laser safety officer Joshua Hadler designed the measurement test bed (J. Hadler and M. Dowell, 'Accurate, inexpensive testing of laser pointer power for safe operation', *Measurement Science and Technology*; published online 7 March 2013). The system consists of a laser power meter and two optical filters to quantify the emissions of different wavelengths of visible and infrared light. The power meter and filters were calibrated at NIST. Lens holders ensure repeatable laser alignment, and an adjustable aperture contains the laser light around the output end of the laser.

"The measurement system is designed so that anyone can build it using off-the-shelf parts for about \$2000," says Hadler. "By relying on manufacturers' traceability to a national measurement institute such as NIST, someone could use this design to accurately measure power from a laser pointer."

www.nist.gov

DILAS launches 40W, 638nm fiber-coupled T-bar modules for cinema projection

Diode laser maker DILAS of Mainz, Germany is now delivering 40W of output power (substantially higher than previously available) from a T-bar-based 638nm 400 μ m/0.22NA fiber-coupled module used for cinema projection.

DILAS says that, via optimization of the chip structures and optical parameters, its tailored bar (T-Bar) architecture delivers high beam quality and power using standard micro-optic fast-axis collimators (FAC) and slow-axis collimators (SAC), all assembled with automated processes. The T-Bar is a monolithic multi-emitter source, allowing the handling of multiple emitters during each manufacturing step, to lower complexity and ease manufacturing. The result is enhanced reproducibility, beam quality and fiber coupling efficiency, says the firm.

The visible 638nm fiber-coupled T-bar offers advantages over conventional lamp-based technology, claims DILAS. In cinema projectors, higher efficiency, much smaller footprint, lower cost of ownership, higher reliability, and higher brightness are all enabled, it adds.

By extending the T-Bar-based scalable concept, more advanced modules will soon be made available to enable development and commercialization of high-power diode laser-based RGB projection laser systems, DILAS concludes.



DILAS' fiber-coupled T-bar module.

Direct, multi-bar diode laser system

DILAS has launched the SD3000 direct, multi-bar diode laser system, which can deliver up to 3kW output at 980nm wavelength to the work piece.

The SD3000 is available with either symmetric spot configuration (SD3000S) or different line focus configurations (SD3000L). Its line focus is homogenized in the long direction.

The SD3000 comes turn-key with a water-water heat exchanger and power supply diode laser driver. The system is equipped with a pilot beam for positioning purposes.

DILAS says that the SD3000 suits surface treatment applications such as hardening and applications that need large spot geometries.

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Advanced Photonix acquires CdS-based opto sensor maker Silonex, creating Advanced Photonix Canada HSOR supply chain issues induce cost-cutting program

Advanced Photonix Inc of Ann Arbor, MI, USA (which designs and makes APD, PIN, and FILTRODE photodetectors, HSOR high-speed optical receivers, and T-Ray terahertz instrumentation) has acquired certain assets of Silonex Inc of Montreal, Canada, a subsidiary of ARCAS Automotive Group (Luxco 1) S.a.r.l., for \$900,000.

Silonex designs and manufactures optoelectronic devices and sensor solutions, for vertical markets including industrial controls, banking, vending, medical and telecoms.

The Silonex acquisition is expected to bring Advanced Photonix more than \$4m in annual revenue and generate positive EBITDA (earnings before interest, taxes, depreciation, amortization and stock compensation) during the

first full fiscal year (to end-March 2014). Engineering and product development for the Silonex products will continue in Montreal, while production will be transitioned either to an off-shore facility or to Advanced Photonix's operations in Camarillo, CA.

"Silonex brings a rich history of product development, new markets, new optoelectronic sensing capabilities with the addition of cadmium sulphide (CdS) and a strong off-shore supply chain and customer base," says Advanced Photonix's president & CEO Rick Kurtz. "We are looking forward to building and leveraging those relationships to expand our revenue growth and lower our unit costs," he adds. "We have had a long relationship with Silonex, working

together as customer and supplier, and believe the synergies of our engineering, sales and customer base will provide a strong foundation for future growth."

To facilitate the transaction, the firm has established the new Canadian subsidiary Advanced Photonix Canada Inc.

"In addition, because our previously announced supply chain issues have lowered expected revenues from the sale of our HSOR line of products, we are introducing a cost-cutting program which includes a 20% wage and compensation reduction by 'C' management and the board of directors over the next five months, and a suspension of the company 401k match," adds Kurtz.

www.silonex.com

Advanced Photonix awarded \$1.5m US Navy missile contract

Advanced Photonix says that it has booked a \$1,562,072 order for a custom photodiode used for the US Navy's Guided Missile Systems, to ship within the next 20 months. The Navy's Guided Missile Weapon System is said to be the world's most modern ship self-defense weapon, and has been designed specifically to provide protection for ships of all sizes.

As a supersonic, light-weight,

quick-reaction, fire-and-forget missile designed to destroy anti-ship missiles, its autonomous dual-mode passive RF-to-IR guidance design — requiring no shipboard support after missile launch — uniquely provides high-firepower capability for engaging multiple threats simultaneously.

"This missile program has been one of the Navy's most reliable missile guided systems," comments

Jean-Pierre Maufras, general manager of the firm's Optosolutions Group. "We have been continuously working with the OEM to improve the products and its reliability," he adds. "This is an ongoing program and we are confident we will see additional business in the near future as we are well positioned to support our customer efforts spanning to 2020."

www.advancedphotonix.com

Albis launches 30GHz short-wavelength photodetector

Albis Optoelectronics AG of Zurich, Switzerland, which designs and manufactures high-speed PIN and APD photodiodes for fiber-optic datacom and telecom applications, has announced the availability of the PQW30A-S, a hermetically packaged, short-wavelength, 30GHz RF photodetector.

The small-sized, pigtailed device is used for the detection of RF-modu-

lated optical signals and combines unique features such as an integrated bias-T, a high-responsivity gallium arsenide photodiode as well as a hermetic enclosure. The combination of these features makes this a one-of-a-kind device that has not been commercially available so far, claims the firm. Key customers are awaiting shipment of the first units, expected for mid-April.

"The addition of PQW30A-S to our family of PQW products strengthens our position in the market for high-speed RF photodetectors," reckons chief technology officer Markus Blaser. "It also underlines our goal to expand our portfolio of packaged detectors that integrate our field-proven high-speed photodiodes," he adds.

www.albisopto.com

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

OPEL announces RF & microwave test results for both n- and p-channel transistors fabricated in POET process

New R&D equipment to be commissioned by the end of June

OPEL Technologies Inc of Toronto, Ontario, Canada — which develops III-V semiconductor devices and processes through US affiliate OPEL Defense Integrated Systems (ODIS Inc) of Storrs, CT — says that it has achieved Milestone 4 in its Planar Optoelectronic Technology (POET) development, achieving radio frequency and microwave operation of both n-channel and p-channel transistors.

The POET process enables monolithic fabrication of gallium arsenide (GaAs) integrated circuits containing both electronic and optical elements on a single wafer. The technology was developed over the past 18 years by chief scientist Dr Geoff Taylor and his team. Potential high-speed and power-efficient applications include devices such as servers, tablet computers and smartphones. III-V semiconductor devices developed by ODIS include infrared sensor arrays and ultra-low-power random access memory.

OPEL says that, with the latest achievement, POET extends the capability of its monolithic platform to cover integration of a complete range of wavelength-division multiplexed (WDM)-capable optoelectronic devices and functions. This is in addition to complementary electronics based on n-channel and p-channel transistors as either field-effect transistors (FETs) or bipolar devices.

Specifically for this milestone, 3-inch POET wafers fabricated at BAE Systems in Nashua, NH, USA yielded submicron n-channel and micron-sized p-channel transistors operating at frequencies of 42GHz and 3GHz, respectively. These operating frequencies are expected to be improved even further in the short term to up to 300–350GHz for the n-channel device.

“Following the success of our vertical-cavity surface-emitting laser (VCSEL) milestone achieved recently [announced in December], this result further verifies POET’s electronic and optical monolithic compatibility, a key advantage of POET as a silicon CMOS replacement,” says OPEL’s executive director Peter Copetti. “Our on-chip optical generation and detection capability is unique in the semiconductor industry,” he claims.

Progress on Taylor’s work at the OPEL lab had been delayed by damage sustained to key equipment during a multi-day power outage caused by Tropical Storm Sandy in late October. However, the rebuild should be completed next week, and the firm expects the affected equipment to be recalibrated and operational again by the end of March. “Given the caliber of the POET team, we are confident that the lost time will be made up, so that it will not have a material impact on the milestone target dates,” Copetti says.

After completing a CDN\$7.2m private placement fundraising in mid-February to fund POET’s commercialization, about \$1.3m in new capital equipment was ordered to upgrade the R&D facility capabilities. OPEL has now completed all necessary site infrastructure upgrades and is awaiting arrival of the new equipment. The firm expects it to be installed, calibrated and commissioned by the end of June.

OPEL reckons that, by enabling increased speed, density, reliability, power efficiency and much lower bill-of-materials and assembly

These operating frequencies [42GHz and 3GHz] are expected to be improved even further in the short term to up to 300–350GHz for the n-channel device

costs, POET can allow continued advances in semiconductor device performance and capabilities for many years, overcoming the current power and speed bottlenecks of silicon-based circuits, and can change the future development roadmaps of applications including mobile devices, computer servers, storage arrays, imaging equipment, networking equipment, transportation systems, and test & measurement instruments.

www.odisinc.com

OPEL amends stock option plan

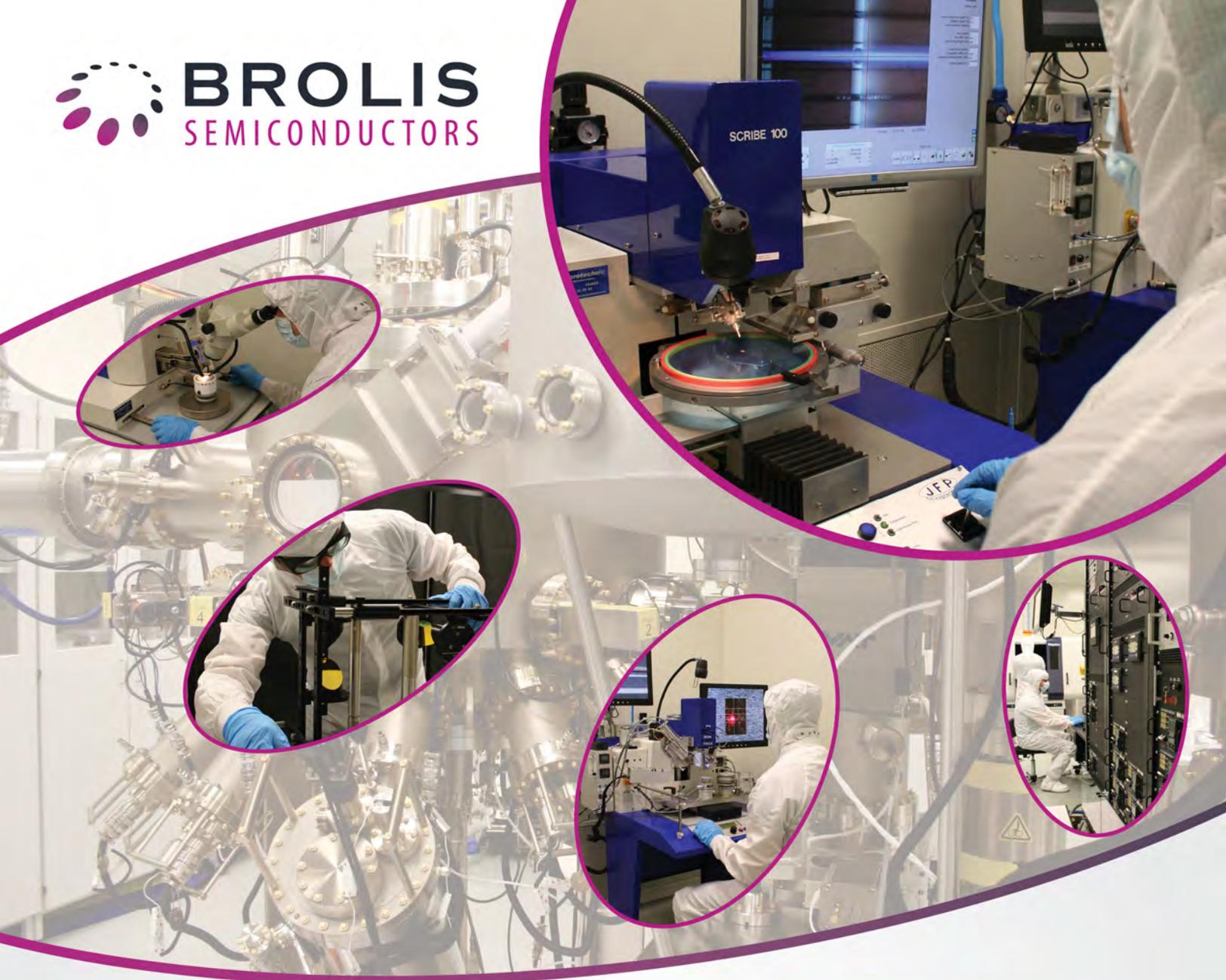
OPEL Technologies says that its board of directors has amended the firm’s stock option plan to increase the number of shares reserved for issuance under the plan from 18,472,000 to 26,475,000. The reserved number of 26,475,000 represents 20% of the issued and outstanding common

shares of the company.

The existing plan was approved by shareholder on 21 June 2011. Amendment is subject to approval by the TSX Venture Exchange (TSXV) and will be submitted for shareholders’ approval at OPEL’s upcoming annual general meeting (AGM) in June.

There are currently 17,399,000 options outstanding under the plan and 461,000 options available for future grants. With the increase in the reserved number, the firm will have 8,003,000 available options for future grants under the amended plan.

www.opeltechinc.com



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Imec offers fully integrated silicon photonics platform through ePIXfab multi-project wafer service

Components include low-loss waveguides, grating couplers, silicon electro-optic modulators and germanium waveguide photo-detectors

Nanoelectronics research center Imec of Leuven, Belgium has launched its fully integrated silicon photonics platform through a cost-sharing multi-project wafer (MPW) service via ePIXfab, the EU-funded silicon photonics foundry consortium coordinated by an Imec-UGent partnership and including members CEA-LETI (France), IHP (Germany) TNO (Netherlands), Tyndall (Ireland), VTT (Finland) and CMC Microsystems (Canada).

The platform aims to enable cost-effective R&D of silicon photonic ICs for high-performance optical transceivers (25Gb/s and beyond) and optical sensing and life-science applications. The integrated components that are offered include low-loss waveguides, efficient grating couplers, high-speed silicon electro-optic modulators and high-speed germanium waveguide photo-detectors.

Since 2007, Imec and its associated laboratory at Ghent University (UGent) have been offering a platform for passive silicon photonic components via ePIXfab for R&D under shared cost conditions. Now,

Imec is extending its silicon photonics offering, using a standard 130nm CMOS toolset, with active components such as high-speed optical modulators and integrated germanium photo-detectors.

"Imec's silicon photonics platform provides robust performance and solutions to integrated photonics products in medical diagnostics, telecom and datacom industries," says Philippe Absil, program director at Imec. "Companies can benefit from our silicon photonics capability through established standard cells, or explore the functionality of their own designs in MPW," he adds. "This Silicon Photonics MPW offer provides a cost-efficient solution, with state-of-the-art performance, design flexibility and superior CD and thickness control," Absil claims.

The first run opens for registration with tape-in on 9 October, and first devices will be out in May 2014. Support, registration and design kit access will be organized by the Europractice IC service, in collaboration with worldwide multi-project wafer partners.

Imec says that its silicon photonics 200mm wafer platform offers extensive design flexibility and includes:

- tight within-wafer silicon thickness variation $3\sigma < 2.5\text{nm}$;
- 3-level patterning of 220nm top silicon layer (193nm optical lithography);
- poly-silicon overlay and patterning (193nm optical lithography);
- 3-level n-type implants and 3-level p-type implants in silicon;
- Ge epitaxial growth on Si and p-type and n-type implants in germanium;
- local NiSi contacts, tungsten vias and copper (Cu) metal interconnects;
- aluminium (Al) bond pads;
- validated cell library with fiber couplers, polarization rotators, highly efficient carrier depletion modulators and ultra-compact Ge waveguide photo-detectors with low dark current; and
- design kit support for Ipkiss, Phoenix and Mentor Graphics software.

www.imec.be

www.epixfab.eu

Leti presents silicon photonic developments at OFC/NFOEC

At the Optical Fiber Communication Conference & Exposition/National Fiber Optic Engineers Conference (OFC/NFOEC 2013) in Anaheim, California, USA (17–21 March), micro/nanotechnology R&D center CEA-Leti of Grenoble, France presented its capabilities for silicon photonics components and device prototyping, and providing updates of its recent work on laser integration and packaging of silicon photonics dies, including fiber-to-die interconnects.

Leti is a founding member of the large Grenoble-based PLAT4M

(Photonic Libraries And Technology for Manufacturing) initiative to establish a technology platform specializing in silicon photonics.

To address all the key challenges of this field and to accelerate the technology's adoption in the telecoms and datacoms sectors, the initiative is focusing on:

- establishing prototyping and manufacturing capabilities on 200mm and 300mm wafers;
- designing and testing silicon photonic components and links;
- developing passive and active silicon photonic components

on silicon-on-insulator (SOI) substrates;

- exploring new solutions for integrated photo-detectors and integrated emitter technologies, including indium phosphide (InP) lasers and vertical-cavity surface-emitting lasers (VCSELs); and
- exploring packaging solutions for the integration of CMOS electronics with SOI photonic integrated circuits (PICs) and for the low-cost connection of dies to fibers.

www.leti.fr

www.ofcnfoec.org

Kotura establishes fabless semiconductor model and strengthens component supply chain

Japanese foundry to produce 100G Optical Engine, using Mindspeed's high-speed, low-power electronics and BinOptics' laser arrays

At the Optical Fiber Communication/National Fiber Optic Engineers Conference (OFC/NFOEC 2013) in Anaheim (17–21 March), Kotura Inc of Monterey Park, CA, USA, which designs and makes silicon photonics application-specific integrated circuits (ASICs) for the communications, computing, sensing and detection markets, announced an agreement with a large semiconductor foundry as well as relationships with strategic partners Mindspeed Technologies Inc of Newport Beach, CA, USA (which designs network infrastructure semiconductors for communications applications) and BinOptics Corp of Ithaca, NY, USA (which makes semiconductor lasers and monolithically integrated optoelectronic components). Kotura says the partnerships will provide it with an effective supply chain to commercialize its 100G Optical Engine — a key component in its industry-first 100Gb/s 4x25 WDM QSFP module (announced at OFC).

Kotura says that the addition of a large Japanese foundry complements its existing in-house fab. The firm will leverage the foundry partner's capabilities for high-volume production of its Optical Engine - a low-power, integrated 100Gb/s chip solution that supports the interconnect fabric for next-generation data-centers and high-performance computing. Kotura claims to be the only silicon photonics provider to offer both wavelength-division multiplexing (WDM) and a parallel version of its Optical Engine in a 3.5 watt QSFP package.

"Our silicon photonics solutions resolve price, performance and reliability issues not currently being addressed by existing approaches,"

reckons president & CEO Jean-Louis Malinge. "In a world full of applications with pressing bandwidth and performance needs, there is tremendous opportunity for silicon photonics to heed the call, starting with the data-center market as our primary target," he adds. "This foundry partnership offers Kotura the fastest and most reliable path to mass production and the ability to scale to meet this demand."

The partnership with Mindspeed enables Kotura to meet the low-power requirements of the QSFP package. "The market wants a QSFP package because of the small footprint," notes Marek Tlalka, Mindspeed's director of product marketing. "Integrating 25G quad drivers and TIAs can be quite a challenge," he adds. "By combining our high-speed, low-power electronics and Kotura's silicon photonics Optical Engine, we can meet the stringent power consumption constraints of a 100Gb/s WDM QSFP module."

Kotura partnered with BinOptics to develop laser arrays, which can be passively flip-chip bonded onto Kotura's Optical Engine, producing a high-volume, low-cost, electronics-style assembly.

"BinOptics' Etched Facet Technology allows III-V photonic device facets to be formed with lithographic precision, enabling low-cost passive alignment with silicon photonics," says BinOptics' CEO & co-founder Dr Alex Behfar. "Eliminating active alignment is one of the key ingredients for economical, large-scale roll-out of silicon photonics-based 100Gb/s solutions."

www.mindspeed.com

www.binoptics.com

www.kotura.com

IN BRIEF

Luxtera's silicon photonics technology used in multi-vendor OIF interoperability demonstration of 4x25G chip-to-module application

At the Optical Fiber Communication/National Fiber Optic Engineers Conference (OFC/NFOEC 2013) in Anaheim (19–21 March), fabless silicon CMOS photonics firm Luxtera of Carlsbad, CA, USA participated in the Optical Internetworking Forum's (OIF) multi-vendor 4 x 25G chip-to-module interoperability demonstration.

Luxtera's silicon CMOS photonics technology enables high-performance computing for applications such as optical networking, CPU interconnect, and data storage. For the demonstration, OIF leveraged Luxtera's technology to showcase how high-speed optical communication devices can be built into the most popular QSFP28 form factor using proven, low-cost silicon manufacturing technology.

"With over 500,000 chipsets sold, Luxtera's silicon CMOS photonics continues to scale to support the mainstream interconnect market by offering reliable, scalable, and cost-effective solutions that fit in the most desired form factor," said VP of marketing Chris Bergey. "QSFP is clearly the datacenter connector of choice for inter-datacenter connectivity as it offers the greatest pluggable module density possible in a 1U faceplate and will dominate the transition to 100G in datacenter switches, much as QSFP 40G is doing today."

www.luxtera.com

www.oiforum.com

Finisar's quarterly revenue down year-on-year, but profits and revenue up sequentially due to datacoms

Next-quarter to be flat-to-up, despite annual telecom price reductions

For its fiscal third-quarter 2013 (ended 27 January), fiber-optic communications component and subsystem maker Finisar Corp of Sunnyvale, CA, USA, has reported revenue of \$238.4m, a drop of almost 5% on fiscal Q3/2012's \$243m a year ago but up 2.7% on \$232m last quarter, driven primarily by growth in sales of 10G and 100G transceivers and transponders for datacom applications.

Sales of products for datacom applications increased by \$7.8m (5.6%) to \$147.7m. However, sales of products for telecom applications fell by \$1.5m (1.6%) to \$90.7m, due to the impact of about one month of the annual telecom price reductions that typically go into effect around 1 January, partially offsetting the rise in unit sales (including tunable XFP transceivers).

On a non-GAAP basis, gross margin has risen from 30.5% last quarter to 30.7%. Operating income rose by from \$15.8m (operating margin of 6.8% of revenue) last quarter to \$17.4m (operating margin of 7.3%) as the firm was able to hold its operating expenses relatively flat while revenue grew. Non-GAAP income was \$16.4m (\$0.17 per diluted share), up from \$14.2m (\$0.15 per diluted share) last quarter. EBITDA (earnings before interest, taxes, depreciation and amortization) rose from \$28.7m (12.4% of revenue) last quarter to \$31.1m (13.1% of revenue).

During the quarter, cash and cash equivalents rose from \$262.4m to \$265.5m. The firm also had about \$40m in principal amount of convertible notes outstanding with a conversion price of \$10.68 per share.

For fiscal fourth-quarter 2013, Finisar expects revenue of \$235–250m. Gross margin is expected to fall back slightly to about 30.5%. "This will be the result of three months of reduced

telecom prices," noted chairman of the board Jerry Rawls. "The higher revenues in the fourth quarter will partially mitigate the impact of the lower telecom prices." Likewise, operating margin should fall back slightly, to about 7%. Earnings per diluted share should be level at about \$0.15–0.19.

"During the third quarter, we continued to invest significantly in technology and product development and made substantial progress on a number of new products for our datacom and telecom products lines [especially in the high-bandwidth products for 40G and above]," said CEO Eitan Gertel during the firm's analysts' conference. "For the telecom market, we shipped a number of our new 100G coherent line-side transponders. All the customer feedback has been very positive, we continued to win new customers and are ramping our capacity to meet demand," he added.

"We continue to invest in the development of next-generation wavelength-selective switches that are smaller, lower power and higher performance," Gertel continued. "Finisar has the broadest offering of Flexgrid WSS product in the industry, which enables the service provider to deploy next-generation

Will we use silicon photonics in our products? The answer is maybe. We'll use whatever makes sense for our customers. So I don't think of silicon photonics as a threat. I just look at it is another technology we will likely eventually use in our product.

optical networks. We also continue to make good progress in our previously won ROADM line-cards project, as well as engaged in a number of new line-card opportunities."

Finisar had a major presence at the Optical Fiber Communication conference (OFC 2013) in Anaheim, CA, USA (17–21 March), at which the firm made several new product announcements.

During the analysts' conference Rawls was asked about the emerging and potentially competitive technology of silicon photonics and whether he thought there was a material meaningful difference between Finisar's monolithic circuitry technology and what silicon photonics could achieve in terms of the size, cost and power. "I don't think so much about technology as I think about products," he replied. "In the enterprise world, we've got them at speeds from 1-gigabit to 100-gigabits. We use indium phosphide, gallium arsenide, CMOS, silicon germanium — any technology that is available that provides the economics and the performance that satisfies our customers. All these technologies are available to us through foundries or through our own factories," Rawls stressed.

"With respect to silicon photonics, it is an interesting technology, but it is one that we haven't used so far in our products because it wasn't economical or it didn't provide competitive performance. In the future, will we use silicon photonics in our products? The answer is maybe. We'll use whatever makes sense for our customers. So I don't think of silicon photonics as a threat. I just look at it is another technology we will likely eventually use in our product."

www.finisar.com

Matthew Peach, Contributing Editor

3SPGroup and Finisar partner on new packaging platform for 980nm cooled pump laser modules

3SPGroup to supply laser chips; gains access to Finisar's expanded China packaging line

3SPGroup, which manufactures optical and optoelectronic components for telecom networks, and fiber-optic communications component and subsystem maker Finisar Corp of Sunnyvale, CA, USA have formally agreed to partner on the development of a new packaging platform for 980nm cooled laser pump modules.

3SPGroup will be the exclusive supplier of the 980nm laser chips used for the platform, and Finisar will implement a manufacturing line based on the platform in its newly expanded facilities in Wuxi, China. Finisar will use the 980nm pump modules in its erbium-doped fiber

amplifier (EDFA) and line-card products for the telecom market. 3SPGroup will use the packaging platform to serve its own customers.

The agreement will give 3SPGroup access to an alternative competitive packaging platform that will improve the fixed-cost absorption of its wafer fab, says 3SPGroup's CEO Alexandre Krivine. "We are proud to be selected as the sole supplier by Finisar for these high-power applications, which is recognition of the leading performance and reliability of our 980nm chips," he adds.

"This partnership provides Finisar

with strategic access to high-performance and highly reliable 980nm chips while leveraging our own expertise in high-volume, cost-effective manufacturing," says Finisar's CEO Eitan Gertel. "This combination allows us to quickly provide the products that our customers are demanding to support growing telecom networks."

The 980nm lasers supplied by 3SPGroup are already fully qualified with what is claimed to be outstanding field reliability. Availability of modules resulting from the new packaging platform is expected by mid-2013.

www.finisar.com

TowerJazz and Avago expand strategic collaboration

Avago's next-generation fiber-optics products to use TowerJazz's SiGe BiCMOS technology

Specialty foundry TowerJazz (which has fabrication plants at Tower Semiconductor Ltd in Migdal Haemek, Israel, and at its subsidiaries Jazz Semiconductor Inc in Newport Beach, CA, USA and TowerJazz Japan Ltd) and Avago Technologies, a supplier of analog, mixed-signal and optoelectronic interface components and subsystems for wireless, wireline and industrial applications, have expanded their strategic collaboration, focusing on Avago's next-generation products using TowerJazz's silicon germanium (SiGe) BiCMOS technology platform. Continued collaboration aims to enable Avago Fiber Optic Products Division (FOPD) to achieve the stringent technical specifications and meet cost and performance requirements for optical networking markets while helping TowerJazz to define and develop its next-generation process technologies.

The technology collaboration between TowerJazz and Avago FOPD has resulted in Avago's recent launch of the Gen4SR, a 10Gbps small-form-factor pluggable optical transceiver (SFP) for short-reach applications. By collaborating with TowerJazz, Avago has unlimited access to TowerJazz's optimized SiGe BiCMOS technology based on both the SBC18H2 process with transistor speeds of 200GHz and the H3 process with transistor speeds of 280GHz, together with mixed-signal CMOS.

"TowerJazz's advanced technology enables Avago Technologies to define and develop a plethora of new products, increasing our market

share with existing and new customers," says Dr Faouzi Chaahoub, senior director of R&D, IC Engineering, at Avago FOPD. "Avago's 10Gbps SFP+ chipset is the first product released deploying TowerJazz's technology. Our collaboration with TowerJazz using their high-performance SiGe BiCMOS will enable us to develop the highest-performance and the lowest-power ICs for Avago's next-generation optical transceivers beyond 10Gbps," he adds.

"Our high-performance SiGe is uniquely positioned in the fiber-optic space, where we offer customers the highest-speed, lowest-power-consumption and lowest-noise SiGe transistors integrated in analog-friendly 0.18µm and 0.13µm nodes," claims Marco Racanelli, senior VP & general manager of TowerJazz's RF/High Performance Analog business unit.

www.towerjazz.com

OneChip forms foundry relationships with IQE and GCS 4" InP wafer processing services to enable high-volume production of PICs for data-center interconnect and passive optical network markets

OneChip Photonics Inc of Ottawa, Canada, which designs optical chips and transceivers based on monolithic photonic integrated circuits (PICs) fabricated in indium phosphide (InP), says that it is working with both epiwafer foundry IQE plc of Cardiff, Wales, UK (to grow epitaxial structures) and with pure-play compound semiconductor wafer foundry Global Communication Semiconductors LLC (GCS) of Torrance, CA, USA (to provide a complete range of InP wafer processing services), enabling the production of OneChip's PICs for the data-center interconnect (DCI) and passive optical network (PON) markets.

OneChip says that its unique, regrowth-free Multi-Guide Vertical Integration (MGVI) platform eliminates the need for multiple epitaxial growth steps, enabling it to decouple epitaxial growth and wafer processing while outsourcing both functions to independent, pure-play commercial foundries.

Under this fabless model, OneChip has been working with IQE for the production of its 4-inch InP-based epiwafers, leveraging the infrastructure and expertise that IQE has gained over 25 years in supporting the semiconductor industry with its outsourcing model. OneChip has also been working with GCS to process its OneChip-designed 4-inch InP-based wafers, leveraging the infrastructure and expertise that GCS has gained through serving high-volume RF electronics markets.

"The iron-doped, semi-insulating 4-inch InP substrates, and the metal-organic chemical vapor deposition (MOCVD) growth technique, required for OneChip's epiwafers, are the same as those used by IQE for its high-volume epitaxy products, so we have strong economies of scale in working together," says OneChip's founder & chief technol-

ogy officer Valery Tolstikhin. As an independent, pure-play epiwafer foundry, IQE fits into OneChip's fabless PIC manufacturing model, he adds.

"OneChip has developed some exciting new integrated photonics products for the high-volume but cost-sensitive, optical communications markets," says IQE's president & CEO Drew Nelson.

"OneChip's use of the fabless manufacturing approach further endorses IQE's outsourcing business model in the field of photonic devices, and we look forward to helping OneChip continue to scale its business as it extends its unique PIC technology to new markets," he adds.

OneChip says that GCS' foundry services, based on its opto and heterojunction bipolar transistor (HBT) processes in InP, are a match for OneChip's fabless model. Further, GCS' opto and HBT and OneChip's PIC technologies share the same process and provide a unique opto-electronic

Working with GCS gives us the commercial, high-volume processing capability we need to meet the strict cost requirements of the data-center interconnect and passive optical network markets

GCS' foundry services, based on its opto and HBT processes in InP, are a match for OneChip's fabless model... GCS' opto and HBT and OneChip's PIC technologies share the same process and provide a unique OEIC platform

integrated circuit (OEIC) platform, enabling — for the first time, it is claimed — both electronic and photonic integration on one substrate, within the same commercially available fabrication process.

GCS offers InP and high-volume RF electronics processing technologies, notes Tolstikhin. "Working with GCS gives us the commercial, high-volume processing capability we need to meet the strict cost requirements of the DCI and PON markets," he adds.

"Our InP-based opto and RFIC process technologies have great synergies with OneChip's PIC technology," reckons GCS' CEO Brian Ann. "We believe OneChip is a company that can create a truly volume business for photonics in the DCI market, with the unique ability to combine PICs and electronics to create the first opto-electronic circuits in InP."

OneChip says that its regrowth-free, PIC-based InP technology has proven successful in the cost-sensitive, high-volume PON market, as its PIC-based PON transceivers and bi-directional optical sub-assemblies (BOSAs) are already being deployed by the world's largest PON system providers.

Now, OneChip is extending this technology to the high-volume DCI market, which requires 100Gbps+ solutions with higher interface density and longer reach than those within the reach of currently deployed systems in 0.85µm and multi-mode fibers. The DCI market also requires lower cost and power consumption than the solutions offered by the traditional telecom component vendors. Simultaneously with the foundry announcements, OneChip also launched a new family of PIC-based 100Gbps optical interconnect solutions.

www.iqep.com

www.gcsincorp.com

www.onechipphotonics.com

Emcore starts volume production of micro-ITLA tunable laser for 40/100/400G coherent applications

Emcore Corp of Albuquerque, NM, USA, which makes components, subsystems and systems for the fiber-optic and solar power markets, recently started volume production of its micro-ITLA (micro-integrable tunable laser assembly) and is ramping output to meet demand.

Since Emcore began sampling customers with the product in 2012, the micro-ITLA has already been designed into several key customer platforms and is currently operating in multiple field trials. To date, more than 400 samples have been shipped.

"By leveraging our leading-edge ITLA technology and in-house semiconductor design and manufacturing expertise, the micro-ITLA provides customers with a highly differentiated tunable laser solution for demanding high-performance telecom applications," says chief operating officer Christopher Larocca.

The micro-ITLA is based on Emcore's Clearlight external-cavity laser (ECL) technology. The firm reckons that — due to its ultra-narrow linewidth, low noise and frequency accuracy — its ECL is the most widely deployed tunable laser source for high-speed 40 and 100Gb/s coherent systems. The micro-ITLA integrates the proprietary ECL technology into a form-factor that is three times smaller and consumes over 1 watt less power than previous-generation ITLAs. It allows tuning to any grid and frequency and has a 15dBm high-output power option, plus advanced features including in-operation frequency fine tune of ± 6 GHz, and in-operation power adjust of 6dB. The micro-ITLA is fully compliant with the OIF (Optical Internetworking Forum) Implementation Agreement (IA) and allows full control and monitoring.

"The smaller form-factor and reduced power consumption enables our customers to design higher densities, at lower cost with improved performance into their 40, 100 and 400 gigabit coherent systems," says VP of business development Jaime Reloj.

The micro-ITLA is fully C-band tunable, and Emcore plans to make available L-band tunability in the same form-factor later in 2013. Other features such as ultra-low power dissipation options and ultra-high output power will become available in the same time frame.

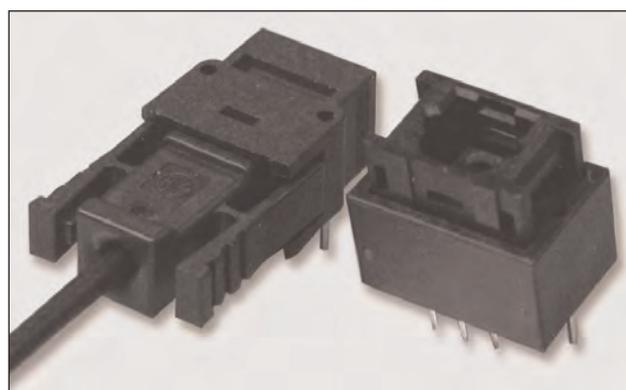
At the Optical Fiber Communications conference & exhibition (OFC 2013) in Anaheim (19–21 March), Emcore hosted a live demonstration of its micro-ITLA for 40/100/400 Gigabit coherent applications, highlighting the flexibility of its tuning capability (to any grid and frequency at different power output levels).

www.emcore.com

Toshiba launches low-current-consumption fiber-optic transmission modules for energy-sensitive applications

Tokyo-based Toshiba Corp has launched the latest addition to its TOSLINK fiber-optic transmission device line-up: fiber optic transmission modules that can send and receive signals from DC to 500kb/s with low current consumption up to a maximum distance of 10m when using APF (all plastic fiber).

A newly developed high-luminosity LED allows the new products to be driven at a lower current (1.5mA) than the existing products. Also, while existing products consume the same current regardless of whether the module is engaged in optical communication or not, the new products has a circuit configuration that drastically reduces current consumption (to 30%[?]) at times of no communication, suiting energy-sensitive appli-



Toshiba TOSLINK fiber-optic transmission module.

cations. The power supply voltage is 5 ± 0.25 V.

The new products will be available in two package types: samples of the horizontal-type transmitting and receiving modules TOTX1353(F) and TORX1353(F) will be available by the end of

March, with mass production in April; samples of the vertical-type transmitting and receiving modules TOTX1353(V,F) and TORX1353(V,F) will be available by the end of April, with mass production in May. The devices are compatible with JIS F05 optical connectors. Operating temperatures span -40°C to 85°C .

Applications include the transmission of control signals in, for example, wind and photovoltaic power generation systems, control devices, amusement machines, and battery controllers.

www.semicon.toshiba.co.jp

Alta's new dual-junction cell sets 30.8% efficiency record InGaP absorber layer added to base GaAs single-junction cell

Alta Devices of Sunnyvale, CA, USA says that the first implementation of its new-generation dual-junction solar cell technology (augmenting its single-junction technology) has set an energy conversion efficiency record of 30.8% for dual-junction solar cells, as verified by the US National Renewable Energy Laboratory (NREL).

The firm already holds efficiency records for single-junction solar cells (28.8%) and single-junction solar modules (24.1%). All records are under one sun and validated by NREL. Alta is currently shipping its single-junction technology.

Alta says that its new dual-junction technology builds on its basic gallium arsenide (GaAs) single-junction solar technology, but implements a second junction (or layer) with indium gallium phosphide (InGaP) as the absorber on

top of the base cell. Because InGaP uses high-energy photons more efficiently, the new dual-junction cell generates more electricity from the same amount of light than a single-junction device.

Higher efficiency directly translates into more electricity generated from smaller surface areas, says Alta. So, applying its highly efficient, thin and flexible mobile power technology to consumer devices can extend the battery life of products such as smartphones, tablets, keyboards, mice, and remote controls, the firm adds.

"With our technology, enough energy can be generated from sunlight to effectively power devices in ways not previously possible," claims president & CEO Chris Norris. "We are working with a number of customers who are designing their mobile products to increase

battery life; and in some cases, we can provide enough energy to eliminate the need to plug into the electric grid."

To help device manufacturers understand the benefits of using its material on their products, Alta has created a calculator to compute the battery life extension for a variety of consumer mobile devices.

According to the calculator, a typical outdoor worker could realize 80% more battery life each day for their mobile phone. Or a student could get over 60% more battery life for their tablet device. These results can be achieved with minimal weight or form-factor penalty on the device design, the firm adds.

The new dual-junction record of 30.8% is an important step towards Alta's target of 38%-efficient cells, notes Norris.

www.altadevices.com/calculator.php

Soitec and Medina College sign cooperative agreement for CPV technology in Saudi Arabia

In February, Soitec of Bernin, France signed a cooperative agreement with Medina College of Technology (MCT) — part of the Saudi Arabian Technical and Vocational Training Corporation (TVTC) — in the presence of TVTC's vice governor Dr Hamad bin Oglia Alogla. The three-year agreement aims to foster applied research in concentrating photovoltaic (CPV) technology in Saudi Arabia while implementing a joint training program on CPV within the TVTC and MCT curricula.

Soitec has installed a CPV demonstration system on MCT's campus to serve as a platform for applied research projects concerning solar energy in the Middle East and CPV performance in sunny, hot and arid conditions. The agreement focuses on knowledge transfer and will enhance the capabilities of Saudi trainers and trainees from MCT. Soitec will provide opportunities for

MCT students to acquire skills on installing, operating, monitoring and maintaining CPV systems.

To initiate the partnership, 10 professors and students from Saudi Arabia will participate in a dedicated training program organized by Soitec at its facility in Freiburg, Germany. Soitec will also help to co-design TVTC's solar industry curriculum, which aims to better prepare MCT students and Saudi nationals to service the burgeoning Saudi solar utility market.

"Our government estimates that demand for electricity in Saudi Arabia should exceed 120GW in 20 years," says Dr Hamad bin Oglia Alogla. "To meet these growing needs, the Kingdom intends to introduce a significant amount of alternative sources in its energy mix," he adds. "With this agreement, we ensure that our students will acquire the most advanced knowledge and

skills regarding solar energy and CPV technology, which they will need when entering their professional lives."

According to K.A. CARE (the institution established by Saudi Arabia's King Abdullah to implement the national renewable energy policy), solar energy will reach 41GW of installed capacity by 2032. "CPV technology is perfectly suited for countries that benefit from year-long high solar irradiation, such as Saudi Arabia," says Gaetan Borgers, executive VP of Soitec's Solar Division. "Thanks to this cooperation with the Medina College of Technology, we will be able to further test and demonstrate our technology's competitiveness under desert conditions while supporting its deployment," he adds. "This agreement also reflects our strong commitment to the Kingdom's educational sector."

www.soitec.com

First Solar becomes Dii shareholder CdTe firm extends commitment to desert power

First Solar Inc of Tempe, AZ, USA — which makes thin-film photovoltaic (PV) modules based on cadmium telluride (CdTe) as well as providing engineering, procurement & construction (EPC) services — has joined Munich-based Dii GmbH as a new shareholder. The firm was previously an associated partner of the Desertec Industrial Initiative since March 2010.

Initiated in 2009 by non-profit-organization Desertec Foundation and reinsurance company Munich Re (together with other founding members ABB, energy groups E.ON and RWE, Deutsche Bank, HSH Nordbank, M+W Zander, MAN Solar Millenium, SCHOTT Solar, SIEMENS, Spain's ABENGOA Solar and Algeria's Cevital industrial group), with partner companies from 17 countries DII aims to create an industrial-scale market by 2050 for renewable energies from the desert regions of North Africa and the Middle East (MENA). Activities include the development of integ-

rated energy markets and the identification of suitable technologies for generating and transmitting energy.

"Our extended dedication to Dii as a shareholder emphasizes First Solar's commitment to the MENA region, where we see tremendous potential to build a sustainable market for solar power," says Christopher Burghardt, First Solar's VP of business development for Europe, the Middle East and Africa. "Dii is the ideal industrial initiative to bring power from the deserts into reality," he adds.

"With the largest solar project pipeline of nearly 3 gigawatt contracted worldwide, First Solar has an extraordinary know how for the implementation of the Desertec vision in the MENA region," comments Dii's CEO Paul van Son. "This fits very well with the rapidly increasing interest of countries in MENA to expand renewable energy capacity and grid infrastructure connecting the emerging MENA market to Europe."

First Solar says it is pursuing a wide range of opportunities to support the MENA region's efforts to cultivate its solar resources. The firm recently established an office in Dubai and is in an advanced stage of opening an office in Saudi Arabia. First Solar is constructing a 13MW solar PV power plant for Dubai Electricity & Water Authority (DEWA) in Seih Al Dahal, about 50km south of Dubai. This is the first phase of the Mohammad Bin Rashid Al Maktoum Solar Park, an AED12bn project that is expected to eventually cover 48 square kilometers and produce 1000MW of energy for the UAE's national grid using both PV and solar thermal technology. First Solar has also constructed a 5MW system for the Masdar Abu Dhabi Future Energy Company and donated a complete 3.2kWp system to the King Abdullah University of Science and Technology (KAUST) New Energy Oasis (NEO) program in Saudi Arabia.

www.dii-eumena.com

First Solar donates thin-film PV modules to Inner Mongolia University of Technology Students for 2013 Solar Decathlon China

First Solar says a team of students from Inner Mongolia University of Technology (IMUT) will use its CdTe thin-film photovoltaic modules to power a house in the 2013 Solar Decathlon China competition. The team consists of 21 graduate and undergraduate students from various majors, including energy and power engineering, architecture, civil engineering and management.

Originally developed by the US Department of Energy in 2002, the Solar Decathlon is a biennial competition that challenges students to use a holistic approach to design and engineer houses with net-zero energy consumption. The competition helps demonstrate that solar-powered homes are fully functional and sustainable, while

promoting innovation and adoption of solar energy technologies.

First Solar donated 150 of its PV modules (with a peak generating capacity of 13kW) to IMUT's 'Team Green Sun' and will provide technical support for the project team, as well as collaborating with IMUT on solar education. This is the third time First Solar has supported the Solar Decathlon competitions.

Team Green Sun's house design for the 2013 Solar Decathlon China is based on the yurt, a tent-like habitat indigenous to Inner Mongolia and other parts of Central Asia. The project aims to address energy issues common in the region, including power grid inaccessibility, water shortages and high heating demands.

"China represents a very important market for First Solar," says

Bruce Yung, First Solar's managing director & VP of business development for China. "The fact that this year's Solar Decathlon is being held here is reflective of the government's commitment to developing the solar industry to meet interlinking economic, energy and environmental goals."

This year is the first time China has hosted the Solar Decathlon competition. It features 22 teams from around the world, with 13 teams from China. The 2013 Solar Decathlon China is the result of an agreement between China's National Energy Administration and the US Department of Energy to encourage energy collaboration between the two countries.

www.sdimut.com

www.firstsolar.com

Magnolia demonstrates 13%-efficient flexible CIGS cell Firm targets further improvements to nanostructured AR coatings

Magnolia Solar Corp of Woburn, MA and Albany, NY, USA says that its subsidiary Magnolia Solar Inc has demonstrated a flexible copper indium gallium diselenide (CIGS) solar cell with an energy conversion efficiency of 13%, rivaling the average efficiency of current PV technologies and showing that flexible thin-film cells are viable for various energy needs, reckons the firm.

The flexible CIGS solar cell, made using thin stainless-steel and titanium substrates, was developed and produced by the US Photovoltaic Manufacturing Consortium (PVMC) on behalf of Magnolia Solar at the State University of New York (SUNY) College of Nanoscale Science and Engineering's (CNSE) Solar Energy Development Center (SEDC) in Halfmoon, NY, USA (which provides a prototyping and demonstration line for next-generation CIGS thin-film solar cells). Headed by CNSE and SEMATECH in Albany, NY, as part of the Department of Energy's

SunShot Photovoltaic Manufacturing Initiative (PVMi), PVMC is an industry-led consortium for cooperative R&D among industry, university and government partners to accelerate the development, commercialization, and manufacturing of next-generation solar systems, acting as a proving ground for innovative solar technologies and manufacturing processes.

The flexible solar cell demonstration is a result of continuing collaborative research between Magnolia Solar, CNSE and PVMC, and is supported by the New York State Energy Research and Development Authority (NYSERDA). To increase the adoption of clean energy, Magnolia Solar intends to continue to work with CNSE to further develop high-efficiency flexible solar cells for defense and commercial applications, making use of their advantages over inflexible solar cells (made using crystalline silicon and thin-film solar cells on glass).

"We are working with the College of Nanoscale Science and Engineering through our R&D center located at CNSE's Albany NanoTech Complex to further improve the PV production process and demonstrate AR [anti-reflection] coating technology on high-efficiency solar cells," says Magnolia Solar Corp's president & CEO Dr Ashok K. Sood. "We are also grateful for NYSERDA's support and for our collaboration with CNSE and the PVMC," he adds.

Magnolia says that it has filed multiple patents to protect its intellectual property, and continues to add to its patent portfolio. The firm is also making progress with further improvements to the CIGS solar cells and nanostructured anti-reflection coating technology (which uses oblique-angle nanostructure growth, enhancing energy absorption and minimizing reflection loss).

www.MagnoliaSolar.com

MiaSolé and KSK commission 11.6MW project in India

Copper indium gallium diselenide (CIGS) thin-film solar panel maker MiaSolé of Santa Clara, CA, USA and power development and generation firm KSK Energy Ventures of India have announced the commissioning of an 11.6MW solar photovoltaic project on 26 February.

The project is under India's Jawaharlal Nehru National Solar Mission and is one of the largest solar power plants in Rajasthan, says MiaSolé. US Export-Import Bank will provide \$9m of debt financing for the project (marking the second MiaSolé project in India that the US Export-Import Bank has supported).

This solar plant is the first large solar project to be taken up by KSK and is adjacent to its 135MW lignite-based power plant and lignite mines at Gurha (v), Bikaner district in Rajasthan. The firm plans to put up 100MW of solar in the next year.

MiaSolé says that the KSK project highlights its ability to scale solar technology at a price that is attractive for both solar developers and utilities. Over the past year, MiaSolé has completed projects in Rajasthan, Gujarat, Maharashtra and Tamil Nadu, making MiaSolé one of India's leading providers of solar energy.

"MiaSolé CIGS solar panels have proven to deliver the best solution for our project and are a compelling solution for the India market," comments KSK director Anil Kumar Kutty.

"This project financing facilitates exports from MiaSolé's California manufacturing center, will boost California's economy and help to create hundreds of local jobs," said US Export-Import Bank chairman Hochberg. MiaSolé has about 200 staff. In 2013, it plans to hire more than 200 extra staff in California to

expand its manufacturing, R&D and commercial activities.

"In 2013, we will expand our global footprint and our business model to invest in projects, acquire project pipeline and partner with leading developers and EPC companies in sustainable markets like India," said MiaSolé's CEO John Carrington. "Ex-Im Bank's support of MiaSolé's technology lowers the cost of project financing, and will expand the deployment of our California-made solar modules in projects globally," he adds.

MiaSolé panels have been used in a variety of projects globally, from large-scale utility scale projects to commercial and residential rooftops. MiaSolé is also developing a flexible solar solution, and last year announced a new flexible solar PV efficiency record of 15.5%.

www.MiaSole.com

US Photovoltaic Manufacturing Consortium and NREL team up to develop thin-film PV cells and modules

Joint effort to enhance CIGS PV manufacturing

The US Photovoltaic Manufacturing Consortium (PVMC), an industry-led collaboration headquartered at the State University of New York (SUNY) College of Nanoscale Science and Engineering (CNSE), has partnered with the US Department of Energy's National Renewable Energy Laboratory (NREL) to improve manufacturing processes for thin-film copper indium gallium diselenide (CIGS) photovoltaic (PV) cells and modules, including products, metrology and reliability that will support the US solar industry in the development, manufacturing and commercialization of next-generation solar PV systems.

"Through this initiative, we look forward to enhancing the manufacturability of thin-film solar PV technologies, which is critical to enabling increased usage in residential, commercial and utility applications across the country," says Dr Pradeep Halder, PVMC chief operating and technology officer and CNSE's VP of Clean Energy Programs.

"This unique partnership between NREL and PVMC will leverage national resources, accelerate commercialization of next-generation solar products, and boost interactions between US research labs and industry manufacturing initiatives," says Joe Hudgins, PVMC's senior VP of business development and strategic alliances. "Together we are leading the national effort to help facilitate the transfer and commercialization of future solar products, equipment and manufacturing lines including thin-film, advanced silicon, and future materials," he adds.

NREL has established processes, measurement and characterization capabilities, and expertise in all the major PV conversion technologies. PVMC will join NREL to support US solar manufacturing by leveraging

decades of knowledge and capabilities in materials and cell processing, advanced testing, metrology and materials analysis, and modeling. These interactions aim to accelerate PVMC program deliverables and help to overcome the gaps and challenges necessary to build a strong US solar industry.

Additionally, the NREL and PVMC collaboration will be expanded to other national labs to create a greater impact on the US PV manufacturing industry. These national partnerships aim to replicate the SEMATECH and CNSE models that have regained and sustained US technology leadership in the semiconductor industry.

Spearheaded by CNSE and SEMATECH as part of the US Department of Energy's (DOE) SunShot Initiative, PVMC is targeting a reduction in the total installed cost of solar energy systems by 75% over the next decade. As an active participant in PVMC's US Thin-Films PV Roadmap, NREL is working with other roadmap members to provide a congruent plan for the national CIGS industry, including module and systems manufacturers, suppliers and end-users, that will identify common challenges and define the areas of technical developments needed to sustain and advance a competitive US photovoltaic industry.

Several initiatives are currently underway to enhance product and manufacturing development, some of which are likely to become industry standards in the future, it is reckoned. In February, SEMI and PVMC signed a memorandum of understanding (MOU) to enhance their cooperation in areas of standards and roadmap activities for the solar thin film industry.

www.uspvmc.org
www.nrel.gov

IN BRIEF

Ascent launches EnerPlex solar charger for Samsung Galaxy S III

Ascent Solar Technologies Inc of Thornton, CO, USA, which makes lightweight thin-film photovoltaic modules based on copper indium gallium diselenide (CIGS) using flexible substrate materials, has announced the retail debut of its EnerPlex solar-assisted battery case for the Samsung Galaxy S III (now available for sale at www.goenerplex.com).

The EnerPlex Surfr for Galaxy S III takes advantage of Ascent's ultra-light, thin and flexible CIGS-based solar panels and enables Galaxy users to charge their smartphones with sunlight, in addition to conventional charging methods, to extend the usage time, says the firm.

"We were pleased and excited by the response the Surfr for the S III garnered at CES 2013 [January's International Consumer Electronics Show in Las Vegas]," says Ascent Solar's president & CEO Victor Lee. "The interest and accolades received continue to affirm the Surfr's position as the premium solar & battery case available on the market," he claims.

The Surfr was displayed at CES along with other new products from the firm.



Galaxy S III with EnerPlex Surfr.

www.EnerPlex.biz
www.AscentSolar.com

Moving forward from 44% to 50% conversion for III-V solar cells

Simulations propose structures that could reach even higher performance for multi-junction devices. **Mike Cooke** reports.

In the past year, researchers have reported record-breaking multi-junction solar cells with conversion efficiencies of up to 44%, and scientists are now looking at overcoming the next performance barrier of 50%.

Multi-junction solar cells work by stacking subcells sensitive to radiation of different wavelengths, with the regions responsive to shorter wavelengths at the top and those responsive to longer wavelengths at the bottom. This means that wider-bandgap materials are used for the top layers, since they absorb short wavelengths, allowing the longer-wavelength radiation to penetrate deeper into the device where it can be converted to electrical energy.

In a theoretical device with an infinite number of varying-bandgap layers, a maximum power conversion efficiency of nearly 87% has been calculated. To approach this sort of performance in reality will require development of materials with high crystalline quality with low numbers of defects. The highest-performing multi-junction cells presently use III-V compound semiconductors with direct bandgaps. Although lower-cost solar cells are generally made from silicon, that material has an indirect bandgap, which means that a larger amount of energy is lost in the initial conversion process, before any other losses come into play.

Here, we survey some of the achievements and

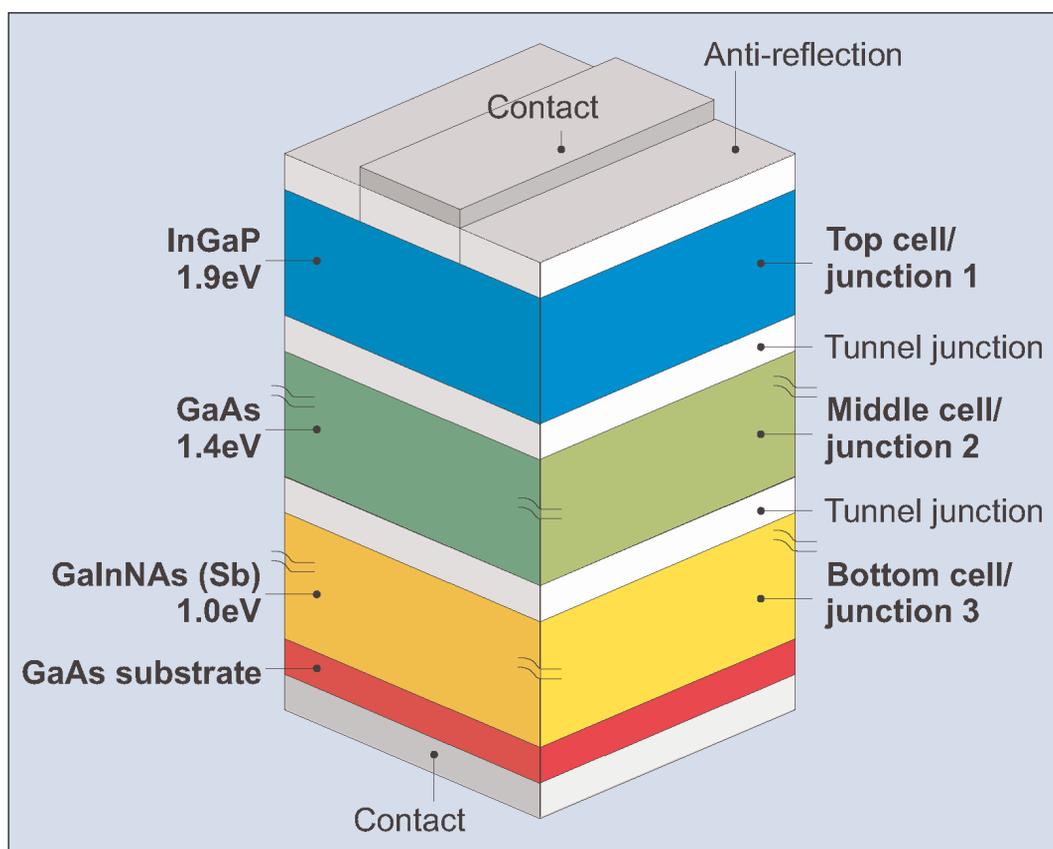


Figure 1. Schematic of Solar Junction/NREL SJ3 multi-junction cell.

prospects for high-performance solar cells based on multi-junction technology.

Concentrating on efficiency

The highest-performing devices generally achieve their peak performance under multiple-sun illumination, a technique known as concentrated photovoltaics (CPV) where optical systems are used to focus light on a small device. This is attractive since it reduces the amount of expensive III-V semiconductor material needed for PV systems.

In October 2012, Solar Junction reported 3-junction solar cells with 44% conversion efficiency under 947-

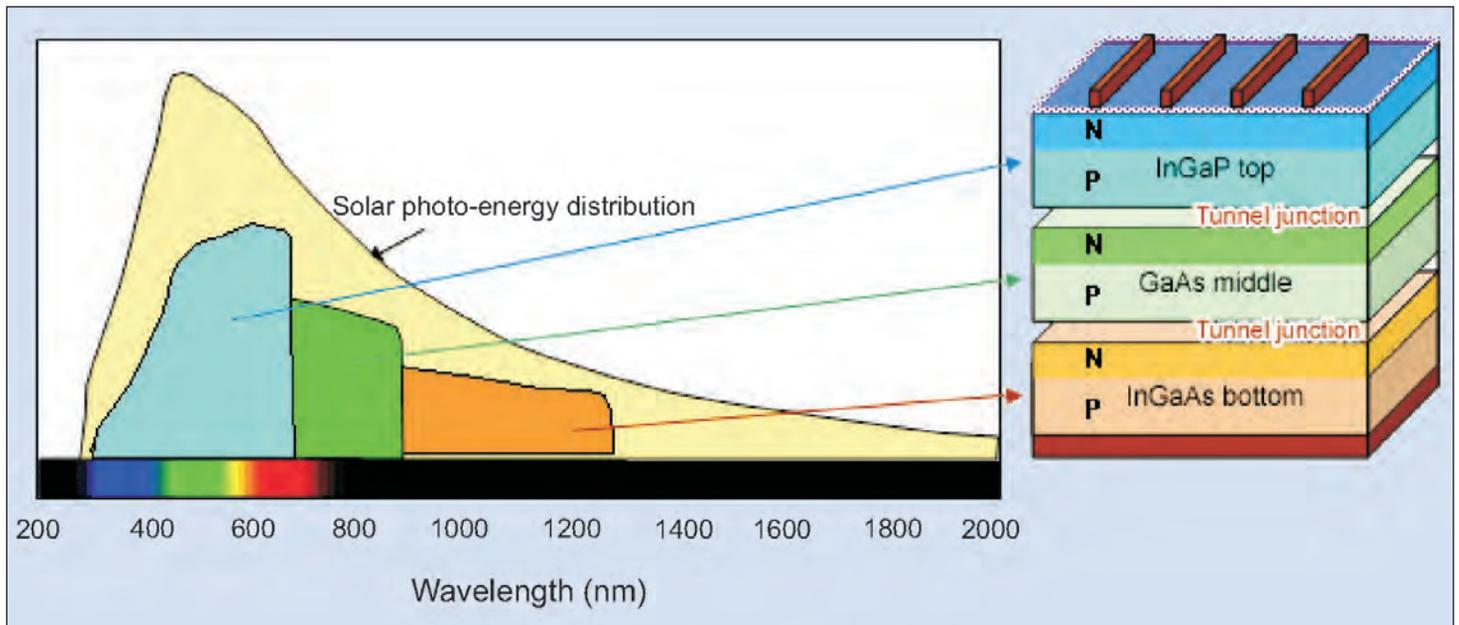


Figure 2. Wavelength distribution of solar photo-energy and wavelength sensitivity of Sharp's triple-junction solar cell.

sun illumination, beating its previous April 2011 record of 43.5% under 418 suns. The records were verified by US National Renewable Energy Laboratory (NREL). The company's founders developed their technology at Stanford University. Also, the firm partners with NREL in its research.

Solar Junction uses molecular beam epitaxy (MBE) to grow its epitaxial material with a proprietary Adjustable Spectrum Lattice Matched (A-SLAM) multi-junction solar cell architecture that provides bandgap tunability over the target range 0.8–1.42eV. The new devices extend the bandgap range to 1.9eV using indium gallium phosphide (InGaP) as the top layer (Figure 1).

The 'dilute-nitride' bottom cell of antimony-doped gallium indium nitride arsenide (GaInNAs(Sb)) is described as the 'heart' of the solar cell design. The bottom layer is important since the quality of upper layers depends on that of those below them.

Solar Junction/NREL has also worked on ultra-concentration tunnel junctions between the subcells. The team looks to four-junction devices as the route to 50% conversion efficiency and beyond.

Sharp in Japan has claimed a record for 1-sun 3-junction solar cells that achieved 37.7% conversion efficiency in December 2012. The firm has also matched Solar Junction's 43.5% with 360-sun illumination. The records were verified at Japan's National Institute of Advanced Industrial Science and Technology (AIST). In the Sharp device, the top cell consisted of InGaP, the middle cell is GaAs and the bottom cell is InGaAs (Figure 2). Again, the electrical connections between cells were through tunnel junctions. The Japanese company is aiming at CPV, as well as space satellite and vehicle applications.

Preparing the way for 50%

One US team looking to 50% multi-junction solar cells is based at California Institute of Technology, US National Institute of Standards and Technology, University of Maryland, and Boeing-Spectrolab Inc [Marina S. Leite et al, *Appl. Phys. Lett.*, vol102, p033901, 2013]

Based on simulations, the researchers propose a structure that could deliver efficiencies greater than 50% with concentrated illumination of 100 suns. The best device would require a lattice-matched structure with a lattice constant of 5.807Å (Figure 3). The layer structure would need a top layer of indium aluminium arsenide (1.93eV bandgap, $\text{In}_{0.37}\text{Al}_{0.63}\text{As}$), a middle layer of indium gallium arsenide phosphide (1.39eV, $\text{In}_{0.38}\text{Ga}_{0.62}\text{As}_{0.57}\text{P}_{0.43}$), and a bottom layer of indium gallium arsenide (0.94eV, $\text{In}_{0.38}\text{Ga}_{0.62}\text{As}$).

The researchers believe that templates with a 5.807Å lattice constant could be produced using strain engineering of single-crystalline layers combined with epitaxial lift-off. The lift-off of the template layer from the bulk substrate would allow it to be reused, reducing cost.

The researchers tested their ideas by producing solar subcells from lattice-matched layers of $\text{In}_{0.52}\text{Al}_{0.48}\text{As}/\text{In}_{0.52}\text{Ga}_{0.47}\text{As}_{0.42}\text{P}_{0.58}/\text{In}_{0.53}\text{Ga}_{0.47}\text{As}$ (1.47eV/1.06eV/0.74eV) on 50mm p-type indium phosphide (InP) substrates using metal-organic vapor phase epitaxy (MOVPE). The subcells were designed to match currents at 12.0mA/cm² density, maximizing power output. Current matching between subcells is a key requirement for achieving maximum performance. Since electric charge is conserved through a solar cell device, it is impossible for subcells to deliver different currents. ▶

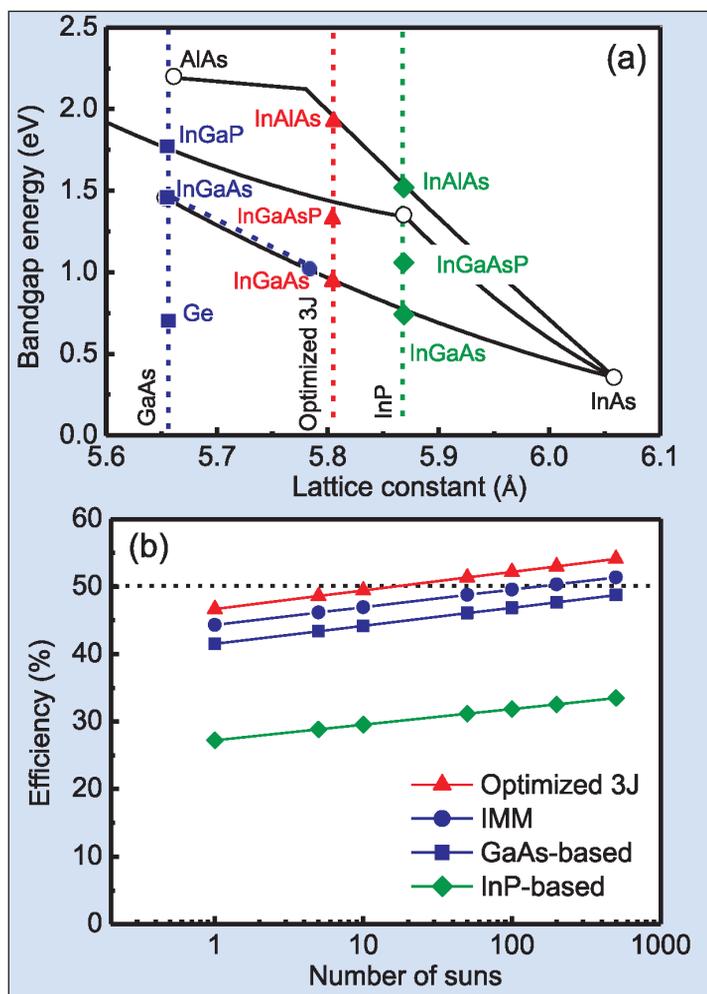


Figure 3. (a) Energy bandgap diagram as a function of lattice spacing for selected III-V compound semiconductor materials. (b) Efficiency as a function of number of suns (light intensity) obtained by detailed-balance calculation for four different triple-junction designs shown in (a), including a recent inverted metamorphic multi-junction (IMM) proposal. The optimized 3-junction design of CalTech, NIST, University of Maryland, and Boeing-Spectrolab (red triangles) can ideally achieve more than 50% in efficiency under 30-suns illumination.

► The subcells were connected in a six-terminal series configuration. A 3-junction device was mimicked by using optical splitting with 850nm and 1200nm long-pass filters to subject the middle and bottom subcells to the spectrum that would remain after passing through upper layers.

The open-circuit voltage of the assembly was 1.8V. This compares with a value from the model of 2.1V. The closed-circuit current was also lower than the design at 10.3mA/cm², due to “resistance and possible leakage current within the electrical contacts between the subcells”. The maximum external quantum efficiency (EQE) of all the cells was around 80%.

A true 3-junction (3J) cell was produced (Figure 4). However, the device was sub-optimal in omitting

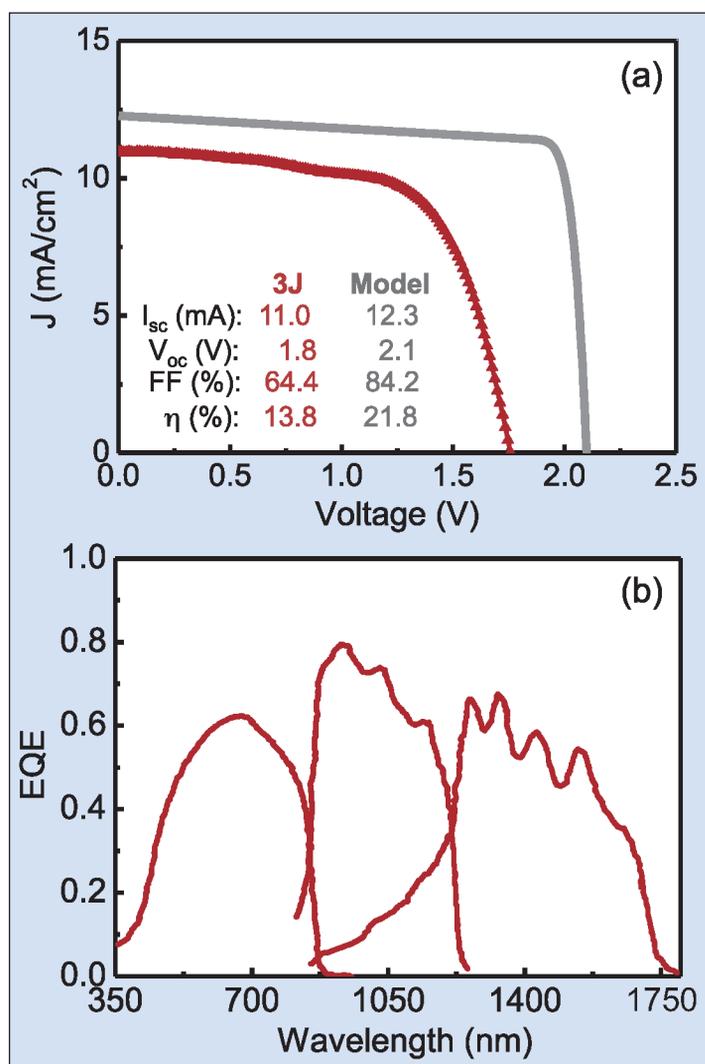


Figure 4. (a) Light current-voltage curve measured under 1-sun AM1.5 direct illumination for InP-based 3-junction test device of California Institute of Technology, US National Institute of Standards and Technology, University of Maryland, and Boeing-Spectrolab Inc (red triangles), compared with 1-dimensional device modeling (grey solid line). (b) External quantum efficiency for InP-based 3J solar cell.

window and back-surface field layers. Also, the thicknesses of the middle (InGaAsP) and bottom (InGaAs) layers were 1 μ m rather than the optimal values.

The researchers comment: “The monolithically grown 3J device shows similar performance compared to the independently connected subcells. This demonstrates the extremely low resistance of the fabricated tunnel junctions, validating our device modeling assumption for the lattice-matched optimized 3-junction solar cells presented earlier.”

Window and back-surface field layers would reduce surface recombination velocity and light absorption losses. Anti-reflective coatings and increased middle and bottom subcell thicknesses would further boost performance. Such improvements could lead to 20%

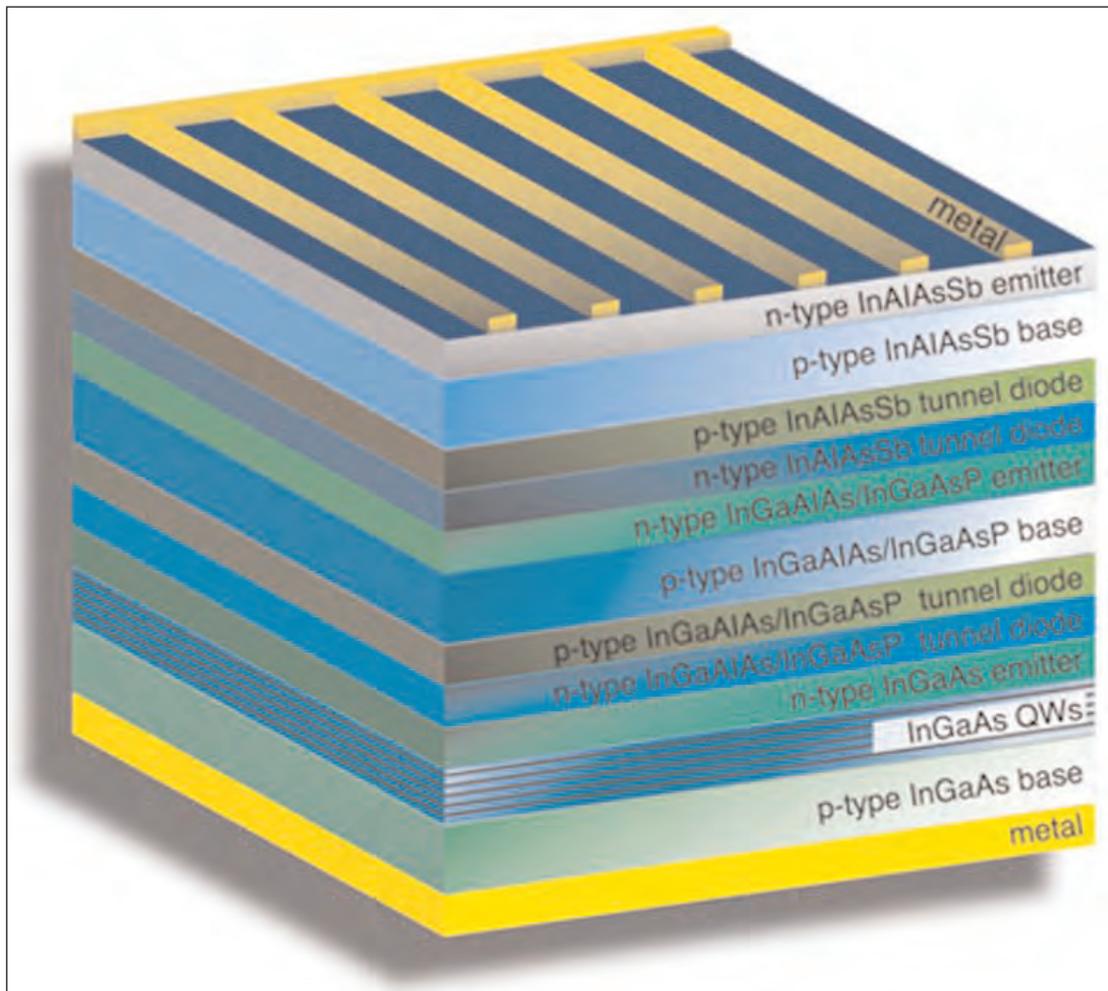


Figure 5. Schematic diagram of multi-junction (MJ) solar cell formed from materials lattice-matched to InP with bandgaps designed for maximum efficiency, according to a design of NRL, Imperial College, and MicroLink Devices Inc (Image: US Naval Research Laboratory)

efficiency under 1-sun illumination.

The researchers comment: "Although the efficiency of this InP-based 3J solar cell is far from the theoretical prediction, the results are promising and demonstrate the capability of growing high-quality Al-rich epitaxial layers, very low-resistance tunnel junctions, and an integrated all-lattice-matched multi-junction solar cell."

Another group that believes 50% efficiency with a 3-junction solar cell is within reach is based variously at US Naval Research Laboratory, Imperial College London and MicroLink Devices Inc [Robert J. Walters, et al, IEEE Photovoltaic Specialists Conference (PVSC), p122, 2011]. The researchers have proposed a design using antimony (Sb) along with the usual III-V compound semiconductor suspects (Figure 5).

The structure is again lattice matched to InP. The bandgaps of the layers have been theoretically optimized for maximum efficiency with the solar radiation spectrum. The bandgaps cover the range 0.7–1.8eV. Normal ternary alloy materials lattice-matched to InP are usually limited to less than ~1.4eV. The researchers therefore propose the use of InAlAsSb

quaternary alloy to give a 1.8eV bandgap, while still being lattice matched to InP.

The NRL team already has extensive experience with Sb-based compounds from work on detectors and lasers that was used in modeling the band structure of InAlAsSb. Along with showing the potential for a direct bandgap of 1.8eV, further simulations created a design with power conversion efficiency of more than 50% under concentrated solar illumination.

Moving from theory to practice, NRL is joining with MicroLink and Rochester Institute of Technology in a US Department of Energy (DoE) Advanced Research Projects Agency-Energy (ARPA-E) project that, over three years, will develop materials and device technologies to realize the design.

Textured ZnO windows

While the epitaxial material for solar cells is the basis for solar cells, it is also important to improve the absorption of light by devices through reducing optical losses such as reflection from the top layer. National Formosa University, Taiwan, has developed a liquid-phase deposition (LPD) process of textured zinc oxide on III-V semiconductor to provide improved absorption for multi-junction solar cells [Po-Hsun Lei et al, J. Phys. D: Appl. Phys., vol46, p125105, 2013].

The textured layer reduces reflection of the incident light over a broad band of wavelengths (300–1000nm). Traditional anti-reflective coatings tend to be wavelength selective. The researchers were seeking a low-cost process to produce randomly textured surfaces as a means to improve solar cell light-absorption performance.

The GaInP/InGaAs/Ge solar cell material formation process consisted of metal-organic chemical vapor deposition (MOCVD) on germanium for the active material and a liquid-phase deposition in a Teflon vessel

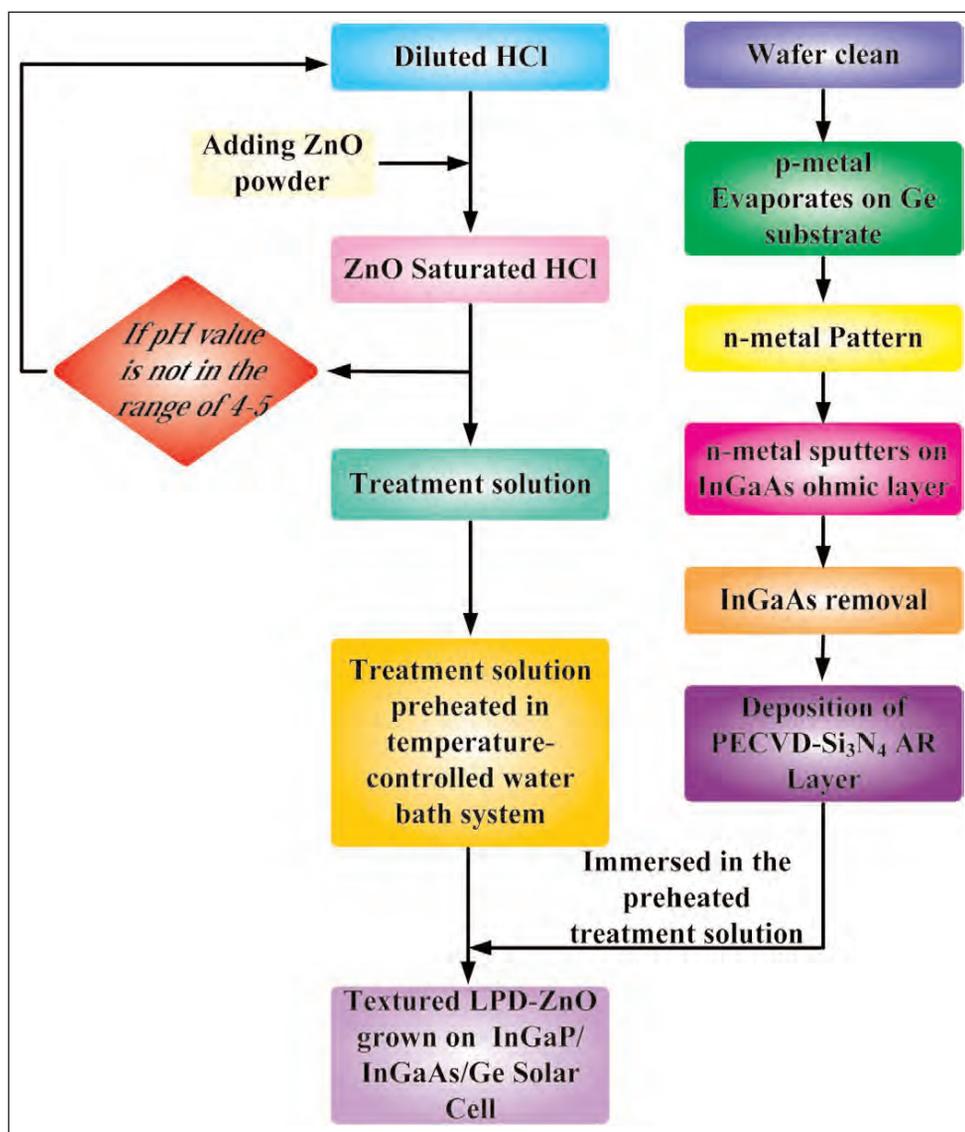


Figure 6. Flow chart for National Formosa University, LPD-ZnO process (left side) and fabrication of GaInP/(In)GaAs/Ge solar cells (right side).

n-contact/window	n-InGaAs/n-AlInP
Sub cell	GaInP
Tunnel junction	p-AlGaAs/n-GaInP
Sub cell	InGaAs
Tunnel junction	n-GaAs/p-GaAs
Substrate	p-Ge

Figure 7. National Formosa University's MOCVD heterostructure.

in a controlled-temperature water bath for the textured zinc oxide layer (Figures 6 and 7).

The epitaxial material was cut up into 5mm x 5mm square chips. The ohmic p-contact was made to the back of the Ge substrate with a gold/zinc/silver/gold alloy. The ohmic n-electrode structure consisted of germanium-gold/nickel/gold on the n-InGaAs top layer. A ridge n-contact was made by partially exposing regions of n-type aluminium indium phosphide (n-AlInP) window layer underneath by etching into the n-InGaAs.

A silicon nitride (Si_3N_4) anti-reflective coating was applied to the n-AlInP using plasma-enhanced chemical vapor deposition (PECVD). The n-InGaAs is used for the electrical contact, but absorbs wavelengths that should be converted by the GaInP layer.

The ZnO was deposited on the silicon nitride. The researchers carried out a number of experiments to optimize the process parameters (pH, temperature) for control of layer thickness and root-mean-square (RMS) roughness. The textured ZnO layer consisted of nests of hexagonal flakes (Figure 8).

The aim of the ZnO layer was to reduce the reflection of light away from the solar cell. The optimum

growth conditions for this were found to be 25°C with 6 mole/liter (M) hydrochloric acid solution. Also, the researchers performed simulations suggesting that the maximum enhancement for solar cells designed for a broad wavelength range would come from 95nm RMS roughness.

A bare solar cell without ZnO had a short-circuit current density of 12.5mA/cm² and energy conversion of 24%. This is similar to the performance achieved by others, according to the researchers. With ZnO deposited from 6M solution at 25°C, these were increased to 14.22mA/cm² and 29.8%, respectively.

Over a series of runs (Table 1), ZnO deposited from 6M solution at 25°C showed small variations in the character of the ZnO layer and in the performance of the solar cells. The RMS roughness of the ZnO layer varied in the range 90–100nm, while the pH value of the growth solution was kept in the range 4–5.

The researchers comment: "The uniformity of the RMS roughness is extremely significant because this is

the primary factor determining the absorbed light intensity or scattering between air and the textured LPD-ZnO.”

The variation in performance values were 3.31% for short-circuit current, 0.87% for open-circuit voltage, 3.75% for conversion efficiency, and 2.51% for fill factor.

The solar cells were also tested at operating temperatures up to 100°C. The variation in open-circuit voltage was 5.8mV/°C for cells without textured ZnO and 5.9mV/°C with textured ZnO. The respective rates for short-circuit current density were 7.9 μ A/°C-cm² and 8.0 μ A/°C-cm².

The performance of solar cells tends to show degraded energy conversion at high temperature, and an increase in thermal resistance from added layers can be a concern for thermal management. The negligible changes in performance at raised temperature suggest that the ZnO layer does not significantly trap heat.

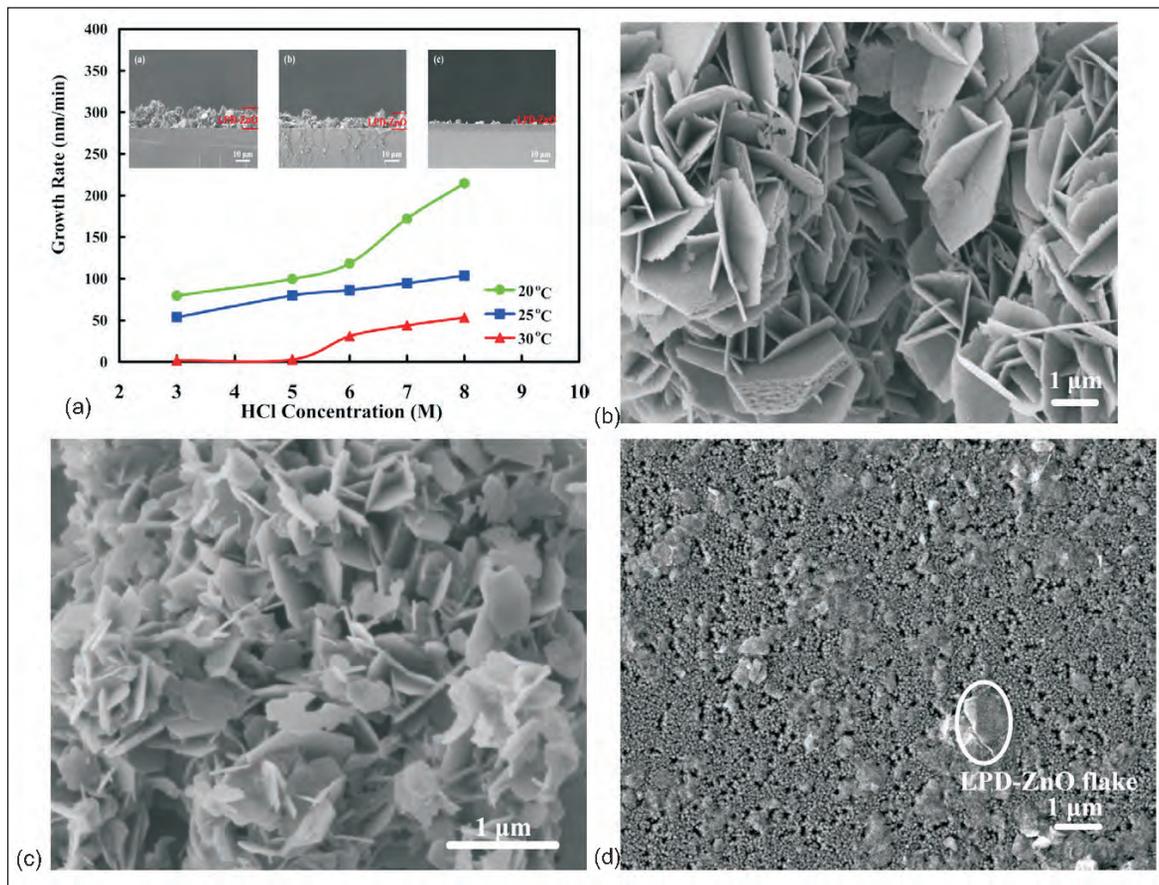


Figure 8. (a) Deposition rate of LPD-ZnO grown on Si₃N₄ as a function of HCl concentration at various deposition temperatures, and FESEM images for LPD-ZnO grown at (b) 20°C, (c) 25°C and (d) 30°C. Insets of (a) show the cross-section FESEM images for LPD-ZnO grown at (a) 20°C, (b) 25°C and (c) 30°C at 6M HCl.

The researchers comment: “Introduction of the textured LPD-ZnO window layer for GaInP/(In)GaAs/Ge solar cells shows similar temperature characteristics as compared with those without the textured LPD-ZnO window layer. This may be attributed to the porosity of LPD-ZnO, which offers a path for reducing the thermal energy.” ■

Table 1. Performance of GaInP/(In)GaAs/Ge solar cells with textured LPD-ZnO window layer grown at 25°C in 6M HCl solution.

Run no.	Short-circuit current density (mA/cm ²)	Open-circuit voltage (V)	Conversion efficiency (%)	Fill factor
1	14.25	2.43	29.71	0.85
2	14.35	2.43	29.65	0.84
3	15.09	2.41	29.64	0.81
4	14.92	2.34	28.43	0.81
5	14.57	2.42	29.78	0.84
6	15.00	2.42	29.79	0.82
7	14.85	2.41	29.81	0.83
8	14.81	2.41	28.92	0.811
9	14.73	2.39	29.50	0.83
10	14.73	2.39	29.63	0.84
11	14.81	2.39	29.81	0.84
12	14.72	2.38	29.80	0.85

New atomic layer deposition process for nitride LED reflector structures

Light output power has been increased by 43% by using an aluminium mirror and titanium dioxide/aluminium oxide distributed Bragg reflector combination.

Researchers in China have developed an atomic layer deposition (ALD) technique to create distributed Bragg reflectors (DBR) for increasing nitride semiconductor light-emitting diode (LED) output power by up to 43% [Hongjun Chen et al, Appl. Phys. Express, vol6, p022101, 2013].

Although some groups have developed DBRs for such purposes before, this is claimed as the first proposal and demonstration of DBRs grown using ALD rather than electron-beam (EB) evaporation. The advantages of ALD over EB evaporation include better thickness uniformity over large-diameter substrates and thickness control at the atomic level.

To develop an ALD process, the researchers from Institute of Microelectronics of Chinese Academy of Sciences and Southeast University changed the composition of the DBR from the usual titanium dioxide (TiO_2) and silicon dioxide (SiO_2) pairs to a titanium dioxide and aluminium oxide (Al_2O_3) recipe. The use of Al_2O_3 also allows better adhesion of Al metal so that Al-mirror/DBR combinations can be developed. With $\text{TiO}_2/\text{SiO}_2$ DBRs, an extra layer of Al_2O_3 is often applied to enable adhesion of Al-metal.

The LED structure (Figure 1) was grown on a patterned sapphire substrate (PSS) by metal-organic chemical vapor deposition (MOCVD). PSS has two effects: improved crystal quality and light extraction. These effects increase the number of photons generated in the active region and their ability to exit the device, respectively.

The sapphire patterning was achieved using photolithography and inductively coupled plasma reactive ion etch (ICP-RIE). The diameter and spacing of the bumps were $2.1\mu\text{m}$ and 900nm , respectively. The pattern height was $\sim 1.3\mu\text{m}$.

The nitride heterostructure consisted of a 30nm GaN buffer, $4.5\mu\text{m}$ n-type GaN contact/buffer, 6-period InGaN/GaN multi-quantum well (MQW), and $0.9\mu\text{m}$ p-GaN contact. A 240nm indium tin oxide (ITO) transparent contact layer was also applied. The metal electrodes for the p- and n-contacts consisted of

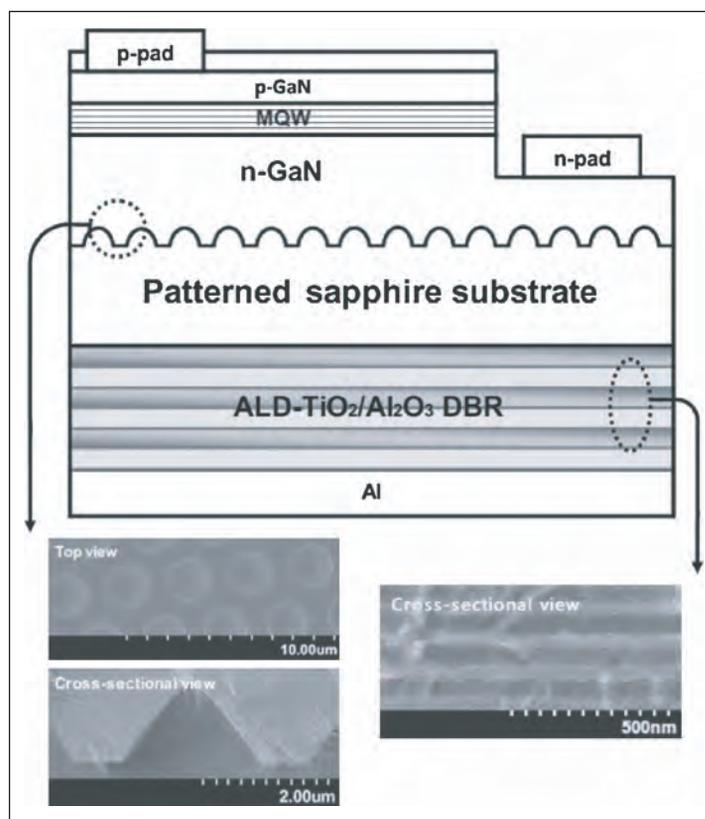


Figure 1. Schematic diagram of LED with backside reflector composed of $\text{TiO}_2/\text{Al}_2\text{O}_3$ DBR and Al mirror grown on backside of PSS. Insets: SEM images of fabricated DBR and PSS.

chromium/platinum/gold. Silicon dioxide was also used as a 100nm passivation layer.

The LED wafer was back-side thinned to $100\mu\text{m}$ before the DBR and Al mirror were applied. The atomic layer deposition was preceded by soft polishing for 30 minutes to minimize the roughness of the surface. The $\text{TiO}_2/\text{Al}_2\text{O}_3$ DBR was designed to maximize reflectivity between 420nm and 500nm. This was achieved with 67nm Al_2O_3 and 49nm TiO_2 .

The ALD used trimethyl-aluminium and water precursors for the Al_2O_3 , and titanium tetrachloride and water for the TiO_2 . The carrier gas was nitrogen. The growth temperature for both materials was 250°C .

This enabled a reduced fabrication time and high-quality thin films. The different material depositions were separated by nitrogen purging to avoid mixing of the respective precursors.

The DBR was capped with 150nm of aluminium deposited using electron-beam evaporation. Devices with $\text{TiO}_2/\text{SiO}_2$ (48.5nm/78.5nm) DBRs deposited using electron-beam evaporation were also produced. These were finished with a 15nm Al_2O_3 adhesive layer and 150nm Al metal.

The LED chips measured $300\mu\text{m} \times 700\mu\text{m}$, defined using laser scribing and singulation. The breaking process of the singulation was found to cause some lift-off of the aluminium from $\text{TiO}_2/\text{SiO}_2$ DBR but not in the case of the new $\text{TiO}_2/\text{Al}_2\text{O}_3$ DBR.

Although DBRs without Al mirror did reflect some light, it was found that the reflectivity became more effective (~95% reflectivity) and nearly independent of wavelength and incident angle with the Al mirror.

Six device types were fabricated on patterned sapphire and one on flat sapphire. The devices on patterned sapphire showed almost identical electrical performance with 3.05V forward voltage at 60mA current injection.

The light output power (LOP, Figure 2) was greatest for an LED with Al-mirror and 3-pair $\text{TiO}_2/\text{Al}_2\text{O}_3$ DBR (Al+3DBR). At 60mA injection the LOP for the

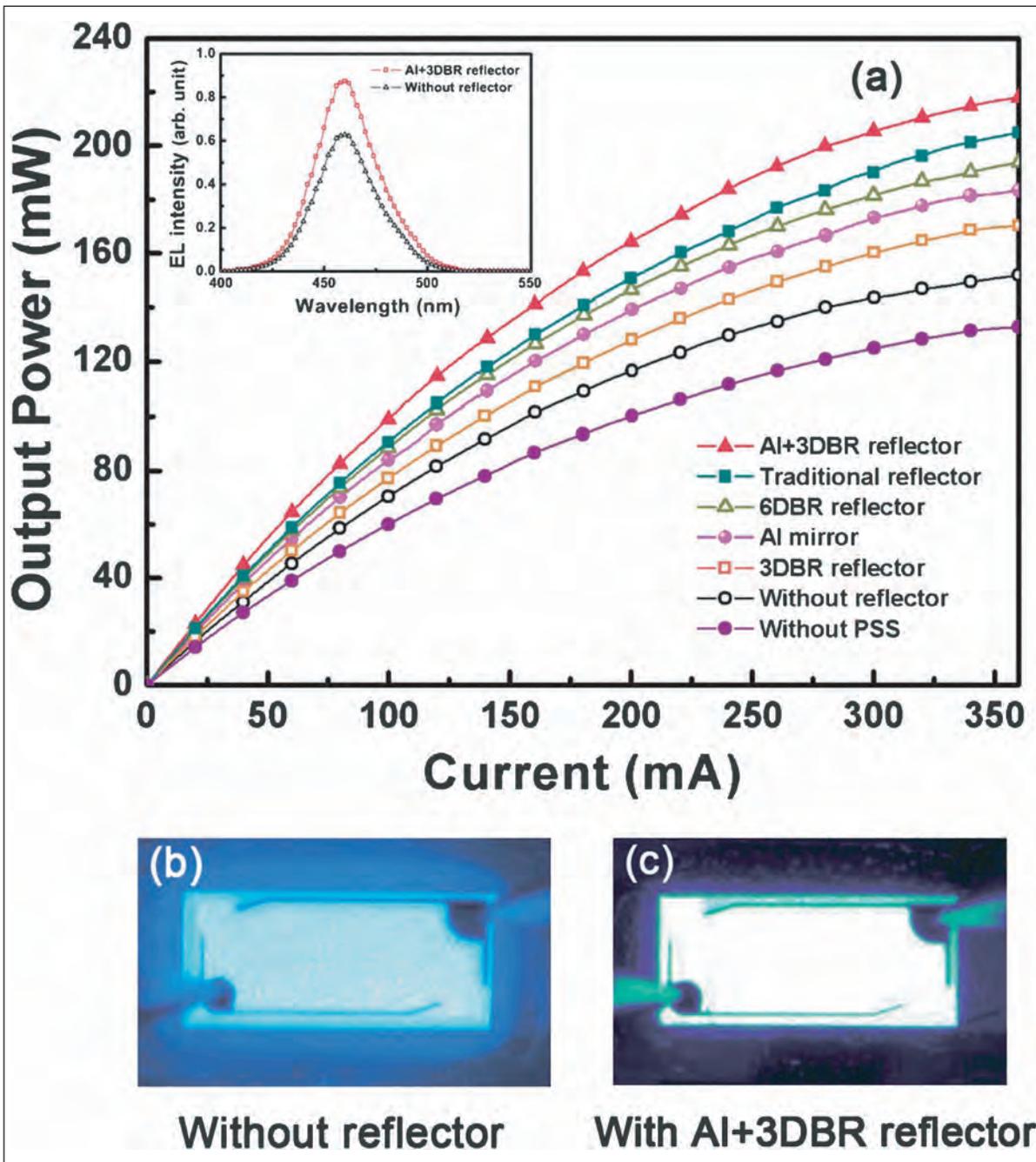


Figure 2. (a) LOP of fabricated LEDs versus injection current. **Inset:** electroluminescence spectra. **(b)** and **(c)** are photographs of LEDs with and without backside reflector in operating state, respectively.

Al+3DBR LED was 65mW, compared with 58.7mW for a conventional 3-pair $\text{TiO}_2/\text{SiO}_2$ DBR reflector, 57.4mW for 6DBR-only, 54.6mW for Al-only, 50mW for 3DBR-only, 45.4mW no-reflector, and 39mW for the device grown on flat sapphire. The light output improvement for the best device was 43.1% over that for the LED with no reflector. The peak wavelength was ~460nm.

The improvement over the traditional reflector structure was attributed to the better uniformity and thickness control of ALD compared with EB evaporation. ■

<http://apex.jsap.jp/link?APEX/6/022101>

Author: Mike Cooke

First lateral insulated-gate bipolar transistors in 4H silicon carbide

What is claimed to be the first 4H-SiC lateral n-channel IGBT demonstrates lower differential on-resistance than a SiC MOSFET.

Researchers in Taiwan and USA have developed lateral insulated-gate bipolar junction transistors (IGBTs) using 4H silicon carbide (SiC) technology [Kuan-Wei Chu et al, IEEE Electron Device Letters, published online 9 January 2013]. "To the best of the authors' knowledge, lateral n-channel IGBTs in 4H-SiC are reported for the first time," they write.

The team consisted of researchers from Taiwan National Tsing Hua University, US Washington State University, and Taiwan's Industrial Technology Research Institute (ITRI).

The lateral IGBTs have potential for high-voltage, high-power and high-temperature applications. Silicon carbide has a wide bandgap that allows for higher critical fields and higher temperature endurance. Often high-power/voltage performance is achieved by using 'vertical' current flow. However, low-voltage devices are generally based on lateral current flow. Developing lateral IGBTs creates the opportunity to monolithically integrate high- and low-voltage devices.

The transistors were created from a 2 μ m p-type epitaxial layer of SiC on a high-purity semi-insulating (HPSI) silicon-face 4H-SiC substrate (Figure 1). The

doping for the various regions of the device were achieved using ion implantation of nitrogen (n-drift and n-buffer), phosphorous (n-emitter) and aluminium (p-collector and p-emitter).

Transistor formation began with mesa isolation. An optional two-step carrier lifetime enhancement process was applied to two of the device variants, consisting of two thermal oxidation steps at 1150°C for 1 hour. The aim was to reduce concentrations of two deep levels that capture carriers, reducing the lifetime.

The devices were then capped with graphite and annealed in argon at 1700°C for 10 minutes. An RCA clean process prepared the deposition of 700Å gate oxide. Next, another anneal step at 1350°C in nitrous oxide (N₂O) was performed. The n⁺-contact consisted of titanium/nickel and the p⁺-contact was titanium/aluminium/nickel, which were vacuum sintered with a 3 minute rapid thermal anneal at 1150°C. The transistor was completed with a titanium/aluminium gate. A titanium/aluminium combination was also used to make metal pads for probe testing.

The best device (IGBT1) had a relatively light doping of the buffer with a nitrogen concentration of 3x10¹³/cm² and used the two-step lifetime enhance-

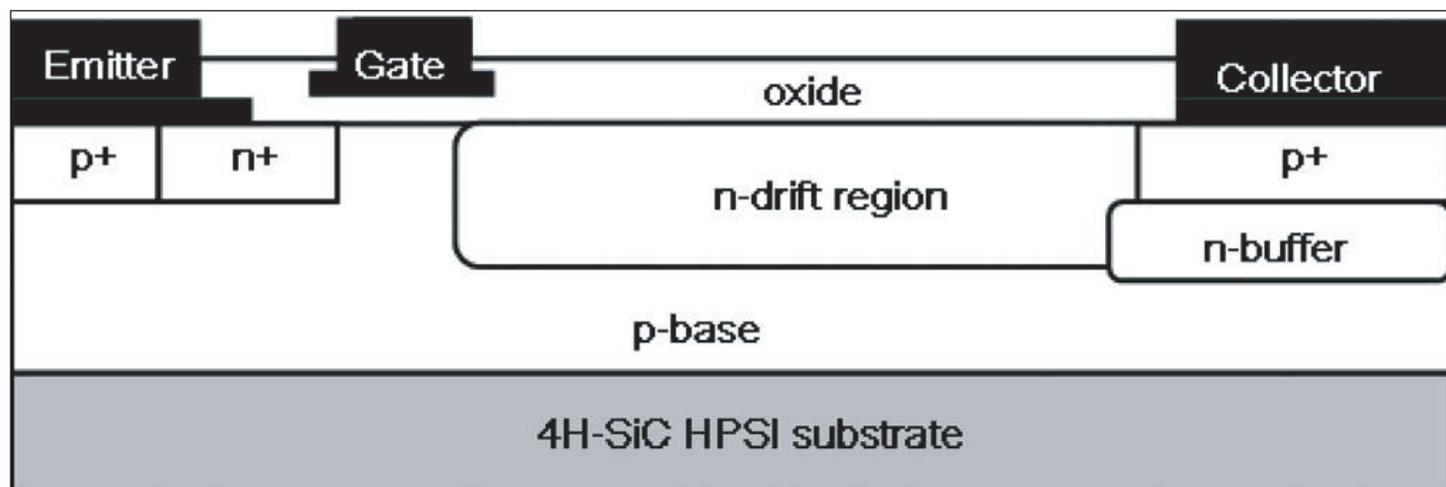


Figure 1. Device structure of lateral IGBT in 4H-SiC. An n-type buffer is included underneath a p-collector and p-base to prevent punch-through.

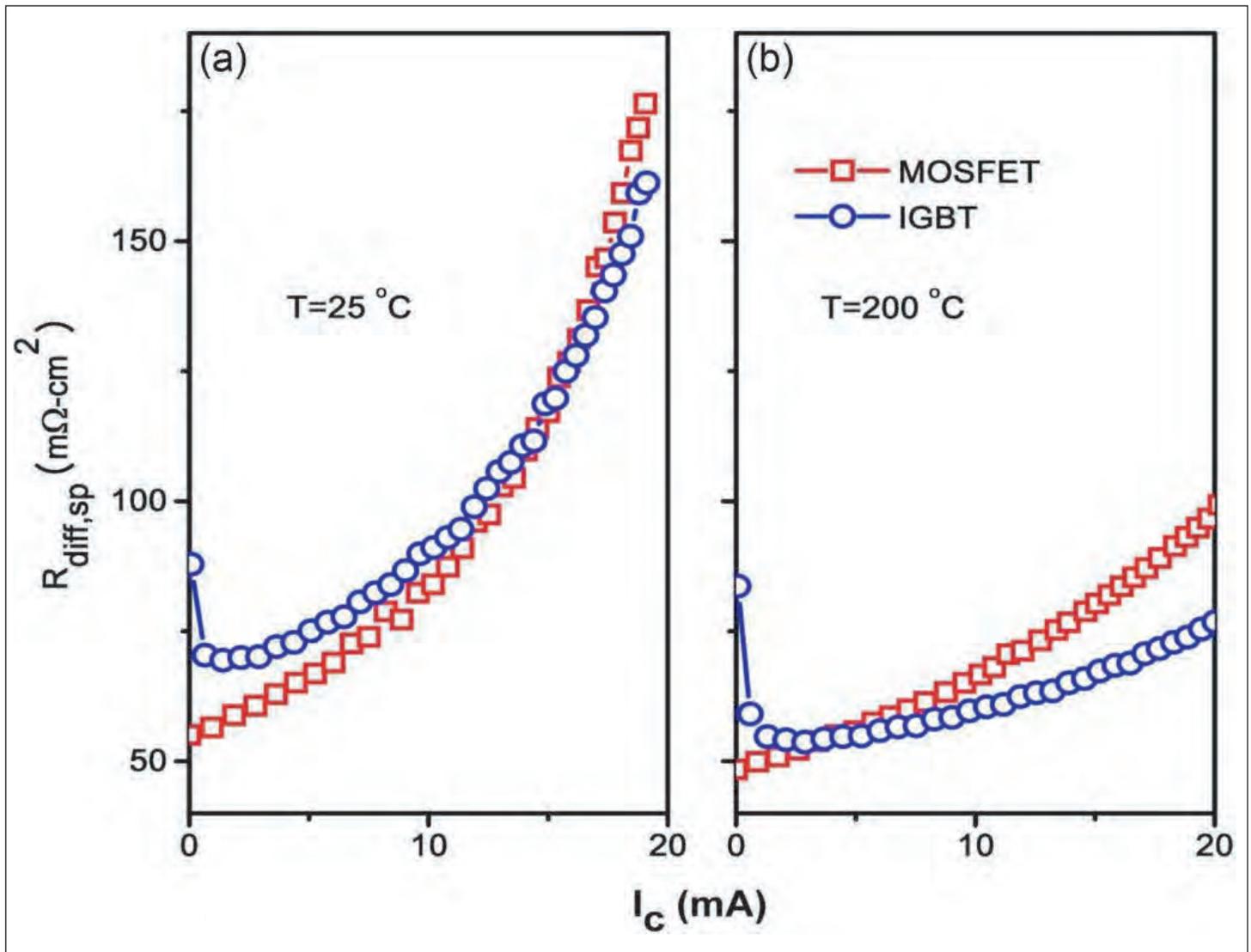


Figure 2. Differential specific on-resistance of MOSFET and IGBT1 (gate potential of 30V) at (a) room temperature and (b) 200°C .

ment process. Such an IGBT with $20\mu\text{m}$ drift region length demonstrated a lower differential on-resistance at 30V gate potential (Figure 2) than a test SiC MOSFET at high current and high temperature (200°C). The cross-over point for room temperature was 15mA collector current. This reduced to 3.7mA at 200°C .

The differential specific on-resistance at 20mA collector current was $161m\Omega\text{-cm}^2$ at room temperature and $77m\Omega\text{-cm}^2$ and 200°C .

IGBT1 with a $20\mu\text{m}$ drift region also showed increased common base current gain of the parasitic p-n-p bipolar junction transistor that is a feature of

such devices. One effect of the increased gain is to increase the saturation current.

However, longer drift regions are needed to create IGBTs with higher breakdown voltage (BV) at zero gate potential. The BVs were tested while immersed in Fluorinert coolant liquid. With a $20\mu\text{m}$ drift region, the BV was 930V. Increasing the drift region to $40\mu\text{m}$ and $80\mu\text{m}$ increased the BV to 1440V and 2670V, respectively. ■

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Author: Mike Cooke

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RF switching from nitride semiconductor varactor technology

Insertion loss of about 1.2dB compares favorably with 1.5dB/2dB for HFET and ferrite-based varactor designs.

Researchers in the USA have developed radio-frequency switches based on nitride semiconductor voltage-controlled capacitors (varactors) [F. Jahan et al, IEEE Electron Device Letters, 9 January 2013]. The team, consisting of engineers from University of South Carolina (USC), Sensor Electronic Technology Inc (SET), Rensselaer Polytechnic Institute (RPI), writes: "The demonstrated switch is fully compatible with III-nitride heterostructure field-effect transistors (HFETs) or metal-insulator-semiconductor HFETs (MISHFETs) and has a great potential for high-performance monolithic microwave integrated circuits (MMICs)."

The varactors consisted of two Schottky contacts deposited over an aluminium gallium nitride on gallium nitride (AlGaN/GaN) heterostructure (Figure 1). The electrodes give capacitively coupled contacts (C3) with the two-dimensional electron gas (2DEG) that forms near the AlGaN/GaN interface. By biasing the varactor, a low capacitance results that blocks RF signals.

According to USC professor Grigory Simin, the purpose of the work was to demonstrate the potential of the C3 varactor and its advantages over FETs in RF switching applications. Two C3 varactors created a switch circuit in a coplanar waveguide (CPW) layout (Figure 2).

The epitaxial structure (Figure 1) was grown on sapphire using metal-organic chemical vapor deposition (MOCVD). The semi-insulating GaN buffer layer was 1.5 μm and the Al_{0.25}Ga_{0.75}N barrier was 20nm. The resulting 2DEG at the AlGaN/GaN interface had a sheet resistance of 300 Ω /square.

The device mesa was formed using reactive ion etch (RIE). The metals used for the CPW and C3 varactor were nickel/gold. The nickel/gold combination gives a Schottky junction with the AlGaN layer. Plasma-enhanced chemical vapor deposition (PECVD) of 10nm silicon nitride passivated the surface of the device.

The device realized a series-shunt switch circuit (Figure 2). The switching was achieved by biasing

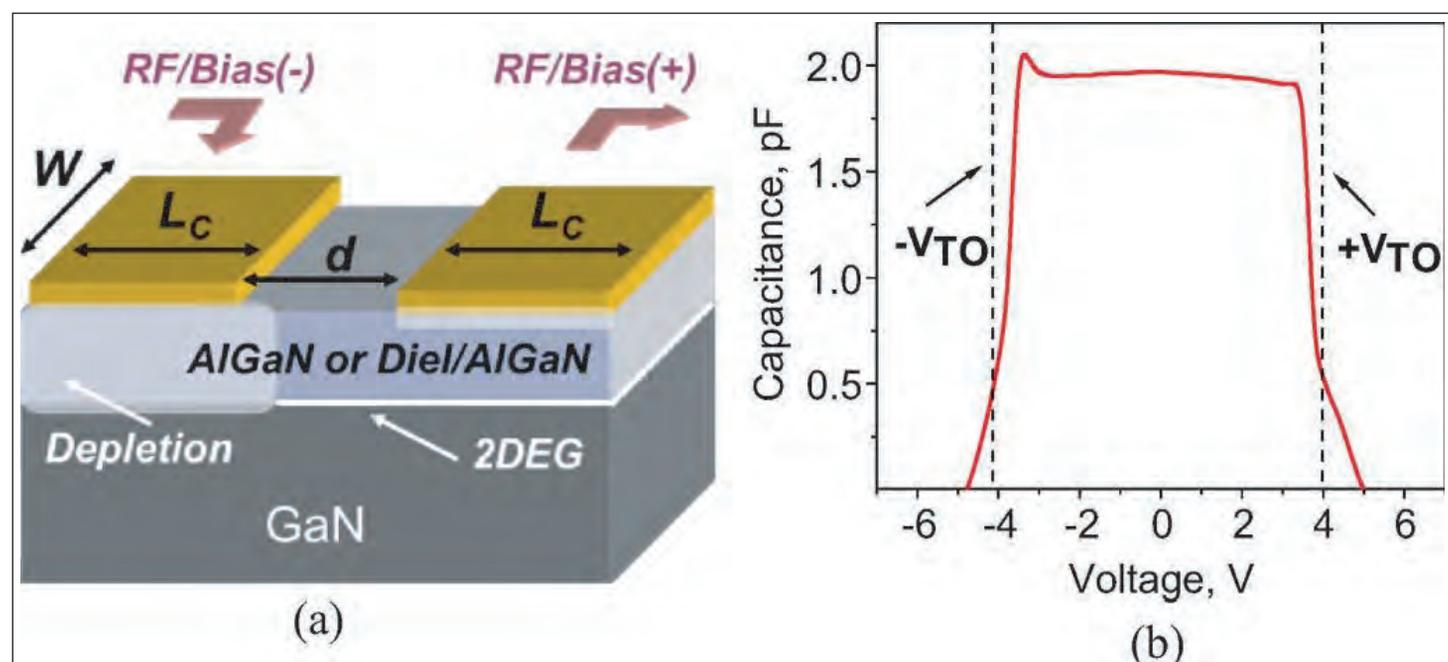


Figure 1. (a) C3 varactor layout. (b) C-V characteristic.

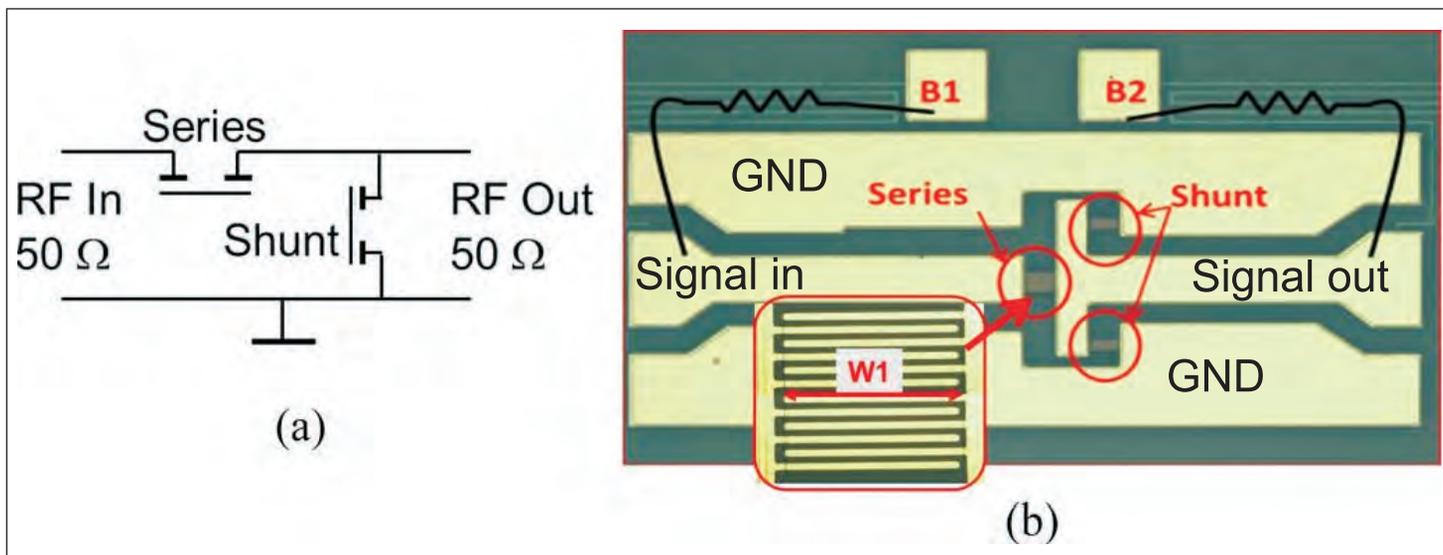


Figure 2. (a) Series–shunt MMIC layout. (b) RF switch image with multi-finger C3 region zoomed in.

through 2.5–5k Ω resistors that consisted of 3 μ m-wide 2–3mm-long meanders of 30nm-thick chromium with two bias terminals (B1 and B2).

A bias voltage of 30V was used to avoid the RF signal from accidentally switching the varactors. At 30V bias, the leakage was 2–10 μ A. The on-state consisted of both bias electrodes at 30V — the series varactor was then unbiased (on-state) and the shunt was biased (off-state). In the off-state, the output line bias was set to 0V — the series varactor was then biased (off-state) and the shunt unbiased (on-state).

Small inductances were introduced in the circuit by narrowing the signal lines and increasing the gap in the CPW pattern. The aim of this was to compensate for the capacitive component of the C3 varactor impedances.

The on-state insertion loss of the switch was less than 1.2dB over the range 4–20GHz. At 18GHz, the insertion loss is 0.8dB. The researchers compare this

insertion loss with that obtained at similar frequencies using HFETs (1.5dB) and ferrite varactors (2dB). However, the insertion loss was more than expected from simulations. The researchers suggest that this could have been due to “imperfect capacitance compensation by the CPW inductance”.

The isolation provided by the switch in the off-state was ~25dB over a broad range of frequencies. At 18GHz this increased to 28dB.

Further features of the C3 varactor switches are a 95V breakdown (compared with 45–50V for an HFET with 2 μ m gate–drain spacing), +34dBm maximum RF power at 10GHz (+38dBm at 18GHz), and stable output power with less than 0.5dB variation during a 100-hour stress test. ■

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Author: Mike Cooke

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Gated anode AlGaN/GaN Schottky barrier diode enables increased forward current

Breakdown voltage not affected, while the turn-on voltage is lowered.

Researchers in Korea have used aluminium gallium nitride (AlGaN) heterostructures similar to high-electron-mobility transistors (HEMTs) to create Schottky barrier diodes (SBDs) with increased forward current without damaging the breakdown performance [Jae-Gil Lee et al, IEEE Electron Device Letters, vol. 34, p.214, 2013, published online 16 January 2013]. The team was based at Hongik and Seoul National universities.

Schottky barrier diodes are used in many power switching applications such as switch mode power supplies (SMPS), converters, and inverters. It is hoped that nitride semiconductor based devices could use superior material properties such as high critical electric field and mobility values to boost performance in terms of breakdown voltage and switching speed.

The researchers used an epitaxial structure grown on a p-type silicon (111) substrate (Figure 1). The buffer consisted of 3–4 μm of GaN on a transition layer. This was followed by a 200Å $\text{Al}_{0.25}\text{Ga}_{0.75}\text{N}$ barrier and a 12.5Å GaN cap.

Table 1. Device characteristics of different types.

L_{AC} (μm)	Characteristics	Type I	Type II	Type III
5	V_{th} (V)	0.37	0.58	1.05
	V_{BD} (V)	489	467	483
	I_F (mA/mm)	168.4	150.0	70.9
	I_R ($\mu\text{A}/\text{mm}$)	2	12	6.2
8	V_{th} (V)	0.38	0.58	1.05
	V_{BD} (V)	801	778	791
	I_F (mA/mm)	133.3	118.0	53.6
	I_R ($\mu\text{A}/\text{mm}$)	3.2	8.2	5.4
13	V_{th} (V)	0.38	0.57	1.06
	V_{BD} (V)	1122	1120	1148
	I_F (mA/mm)	108.2	89.1	39.5
	I_R ($\mu\text{A}/\text{mm}$)	2.7	16	9.5
18	V_{th} (V)	0.37	0.57	1.06
	V_{BD} (V)	1440	1472	1451
	I_F (mA/mm)	92.2	71.3	32.5
	I_R ($\mu\text{A}/\text{mm}$)	2.2	20	16

V_{th} : turn-on voltage (current density 1mA/mm);

V_{BD} : average breakdown voltage (leakage current 1mA/mm);

I_F : forward current density (at 1.5V);

I_R : reverse leakage current density (at 100V).

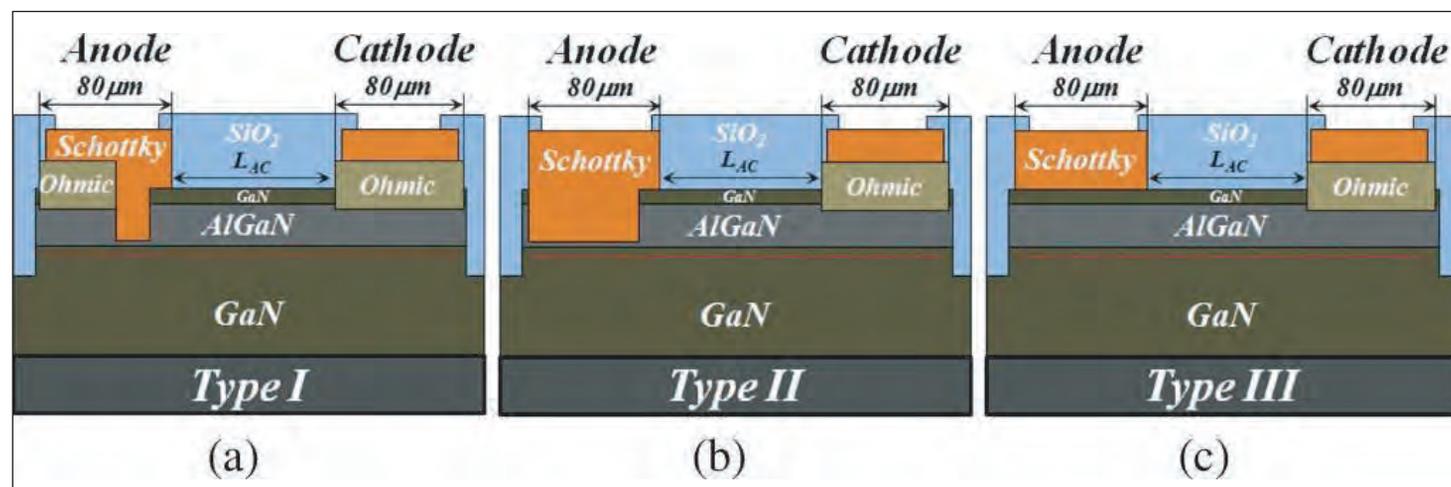


Figure 1. Cross-sectional schematics of AlGaN/GaN-on-Si rectifiers. (a) Rectifier with gated ohmic anode (type I), (b) recessed SBD (type II), and (c) conventional SBD (type III). Both anode and cathode contact areas are 80 μm x 100 μm . Type I has a 3 μm -wide recessed region. The distance from the recessed edge to the Schottky overhang edge is 2 μm in types I and II.

The rectifier with a gated ohmic anode was processed in a similar way to HEMTs with recessed gate, but with the gate and source being on top of each other (Figure 1a).

The Schottky contact of the 'gate' was recessed to leave 50Å between the electrode and two-dimensional electron gas (2DEG) channel. This was to ensure complete depletion of the 2DEG under the 'gated-anode' Schottky barrier. Without depletion, the device would operate as a resistor without rectifying capability.

The SBD structure was achieved with inductively coupled plasma reactive ion etching (ICP-RIE) for mesa isolation, silicon/titanium/aluminium/molybdenum/gold ohmic contacts annealed at 830°C for 30 seconds in nitrogen, more ICP-RIE for recessing, nickel/gold for the Schottky contact, and a 280nm silicon dioxide surface passivation.

The researchers see their device as being a combination of Schottky diode and normally-off FET (Figure 2). The effect of the combination is to lower the turn-on voltage without affecting the breakdown voltage characteristics (Table 1). Also, the forward current at 1.5V was 2–3x that of a conventional SBD (i.e. the type III device of Figure 1c).

The researchers compared their device to one with a forward current of ~70mA/mm, turn-on voltage of 0.2V,

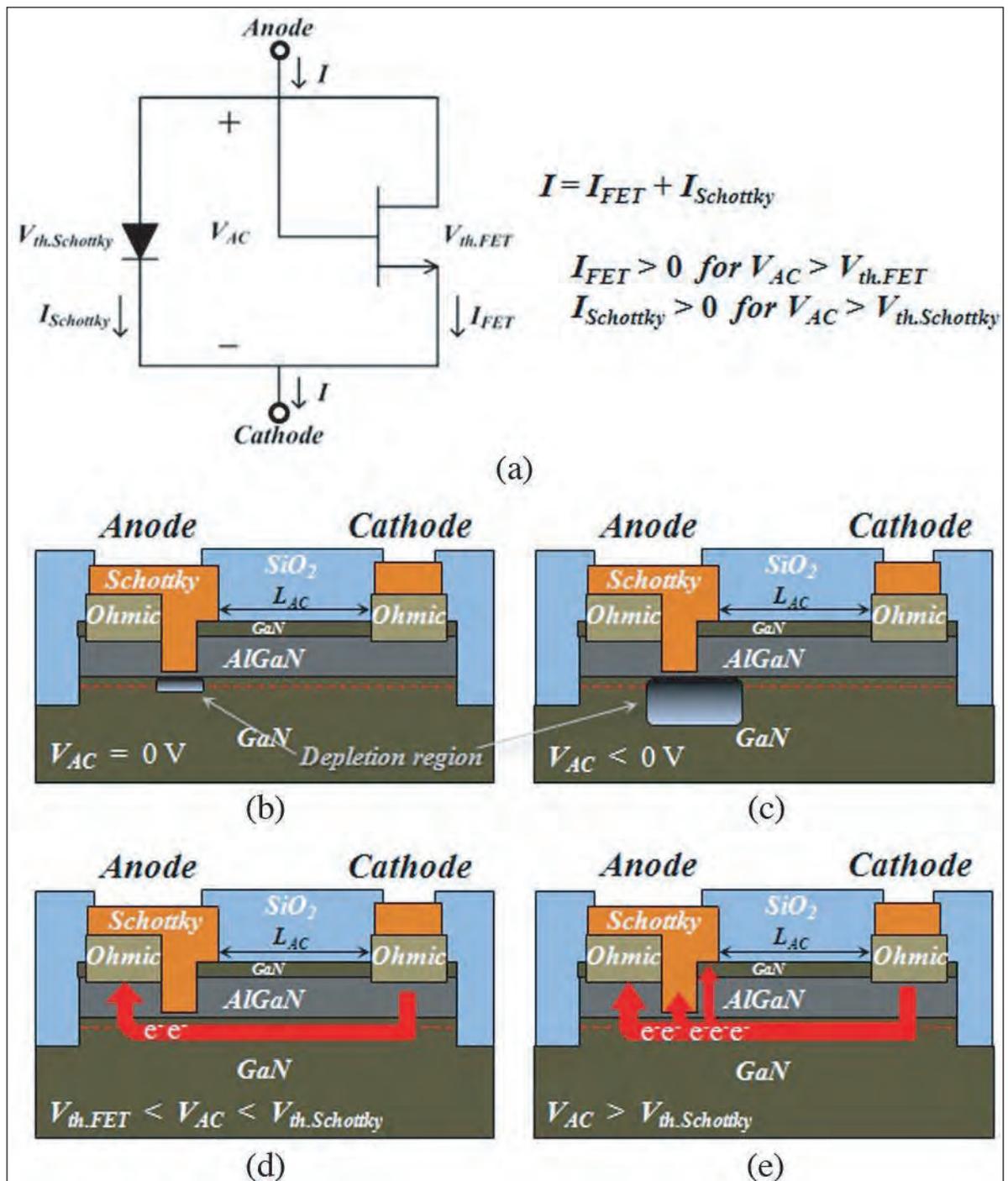


Figure 2. (a) Circuit model and operation mechanism of AlGaN/GaN rectifier with a gated ohmic anode. (b) Zero bias ($V_{AC} = 0V$), (c) reverse bias ($V_{AC} < 0V$), (d) small forward bias ($V_{th,FET} < V_{AC} < V_{th,Schottky}$), and (e) large forward bias ($V_{AC} > V_{th,Schottky}$) conditions. $V_{th,FET}$: Turn-on voltage of FET; $V_{th,Schottky}$: turn-on voltage of the Schottky diode.

and breakdown of 390V. This device was reported by Hong Kong University of Science and Technology in 2008. This earlier diode was also based on a nitride HEMT structure with an anode–cathode distance (LAC) of 10µm. Rather than recessing the gate, a fluorine plasma treatment was used to achieve normally-off behavior. ■

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Author: Mike Cooke

Double-gate HEMT explores current collapse in nitride devices

Gate field-plates are more effective than source field-plates, a study by China's SINANO concludes.

Suzhou Institute of Nano-tech and Nano-bionics (SINANO) in China has been using double-gated nitride semiconductor high-electron-mobility transistors (HEMTs) to understand the effects of field-plates in improving dynamic performance [Guohao Yu, IEEE Electron Device Letters, vol34, p217, 2013, published online 15 January].

Nitride HEMTs are being intensively developed for high-power electronics in high-frequency amplification and power switching applications. Often high performance in DC operation is lost when the HEMT is switched — for example, the on-current collapses when the gate signal is pulsed. It is thought that such effects are related to charge trapping that masks the effect of the gate on current flow. Field-plates on the source and gate electrodes have been used to manipulate the electric field in the device, mitigating such current-collapse phenomena.

SINANO proposed and fabricated the double-gate device “for the first time” in an effort to understand the action of such field-plates. With understanding, the researchers hope to further improve nitride HEMT performance and to bring these devices closer to wide commercial application.

The nitride semiconductor heterostructure (Figure 1)

Table 1. τ_{fd} and R_{onD} versus off-state top-gate voltage.

Top-gate voltage	τ_{fd}	R_{onD}
-5V	1.25 μ s	480 Ω
-10V	0.93 μ s	440 Ω
-15V	0.8 μ s	420 Ω

was grown on sapphire by metal-organic chemical vapor deposition (MOCVD). The gallium nitride (GaN) buffer was 2 μ m thick, separated from a 30nm $Al_{0.3}Ga_{0.7}N$ barrier by 1nm of AlN. The structure resulted in a two-dimensional electron gas (2DEG) channel with sheet resistance of 400 Ω /square, mobility 1080cm²/V-s and carrier density 1.44x10¹³/cm².

Mesa isolation of the transistors was achieved with a chlorine/boron trichloride plasma etch. The ohmic contacts consisted of titanium/aluminium/nickel/gold annealed at 850°C for 30 seconds in nitrogen. The gate electrode was nickel/gold. The top gate with the same composition was deposited on 165nm of silicon nitride (Si₃N₄). The electrode pads were accessed by etching through the SiN dielectric.

The device dimensions were: gate-source spacing 5 μ m, gate-drain 12 μ m, gate width 100 μ m, gate

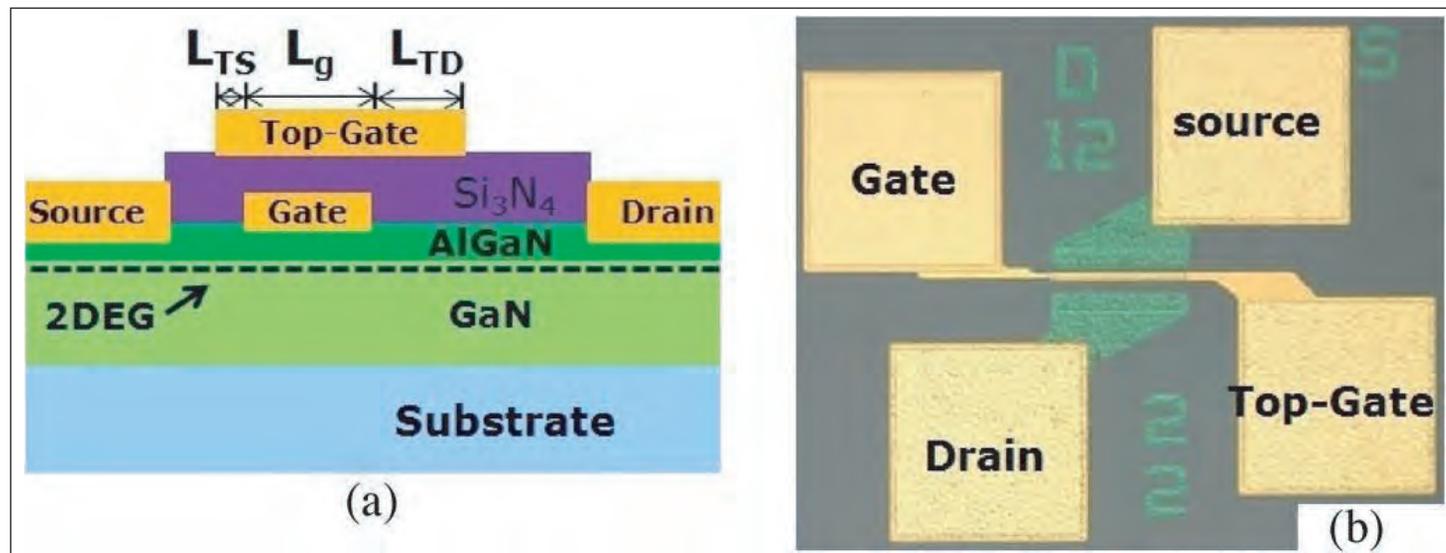


Figure 1. (a) Schematic cross-section of AlGaN/GaN DG-HEMT. (b) Optical image of DG-HEMT.

length $2\mu\text{m}$, top-gate overhang towards source (LTS) $2\mu\text{m}$, and top-gate overhang towards drain (LTD) $4\mu\text{m}$.

The HEMT structure (top-gate floating) had a negative threshold (normally-on/depletion mode) at -3.4V , $\sim 34\text{mA}$ 10V drain current at $+1\text{V}$ gate potential, and $+1\text{V}$ gate on-resistance of 115Ω .

The dynamic testing of the device was designed to mimic the behavior of source field-plate (SFP) and gate (GFP) field-plate by suitable biasing of the top gate. The SFP mode was achieved by grounding the top gate at 0V throughout the test cycle. The GFP mode consisted of biasing the top-gate in step with the ordinary gate at $+1\text{V}$ for the on-state and -5V for the off-state.

The falling delay time (τ_{fd}) was measured as the time taken for the output voltage to fall to 10% of the peak-to-peak value (Figure 2). The dynamic on-resistance ($R_{on,D}$) was also measured by the average from this 10% time up to the next switch-off point.

The results show that without field-plates, the HEMT structure suffers from serious degradation due to switching: the falling delay time is $2.75\mu\text{s}$ and the dynamic on-resistance is 2916Ω . Both SFP and GFP setups give distinct improvements, with the GFP-mode giving the best results of $1.05\mu\text{s}$ delay and 470Ω on-resistance.

The researchers explain: "In the AlGaIn/GaN HEMT, the peak electric field usually locates under the drain-side gate edge; the higher the peak electric field is, the more charges are trapped in the regions adjacent to the gate electrode during the OFF-state. The FPs, i.e. both the SFP and the GFP, can effectively suppress the peak electric field by leveling the electric-field distribution underneath the gate electrodes; therefore, less charge is trapped. As a result, the dynamic performances can be much improved."

While the above setup mimics the behavior of standard field-plates, the researchers also explored different biasing conditions of the double-gate. For example, with -5V gate and 0V top-gate off-state and $+1\text{V}$ gate and 20V top-gate on-state, the delay was reduced to $0.78\mu\text{s}$ and the dynamic on-resistance was lowered to 430Ω . The improved behavior is attributed to partial compensation of the 2DEG carrier loss to charge trapping by the higher potential top-gate.

The researchers also looked at changing the negative top-gate potential during the off-state and having 0V top-gate during the on-state (Table 1). The most negative value tested had a similar delay to the previous case of $0.8\mu\text{s}$. However, the on-resistance was reduced to 420Ω . The researchers suggest that the improved performance here could be due to suppression of elec-

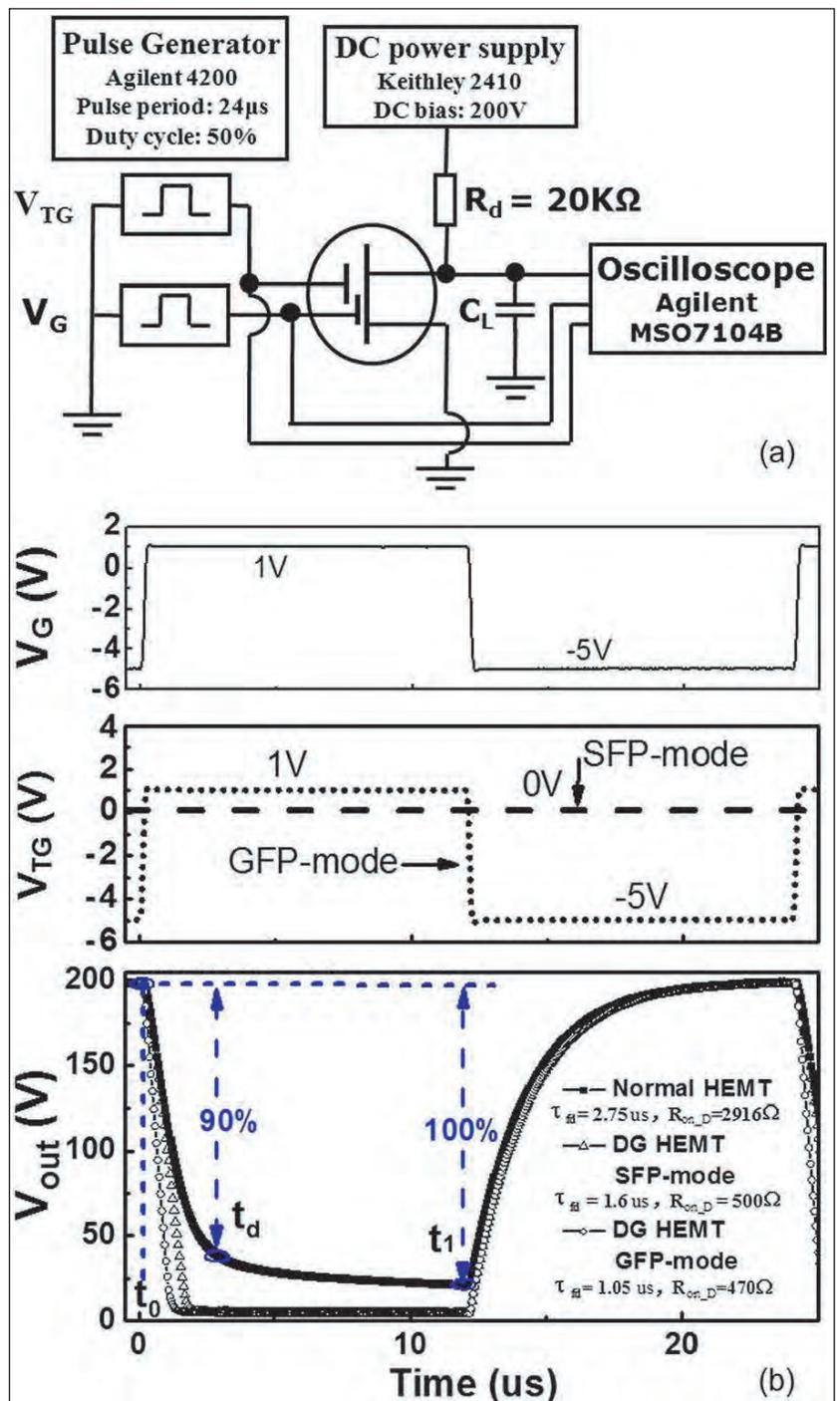


Figure 2. (a) Schematic of the dynamic testing system. (b) Input pulse signals and drain output voltage (V_o) waveforms of DG-HEMT working at SFP and GFP modes and in a normal HEMT.

tron injection/trapping from the gate edge into the AlGaIn barrier in the off-state.

The researchers conclude that the GFP improves dynamic performance more than the SFP does, which is explained by two factors: 2DEG compensation during the ON-state; and less negative charge trapping during the OFF-state. ■

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Author: Mike Cooke

Balanced record for InAlGaN high-electron-mobility transistor

Notre Dame and IQE use InAlGaN barrier layers to achieve f_T and f_{max} cut-off frequencies of 230GHz and 300GHz for a GaN HEMT.

University of Notre Dame (UND) in the USA and epiwafer maker IQE have claimed record-breaking balanced frequency performance for a nitride semiconductor high-electron-mobility transistor (HEMT) using indium aluminium gallium nitride (InAlGaN) barriers [Ronghua Wang et al, IEEE Electron Device Letters, published online 23 January 2013].

Nitride HEMTs with rectangular gates can have high-performance current-gain cut-offs (f_T), while power-gain cut-off frequencies (f_{max}) are enhanced by using T-shaped gate profiles. Ideally the two cut-off frequency characteristics should be close to one another for best performance. Using a rectangular gate reduces parasitic capacitance; T-gates are more conductive.

The UND/IQE devices used InAlGaN barriers to enhance the channel mobility, allowing a T-gate to be used. The epitaxial structure (Figure 1) was grown on silicon carbide (SiC) using metal-organic chemical vapor deposition (MOCVD). The ohmic contact metal electrodes consisted of titanium/gold on 140nm-thick n-GaN source-drain regions re-grown using molecular beam epitaxy (MBE). The source-drain distance was 0.8 μ m.

T-gates were produced that consisted of nickel/gold. There was no passivation. The width of the T-gate was 2 μ m x 2 μ m. The stem height was ~100nm. The head of the T was 350–400nm and the foot was 40–100nm.

Hall measurements gave the epitaxial material a sheet resistance of 195 Ω /square, a carrier density of 1.8x10¹³/cm², and mobility of 1770cm²/V-s.

The maximum drain current for a 40nm gate device was 1.8A/mm at 1V gate potential. The peak extrinsic transconductance of the same device was 770mS/mm. The current-gain (f_T) and power-gain (f_{max}) cut-off frequencies (Figure 2a) were 230GHz and 300GHz, respectively (133/260GHz before de-embedding). The drain bias for the transconductance and frequency measurements was 5.6V.

The geometric mean of f_T and f_{max} (square root of product) was 263GHz. The balanced frequency performance is claimed as a record for devices with InAlGaN barriers (with no back-barrier). The researchers

Barrier	In _{0.15} Al _{0.85} Ga _{0.04} N	11nm
Spacer	AlN	1nm
Channel	GaN	55nm
Buffer	Seminsulating Ga	1.8 μ m
Nucleation	AlN	100nm
Substrate	SiC	

Figure 1. Epitaxial structure of HEMTs.

The geometric mean of f_T and f_{max} (square root of product) was 263GHz. The balanced frequency performance is claimed as a record for devices with InAlGaN barriers (with no back-barrier)...

Incorporation of re-grown contacts with a lower contact resistance and use of shorter gate lengths in conjunction with back-barriers (provided this is done without compromising the channel mobility) promise f_T/f_{max} near 350GHz

reference as the previous best a 30nm-gate device with InAlN barrier that achieved f_T/f_{max} of 205/220GHz, reported in 2011 by Switzerland's ETH Zurich. They also compare their device with a range of other reports from the research literature (Figure 2b).

The UND/IQE devices did show larger extrinsic parasitic delay effects due to the capacitance arising from the T-head of the gate compared with rectangular gates. The researchers believe this effect can be reduced by lengthening the T-stem to more than 200nm. Also, gate recessing would be beneficial in increasing transconductance.

The researchers add: "Furthermore, incorporation of re-grown contacts with a lower contact resistance and use of shorter gate

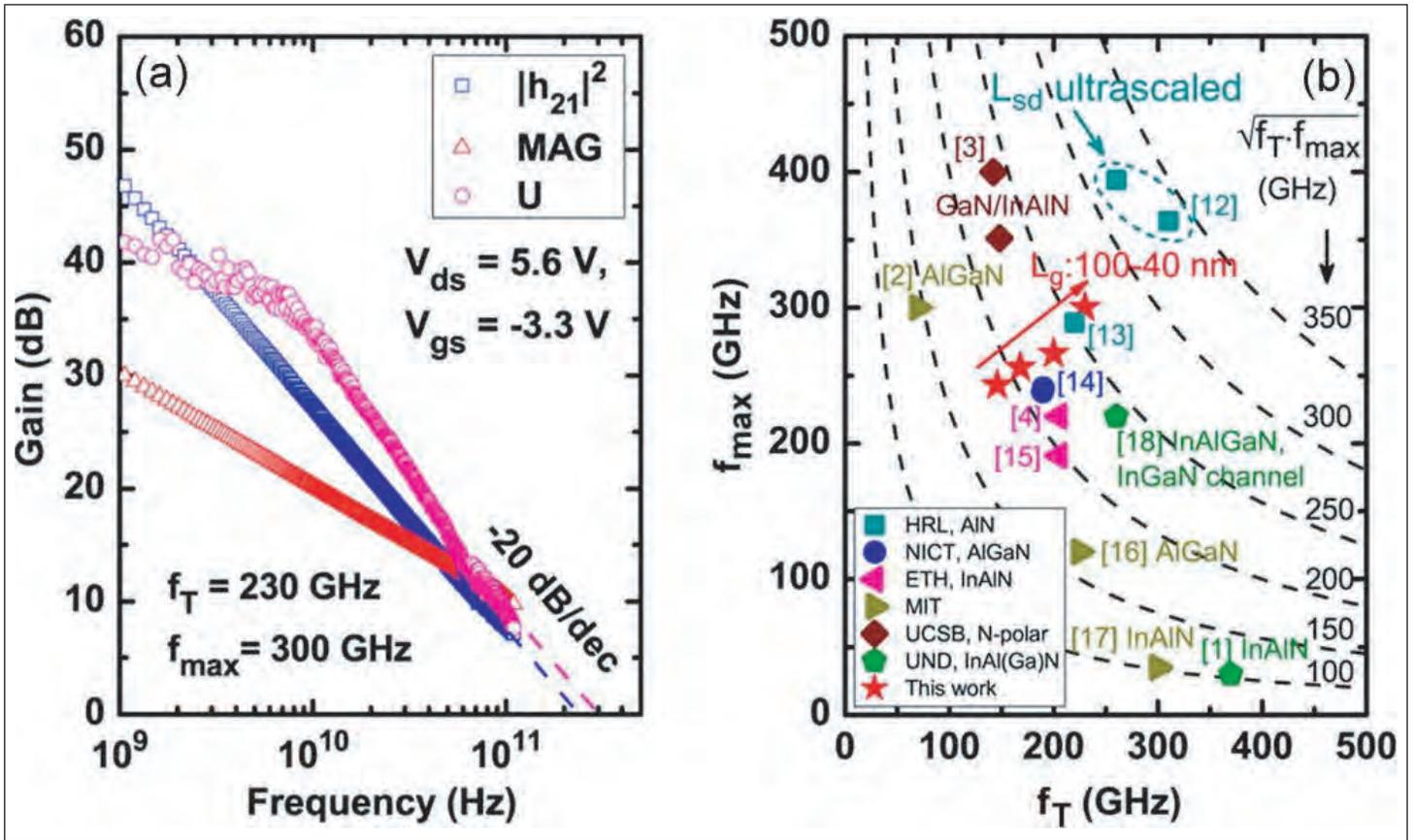


Figure 2. (a) Small-signal RF performance of a 40nm-long HEMT showing $f_T/f_{max} = 230/300$ GHz. (b) Comparison of f_T and f_{max} of Notre Dame/IQE devices with state-of-the-art depletion-mode (normally-on) GaN-based HEMTs from research literature. The 'Lsd ultrascaled' devices (2011) included back-barriers.

lengths in conjunction with back-barriers (provided this is done without compromising the channel mobility) promise f_T/f_{max} near 350GHz."

This work was financially supported by the US Defense Advanced Research Projects Agency's Nitride Electronic NeXt-Generation Technology program,

the US Air Force Office of Scientific Research, and the US Air Force Research Laboratory/Missile Defense Agency. ■

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Author: Mike Cooke

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Etch stop structure opens up gate recess improvement for GaN MISFET

MIT has achieved a maximum effective mobility of $1131\text{cm}^2/\text{V}\cdot\text{s}$, significantly better than other reported results.

A team at Massachusetts Institute of Technology has developed an etch stop technique to improve performance of recessed-gate nitride semiconductor metal-insulator-semiconductor field-effect transistors (MISFETs) [Bin Lu et al, IEEE Electron Device Letters, published online 24 January 2013].

Recessing involves etching the top barrier layers of nitride heterostructure FETs to bring the gate closer to the two-dimensional electron gas (2DEG) channel. This increases the electrostatic control and also tends to shift the threshold voltage from negative to positive values. Positive thresholds give normally-off/enhancement-mode operation for the transistor. Normally-off operation is preferred for fail-safe power switching and low-power consumption.

However, recessing usually involves plasma etching that damages the semiconductor heterostructure, reducing performance. In particular, plasma damage creates a high density of defect states, degrading the channel mobility in the recessed region. This increases on-resistance.

Another problem is that the etch process is difficult to control, creating unpredictable device performance. This becomes even worse when different recessing is needed in devices being fabricated at the same time because the etch process proceeds at different rates according to the aspect ratio of the recessed region.

The MIT researchers have developed the new barrier structure to enable them to overcome these problems, significantly improving performance.

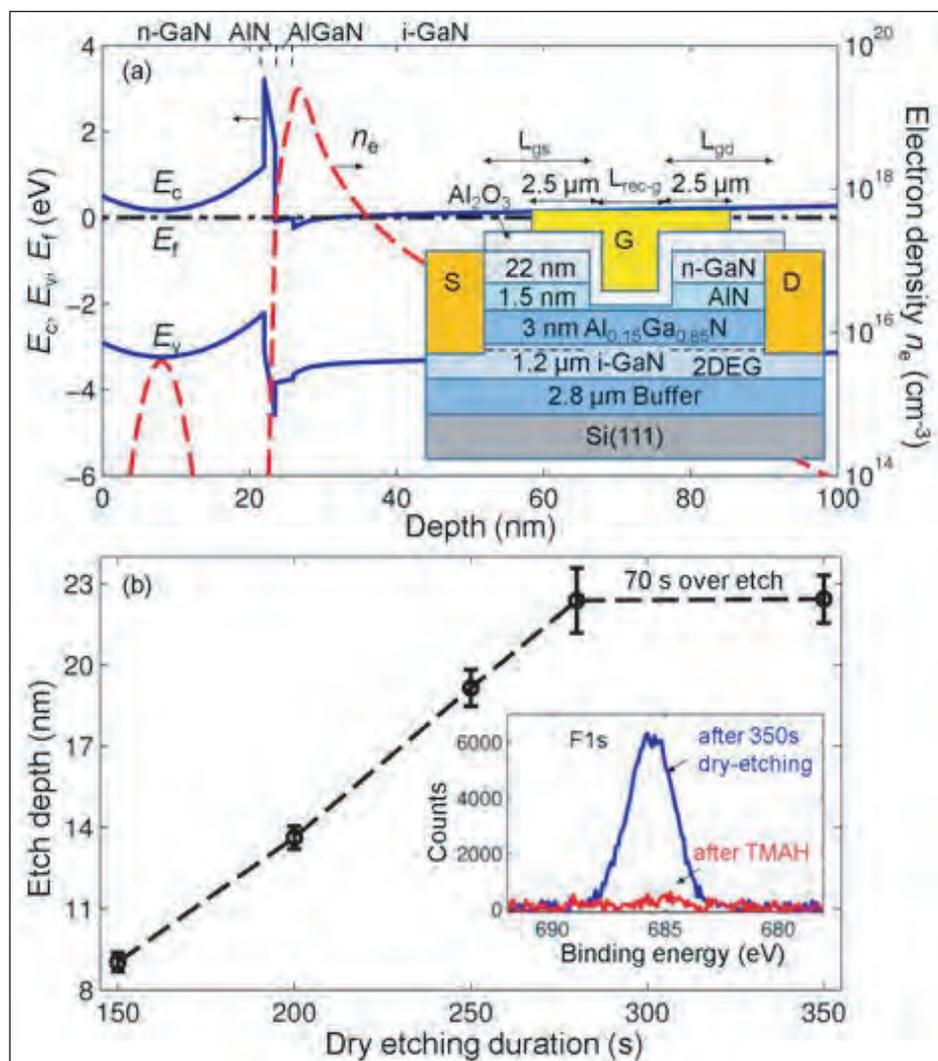


Figure 1: (a) Band structure and electron density profile of MIT wafer structure. Inset shows relevant dimensions of recessed-gate GaN MISFET. (b) Recess depth as a function of etch duration. Inset: XPS F1s signal of sample dry-etched for 350 seconds and subsequently wet-etched by TMAH.

The epitaxial structure (Figure 1a inset) was grown on 4-inch (111) p-type silicon using metal-organic chemical vapor deposition (MOCVD). The top n-type gallium nitride (GaN) layer was doped with silicon at a concentration of $3\text{--}6 \times 10^{18}/\text{cm}^3$. The effect of the

doping is to deplete the maximum electron density in the n-GaN to less than $10^{16}/\text{cm}^3$ (Figure 1a).

The 2DEG characteristics are sheet resistance $580\Omega/\text{square}$, electron mobility $1530\text{cm}^2/\text{V}\cdot\text{s}$, and sheet charge density $7 \times 10^{12}/\text{cm}^2$.

Devices were isolated from each other through mesa etching. The ohmic metal electrodes for the source-drain contacts consisted of titanium/aluminium/nickel/gold.

The gate recess etch used the selectivity for n-GaN over AlN of a fluorine-based electron-cyclotron-resonance reactive ion etching (ECR-RIE). The selectivity arises from the non-volatility of aluminium fluoride (AlF_3). The etch gas recipe consisted of 5 standard cubic centimeters per minute (sccm) of boron trichloride and 35sccm of sulfur hexafluoride at 35mtorr. The etch time of 350 seconds was found to completely remove the n-GaN layer (Figure 1b). A further 70 seconds of over-etch time was added.

The dry etch damage was repaired by first oxidizing the exposed AlN and wet etching in tetramethylammonium hydroxide (TMAH) at room temperature for 1 minute. X-ray photoelectron spectroscopy (XPS) analysis showed much reduced fluorine at the AlN surface after the treatment (Figure 1b inset).

The AlN surface was further cleaned with ultraviolet-ozone and hydrochloric acid before atomic layer deposition (ALD) and annealing of aluminium oxide dielectric as gate insulation. The T-gate metal electrode consisted of nickel/gold. Finally a further annealing step was then carried out to reduce the positive fixed charge that can arise in aluminium oxide.

The threshold voltage of a $3\mu\text{m}$ gate device was positive, at $+0.3\text{V}$, indicating normally-off enhancement-mode operation (Figure 2).

The subthreshold swing was $62\text{mV}/\text{dec}$, a value close to the $60\text{mV}/\text{dec}$ room-temperature limit for planar-gate devices. In fact, a comparison (i.e. non-recessed) planar-gate device had a somewhat higher swing of $76\text{mV}/\text{dec}$.

The on-resistance of the devices was similar, at around $10\Omega\cdot\text{mm}$, with a source-drain distance of $11\mu\text{m}$. The maximum drain current was relatively low, the researchers write, "due to the large gate length and gate-to-source distance, relatively low 2DEG density ($7.1 \times 10^{12}/\text{cm}^2$) and high contact resistance ($1.2\Omega\cdot\text{mm}$) of the non-optimized ohmic contact."

The maximum effective mobility of the recessed

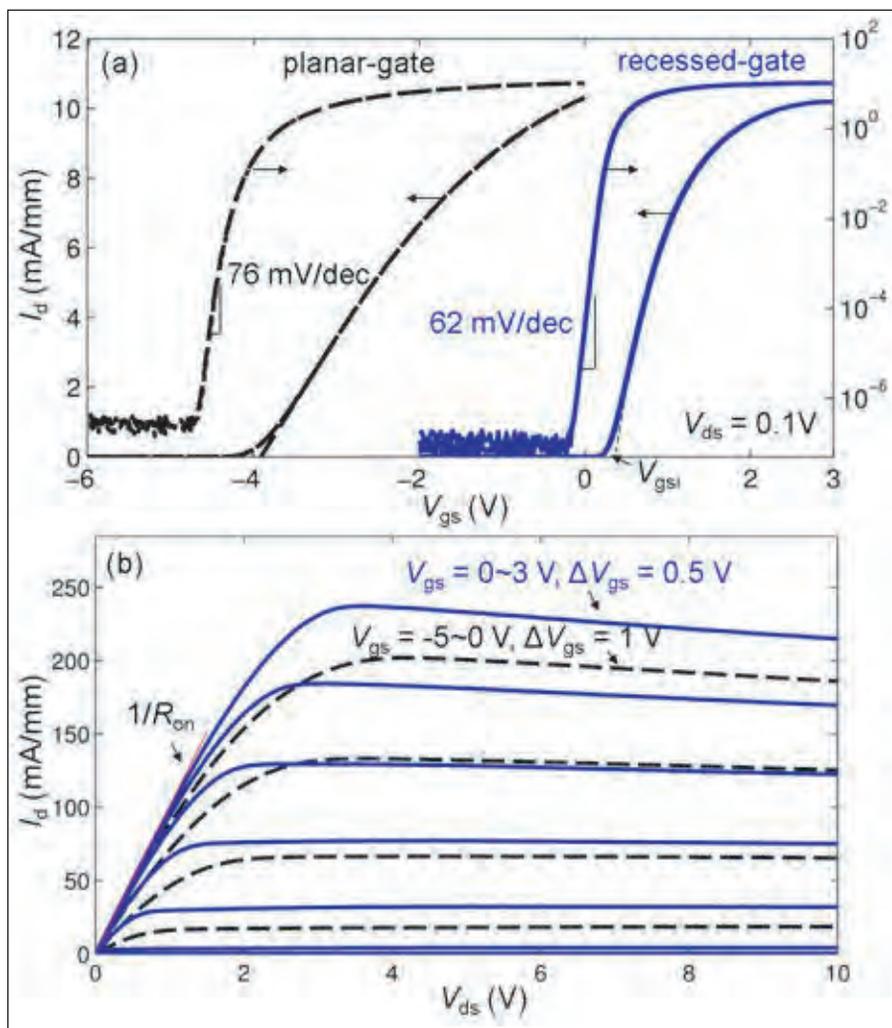


Figure 2: (a) I_d - V_{gs} characteristics at $V_{ds} = 0.1\text{V}$ with bi-directional gate sweep; (b) I_d - V_{ds} characteristics. The recessed-gate transistor had $L_{\text{rec-g}} = 3\mu\text{m}$ and $L_{\text{gs}} = L_{\text{gd}} = 4\mu\text{m}$. The planar-gate transistor (dashed line) has same L_{sd} with $L_g = 8\mu\text{m}$ and $L_{\text{gs}} = L_{\text{gd}} = 1.5\mu\text{m}$.

device extracted from capacitance-voltage (CV) measurements was $1131\text{cm}^2/\text{V}\cdot\text{s}$, somewhat lower than the Hall value of the 2DEG given above. However, the effective value is significantly better than other reported results on normally-off GaN MISFETs, according to the researchers.

Further CV measurements led the researchers to conclude: "The recessed-channel dielectric/semiconductor interface has very low interface state density, which results in small hysteresis and frequency dispersion in the CV measurements."

Three-terminal breakdown was also measured at 50V for 0V gate, gate-length $3\mu\text{m}$, gate-drain $12\mu\text{m}$ and drain leakage $68\text{nA}/\text{mm}$.

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Author: Mike Cooke

High-frequency InAs quantum well transistors for future system on chip and RF

Researchers in the USA have achieved the best combination of cut-off frequency and maximum oscillation frequency ever reported for any III–V MOSFET technology.

Researchers from GLOBALFOUNDRIES, SEMATECH and Massachusetts Institute of Technology (MIT) have extended their indium arsenide quantum well metal-oxide-semiconductor field-effect transistor (InAs QW MOSFET) technology to some of the highest and most balanced frequency performance yet seen [Dae-Hyun Kim et al, IEEE Electron Device Letters, published online 4 January 2013]. Many of the improvements in the latest work are attributed to the dramatically higher quality interface between dielectrics and III-V semiconductors enabled by atomic layer deposition (ALD) techniques developed in the last few years.

The device material was grown on an indium phosphide (InP) substrate (Figure 1). The structure featured a 300nm indium aluminium arsenide ($\text{In}_{0.52}\text{Al}_{0.48}\text{As}$) back barrier/buffer, silicon delta-doping, a 5nm InAlAs spacer, a 10nm channel, a 2nm InP etch stop, and a 10nm indium gallium arsenide ($\text{In}_{0.53}\text{Ga}_{0.47}\text{As}$) cap. The channel consisted of an InGaAs/InAs/InGaAs sandwich. The structure had a room-temperature Hall mobility of $8000\text{cm}^2/\text{V}\cdot\text{s}$ and sheet carrier density of $1 \times 10^{12}/\text{cm}^2$.

Transistor formation consisted of mesa isolation, molybdenum/titanium/molybdenum/gold ohmic source-drain, silicon dioxide (SiO_2) plasma-enhanced chemical vapor deposition (PECVD), electron-beam lithographic patterning and plasma/wet etch of the gate recess, atomic layer deposition of the 3nm aluminium oxide (Al_2O_3) gate insulator, and deposition of a palladium/gold gate electrode.

A 100nm-gate-length device demonstrated a positive threshold of 0.2V for $1\mu\text{A}/\mu\text{m}$ drain current at 0.5V drain bias. A positive threshold is desired for low-power-consumption enhancement-mode/normally-off transistors. The subthreshold swing was relatively low, at 105mV/dec, and the drain-induced barrier lowering was 100mV/V. These values are described as 'excellent' in the research paper.

The gate leakage was suppressed to less than $1\text{nA}/\mu\text{m}$ at all measured biases by the Al_2O_3 insulation. This is a factor of 10^5 better than the forward bias values typical of III-V high-electron-mobility transistors (HEMTs) that depend on metal-semiconductor Schottky barriers to isolate the gate electrode.

The on-resistance for the InAs QW MOSFET at 0.8V

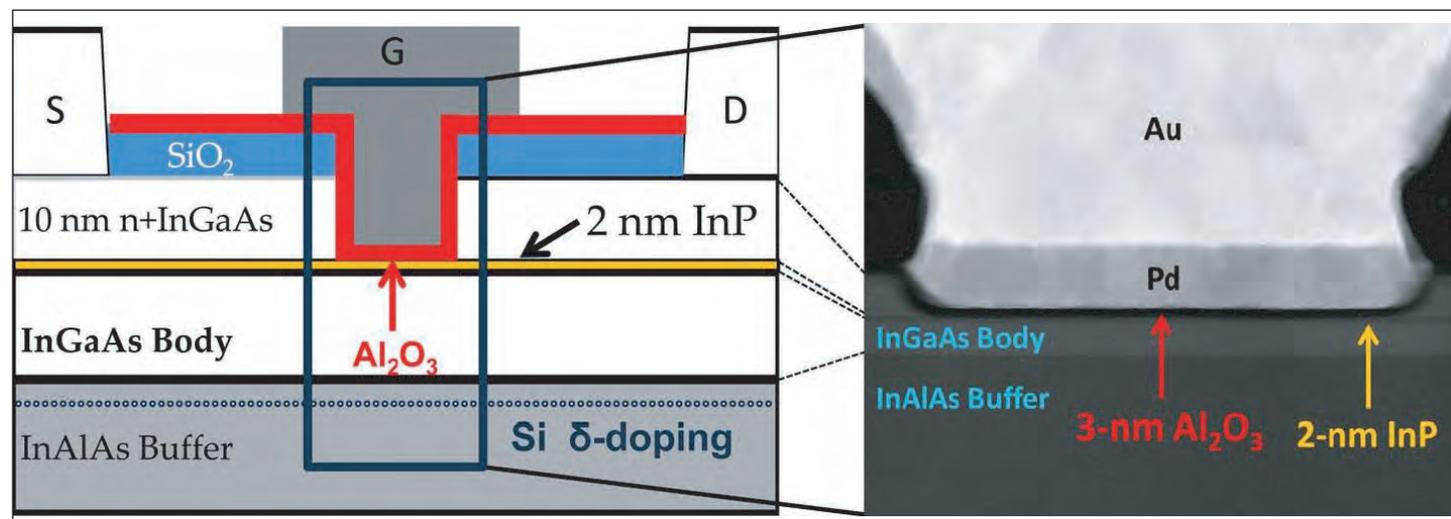


Figure 1. (Left) Device schematic and (right) transmission electron micrograph (TEM) image for the cross section of 100nm InAs MOSFETs with 3nm Al_2O_3 .

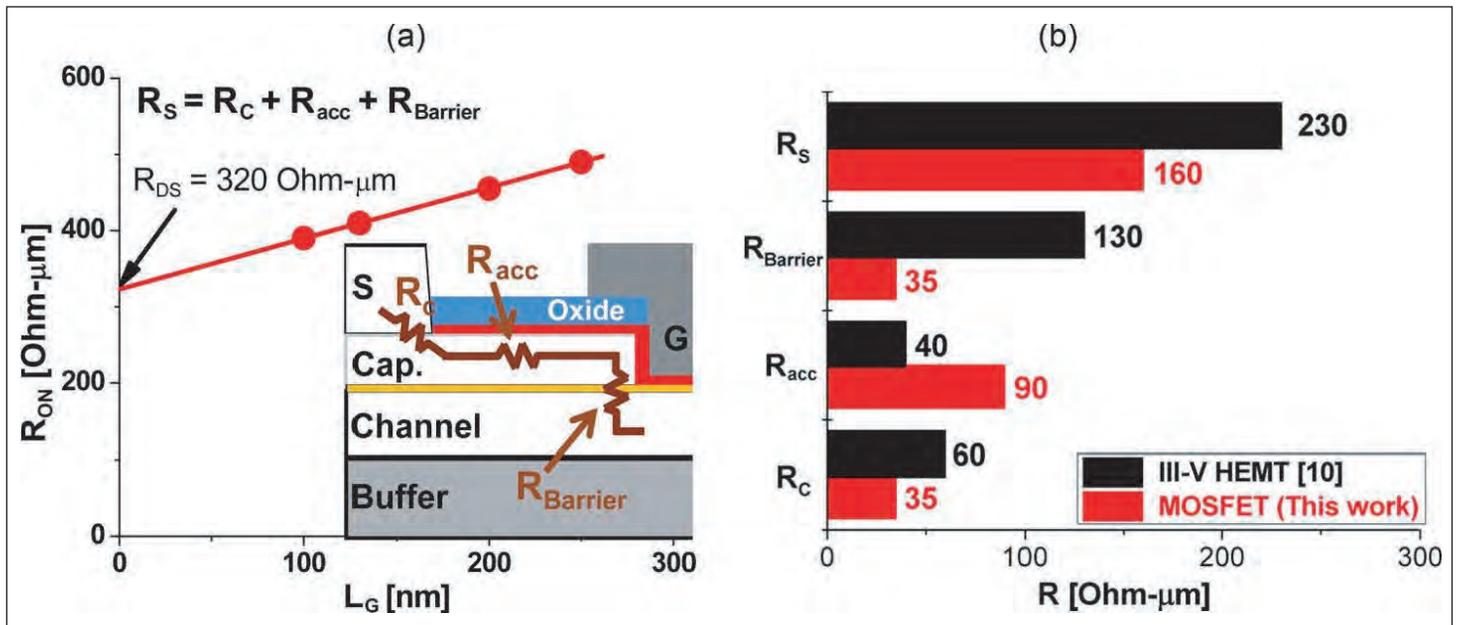


Figure 2. (a) R_{ON} as a function of L_G for InAs MOSFETs and (inset) simple model for R_S and (b) extracted components for R_S which arise from transmission line method (TLM) and R_{ON} analysis.

gate potential was $370 \Omega\text{-}\mu\text{m}$. The researchers comment: "This outstanding R_{ON} contributes to the maximum transconductance ($g_{m,max}$) = $1720 \mu\text{S}/\mu\text{m}$ at $V_{DS} = 0.5\text{V}$."

The frequency dependence of the devices was tested between 0.5GHz and 50GHz. The cut-off frequency (f_T) of a 100nm-gate device of width $2 \times 20 \mu\text{m}$ was 248GHz. The maximum oscillation (f_{max}) was 302GHz. The researchers write: "To the knowledge of the authors, these are the best combination of f_T and f_{max} at $V_{DS} = 0.5\text{V}$ ever reported in any III-V MOSFET technology, and approach to advanced III-V HEMTs with similar gate lengths."

The researcher concluded with an analysis of the source resistance (R_S) obtained by comparing devices

with different gate lengths (L_G). The team used a model that decomposed R_S into three terms: contact resistance (R_C) between the non-alloyed ohmic metal electrode and n^+ -GaN semiconductor, access resistance (R_{acc}) between the ohmic and gate regions, and, finally the resistance of the InP etch stop barrier ($R_{Barrier}$). The researchers believe the dominant component is R_{acc} , which was estimated to be around 56% of the total (Figure 2). The application of a self-aligned ohmic contact process design is expected to significantly reduce the source resistance in the future. ■

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Author: Mike Cooke

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Chicago, USA
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Fax: +1 312 544 7188
metalorganicsNA@akzonobel.com

Europe, Middle East and Africa:

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Fax: +1 510 790 6241
www.mathesontrigas.com

Mining & Chemical Products Ltd
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Power + Energy Inc

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USA
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www.praxair.com/electronics

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Tel: +44 151 334 2774
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Fax: +1 716 833 2926
www.williams-adv.com

6 Deposition equipment

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www.riber.com

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USA
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Fax: +1 952 934 2737
www.svta.com

Temescal, a part of Ferrotec

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MicroChem Corp

1254 Chestnut St. Newton,
MA 02464,
USA

Tel: +1 617 965 5511

Fax: +1 617 965 5818

www.microchem.com

Power + Energy Inc

(see section 10 for full contact details)

Praxair Electronics

(see section 5 for full contact details)

8 Wafer processing equipment

EV Group

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Plasma-Therm LLC

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Power + Energy Inc

(see section 10 for full contact details)

SAMCO International Inc

532 Weddell Drive,
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Tel: +1 408 734 0459

Fax: +1 408 734 0961

www.samcointl.com

SPP Process Technology Systems Ltd

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Veeco Instruments Inc

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9 Materials & metals

Goodfellow Cambridge Ltd

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www.cambridge-fluid.com

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Germany

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www.csleansystems.com

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Fax: +1 215 942-9300

www.powerandenergy.com

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San Luis Obispo, CA 93401,
USA

Tel: +1 805 541 9299

Fax: +1 805 541 9399

www.saesgetters.com

11 Process monitoring and control

k-Space Associates Inc

2182 Bishop Circle
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MI 48130, USA

Tel: +1 734 426 7977

Fax: +1 734 426 7955

www.k-space.com



k-Space Associates Inc specializes in in-situ, real-time thin-film process monitoring tools for MBE, MOCVD, PVD, and thermal evaporation. Applications and materials include the research and production line monitoring of compound semiconductor-based electronic, optoelectronic, and photovoltaic devices.

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LayTec AG

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Germany
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Fax: +49 30 3180 8237
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.

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www.wepcontrol.com

12 Inspection equipment

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Germany
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Fax: +49 (0)721 595 4587
www.bruker-axs.de

13 Characterization equipment

J.A. Woollam Co. Inc.

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Tel: +1 402 477 7501
Fax: +1 402 477 8214
www.jawoollam.com

Lake Shore Cryotronics Inc

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14 Chip test equipment

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SUSS MicroTec Test Systems

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Waterbury Center, VT 05677,
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Tel: +1 800 685 7877
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www.suss.com

15 Assembly/packaging materials

ePAK International Inc

4926 Spicewood Springs Road,
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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

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(see section 3 for full contact details)

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Fax: +1 716 833 2926
www.williams-adv.com

16 Assembly/packaging equipment

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2301, Switzerland
Tel: +41 329257111
Fax: +41 329257115
www.ismeca.com

Kulicke & Soffa Industries

1005 Virginia Drive,
Fort Washington, PA 19034, USA
Tel: +1 215 784 6000
Fax: +1 215 784 6001
www.kns.com

Palomar Technologies Inc

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Carlsbad, CA 92010, USA
Tel: +1 760 931 3600
Fax: +1 760 931 5191
www.PalomarTechnologies.com

TECDIA Inc

2700 Augustine Drive, Suite 110,
Santa Clara, CA 95054, USA
Tel: +1 408 748 0100
Fax: +1 408 748 0111
www.tecdia.com

17 Assembly/packaging foundry

Quik-Pak

10987 Via Frontera,
San Diego, CA 92127, USA
Tel: +1 858 674 4676
Fax: +1 8586 74 4681
www.quikicpak.com

18 Chip foundry

Compound Semiconductor Technologies Ltd

Block 7, Kelvin Campus,
West of Scotland, Glasgow,
Scotland G20 0TH,
UK

Tel: +44 141 579 3000

Fax: +44 141 579 3040

www.compoundsemi.co.uk

United Monolithic Semiconductors

Route departementale 128,
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France

Tel: +33 1 69 33 04 72

Fax: +33 169 33 02 92

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19 Facility equipment

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USA

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Fax: +1 541 917 3623

www.marlerenterprises.net

20 Facility consumables

W.L. Gore & Associates

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Fax: +1 410 506 8749

www.gore.com

21 Computer hardware & software

Ansoft Corp

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Pittsburgh, PA 15219,
USA

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Fax: +1 412 471 9427

www.ansoft.com

Crosslight Software Inc

121-3989 Henning Dr.,
Burnaby, BC, V5C 6P8,
Canada

Tel: +1 604 320 1704

Fax: +1 604 320 1734

www.crosslight.com

Semiconductor Technology Research Inc

10404 Patterson Ave., Suite 108,
Richmond, VA 23238,
USA

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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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Tel: + 33 (0)1 30 47 29 03

E-mail: jean-luc.ledys@neuf.fr

25 Resources

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15–17 April 2013

9th International Conference on Concentrator Photovoltaic Systems (CPV-9)

Phoenix Seagaia Resort, Miyazaki, Japan

E-mail: info@cpv-9.org

www.cpv-9.org

29 April – 3 May 2013

SPIE Defense, Security, and Sensing 2013

Baltimore Convention Center, Maryland, USA

E-mail: customerservice@spie.org

<http://spie.org/defense-security-sensing.xml>

5–8 May 2013

IEEE Optical Interconnects Conference (OI Conference 2013)

Eldorado Hotel & Spa, Santa Fe, NM, USA

E-mail: m.figueroa@ieee.org

www.oi-ieee.org

12–16 May 2013

World of Photonics Congress, incorporating European Conference on Lasers and Electro-Optics and International Quantum Electronics Conference (CLEO/Europe-IQEC 2013)

International Congress Centre Munich (ICM), Germany

E-mail: info@photonics-congress.com

www.world-of-photonics.net/en/photonics-congress/start

13–16 May 2013

21st LASER World of Photonics

Messe München, Munich, Germany

E-mail: info@world-of-photonics.net

www.world-of-photonics.net

12–17 May 2013

223rd Electrochemical Society (ECS) Meeting

Toronto, Ontario, Canada

E-mail: meetings@electrochem.org

www.electrochem.org/meetings/biannual/fut_mtgs.htm

13 May 2013

JEDEC's 28th Annual ROCS (Reliability of Compound Semiconductors) Workshop

Hilton New Orleans Riverside, New Orleans, LA, USA

E-mail: ptanner@jedec.org

www.jedec.org/home/gaas

13–16 May 2013

2013 CS MANTECH: International Conference on Compound Semiconductor Manufacturing Technology

Hilton New Orleans Riverside, New Orleans, LA, USA

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www.csmantech.org

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2–5 June 2013

15th European Workshop on Metalorganic Vapour Phase Epitaxy (EWMOVPE 2013)

Technology Centre in Aachen, Germany

E-mail: ewmovpe2013@jara.org

www.jara.org/index.php?id=606

5–6 June 2013

SEMI CON Russia 2013

Moscow, Russia

E-mail: eweller@semi.org

www.semiconrussia.org/en

24–25 June 2013

euroLED 2013

The ICC, Birmingham, UK

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www.euroLED.org.uk

1–2 July 2013

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www.greenworldconferences.com

9–11 July 2013

SEMICON West 2013

San Francisco, CA, USA

E-mail: semiconwest@xpressreg.net

<http://semiconwest.org>

22–23 July 2013

SolarTech Expo India 2013

New Delhi, India

E-mail: ds@greenworldconferences.com

www.greenworldconferences.com

4–10 August 2013

15th Summer School on Crystal Growth (ISSCG-15)

Gdansk, Poland

E-mail: isscg15@mif.pg.gda.pl

<http://science24.com/event/isscg15>

5–6 August 2013

SolarTech Expo Spain 2013

Valencia, Spain

E-mail: ds@greenworldconferences.com

www.greenworldconferences.com

11–16 August 2013

17th International Conference on Crystal Growth and Epitaxy (ICCGE-17)

Warsaw, Poland

E-mail: iccge17sec@mail.unipress.waw.pl

<http://science24.com/event/iccge17>

25–29 August 2013

SPIE Optics + Photonics 2013

San Diego Convention Center, CA, USA

E-mail: customerservice@spie.org

<http://spie.org/optics-photonics.xml>

4–6 September 2013

SEMI CON Taiwan 2013 - LED Taiwan 2013

TWTC Nangang Exhibition Hall, Taipei, Taiwan

E-mail: ali@semi.org

www.semicontaiwan.org/en

22–26 September 2013

39th European Conference on Optical Communications (ECOC 2013)

ExCeL London Exhibition Centre, London, UK

E-mail: carina.meakins@nexusmediaevents.com

www.ecoc2013.org

23–26 September 2013

SPIE Security+Defence 2013

Internationales Congress Centre Dresden, Germany

E-mail: info@spieeurope.org

<http://spie.org/security-defence-europe.xml>

23–26 September 2013

SPIE Remote Sensing 2013

Internationales Congress Centre Dresden, Germany

E-mail: info@spieeurope.org

<http://spie.org/remote-sensing-europe.xml>

23–26 September 2013

5th International Conference on One dimensional Nanomaterials (ICON 2013)

Annecy, France

E-mail: icon2013@grenoble.cnrs.fr

www.icon2013.fr

24–26 September 2013

3rd International LED professional Symposium + Expo (LpS 2013)

Bregenz, Austria

E-mail: symposium@led-professional.com

www.led-professional-symposium.com

30 September – 4 October 2013

28th European Photovoltaic Solar Energy Conference and Exhibition (EU PVSEC 2013)

Parc des Expositions Paris Nord Villepinte, Paris, France

E-mail: press@wip-munich.de

www.photovoltaic-conference.com

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