

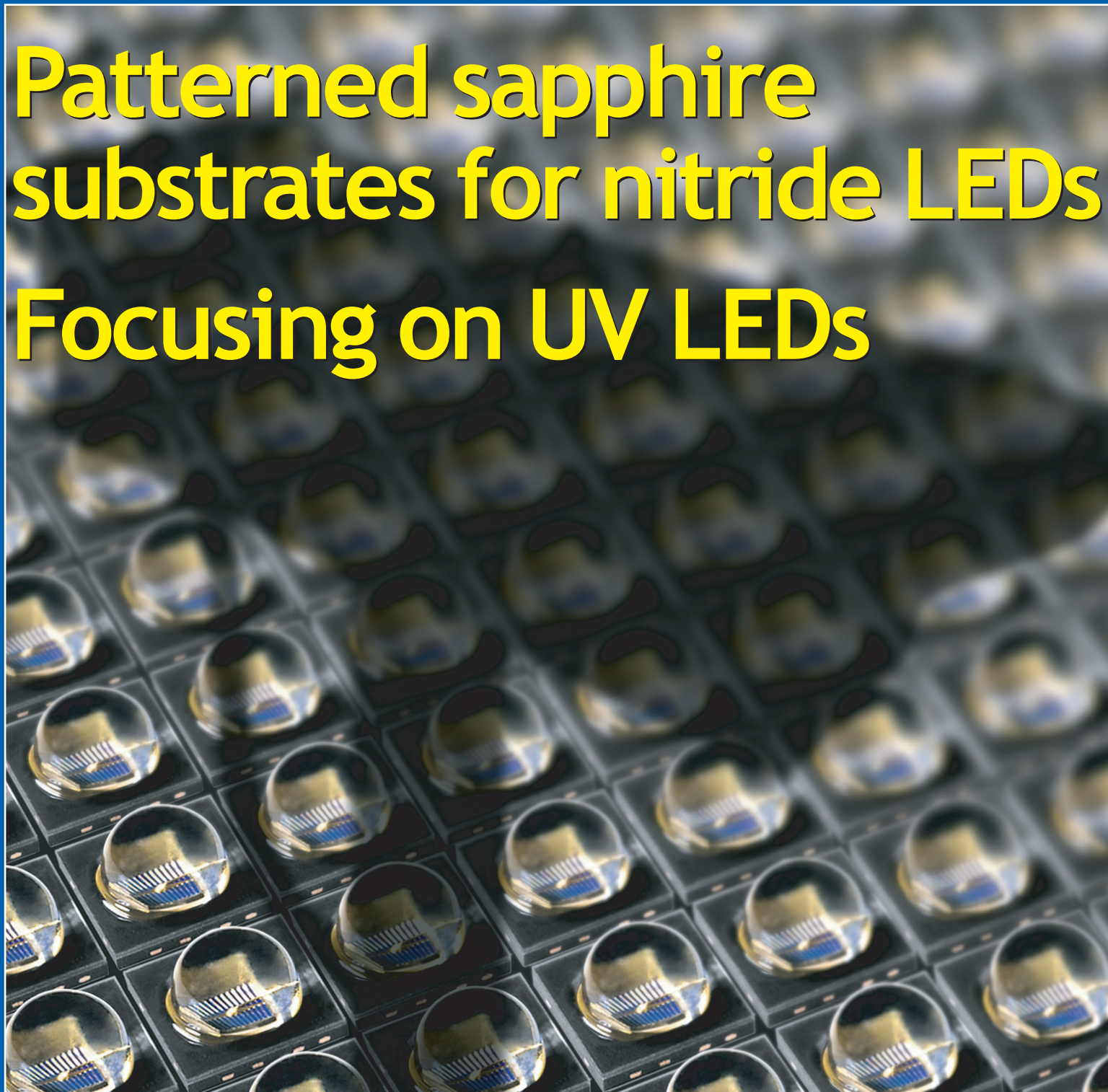
semiconductor TODAY

COMPOUNDS & ADVANCED SILICON

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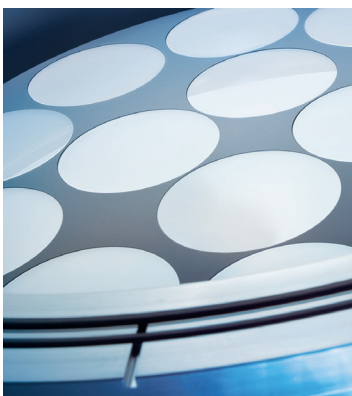
Patterned sapphire substrates for nitride LEDs Focusing on UV LEDs



RFMD forms Compound Semi Group • NeoPhotonics buys Santur
Veeco opens Taiwan center • Acreo spins off Ascatron

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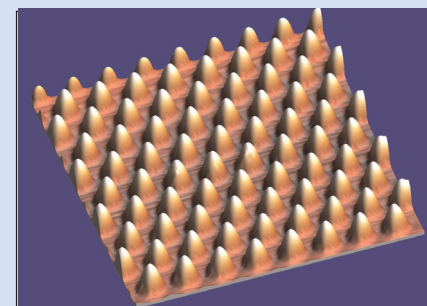
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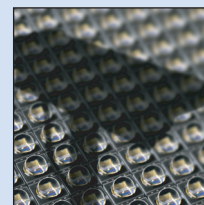
p22 SemiSouth's new SDB05S120 1200V/5A SiC Schottky diodes in true surface-mount packages.



p26 Jennifer Cormack, SiC manager at Raytheon UK's Glenrothes facility, receiving Operations Excellence award.



p100 Formerly flat, truncated shapes polished and rounded by wet etch of patterned sapphire substrate.



Cover: Osram Opto Semiconductors' new IR OSLOLON SFH 4715S, which is claimed to be the smallest infrared LED with more than 1W of optical power.

The device measures just 3.75mm x 3.75mm and hence can facilitate very compact illumination units for CMOS and CCD cameras. **p67**

Patterns of development

In this issue we include a focus on patterned sapphire substrates, and how they can be used as a low-cost method for improving the performance of nitride-based LEDs and solar cells (see page 120). As an example, on page 118 we report how Taiwanese researchers have developed a sapphire nanopatterning technique that increases the external quantum efficiencies of nitride LEDs by 2.4x over devices grown on conventional sapphire. Following on from those articles, on page 125 Imtec Acculine discusses how high-temperature wet etching can be made to work for patterned sapphire substrates — as a cheaper, faster and more scalable alternative to dry etching — even if polishing touch-up work is required on the wafers to increase light extraction efficiencies.

Also in this issue we focus on ultraviolet LEDs in a series of articles on pages 110, 112 and 114 that give examples of some of the many device structures and methods aimed generally at pushing emission to shorter, deep UV wavelengths and increasing the emission intensity. Also, on page 108 we report what is claimed to be the first demonstration of a GaN-based planar metal-semiconductor-metal avalanche photodiode (APD) sensitive to ultraviolet light.

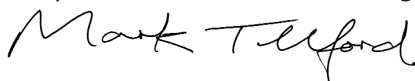
Elsewhere in the issue, on pages 6–8 we report how market research firms have been reducing their forecasts for full-year 2011 sales in the LED sector. This is driven by the slowdown in demand for TV backlighting and — more specifically — the subsidy-driven boom in MOCVD reactor sales in China turning to push-outs of orders by Chinese LED makers as credit has tightened. This has led to MOCVD system maker Aixtron reducing its full-year 2011 revenue guidance from €800–900m to €600–650m (see page 41). As we close for press, these trends are being confirmed in the third-quarter results and fourth-quarter guidance of not only Aixtron but also fellow MOCVD system maker Veeco (to be covered in detail next issue). However, in the longer-term, it is expected that a return to growth will be driven by the mass adoption of LED lighting.

In optical communications, two notable developments are the acquisition by Eurazeo Croissance of France's 3S Photonics (page 69), and the acquisition by NeoPhotonics of fellow photonic integrated circuit (PIC)-based firm Santur (page 72). Also, on pages 75–84, we cover the many product launches and demonstrations at this year's European Conference on Optical Communications (ECOC).

Just the week before we closed for press there was also news that the severe flooding that in recent weeks has claimed hundred of lives in Thailand has now shut down contract manufacturer Fabrinet's operations in Thailand until the end of 2011, with one plant flooded and a nearby plant cut off. Customers impacted include Opnext, Oclaro, JDSU and Infinera (see page 74). Fortunately, none of the above firms have reported any casualties among staff. However, all are currently in the process of shifting manufacturing to alternative sites, and expect fourth-quarter revenues to be impacted. The severity of the impact for each firm individually is perhaps dependent on the proportion of their production outsourced to contract manufacturing, and the ability to duplicate manufacturing at in-house facilities, but the event highlights the importance of second sourcing.

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

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

Regular issues contain:

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

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ALWAYS ONE STEP AHEAD



HIGHER PRODUCTIVITY // With almost 30 years of experience AIXTRON stands for proven engineering power and dedicated customer support: Our equipment serves a diverse range of customers to manufacture highest LED volumes at lowest cost.

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AIXTRON

LED capital spending forecast cut by 13% due to LED TV sales slowdown China market showcased in updated report

Recognizing the long-term potential of solid-state lighting and high-brightness LEDs, the Chinese government has supported both demand and supply sectors of the industry, estimated by some analysts to grow from about \$10bn in 2010 to over \$100bn worldwide by 2020, according to 'The China LED Fab Industry Report' of global industry association Semiconductor Equipment and Materials International (SEMI), which provides a summary of the rapidly growing China LED industry, including the latest data on capital and equipment spending, fab capacity, and sales rankings of Chinese LED makers. The report is prepared by SEMI China-based market analysts and is based on the SEMI Opto/LED Fab Watch and Forecast service that monitors LED capital spending at over 160 fabs worldwide.

In recent years, China and various local governments have adopted a series of industrial planning policies and incentives to promote the development of solid-state lighting. China has become the world's leading consumer of solid-state lighting and the leading producer of LCD TVs (currently the leading demand driver of high-brightness LEDs).

In response to these market developments, LED production investments have escalated rapidly. From 2010 to 2012, the report forecasts that gallium nitride (GaN) epitaxial wafer production capacity will grow more than 300% to 1,282,000 wafers per month (2-inch equivalents), with metal-organic chemical vapor deposition (MOCVD) system installations growing from a cumulative total of 323 tools in 2010 to over 1000 tools by the end 2012. Capitalizing on this growth, ten new sapphire substrate projects (a market cur-

rently dominated by non-Chinese suppliers) have been announced.

The latest update of the Opto/LED Fab Watch also reflects current LED capital and equipment spending dynamics resulting in the slowdown of LCD TV sales worldwide. The China LED market in particular both drives and reflects global LED demand and capital spending. Sales of LCD TVs (currently the primary application for LEDs) are expected to be down to 32 million units (compared with the previously expected 40 million), as LG, Sony, Samsung and Panasonic have all cut sales forecasts for the year. According to Digitimes, Taiwan-based LED firms reported July revenues down 6.35% for the month and 18.8% for the year. IMS Research forecasts a market of \$8.4bn in GaN devices in 2011, up only 4% on 2010.

The Opto/LED Fab Watch and Forecast service reflects the impact of the forces on LED capital and equipment spending and capacity on a global, regional and fab-by-fab basis. The latest update reduces the equipment spending forecast by 13% from the May report, but this is still a 23% increase over 2010 spending. The report provides details of these changes down to the fab level, including the movement of some spending by Taiwan LED makers to their China joint venture projects.

www.semi.org/node/38486

The latest update reduces the equipment spending forecast by 13% from the May report, but this is still a 23% increase over 2010 spending

III-V terrestrial CPV to grow at CAAGR of 75% Si-based PV to fall from 82% of installations to 74% by end-2016

Increasing demand for green energy solutions that will replace the global dependence on fossil fuels will push terrestrial photovoltaic installations to almost 200GW by 2016, with III-V compound semiconductor-based concentrator photovoltaics (CPV) technology growing at a compound average annual growth rate (CAAGR) of 75% for 2011–2016, forecasts the Strategy Analytics Gallium Arsenide and Compound Semiconductor Technologies (GaAs) service report 'Terrestrial Opportunities for Compound Semiconductor Photovoltaic'.

The terrestrial PV market was estimated to be worth over \$80bn in 2011, with conventional silicon-based technology dominating roughly 82% of the total market, and will grow at a CAAGR of 10% to \$100bn by 2016, forecasts market research firm Strategy Analytics.

"While conventional silicon-based technologies will continue to dominate PV installations, that will decline to 74% by the end of 2016," predicts Asif Anwar at Strategy Analytics. "Thin-film and CPV technologies will be the primary challengers to Si-based PV installations. Strategy Analytics predicts that the CPV market will grow at a faster rate than conventional PV technologies and account for almost 5% of new PV installations by 2016," he adds.

"Even though the performance capabilities of III-V CPV technologies are well established, deployment has been limited to date," notes Eric Higham, GaAs Service Director. "However, the III-V CPV industry has successfully established III-V CPV technologies as economical and competitive alternatives to conventional technology solutions."

www.strategyanalytics.com

IMS downgrades 2011 packaged LED market growth to 1% ...despite 29% rise in lighting revenues

After 60% growth in 2010, the gallium nitride (GaN) LED market is expected to pause in 2011, rising just 1% to \$8.7bn, according to IMS Research's latest 'Quarterly GaN LED Supply/Demand Report'.

The market research firm says the slowdown can be attributed to:

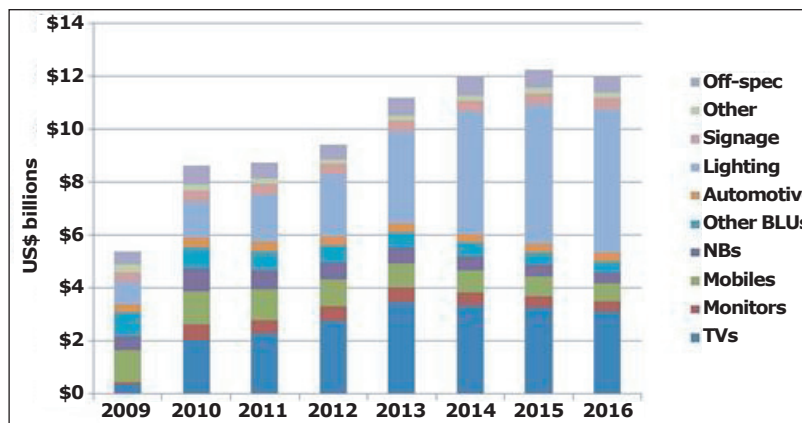
- Slower-than-expected growth in backlighting (which accounts for over 60% of GaN LED revenues). After 80% growth in 2010, backlighting is expected to fall 3% in 2011 to \$5.4bn, despite 36% unit growth due to aggressive price cuts.

- Supply growing more than two times faster than demand, as both existing players and many new entrants significantly expanded capacity in a disappointing year for demand, putting pressure on prices. Unyielded 2"-equivalent wafer capacity is expected to rise 67% in 2011 compared with a 29% increase in LED demand to 75bn die, causing the second-half 2010 surplus to widen in 2011.

- The growing over-supply has led to drops in average selling price (ASP) of up to 44% for 2011, depending on the segment, and a blended ASP decline of 21%. With costs falling more slowly than expected on under-utilization, margins have worsened for most LED makers.

"All the LED backlighting segments are expected to fall in revenues in 2011 except for TVs, which are now expected to rise 13%," says IMS Research senior VP Ross Young.

"However, the growth in TVs is not sufficient to offset the weakness in other segments," he adds. "In addition, the LED TV market is growing below expectations in 2011 on overall TV market weakness in developed countries which are most able to afford LED TVs and price sensitivity in the developing countries which are enjoying the fastest growth. As a result, we have revised downward our LED penetration into TVs from 45% to 43% in 2011, up from 23% in 2010, and from 73% to 68% in 2012."



Packaged LED revenue by application, 2009–2016 (in \$bn).

The lighting market is the fastest-growing application for packaged LEDs in 2011, rising 24% to \$1.7bn and reaching a 20% share of packaged LED revenues (up from 16% in 2010). Despite the rapid growth, LEDs are only expected to achieve a 1% unit share and 14% revenue share of the lighting market in 2011, leaving significant potential for future growth, notes IMS.

"Looking forward, we expect faster revenue growth for packaged LEDs through 2015, with both backlighting and lighting growing in 2012 and 2013 and lighting offsetting declines in backlighting in 2014 and 2015, with all major panel markets saturated by LEDs from 2014," says Young. "However, by 2016, lighting growth will slow and won't be able to offset the growing weakness in backlighting, worsened by gains from AMOLEDs [active-matrix organic LEDs]," he adds.

In its latest quarterly report, IMS has extended all forecasts to 2016, with the lighting market forecasted to 2020. LED lamp and luminaire revenues are expected to rise to \$74bn in 2020, reaching a 42% unit share and a 73% revenue share of the lighting market as costs and prices fall and incandescent bans take effect worldwide. However, by the end of the forecast period, LED growth is expected to slow on increased penetration and long lifetimes, with LED lamp revenues falling from 2018, limiting the

window for companies to take advantage of the growth in LED lighting.

In Q2/2011, LED TV panel shipments rose 22% quarter-

to-quarter and 82% year-on-year, but were 10% below suppliers' targets. LG Display remained top in TV panel and LED TV panel share, while Samsung led in LED consumption for TVs, at 1.2bn 20x40mil equivalents. The average number of 20x40mil LED equivalents per LED TV fell 6% quarter-to-quarter (to 165) on product mix changes.

LED monitor panels rose 5% quarter-to-quarter and 115% year-on-year to earn a 43% share, up from 41%. Q2/2011 LED monitor panel shipments were 13% below target due to weakness in the monitor market. LG Display led in monitor panels, LED panels and LED consumption.

In Q2/2011, notebook displays were 100% penetrated by LEDs for the first time. In Q3/2011, due to the strength of the tablet market, notebook panels measuring <10" are expected to overtake 14.x" panels as the second most popular size. LG overtook Samsung in notebook panels, LED panels and LED consumption.

IMS Research's latest Quarterly GaN LED Supply and Demand Report also tracks and forecasts MOCVD shipments, LED capacity by manufacturer, LED and MOCVD supply/demand, sapphire supply and demand, sapphire pricing, and quarterly notebook, monitor and TV panel shipments by backlight type, size, resolution and refresh rate.

www.ledmarketresearch.com

Strategies Unlimited lowers 2011 HB-LED revenue growth forecast to 9.8%

Expanding supply and slowing demand for TV backlighting depress LED prices

Revenues for high-brightness light emitting diodes (HB-LEDs) grew 108% to \$11.2bn in 2010, driven by applications in TV backlight units, according to the 'High-Brightness LED Market Review and Forecast - 2011' by Strategies Unlimited. Growth is quieting down though, as expanding supply and a slowdown in overall TV demand in 2011 pushed LED prices drastically lower, says the market research firm.

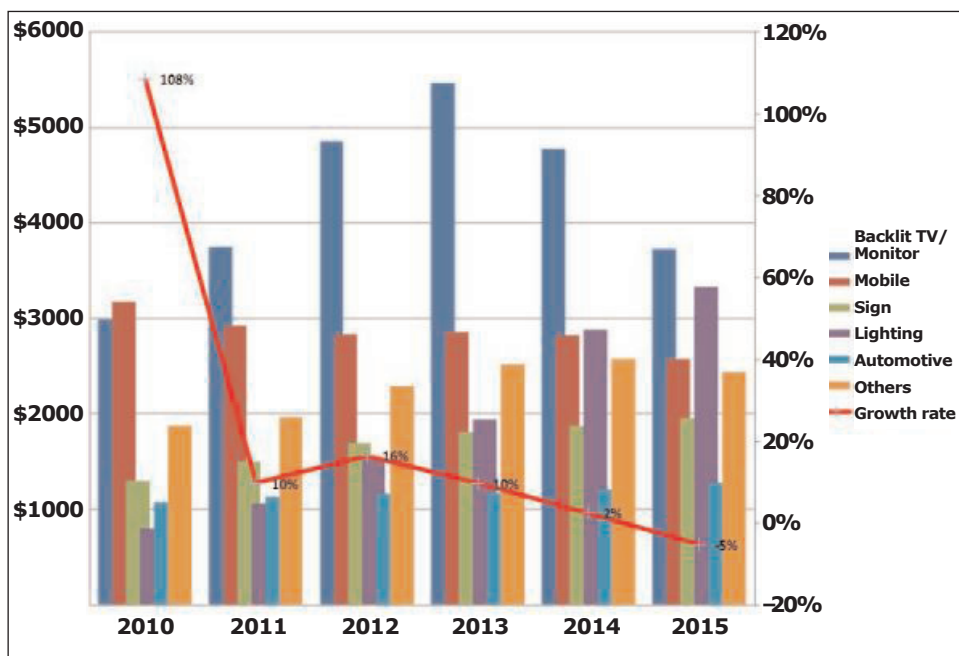
Except for certain specialized applications (such as headlamps), LED prices have plummeted 20–40% recently. Strategies Unlimited has consequently lowered its forecast for HB-LED revenue in 2011 to \$12.3bn, up just 9.8% year-on-year.

Strategies Unlimited predicts that this industry correction will take weaker and/or newer LED manufacturers out of the market — like many from China who entered the market during 2010 — hence consolidation is expected in China. As LEDs become more like commodities, only strong manufacturers with deep pockets will survive the fluctuations, the firm forecasts.

Revenue will peak in 2014, hitting \$16.2bn, before dropping off to \$15.3bn in 2015, it is reckoned. However, after lighting takes over as the growth driver for HB-LED adoption (predicted to occur in 2015) revenues will return to growth.

The LED price drop could lead to higher LED adoption, particularly in lighting, where LEDs are about 30% of the bill of materials (BOM). For example, a high-quality, large-volume 1W cool-white packaged LED with delivery in September 2011 was quoted at about \$0.65. Revenues of LEDs for lighting should see compound growth of 33% over the forecast period.

The worldwide signage industry experienced explosive growth to



HB-LED market by revenue and year-on-year growth rate, 2010-2015.

\$3.4bn in 2010, including the domestic Chinese market growing 54% to \$1.9bn and expected to continue growing at 14% compounded annually through 2015. LED revenues for signs were \$1.1bn in 2010, and are expected to grow to about \$1.6bn in 2015. About 83% of worldwide signs were manufactured in China in 2010, and the trend toward Chinese manufacturing will continue.

Strategies Unlimited forecasts that LEDs for mobile devices will experience declining revenues 2010–2015, despite fast-growing device adoption (with smartphone units growing at 30% and tablet computers at 57%, compounded

The LED price drop could lead to higher LED adoption, particularly in lighting, where LEDs are about 30% of the bill of materials

annually). Most mobile appliances (such as feature phones and notebooks) have reached saturation, and price suppression will contribute to LED revenues falling by 4.1% compounded annually (the only segment with negative growth through the forecast period).

Automotive applications brought in \$1.1bn in LED revenues in 2010, due mainly to China-based growth. However, as China cools off in 2011 and the Japanese tsunami disrupted supply chains, growth in this sector in 2011 has been revised downwards to just 5%. Nevertheless, increased use of LEDs in daytime running lights (DRLs) and headlamps will drive revenue growth for LEDs in exterior automotive lighting to 10%, compounded annually. In contrast, falling prices and saturation of LEDs in instrument panels — reaching 90% in 2015 — will erode LED revenue for that segment by 2% over the forecast period, concludes Strategies Unlimited.

www.strategies-u.com

Mobile handsets to comprise 50% of \$6.4bn GaAs device revenues in 2015

34% growth to \$5bn in 2010 driven by multi-mode, multi-band technology

Handset developments (such as smartphones and other multi-mode, multi-band devices) drove revenue growth of 34% (to \$5bn) for the overall GaAs device market in 2010 and will push GaAs device revenue to nearly \$6.4bn in 2015, according to the Strategy Analytics GaAs and Compound Semiconductor Technologies Service (GaAs) Forecast and Outlook 'GaAs Industry Forecast 2010-2015'.

As consumers continue to embrace mobile data applications, operators are expanding wireless networks and developing new mobile devices, says the market research firm. Strategy Analytics hence forecasts that device shipments into mobile handset applications will account for 50% of total GaAs device revenue in 2015, when more than 20.8bn GaAs devices will ship into all market applications. In addition to GaAs

devices, the report also forecasts growth for semi-insulating (SI) bulk and epitaxial GaAs substrates.

"Driven by the mobile handset segment, 2010 proved to be a banner year for GaAs devices," notes Eric Higham, director of the Strategy Analytics GaAs and Compound Semiconductor Technologies Service. "Smartphones and other types of handsets are becoming increasingly sophisticated in order to accommodate multiple bands, multiple standards and features like GPS, Wi-Fi and Bluetooth. This is increasing the number of GaAs devices required per handset," he adds.

"While handset content will continue to drive the GaAs market, infrastructure and military opportunities for GaAs will also increase," comments Asif Anwar, director in the Strategy Analytics Strategic Technologies Practice.

SI GaAs substrate and epi markets to show 6% CAAGR unit growth to 2015

...but falling prices to limit epi revenue growth to CAAGR of 1%

The recovery of the GaAs market that began in second-half 2009 continued throughout 2010, resulting in a 26% increase in demand for semi-insulating (SI) GaAs bulk substrates, says Strategy Analytics. The market research firm now estimates that the total SI GaAs bulk substrate market will grow at a compound annual average growth rate (CAAGR) of 6% to more than 44,300ksi (thousand square inches) in 2015.

Merchant demand accounted for 90% of the total in 2010. The corresponding market revenue for SI GaAs bulk substrates will grow to

an estimated \$265m in 2015.

Strategy Analytics also estimates that the total SI GaAs epitaxial substrate market (merchant and captive) increased in area by 30% in 2010 to nearly 30,000ksi. The firm forecasts that the total SI GaAs epi substrate market will grow at a CAAGR of 6% to more than 40000ksi in 2015. However, falling prices will limit growth in the total market value (in terms of revenue) to a CAAGR of 1%. However, even with this slow growth, the market value should rise to \$543m in 2015, reckons Strategy Analytics.

www.strategyanalytics.com

IN BRIEF

GaN products gaining acceptance in commercial markets

The performance capabilities of devices made from gallium nitride material are drawing attention from compound semiconductor manufacturers for applications in defense, wireless infrastructure, CATV, satellite and power electronics markets, notes the Strategy Analytics GaAs and Compound Semiconductor Technologies Service (GaAs).

The viewpoint from market research firm Strategy Analytics summarizes technology, product, contract, financial and employment developments from firms such as RF Micro Devices, Skyworks Solutions, Anadigics, Agilent, Hittite Microwave, TriQuint Semiconductor, Avago, NXP Semiconductors and Freescale Semiconductor, addressing commercial and military applications that use GaAs, GaN, SiC and CMOS technologies.

"Based on product announcements and company displays at the recently concluded International Microwave Symposium show in Baltimore, it is clear that GaN is really gaining a foothold in the compound semiconductor market," notes Eric Higham, director of the Strategy Analytics GaAs and Compound Semiconductor Technologies Service.

"Manufacturers are finding that the superior power handling and 'green' capabilities of GaN technology enable them to develop some compelling products," he adds.

"GaN products have been used in defense products for some time," comments Asif Anwar, director, Strategy Analytics Strategic Technologies Practice. "They are now gaining acceptance in commercial wireless infrastructure, CATV, satellite and power electronics markets," he concludes.

TriQuint lowers Q3 revenue guidance by 8%

TriQuint Semiconductor Inc of Hillsboro, OR, USA, which provides RF front-end product maker and foundry services to mobile device, networks, and defense & aerospace markets, says that for third-quarter 2011 it has lowered its guidance for revenue by about 8%, from \$225–235m to \$210–215m (compared with \$228.8m in Q2 and \$237m a year ago in Q3/2010).

The firm has also lowered its guidance for non-GAAP net income per share from \$0.16–0.18 to

\$0.09–0.11 (compared with \$0.17 in Q2 and \$0.27 a year ago in Q3/2010).

The reduction in expected revenue and profitability is attributed primarily to reduced demand from TriQuint's largest customer, weakness in the communications infrastructure market, and softening demand from the China market.

TriQuint has also lowered its guidance for non-GAAP gross margin from 40–42% to 35–37%. The largest drivers of the sequential

reduction in non-GAAP gross margin from Q2's 41.4% are said to be product mix and costs associated with ramping new products.

However, the firm now expects non-GAAP operating expenses (including litigation expenses) to be cut further from Q2's \$65.6m, to about \$60m for Q3 (rather than the previously expected \$64–65m).

Despite the downward revisions for Q3, TriQuint concludes that it expects a return to strong sequential revenue growth in Q4/2011.

SpanTech Microwave appointed as sales rep in Spain and Portugal

TriQuint has appointed SpanTech Microwave Technology S.A. of Málaga, Spain as sales representative supporting RF and microwave design needs in Spain and Portugal.

SpanTech has 20 years of indus-

try expertise in the region.

"TriQuint is pleased to welcome SpanTech as our Iberian representative," says Todd DeBonis, VP of global sales & strategic development. "SpanTech is well positioned

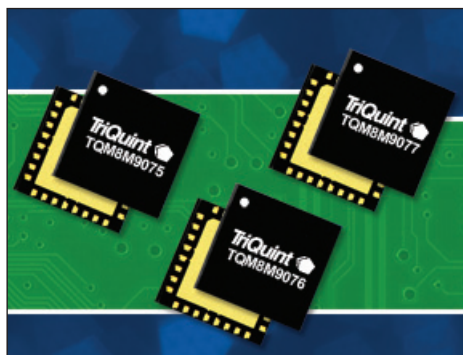
to provide RF technical and design assistance to support TriQuint's innovative portfolio of mobile device, network infrastructure, defense and aerospace solutions."

www.spantech.es

Integrated digital VGAs with wide gain control, low noise and high efficiency and linearity

At European Microwave Week (EuMW 2011) in Manchester, UK (11–13 October), TriQuint Semiconductor launched a family of broadband, digitally controlled variable gain amplifiers (DVGAs) that combine high linearity, gain and output power with a low noise figure and a broad range of output gain control. The integrated products are internally matched at 50 Ohms and can reduce bill of materials (BOMs), increase efficiency and reduce overall costs, claims the firm. The new DVGAs suit public safety, 3G/4G wireless base-station transceivers, remote radio heads, point-to-point microwave links and satellite communications terminal applications, it adds.

The TQM8M9075, TQM8M9076, and TQM8M9077 combine a high-performance gain block with a precision digital step attenuator to amplify input signals in 0.5dB steps from 0 to 31.5dB based on com-



TriQuint's TQM8M9075, TQM8M9076, and TQM8M9077 digital VGAs.

mands delivered through a 6-bit serial control interface. They can be used in the IF and RF sections of a receiver to amplify or attenuate incoming signals, especially to levels desirable for analog-to-digital converters. They can also be used in the transmit chain to vary gain levels to amplifier stages.

A broad operating range of 500MHz to 4GHz and integrated performance advantages make the

DVGAs suitable for many wireless communications systems, enabling RF designers to use one device across multiple applications, says TriQuint. Their noise figure (as low as 2.9dB) and high linearity (OIP3 up to 38.5dB) can be critical to ensuring the best possible overall performance, it adds. In addition, their attenuator accuracy (0.3 + 4% of attenuation setting) provides precision gain control throughout their 31.5dB range.

The TQM8M9075, TQM8M9076 and TQM8M9077 operate from a single 5VDC power supply at currents of between 87 and 125mA, have an operating temperature range of -40°C to +85°C, and have a minimum mean-time-to-failure (MTTF) of 1000 years at a mounting temperature of +85°C.

Samples of the three new DVGAs as well as evaluation boards are available now.

www.triquint.com

Advanced Microwave Module Assembly facility in Richardson expanded with new die-attach equipment

RF front-end product and foundry services provider TriQuint Semiconductor Inc of Hillsboro, OR, USA has expanded its Advanced Microwave Module Assembly (AMMA) facility at its Richardson, TX, USA design and manufacturing center to provide one-stop convenience and security.

The facility has grown with the recent addition



Exterior view of TriQuint Semiconductor's facility in Richardson, Texas.

of new die-attach equipment. Die-level devices can now be fabricated, tested, packaged and shipped to customers from one secure location. AMMA supports a wide variety of industry-standard RF packages and can also meet custom design needs, the firm says.

"Our packaging expertise expands TriQuint's portfolio of integrated solutions for convenience and lower overall system costs," says Defense & Aerospace VP, James L. Klein.

www.triquint.com/prodserv/markets/military/amma.cfm

TriQuint wins Momentum Dallas award

At its annual awards luncheon on 12 October, the Dallas Regional Chamber of Commerce presented RF front-end product and foundry services provider TriQuint Semiconductor Inc with its 2011 Momentum Dallas award, which recognizes one company that has experienced significant job growth and fostered positive economic momentum in the Dallas region.

TriQuint's facility in Richardson, TX sits on 33 acres, contains 550,000ft² of workspace, and 48,000ft² of Class 1 cleanroom space. By the end of 2011, TriQuint expects to employ more than 750 staff there, including about 230 new full-time

positions in the last two years.

This headcount growth of 43% at Richardson should help to support future demand, says TriQuint. The firm is currently qualifying 6" GaAs wafer production capabilities similar to its headquarter facility in Hillsboro, Oregon. TriQuint has also expanded its Advanced Microwave Module Assembly (AMMA) facility in Richardson to provide one-stop convenience and security.

The Richardson site is a US Department of Defense (DoD)-accredited 'Trusted Foundry' (Category 1A) and is a supplier of GaAs and GaN foundry services.

www.dallaschamber.org

ACS Fellowship

At the American Chemical Society's 242nd national meeting on 29 August, TriQuint plasma process engineer Dr Trish Beau regard Smith of Richardson, TX was inducted into the ACS' 2011 Class of Fellows, along with 212 other distinguished scientists (making 568 Fellows in total to date).

The ACS Fellow program began in 2009 to recognize scientists from academe, industry and government who have demonstrated outstanding accomplishments in chemistry and made significant contributions to the ACS.

www.acsdfw.org

TriQuint named one of Fortune Magazine's 100 Fastest-Growing Companies in 2011

TriQuint Semiconductor has been named to Fortune Magazine's annual 100 Fastest-Growing Companies list. The firm ranked 49th in profit growth based on several financial performance metrics over a three-year period. TriQuint says that its growth was due in part to significant design wins across several high-growth markets including smartphones, tablets, 3G/4G base-stations, optical net-

works and cable systems.

"We will continue our focus on RF innovation and manufacturing technology to simplify our customers' designs, and help them meet the demand for more connectivity," says president & CEO Ralph Quinsey.

To qualify for Fortune Magazine's annual 100 Fastest-Growing Companies list, a company (foreign or domestic) must be trading on a major US stock exchange; report

data in US dollars; file quarterly reports with the US Securities & Exchange Commission (SEC); and have a minimum market capitalization of \$250m. Companies that meet these criteria are ranked by revenue growth rate, EPS (earnings per share) growth, and three-year annualized total return for the period ended 30 June.

<http://money.cnn.com/magazines/fortune/fortunefastestgrowing/2011>

IN BRIEF

Anadigic's HELP4 PA powers Casio's G'zOne smartphone

Anadigics Inc of Warren, NJ, USA is shipping production volumes of its AWT6621 — which is part of its fourth-generation High-Efficiency-at-Low-Power (HELP4) power amplifier (PA) product family — to Casio for the G'zOne IS11CA smartphone.

The G'zOne IS11CA features an IPS 3.6 inch display, 8 megapixel camera, and Android 2.3 Gingerbread operating system. These features are combined with a shockproof, dustproof and waterproof design to offer KDDI subscribers a rugged smartphone option for the EV-DO Rev B network in Japan.

"Our HELP4 power amplifiers continue to set the performance standard with the industry's highest efficiency and lowest quiescent current, providing mobile device manufacturers with a proven solution to longer battery life," claims Michael Canonico, Anadigics' senior VP of worldwide sales.

As well as a high level of integration (including internal voltage regulation and a 'daisy chainable' directional RF coupler with 20dB directivity, all in a 3mm x 3mm footprint), the AWT6621 PA uses the firm's InGaP-Plus technology to achieve optimal efficiency across low-range and mid-range output power levels (via three mode states) and to provide what are claimed to be the industry's lowest quiescent currents (<2mA). Average current consumption is cut by 30% from previous-generation PAs. The AWT6621 can hence extend battery life in handsets, smart phones, tablets, netbooks and notebooks. The HELP4 PAs also provide highly efficient operation in CDMA, WCDMA, and HSPA+ applications.

www.anadigics.com

SiGe acquisition boosts Skyworks to leading position in wireless networking market

Skyworks Solutions Inc of Woburn, MA, USA (which manufactures high-reliability analog and mixed-signal semiconductors) reckons that, with its acquisition in June of SiGe Semiconductor Inc of Andover, MA, USA (a fabless supplier of highly integrated RF front-end solutions enabling wireless connectivity), it has captured the market leader position in wireless networking. The firm says that its connectivity solutions can be found powering Internet access devices including smart phones, set-top boxes, gateways, BluRay players, gaming consoles, tablets and personal computers, high-power access points and routers.

"Following the SiGe acquisition, we believe Skyworks' modules are enabling more than one-third of the world's wireless radios, significantly more than any other single company," comments Allen Noguee, principle analyst at market

research firm In-Stat. "And with wireless networking providing bandwidth for smart phones and expanding connectivity in tablets and other consumer devices, Skyworks is well positioned to capture additional market share in this fast-growing market," he adds.

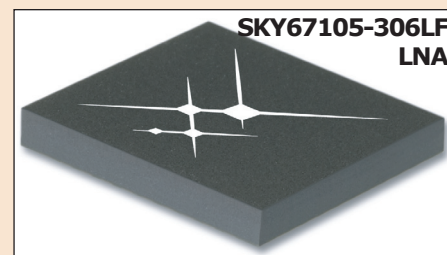
"With the addition of SiGe's product portfolio and intellectual property, Skyworks is delighted to be enabling mobile connectivity across a broader spectrum of wireless networking markets and applications," says Liam K. Griffin, executive VP & general manager of high-performance analog at Skyworks. "Our combined product portfolio allows us to offer customers a breadth of best-in-class solutions and capitalize on our position in tablets and smart phones, where wireless networking attachment rates are approaching 100%, as well as home automation and energy management," he adds.

Skyworks unveils high-gain, high-linearity LNAs for cellular infrastructure

Skyworks Solutions has launched a series of high-gain, two-stage low-noise amplifiers (LNAs) employing both GaAs pHEMT and HBT technologies, offering very low noise figure, high linearity and what is claimed to be excellent return loss in a small, quad flat, 4mm squared leadless package.

On-die, active-bias design ensures consistent performance and enables unconditional stability. The pHEMT front-end enables ultra-low noise figure, while the HBT-based output stage provides both high linearity and efficiency.

The SKY67105-306LF (0.6–1.1GHz) and SKY67106-306LF (1.5–3.0GHz) high-gain, LNAs suit cellular infrastructure applications such as tower-mounted amplifiers, remote



radio units, repeaters and base stations, says the firm. The new LNAs also enable traditional wireless infrastructure OEMs and broad market wireless OEMs that provide small cost-sensitive receivers to offer very low-noise amplification (<0.75db noise figure), high linearity (+38dBm OIP3), and higher gain (>32db) than typically provided by a single-stage LNA solution.

www.skyworksin.com

RFMD forms Compound Semiconductor Group

New business group extends expertise to high-growth non-RF markets

RF Micro Devices Inc of Greensboro, NC, USA has announced a strategic initiative to extend its compound semiconductor technologies into a broad array of adjacent non-RF growth markets. The initiative includes the formation of a Compound Semiconductor Group (CSG), operating alongside RFMD's Cellular Products Group (CPG) and Multi-Market Products Group (MPG). RFMD forecasts that the total available market (TAM) for non-RF applications addressed by CSG will exceed \$1.5bn in 2015.

CSG aims to create new high-power and high-performance products using the firm's gallium nitride (GaN) and gallium arsenide (GaAs) process technologies. The group will encompass RFMD's Power Electronics product line as well as the firm's Foundry Services business unit. It will also include RFMD's New Technology Commercialization Center (NTCC), with responsibility for new technology incubation, including the firm's cooperative R&D agreement with the National Renewable Energy Laboratory (NREL) related to the commercialization of GaAs-based

concentrated photovoltaic cells (CPV).

Bob Van Buskirk, currently president of RFMD's Multi-Market Products Group, will lead the Compound Semiconductor Group. He was previously CEO & president of Sirenza Microdevices Inc (a supplier of RF components for communications applications), which was acquired by RFMD in November 2007. Prior to Sirenza, Van Buskirk held senior positions at Northrop Grumman (formerly TRW), including responsibility for commercializing its GaAs compound semiconductor technology and leading the development and growth of its compound semiconductor foundry business.

Norm Hilgendorf, currently RFMD's VP of corporate development, will become corporate VP & president of the Multi-Market Products Group. He joined RFMD in November 2007 from Sirenza, where he was most recently chief operating officer. RFMD says that Hilgendorf has many years of senior management experience, including sales and general management, in multi-market organizations and in the wide range of end markets served by MPG.

"Bob is a recognized industry veteran in compound semiconductor technologies and he has consistently led his organizations to outstanding growth," comments RFMD's president & CEO Bob Bruggeworth. "Similarly, Norm Hilgendorf will hit the ground running, given his exceptional operational background and personal involvement in the strategic planning and corporate development for our multi-market organization," he adds.

"The formation of RFMD's Compound Semiconductor Group adds an incremental layer of new opportunities to energize our future growth without materially impacting operating expenses," says Bruggeworth. "In our advanced technology organizations we have been exploring strategic opportunities to exploit our world-class compound semiconductor expertise and, with the formation of CSG, we have in place the leadership and organization to capture incremental, profitable revenue in high-growth non-RF markets," he believes.

www.rfmd.com

RFMD launches 400–3500MHz broadband SPDT switch

RFMD has launched the RF1602 single-pole dual-throw (SPDT) switch, designed for switching applications requiring very low insertion loss, high isolation, and high power handling capability coupled with minimal DC power consumption. With a frequency range of 400–3500MHz, perform-

ance has been optimized for cellular applications demanding stringent linearity requirements, such as SV-LTE, WCDMA and CDMA.

The RF1602 offers high isolation between RF ports (typically 42dB at 1GHz), providing greater separation between transmit and receive paths. Insertion loss is typically 0.3dB at

1GHz. Linearity (IIP2) is typically 129dBm.

With no external DC blocking capacitors required on RF paths unless DC is applied externally, the RF1602 is packaged in a compact 2mm x 2mm x 0.55mm 12-pin QFN package. Pricing begins at \$1.14 each for 25 pieces.

2.4GHz front-end module for ZigBee and WiFi

RFMD has launched the RF6505, which integrates a complete solution in a single front-end module (FEM) for ZigBee (802.15.4-based systems for remote monitoring and control) and WiFi (802.11b/g) applications in the 2.4–2.5GHz band.

The 3.3V FEM integrates the power amplifier plus harmonic filter in the transmit path and low-noise amplifier with bypass mode in the receive path.

The module provides a single balanced TDD access for Rx and Tx

paths, along with two ports on the output for connecting a diversity solution or a test port.

Features include P1dB output power of 27dBm and gain of 28dB (Tx) and gain of 10dB and a noise figure of 2.5dB (Rx).

M/A-COM Tech launches 1-bit digital attenuator for CATV applications

M/A-COM Technology Solutions Inc of Lowell, MA, USA (which makes semiconductors, components, and subassemblies for RF, microwave and millimeter-wave applications) has launched the MAAD-010305, a 15dB step GaAs monolithic microwave integrated circuit (MMIC) 1-bit digital attenuator for CATV and set-top box (STB) front-end applications.

Designed to condition cable input signals to the STB, the device is suited to use where high accuracy, very low power consumption, and low intermodulation products are required.

"We are very pleased to continue the expansion of our 75Ω product portfolio with the introduction of this highly linear, 15dB digital attenuator," says product manager Graham Board. "This device is ideally suited for use in high-volume, cost-sensitive customer premises equipment," he adds.

The MAAD-010305 is fabricated as a monolithic GaAs integrated circuit using a mature pHEMT process that features full chip passivation for performance and reliability.

Available in an RoHS-compliant, lead-free SOT-25, five-lead surface-mount plastic package, the attenuator is designed for operation from DC to 1.1GHz, and is characterized by low insertion loss of 0.3dB and allows for positive and negative voltage control, complemented by 75Ω impedance.

Input and output return losses are both 14dB, input IP3 is 46 dBm, and P1dB is 20dBm. Composite triple beat (CTB) performance is 70dBc and composite second order (CSO) performance is 66dBc (157 channels, PIN = 35dBmV/Ch).

www.macomtech.com

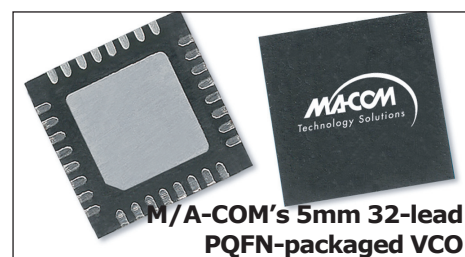


M/A-COM Tech adds VCOs with low phase noise, wide tuning range and low current consumption

M/A-COM Technology Solutions Inc has launched a new set of voltage controlled oscillators (VCOs) suited to point-to-point radio, point-to-multipoint radio, communications systems, and low-phase-noise applications. The firm says that the InGaP HBT-based VCOs are easily integrated into a phase lock loop (PLL), using a divide-by-two output.

Packaged in a lead-free 5mm, 32-lead PQFN package, the VCOs feature an integrated buffer amplifier. The package also has low lead inductance. Operating with a case temperature at or below 85°C, the VCOs allow for a mean time before failure (MTBF) of 2,500,000 hours. With a 5V bias supply, they operate in the 8.4–11.8GHz frequency band.

The 9.2–10.2GHz MAOC-009871, 11.0–11.8GHz MAOC-009872 and 8.4–9.25 GHz MAOC-010334 meet the high-performance requirements of high-capacity digital radios by optimizing for low phase noise (–113, –112 and –115dBc/Hz,



M/A-COM's 5mm 32-lead PQFN-packaged VCO

respectively, at 100kHz offset), wide tuning range (with a tuning sensitivity of 0.18, 0.19 and 0.14GHz/V, at the RF port), and low current consumption (185, 165 and 168mA, respectively).

"The MAOC-009871, MAOC-009872 and MAOC-010334 are expansions to M/A-COM Tech's point-to-point VCO product family," says product manager Jack Redus. "Low phase noise and low DC power consumption are key product features that are beneficial for cellular backhaul radios," he adds. "The full product family consists of 15 standard product VCOs covering 5.7–14.2GHz. Custom frequency ranges are available upon request."

M/A-COM adds S-band digital phase shifters

M/A-COM Tech has launched a set of S-band digital phase shifters for communications, electronic warfare (EW), and radar applications. The firm says that the phase shifters, which are housed in 4mm 24-lead PQFN packages and controlled with a single +5V serial or parallel control line, facilitate easy implementation in communication antennas, phased array radars, weather radars, and EW receivers.

Specifically, the S-band GaAs pHEMT 4-bit and 6-bit digital phase shifters meet the high-performance requirements of communications and radar system manufacturers, optimizing for fast switching speed, low phase error, and serial or parallel control capability, adds the firm.

"M/A-COM Tech's new 2.3–3.8GHz digital phase shifters maintain low phase error and low attenuation variation over the 360° range," says product manager Kevin Harrington. "The built-in CMOS driver allows for serial or parallel control while in a small form factor," he adds.

The MAPS-010144 4-bit digital phase shifter provides 360° phase shift range with a step size of 22.5°. Insertion loss is 2.5dB, with a low ±0.5dB attenuation variation and ±4.0° phase accuracy over the 2.3–3.8GHz frequency range.

The MAPS-010164 6-bit digital phase shifter provides 360° range with a 5.625° step size. Insertion loss is 3.2dB, with a low ±0.6dB attenuation variation and ±5.0° phase accuracy over 2.3–3.8GHz.

GaAs foundry WIN chooses VIPER RF as approved design partner

Taiwanese GaAs foundry WIN Semiconductors Corp has entered into an agreement under which VIPER RF Ltd of Sunderland, UK will offer design support and specialized RF expertise to help customers develop chips using WIN's process technologies and design tools.

Founded in 1999, WIN was the first pure-play 6" GaAs foundry and is said to be the largest in the world. The firm has two 6" wafer fabs, providing dedicated foundry services to both design houses and integrated design manufacturer (IDM) partners. The foundry says that it services the growing demand for low-cost manufacturing of high-speed GaAs MMICs and RFICs, with expertise in HBT and pHEMT MMIC fabrication, and that its team provides continuous R&D to meet customers' technology requirements.

VIPER RF is a microwave & RF IC design and development consultancy and product-based company founded in 2008 that addresses markets

including defence and security, communications and wireless applications, covering frequencies in the range DC–100GHz.

"VIPER RF has a wealth of experience in GaAs MMIC and RFIC design, particularly in the application areas that we address, such as high-end cellular communications, WLAN products, satellite communications and automotive radar," says WIN's VP sales & marketing Brian Lee.

"They will be able to give our customers a high level of design support and help them to achieve the best from using the WIN GaAs process," he believes.

"We look forward to a long and mutually profitable relationship helping customers to use WIN's foundry services," says VIPER RF's CEO Jim Mayock.

Both VIPER and WIN exhibited at European Microwave Week 2011 in Manchester, UK (11–13 October).

www.winfoundry.com

www.viper-rf.com

WIN releases PP15-50/PP15-51 next-gen 0.15µm power PHEMT process

Taiwan's WIN Semiconductors has released the PP15-50/PP15-51 0.15µm GaAs PHEMT foundry process for high-frequency power products operating at up to 6V.

The PP15-50 and PP15-51 technologies use an optimized device structure and a proven 150mm manufacturing process to provide performance through 40GHz. The process is an extension to WIN's PP15 technology platform, and demonstrates a cut-off frequency f_T of more than 80GHz and power density of 850mW/mm at 29GHz, with more than 10dB of gain and 50% power-added efficiency (PAE).

The process is designed to operate at a drain bias of 6V, and exhibits typical breakdown voltages of 16V, with a process

minimum of 14V, providing substantial operating margin for ultra-high product reliability.

WIN says that the technology is suited to a range of products including saturated and linear amplifiers for the point-to-point market, radar, instrumentation, electronic warfare (EW), and optical driver applications.

Furthermore, the platform is available on 50µm (PP15-50) and 100µm (PP15-51) substrate thicknesses, with optional BCB scratch protection.

Process design kits (PDKs) for Agilent's ADS and AWR's Microwave Office will be available on WIN's website.

Active device samples are available now.

www.winfoundry.com

IN BRIEF

Low-noise frequency divider programmable to divide-by-1 or -3 up to a record 13GHz

Hittite Microwave Corp of Chelmsford, MA, USA (which designs and supplies analog and mixed-signal RF, microwave and millimeter-wave ICs, modules and subsystems as well as instrumentation) has launched a low-noise programmable frequency divider for use in signal generation architectures in test equipment, laboratory systems and various military applications.

The HMC861LP3E is a low-noise programmable frequency divider that can be programmed to divide-by-1 or divide-by-3, and accepts input frequencies from 100MHz to 13GHz. Additive phase noise is just -152dBc/Hz in divide-by-1 mode, and -153dBc/Hz in divide-by-3 mode. The versatile frequency divider accepts input signal levels from -10dBm to $+10\text{dBm}$, while delivering $+2\text{dBm}$ of output power. The wide input frequency and power level ranges and the low single-sideband phase noise suit synthesizer and phase-locked loop (PLL) applications in wideband and high-data-rate communication systems, says Hittite.

The division ratio is selected by a single CMOS-compatible input, and the device is powered from a $+5\text{V}$ supply. Hittite claims that the HMC861LP3E is the only known MMIC divide-by-3 available on the market that operates to 13GHz.

The HMC861LP3E is housed in a miniature 3mm x3mm RoHS-compliant QFN leadless SMT package and is specified for operation over -40°C to $+85^\circ\text{C}$.

www.hittite.com

TowerJazz and Presto collaborate on SiGe foundry

Presto's hubs support integrated test & production services for SiGe designs targeting high speed communications

Specialty foundry TowerJazz (which has two fabrication plants at Tower Semiconductor Ltd in Migdal Haemek, Israel plus one at US subsidiary Jazz Semiconductor in Newport Beach, CA) and Presto Engineering of San Jose, CA, USA, which delivers integrated test & product engineering services to both integrated device manufacturers (IDM) and fabless companies, have announced a strategic collaboration to deliver comprehensive services for companies developing high-speed communications products using TowerJazz's silicon germanium (SiGe) technology. The alliance covers wafer-level and packaged part development activities, from design characterization to volume production, probing and final test. TowerJazz's foundry customers now have access to the full range of semiconductor services from Presto Engineering's hubs in Silicon Valley, Europe and Israel.

"We have seen a significant growth in design starts for high-speed communications devices, driven in part by expansion of 100 Gigabit networks and the shift to E-band wireless infrastructure systems," says Presto's founder & CEO Dr Michel Villemain. "Time-to-volume production is key in these fast-growing markets and having a proven SiGe test and product engineering solution will be vital for our common customers' success. We look forward to working closely with the TowerJazz foundry team to make that a reality," he adds.

"Combining our leading position in SiGe process technology with col-

laborations such as the one announced today with Presto, provides our customers the ability to speed product development of new communication products," says Dr Marco Racanelli, senior VP & general manager of TowerJazz's RF & High Performance Analog Business Group. "Presto's hub locations in the US and Israel are also well-suited to our global footprint that now includes 8-inch fabs in the US, Israel and Japan."

The demand for high-speed interconnects continues to exceed industry analyst expectations, according to market research firm Dell'Oro Group. As cited in its recent report, the adoption of 100 Gigabit solutions is occurring faster than that of 40 Gigabit, driving projected revenues to nearly \$1bn by 2013 and \$2bn by 2015. TowerJazz's enhanced SiGe BiCMOS technology is aimed at replacing GaAs components in high-growth markets such as high-speed communications. TowerJazz claims that SiGe provides significant integration and cost advantage over GaAs, with demonstrated performance of up to 200GHz as well as noise and power performance that is competitive with GaAs while offering as much as 40% lower die cost. Also included are CMOS options to enable mixed-signal and digital functions on the same chip, further reducing cost of the complete system.

Presto offers TowerJazz's customers comprehensive RF testing services in Ka-band and E-band, including both frequency- and time-domain tests, noise and power measure-

ments, jitter, phase noise and bit-error-rate (BERT) measurements. The Presto hubs complement their test services with test program generation, special probe technology development for RF applications, probecards and load-boards realization. Besides test, Presto offers comprehensive turn-key solutions including qualification (reliability testing for temperature, environmental and electrical stresses), both physical and electrical fault isolation and failure analysis, all the way to supply chain management.

SBC18H3 is TowerJazz's third-generation 0.18 μ m SiGe technology and offers transistors with an f_T of 240GHz and an f_{MAX} of 260GHz in what the firm says is a cost-effective and analog-friendly 0.18 μ m node. IP of high-speed components such as transimpedance amplifiers (TIAs), laser drivers, serializer & deserializer (SerDes), and clock & data recovery (CDR) ICs from H2 and HX can be readily ported to the new H3 process since they are all in the same 0.18 μ m node, allowing them to benefit from improved performance as well as reduced power consumption and noise, TowerJazz says.

Presto and TowerJazz exhibited at industry conferences including:

- GSA's Semiconductor Ecosystem Summit (6 October) in Santa Clara, CA, USA;
- European Microwave Week 2011 (11-14 October) in Manchester, UK;
- TowerJazz Global Symposium (3 November) in Newport Beach, CA, USA.

www.presto-eng.com

TowerJazz redeems US convertible notes due December 2011

Jazz Technologies Inc has completed a voluntary transaction to early redeem the remaining \$35,091,000 principal amount of its outstanding 8% notes due 31 December 2011.

If not redeemed, the notes were convertible into Tower Semiconductor's shares.

The redemption was financed from available cash on hand, saving

more than \$600,000 of interest.

Neither Jazz Semiconductor nor its parent firm Jazz Technologies Inc have any notes due before 2015.

www.towerjazz.com

Imec demos SiGe:C HBTs with 245GHz f_T and 450GHz f_{max}

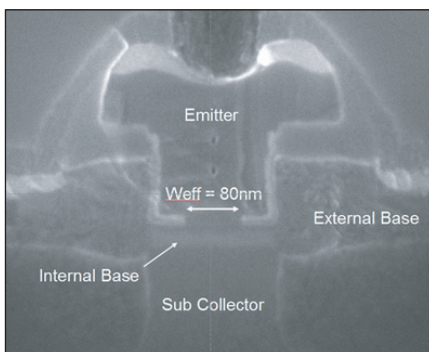
Imec of Leuven, Belgium has realized a SiGe:C heterojunction bipolar transistor (HBT) with a current-gain cut-off frequency (f_T) of 245GHz and a power-gain cut-off frequency (f_{MAX}) of 450GHz, a key enabler for future high-volume millimeter-wave low-power circuits to be used in automotive radar applications. IMEC recons that the 245GHz/450GHz HBT devices also pave the way to silicon-based millimetre-wave circuits penetrating the so-called THz (terahertz) gap, enabling enhanced imaging systems for security, medical and scientific applications.

The very high-speed devices have a fully self-aligned architecture through self-alignment of the emitter, base and collector regions, and implement an optimized collector doping profile. Imec says that, compared with III-V HBTs, SiGe:C HBTs combine high-density and low-cost integration, making them suitable for consumer applications. Such high-speed devices can open up new application areas, working at high frequencies with lower power dissipation, or applications that require a reduced impact of process, voltage and temperature variations at lower frequencies for better circuit reliability.

To achieve very high-speed requirements, SiGe:C HBTs need further up-scaling of device performance. Thin sub-collector doping profiles are generally believed to be necessary for this, says Imec. Usually, the collector dopants are introduced in the beginning of the processing and are thus exposed to the complete thermal budget of the process flow. This complicates accurate positioning of the buried collector.

By in-situ arsenic doping during simultaneous growth of the sub-collector pedestal and SiGe:C base, Imec has introduced both a thin, well controlled, lowly doped collector region near the base and a sharp transition to the highly doped collector without complicating the process.

This has resulted in a considerable increase in overall HBT performance: peak f_{MAX} values above 450GHz are



Cross sectional micrograph of HBT after end-of-line processing.

obtained with a high early voltage, a BV_{CEO} of 1.7V and a sharp transition from the saturation to the active region in the I_C - V_{CE} output curve.

Despite aggressive scaling of the sub-collector doping profile, the collector-base capacitance did not increase much. Moreover, current gain is well defined, with an average around 400. Also, the emitter-base tunnel current, visible at low V_{BE} values, is limited as well.

www.imec.be

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IN BRIEF

Global Symposium

The sixth annual TowerJazz Global Symposium (TGS) in Newport Beach will consist of an Aerospace and Defense focused day on 2 November and a Commercial Day on 3 November. This year the firm highlights its aim to be the global source for a broad range of customized technologies and unique design enablement platforms for diverse solutions. Guest speakers include executives from Microsemi, SaberTek and SRI plus professors from University of California, Irvine (UCI) and San Diego (UCSD).

The Aerospace & Defense day features an overview of TowerJazz technologies such as SiGe and CMOS image sensors, as well as a presentation on radiation tolerance by Jonathan Pellish of NASA Goddard. The keynote by Dr Phil Perconti, director Science and Technology Division of the US ARMY Night Vision and Electronic Sensors Directorate (NVESD), focuses on 'Army Future Trends for CMOS Image Sensors and IR Read-Out Integrated Circuits'.

The Commercial day's keynote is by CEO Russell Ellwanger. Also, company executives will provide overviews and updates on TowerJazz's range of technology solutions including SiGe/RF/high-performance analog, power management, CMOS image sensors, MS/CMOS and its design enablement capabilities. The firm has expanded its capacity and will discuss its recent acquisition of the fab in Nishiwaki, Japan as well as its business strategy.

All participants will have an opportunity to meet with top executives from TowerJazz as well as leading semiconductor industry companies. Major electronic design automation (EDA) vendors and IP providers will be available to discuss updated design solutions.

<http://towerjazz.com/tgs/#tgs>

TowerJazz expands design kits for Agilent's ADS 2011 software

Specialty foundry TowerJazz has made available additional high-speed silicon germanium (SiGe), silicon-on-insulator (SOI) and RF CMOS process design kits (PDKs) for its 0.18 μ m process platform.

The kits were developed for use with Agilent Technologies Inc's Advanced Design System (ADS) 2011 electronic design automation (EDA) software and target cell-phone front-end module components such as SOI antenna switches and SiGe power amplifiers as well as high-frequency products for optical networks, automotive, radar and 60GHz WiFi, and other high-speed interfaces such as those supporting Light-Peak and Thunderbolt standards. The PDKs are designed to help customers get new products to market faster by providing an accurate and productive work environment for RF CMOS, SiGe MMIC and power amplifier design solutions.

TowerJazz and Agilent demonstrated the new PDKs at European Microwave Week (EuMW) in Manchester, UK (10-14 October) and at the TowerJazz Global Symposium (TGS) in Newport Beach (3 November).

The new ADS design kits are available for SOI-based RF CMOS processes targeting cell-phone antenna switch applications, high-power SiGe technology targeting power amplifier applications, as well as high-speed SiGe BiCMOS with speeds of up to 200GHz (SBC18HA/HXL/H2). ADS 2011 enables multi-technology simulation with multiple PDKs, including modeling of packaging effects for RF module and RF system-in-package circuit co-design. Also included is a power amplifier design library with characterized power cells for use in wireless front-end module applications in cell phones and WiFi devices. The design kits support a complete ADS front-to-back design flow with an embedded TowerJazz Inductor Toolbox and CNEX netlist

definitions for layout-versus-schematic support. The new PDKs work seamlessly with ADS 2011, ADS 2009 Update 1 and all prior ADS releases.

Developed in collaboration with Agilent, the enhanced design platform enables the co-simulation of components designed in different process technologies, accelerating module and system-level development, says Dr Marco Racanelli, senior VP & general manager of TowerJazz's RF & High Performance Analog Business Group and Aerospace & Defense Business Group. "As silicon expands its domain in product areas previously occupied by III-V technology, we are seeing Agilent's ADS platform growing in popularity with our customers and, by offering a complete ADS design kit including layout tools and integrated EM support, we give our customers the advantage of Agilent's proven expertise in RF and microwave design. The outcome is faster design cycles as well as consistent results and possibly higher yields for our mutual customers," he adds.

"As a leader in the GaAs MMIC world, we are continually looking for ways to extend our footprint for RF CMOS and SiGe BiCMOS design support," says Juergen Hartung, foundry program manager of Agilent's EEs of EDA organization. "These kits offer us a means to achieve that goal. For our customers, the benefit is substantial: access to the industry's most comprehensive RF and microwave design platform using Momentum, the industry-leading 3D planar EM simulator, our integrated full 3D FEM engine, advanced RF design and analysis support, and industry-proven design-for-manufacturing capabilities inside ADS," he adds. "Such functionality underscores why the majority of MMIC designers now choose ADS to increase performance, consistency and yield."

www.towerjazz.com

www.agilent.com/find/eesof

IHP expands SiGe PDKs for Agilent's ADS 2011 software

IHP - Innovations for High Performance Microelectronics, Frankfurt (Oder), Germany (an institute of the Leibniz Association), has announced the availability of Advanced Design System (ADS) process design kits (PDKs) for its 0.25 μ m (SG25H3) and 0.13 μ m (SG13S) silicon germanium (SiGe) processes.

The upgraded and further improved kits work seamlessly with Agilent Technologies Inc's ADS 2011 and ADS 2009 Update 1 electronic design automation (EDA) software for communications applications, as well as prior ADS releases, and enable both IHP and Agilent customers to take full advantage of the breakthroughs in ADS 2011.

IHP's PDKs enable RF designers to design MMICs such as low-noise amplifiers (LNAs), mixers and power amplifiers (PAs). Specifically, the SiGe PDKs include a complete set of MOSFETs, SiGe bipolar transistors, passive components such

as poly resistors, MIM capacitors and inductors, diodes and contacts. The technology contains two thick aluminum layers for high-Q passive elements. Key layout components are fully scalable and are characterized to meet the IHP technology's performance. The PDKs also support a complete ADS front-to-back design flow with design rule check (DRC) rules.

"Customers require dedicated RF design flow support to handle the advanced challenges of today's sophisticated RF and microwave designs," says Dr Renè Scholz, head of IHP's MPW & Prototyping Service. "Agilent's ADS platform has grown in popularity for silicon-based RFIC design, and offering a complete ADS design kit, including layout tools and integrated EM support, gives us and our customers the advantage of Agilent's proven expertise in RF and microwave design. Additionally, our customers gain confidence about the accuracy of their designs

at high frequencies and avoid additional design cycles," he adds.

"The combination of ADS and the IHP's SiGe design kits provides our mutual RF customers access to a powerful, integrated design solution for a fast and efficient RFIC design flow," says Juergen Hartung, foundry program manager of Agilent's EESof EDA organization. "With these kits, our customers can now enjoy the industry's most comprehensive multi-technology design platform using qualified substrate definitions files for Momentum, the industry-leading 3D planar EM simulator, our integrated full 3D FEM engine, industry-proven design-for-manufacturing capabilities inside ADS, and an upgraded design rule checker," he claims. "The kits have dedicated RF & microwave design support like a MMIC toolbar personality and transmission-line libraries to help streamline the MMIC design process."

www.ihp-microelectronics.com
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NXP's SiGe:C yields lowest-power Ku-band downconverters for sat TV receivers

NXP Semiconductors N.V. of Eindhoven, Netherlands has launched the TFF101xHN, a family of integrated downconverters for use in low-noise block (LNB) 10.7–12.75GHz Ku-band satellite receiver systems.

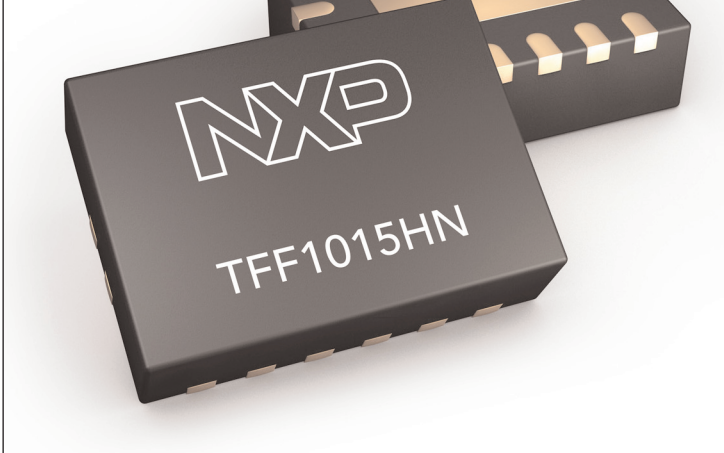
The LNB downconverter is the device at the front of a parabolic satellite dish antenna that receives the very low-level microwave signal from the satellite, amplifies the signal and converts it to a lower frequency band in order to send it down the cable to the indoor receiver. The Ku band (Kurtz-under band) is primarily used for satellite communications, particularly for editing and broadcasting satellite television.

The downconverters are the most recent additions to NXP's portfolio for satellite LNB, including other discrete products such as oscillators, amplifiers and switches, to provide complete coverage for all LNB architectures. Designed for downlink signal reception for TV satellite dishes, the new DVB-S compliant downconverters consume 50% less current ($I_{cc} = 52\text{mA}$) than other integrated solutions, increasing the lifetime of the LNB and improving its reliability, it is claimed.

The TFF101xHN family offers simplicity and integration in a leadless 16-pin DHVQFN16 (2.5mm x 3.5mm x 0.85mm) package with a conversion gain ranging from 37dB to 45dB. They also offer integrated phase noise of 1.5 degrees RMS (10kHz-13MHz integration bandwidth) and a low noise figure of 7dB. Additionally, this high level of integration guarantees stability of the local oscillator (LO), which improves overall system reliability by eliminating LO drift over lifetime due to temperature changes.

The TFF101xHN family is backed by NXP's proprietary QUBiC4 SiGe:C processes and RF intellectual property. Available since 2002,

NXP's TFF1015HN integrated downconverters for low-noise block 10.7–12.75GHz Ku-band satellite receiver



QUBiC4 technology has been widely deployed in the field and offers more consistent parameter performance compared to gallium arsenide technology, NXP claims, speeding migration from GaAs to silicon and delivering more functionality in less space. High integration reduces the design footprint and enables more cost-competitive designs in small PCB real-estate, it adds, as well as improving reliability and offering savings in manufacturing expenditure.

For satellite LNB makers, due to the high integration level of functionality and the need for just seven external components and no inductors, assembly is also made easy. The TFF101xHN family comes in four fully RF-tested versions with pre-set LO frequencies, which reduces the need for manual adjustments on the production line, speeding up the manufacturing process and time to market, as well as lowering operating costs, the firm says.

High integration reduces the design footprint and enables more cost-competitive designs in small PCB real-estate

"The new TFF101xHN downconverters take advantage of our state-of-the-art QuBiC4 SiGe:C technology, offering more functionality in less space, with better performance and lower power consumption than other solutions," claims Greg Baker, NXP's senior director &

manager, RF small-signal product line. "Our RF small-signal portfolio based on QuBiC4 enables a wide range of applications from mobile platforms, personal navigation devices, software-defined radio and e-metering, to AESA radars, satellite DBS and VSAT, base-stations, point-to-point radio links and WLAN, where high frequency and high integration levels are essential," he adds.

"After consultation with satellite LNB makers, we have developed an improved and fully integrated downconverter solution that reduces both power consumption and time to market," says Guido Bekkers, worldwide marketing manager, RF satellite products. "This level of integration isn't common in the LNB market, which is dominated by discrete solutions characterized by the chance of LO drift, something which our downconverters completely eliminate. Savings in assembly time also means that the TFF101xHN offers LNB makers a solution with a very low cost of ownership."

Multiple gain types are available. The 39dB TFF1015HN and the 42dB TFF1017HN are available now via distributors. The 36dB TFF1014HN and the 45dB TFF1018HN will be available in early October.

www.nxp.com

Renesas launches SiGe:C HBT with 0.75dB NF at 5.8GHz

Japan's Renesas Electronics Corp has introduced a new SiGe:C HBT, the NESG7030M04, for use as a low-noise amplifier in applications including wireless local-area networks (WLAN) and satellite radios.

The device uses newly developed carbon-doped silicon-germanium process technology in response to demand for even lower noise and to provide solutions for the 12GHz+ frequencies in satellite broadcasting.

The new SiGe:C HBT amplifies a weak microwave signal received wirelessly to an appropriate level and achieves a noise figure of 0.75dB (an improvement of 0.35dB over earlier Renesas SiGe HBTs), which is claimed to be industry-leading low-noise performance for the 5.8GHz band used by WLAN.

Also, gain at the minimum noise level is 14.0dB. This allows communication sensitivity to be increased in end products and signal trans-

mission errors to be reduced, so the new HBT can achieve equivalent performance to earlier Renesas products at just a quarter of the operating power consumption.

In earlier silicon-based HBTs, it was not possible to avoid a reduction in the collector-emitter breakdown voltage in exchange for reducing noise, and this limited the range of applications of devices, Renesas says. In the new device, it has optimized the collector-base profile, making it possible to guarantee a breakdown voltage rating of 4.3V. This increases the range of supply voltages that can be used and enables stable operation over a wide frequency range, from a few MHz to the 14GHz band. This enables use of the device in a wider range of applications, e.g. it can support all industrial, scientific & medical (ISM)-band applications, including smart grid, smart meter, and home-area

network (HAN) applications.

Also, since the new transistor was developed for microwave use, it is supplied in Renesas' 'M04' industry-standard 4-pin thin-form mini-moulded package, which can help to reduce the number of steps in manufacturing end-user products. Examples include simplifying the mounting evaluation process due to the track record of existing packages, and using an existing circuit board pattern and slightly modifying the surrounding circuits.

Renesas is also committed to deploying the new SiGe:C HBT process in the development of microwave ICs.

Samples of the new SiGe:C HBT are available now. Mass production will start in November at 1 million units per month, and should reach 50 million per month together with existing SiGe HBTs.

www.renesas.eu

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Ascatron spun off from Sweden's Acreo as first independent pure-play SiC foundry

High-volume fab planned for 50,000 6" wafers per year

Swedish microelectronics and optics research institute Acreo AB of Kista, Sweden, has announced the foundation of Ascatron. Based on silicon carbide (SiC) technology developed at Acreo, Ascatron will specialize in the manufacturing of energy-efficient SiC semiconductors. Target customers are suppliers of power devices and modules to the power electronic industry.

Ascatron is claimed to be the first independent 'pure play' SiC foundry offering a complete fabrication service from device epitaxy to diced wafers.

"Now is the right time to build up production capacity for SiC devices. The demand for our epi service has increased significantly and we have run our two R&D reactors at a maximum capacity over the last two years," says Acreo's CEO Mårten Armgarth. "The commer-

cialization of our SiC process technology is in line with our mission to transfer research results to industry. When a technology is mature enough and the market demand is identified, our strategy is to look at the possibilities to start a new company," he adds.

"With our know-how in development of different types of SiC devices, Ascatron can optimize the fabrication process to the design and specifications required by the customer," says Adolf Schöner, manager of the SiC group at Acreo and co-founder of Ascatron.

"We will focus on fast delivery of small series for market verification, followed by a production ramp-up in accordance with the customer needs."

Ascatron is starting to scale-up the SiC fabrication technology, developed at Acreo, during

September. Ascatron is initially using the established 4" wafer SiC process line at Acreo's Electrum Laboratory in Kista, Sweden.

As part of the roadmap to serve the growing SiC industry, Ascatron plans to build up a dedicated large-volume SiC device production fab, capable of handling more than 50,000 6" wafers per year.

Acreo will continue R&D activities in SiC semiconductors, focusing on device and module design for energy-efficient power electronics. To accelerate the implementation of efficient power electronics, Acreo says that it plans to start the SiC Power Center, a platform for application-oriented R&D activities in a collaboration between industry, research institutes and universities.

www.ascatron.com

www.acreo.se/nanoelectronics

SemiSouth launches 1200V/5A SiC Schottky diodes in true surface-mount packaging

SemiSouth Laboratories Inc of Starkville, MS, USA, which designs and manufactures silicon carbide (SiC) transistor technology for high-power, high-efficiency, harsh-environment power management and conversion applications, has launched 1200V/5A diodes in true, compact DPAK (TO-252) surface-mount packaging, which provides the necessary creepage distance and does not require a center pin.

Like many SiC diodes from SemiSouth, the new SDB05S120 parts feature a positive temperature coefficient for ease of paralleling. Switching behavior is independent of temperature and the devices have a maximum operating temperature of 175°C.

SemiSouth's new Schottky diodes also have a zero reverse recovery current and voltage. Furthermore,



SemiSouth's SDB05S120 1200V/5A SiC Schottky diode.

the device's footprint is just 0.385-inches x 0.260-inches and the profile is 0.090-inches.

"We have designed these parts to be as user-friendly as possible,

with many features that enable designers to realize the benefits of SiC technology quickly and easily," says VP sales & marketing Dieter Liesabeths.

The major application for these new SiC diodes lies in photovoltaic micro-inverters, but the devices are also suitable for use in SMPS,

power factor correction (PFC) circuits, induction heaters, uninterruptible power supplies (UPS) and motor drives.

www.semisouth.com

Cree adds TO-252 D-Pak packaged Z-Rec SiC Schottkys in 2A, 5A, 8A and 10A ratings

Cree Inc of Durham, NC, USA says that the latest addition to its 1200V silicon carbide (SiC) Schottky diode range includes four new surface-mount devices in 2A, 5A, 8A, and 10A current ratings (the C4D02120E, C4D05120E, C4D08120E and C4D10120E series, respectively) in industry-standard surface-mount TO-252 D-Pak packages.

Cree claims to be the first manufacturer to offer this comprehensive range of current ratings for commercially available 1200V SiC Schottky diodes in the surface-mount D-Pak package. Designers of systems, such as solar micro-inverters, now have more options to develop smaller, lighter and less costly power conversion circuits, the firm adds. The new surface-mount devices deliver the same performance as Cree's TO-220 Schottky diodes, but with a smaller PCB footprint and lower profile. The operating junction temperature for all C4DXX120E devices is rated for -55°C to $+175^{\circ}\text{C}$.

"These new surface-mount devices provide all the proven benefits of SiC Schottky diodes — zero reverse recovery losses, temperature-independent switching,



Cree's C4D10120E 10A, 1200V SiC Schottky diode.

higher-frequency operation with low EMI, and significantly higher surge and avalanche capability — with a smaller footprint and a lower board-mounted profile," says Cengiz Balkas, Cree's VP & general manager, Power and RF. "The new 2A device is ideally suited for lower-power applications, allowing them to benefit from the advantages of SiC while providing the best performance and cost option. With the addition of the 8A and 10A devices, the same space and cost savings can be extended to higher-power applications," he adds.

"There are significant design advantages to implementing SiC

power devices in high-efficiency power electronics systems, including the ability to achieve higher current and voltage ratings with fewer components," says Balkas. "By reducing the component count, designers can achieve lower overall system costs with increased reliability and maximum efficiency," he adds.

"When used in conjunction with Cree's new series of 1200V SiC power MOSFETs in an all-SiC design, these Schottky diodes make it possible to achieve high-efficiency power electronics systems with switching frequencies that are 5–8x higher when compared to conventional silicon solutions," Balkas continues. "The higher switching frequencies enable smaller magnetic and capacitive elements, thereby shrinking system size, weight and cost."

The C4DXX120E surface-mount Schottky diodes are fully qualified and released for production use.

www.cree.com/power

Mitsubishi to launch next-gen SiC inverter for railcars

Tokyo-based Mitsubishi Electric Corp says that it is to launch a next-generation traction inverter system incorporating large-capacity silicon carbide (SiC) power modules. Railcar systems fitted with the traction inverter can achieve 30% energy savings, require less maintenance and emit less noise than conventional silicon (Si) power modules, it is reckoned. The first commercial application, following a series of ongoing field tests starting in January 2012, is expected to be in railcars of Tokyo Metro Co Ltd.

Compared to Si-based power modules used in current traction inverters, the new SiC power module offers key improvements, says Mitsubishi Electric. In addition to 30% reduced power loss in the traction inverter, inverter size and weight have each been reduced by 40%.

The new inverter system can also enhance the performance of regenerative brakes, leading to the production of more regenerative electricity, says the firm. Incorporating two 1700V and 1200A SiC chips, the new inverter's high-

frequency switching capability also leads to 40% less power loss in the motor. Furthermore, the inverter emits up to 6dB less noise compared to conventional models, Mitsubishi Electric claims.

Railways are garnering renewed attention as a means of reduced-carbon transportation, says the firm. Continued improvements in railcar equipment performance, including the new inverter system, are expected to lower the environmental impact of railways further, it adds.

www.MitsubishiElectric.com

TriQuint launches 18W GaN HEMT for up to 6GHz

TriQuint Semiconductor Inc of Hillsboro, OR, USA has launched the T1G6001528-Q3, a gallium nitride (GaN) packaged HEMT RF power transistor that delivers high output power and efficiency over a wide bandwidth (DC to 6GHz), suiting defense and commercial wireless communications, avionics, radar systems, electronic warfare jammer amplifiers, test equipment and applications in which high-power, broad frequency coverage and high efficiency are critical.

Commercial and defense systems place stringent demands on RF power devices, says TriQuint. They must combine high RF output power with high efficiency and gain across a wide bandwidth. The T1G6001528-Q3 is fabricated using the firm's 0.25 μ m GaN on SiC process, which incorporates field-plate techniques that enhance RF output power and efficiency at high drain bias operating conditions.



TriQuint's T1G6001528-Q3 GaN HEMT.

This has benefits for system designers because overall costs can be reduced as fewer RF power transistors and amplifiers are required to deliver a specific power level, which can decrease the system's bill of materials and reduce thermal management requirements, says TriQuint.

"Nearly every application today requires RF power devices that are optimized for not just one, but all performance parameters," says

Richard Martin, Defense & Aerospace Transistor marketing manager. "The T1G6001528-Q3 is an excellent example of how gallium nitride technology can be applied to meet these challenges without trading off a key performance metric just to satisfy another," he claims. "Compared to even robust technologies like GaAs, GaN provides superior wideband power, efficiency and gain." The new packaged transistor delivers P3dB output power of at least 18W with drain efficiency of more than 60% at 6GHz, while providing the high gain (10dB) and ruggedness required by current applications, Martin adds.

The T1G6001528-Q3 operates from a 28V_{DC} power supply, will deliver its rated output power into a maximum VSWR of 10:1 without damage, and is housed in TriQuint's compact, low-thermal-resistance earless solder-down package.

www.triquint.com

GaN RF MMIC switches operating at 10–40W cw and 6–18GHz

At European Microwave Week in Manchester, UK (11–13 October), TriQuint launched a family of reflective MMIC RF and microwave SPDT switches combining the higher power-handling ability of GaN with high speed, low insertion loss, high isolation and broad frequency coverage of DC to 6, 12 or 18GHz. The switches allow designers of defense, aerospace or high-performance commercial systems to use much smaller semiconductor devices in many applications where the only alternative previously was to use larger, heavier electro-mechanical devices, says the firm. The new devices are also claimed to be the first solid-state solution to handle this much power.

The GaN switch family includes: the TGS2351-SM packaged in a 4mm x 4mm, 24-lead, air-cavity ceramic QFN package, and three die-level switches, the TGS-2351 (DC to 6GHz, 40W CW), the

TGS2352 (DC to 12GHz, 20W CW) and the TGS2353 (DC to 18GHz, 10W CW). The TGS2351-SM's air-cavity ceramic package uses proprietary techniques to offer enhanced protection for the GaN die while also effectively dissipating more heat in a way not achievable with fully encapsulated plastic packaging form factors. Packaged versions of the 12 and 18GHz die-level devices are in development.

TriQuint says that GaN has a unique power-handling advantage over GaAs FETs and PIN diodes when employed in switches — GaAs FETs, although solid-state, can handle only a few watts of power, whereas PIN diodes can handle higher power but typically consume more DC energy. In contrast, TriQuint's HEMT GaN-on-SiC process enables its MMIC switches to handle up to two and a half times more on-state power and eight times more off-state power

than a GaAs FET switch fabricated in a typical 0.25 μ m GaAs process, it is claimed. They do so while consuming minimal current, remaining highly stable over temperature, and delivering performance comparable to or better than that of GaAs FETs or diodes, the firm adds. GaN switches are also orders of magnitude smaller than some electro-mechanical switches.

"TriQuint innovation and GaN product development has led to another break-through device that offers performance advantages in size, weight and power that should be of particular interest to defense and aerospace designers," says GaN product manager Grant Wilcox. "GaN switches have the potential to shrink the size of the host product and lower its power consumption with performance not previously offered by a solid-state switch solution."

High-power 700MHz to 2.2GHz GaN power transistors launched

RF Micro Devices Inc of Greensboro, NC, USA has launched the RFG1M series of high-power gallium nitride broadband power transistors (BPTs), optimized for commercial wireless infrastructure, military communications and general-purpose amplifier applications in the 700MHz to 2.2GHz frequency band.

Using a 48V high-power-density GaN high-electron-mobility transistor (HEMT) process optimized for high peak-to-average ratio applications, the RFG1Mxxxxx amplifiers achieve high efficiency and flat gain over a broad frequency range in a single amplifier design, says RFMD.

Typical peak modulated power is >120W for the RFG1M09090 and >240W for the RFG1M09180 (both operating at 700–1000MHz, suiting WCDMA and LTE applications), and >90W for the RFG1M20090, and >180W for the RFG1M20180 (both operating at 1.8–2.2GHz, suiting constant envelope, pulsed and WCDMA and LTE applications).

The RFG1M series devices are input-matched GaN transistors with advanced heat-sink technology in an air-cavity flanged ceramic 2-pin, RF400-2 package, providing ther-



mal stability at operating temperatures of -25°C to 85°C .

Ease of integration is accomplished through the incorporation of simple, optimized matching networks external to the package that provide wideband gain, efficiency, and potential high-linearity performance in a single amplifier.

All parts are RF tested for 3GPP performance, and for peak power using IS95. Large-signal models are also available. Pricing begins at \$316.80 each for five pieces.

RFMD launches 280W GaN wideband S-band pulsed power amplifier

RF Micro Devices has launched the RF3928, a 50V, 280W high-power discrete amplifier designed for S-band pulsed radar, air traffic control & surveillance, and general-purpose broadband amplifier applications.

Using a high-power-density GaN HEMT process, the amplifiers achieve high pulsed output power of 280W, high drain efficiency of 52%, and flat gain over a broad frequency range (2.8–3.4GHz) in a single hermetic, flanged ceramic package.

Through the use of advanced heat sink and power dissipation technologies, the package provides

what is claimed to be excellent thermal stability over the operating temperature of -40°C to 85°C .

In addition, ease of integration is accomplished through the incorporation of simple, optimized matching networks (for high terminal impedances) external to the package that provide wideband gain (with small-signal gain of 12dB) and power performance in a single amplifier.

Also available is an optimized evaluation board layout for 50W operation.

www.rfmd.com

IN BRIEF

RFMD introduces 225W and 280W GaN wideband pulsed power amplifiers

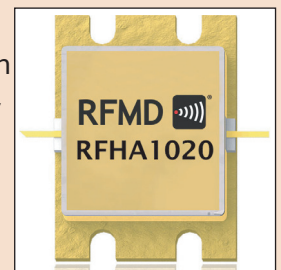
RF Micro Devices has launched two new high-power discrete amplifiers designed for L-band pulsed radar, air-traffic control and surveillance, and general-purpose broadband amplifier applications. Both are based on gallium nitride (GaN) high-electron-mobility transistors (HEMTs) and integrate matching components for high terminal impedances.

Operating at a supply voltage of 50V, the RFHA1020 provides pulsed output power of 280W (with a 100 μs pulse width at 10% duty cycle).

Operating at a supply voltage of 36V, the RFHA1023 provides pulsed output power of 225W (with a 1ms pulse width at 10% duty cycle).

Both amplifiers have 55% drain efficiency and small-signal gain of 15dB.

They are packaged in a hermetic, flanged ceramic package that provides what



is claimed to be excellent thermal stability with advanced heat-sink and power dissipation technologies. Ease of integration is accomplished through the incorporation of single, optimized matching networks that provide wideband gain and power performance in a single amplifier covering the 1.2–1.4GHz frequency band.

For both amplifiers, an evaluation board is available with layout optimized for 50 Ω operation.

www.rfmd.com

Raytheon awards UK team for high-temperature silicon carbide technology

Engineers at Uxbridge-based Raytheon UK's facility in Glenrothes, Scotland have been recognised by parent company Raytheon USA for their research, development and manufacturing expertise in the latest high-temperature silicon carbide (HiTSiC) technology. The team received an Operations Excellence award after being selected from over 2000 competing innovations from within Raytheon's global portfolio.

Through advances in SiC wafer processing and individual device design technology, the HiTSiC program has demonstrated the first CMOS transistors operating at more than 300°C. At the European Conference in Silicon Carbide and Related Materials 2010 (ECSCRM) in Oslo, Norway, Raytheon UK's HiTSiC team demonstrated 10 times higher logic complexity and significantly faster processing than earlier-generation technologies.

Raytheon says that the Scottish-developed HiTSiC technology has the potential to be a 'game changer' in aerospace, energy and green-related applications, through enabling CMOS (complementary metal-oxide-semiconductor) integrated circuits and transistors to operate at temperatures of 300–400°C.

Aerospace applications include: more efficient aero engines (where electronic monitoring and control can be developed in-situ in harsher areas of the engine); the transition from hydraulic to electric actuation in aerospace (where higher-temperature-capable power and control electronics can be co-located with the brakes); and aerospace actuation (being driven towards future more-electric aircraft, in order to increase fuel efficiency and lower emissions). New technologies such as HiTSiC also offer the potential of light-weight power through air cooling.

Also, the challenges faced by the oil and gas industry in making



Jennifer Cormack, Silicon Carbide manager, at Raytheon UK's Glenrothes facility, receiving the Operations Excellence award from Dan Crowley, president of Raytheon Network Centric Systems, USA.

'deep reserves' economically viable can potentially be helped by the development of electronics that can withstand 300°C, says Raytheon. This also enables the firm to use the technology in next-generation high-efficiency, low-weight power conversion products.

"This Operations Excellence award is a significant recognition of the technologists and engineers at Raytheon UK who have developed a unique technological capability for Scotland, whilst achieving a world first," comments Lindsay Roy, MP for Glenrothes. "Raytheon's cutting-edge capabilities being developed in Scotland will add value and skills to our economy, as the business addresses a new market estimated at more than \$40m annually."

Economic development agency Scottish Enterprise has commended Raytheon's HiTSiC technology and diversification into new global growth markets. "The role of Scottish Enterprise is to help identify

and promote the best opportunities for economic growth within companies like Raytheon UK globally, because Scotland's engineering capabilities are well regarded in a wide range of technology areas," says Ian McMahan, head of aerospace, defence and marine at Scottish Enterprise. "Developing a technology for one sector that can then be used in different sectors is where the greatest commercial gain can be achieved," he adds. "Raytheon is an excellent example of a Scottish inward investor that has invested to gain a world-leading position in enabling technologies. Raytheon's Scottish engineering team is a vital part of the international technology development work it is undertaking to address new market segments for extreme environment sensors and instrumentation which can be used in areas such as aerospace, oil and gas, and geothermal exploration."

www.raytheon.co.uk

Raytheon's Air and Missile Defense Radar modules pass 1000-hour RF Operating Life test

Raytheon Company of Waltham, MA, USA says that its gallium nitride-based transmit/receive (T/R) modules for the US Navy's Air and Missile Defense Radar (AMDR) program have passed a significant developmental testing milestone, exceeding Navy-specified requirements for extended, measured performance (demonstrating no degradation after more than 1000 hours of testing).

Currently working on Phase II of the AMDR program, Raytheon is developing a technology demonstrator for the system's S-band radar and radar suite controller. During testing, the modules demonstrated consistent power output across multiple channels. The more than 1000-hour Radio Frequency Operating Life test was a self-imposed early milestone for Raytheon.

"The threats that AMDR is designed to counter require leap-ahead technology that Raytheon is ready to deliver," says Raytheon Integrated Defense Systems' Kevin Peppe, VP of Seapower Capability Systems. "We are seeing our gallium nitride modules exceed the program's performance requirements, which ensures that the Navy will get the capability and reliability they need for this sophisticated radar system at an affordable cost."

AMDR provides capabilities for the Navy beginning with the Arleigh Burke-class destroyers. It fills a critical gap in the joint forces' integrated air and missile defense capability, enabling effective missile defenses to be deployed in a flexible manner wherever needed, says Raytheon. The radar suite consists of an S-band radar, X-band radar and radar suite controller. The system is fully scalable, enabling the radar to be sized according to mission need and to be installed on ships of varying size, as necessary to meet the Navy's current and

future mission requirements. The radar's digital beam-forming capability enables it to perform multiple simultaneous missions (a critical feature that makes the system affordable and operationally effective for the Navy).

Raytheon says that its expertise working with large-scale active phased-array radars spans the frequency spectrum from UHF to X/Ku-band and dates back to the Cobra Judy and Upgraded Early Warning Radar programs, continuing currently with the Dual Band Radar, AN/TPY-2 and Cobra Judy Replacement programs. The experience gained from these programs will ensure that the AMDR S- and X-band radars operate in coordination across a variety of operational environments, the firm says.

Modules demonstrated consistent power output across multiple channels

Also, it has so far produced more than 1.8 million AESA (active electronically scanned array) T/R modules and has decades of experience working with adaptive beam-forming technologies.

Work on the AMDR program is performed at Raytheon Integrated Defense Systems' headquarters in Tewksbury, MA; at the Surveillance and Sensors Center in Sudbury, MA; at the Seapower Capability Center in Portsmouth, RI; and at the Integrated Air Defense Center in Andover, MA. Raytheon has partnered with General Dynamics Advanced Information Systems and naval architect Gibbs & Cox in the concept and technology development of the next-generation radar.

www.raytheon.com

IN BRIEF

Hittite launches GaN MMIC PA delivering 10W at 0.1–10GHz

Hittite Microwave Corp of Chelmsford, MA, USA, which designs and supplies analog and mixed-signal RF, microwave and millimeter-wave ICs, modules, subsystems and instrumentation, has launched a new GaN HEMT MMIC wideband power amplifier (PA) suiting test & measurement equipment and military EW (electronic warfare) and ECM (electronic counter-measures) applications up to 10GHz.

The HMC999 is a GaN HEMT MMIC distributed power amplifier chip that operates at 0.01–10GHz. The wideband PA provides 11dB of gain, +38dBm of output power at 1dB gain compression, and +47dBm output IP3 at mid-band. For less demanding applications, it can be operated from a drain voltage as low as +28V while still producing 5W of saturated output power.

When biased for maximum output power, the HMC999 consumes 1100mA of quiescent current from a +48V supply, and achieves about 18% power-added efficiency (PAE) at saturation. The compact MMIC power amplifier delivers 10W of saturated output power in a chip area of just 7mm², equating to a power density of 1.5W/mm² across three decades of bandwidth.

Hittite Microwave says that the HMC999 is extremely robust and is designed to operate reliably into partially reflective loads and to tolerate very high incident power levels.

The HMC999 is matched to 50 Ohms on-chip, and requires several external bias decoupling capacitors and an external bias tee for drain bias injection.

www.hittite.com

EPC adds second-generation 100V, 30mΩ eGaN FET

Efficient Power Conversion Corp (EPC) of El Segundo, CA, USA has introduced the EPC2007 as the newest member of its second-generation enhanced-performance gallium nitride on silicon (eGaN) field-effect transistor (FET) family (launched in March with the EPC2001 and EPC2015, and added to in June with the EPC2010 and in August with the EPC2012 and EPC2014).

The EPC2007 FET is a 1.87mm², 100V_{DS}, 6A device with a maximum on-resistance R_{DS(ON)} of 30mΩ. The firm says that this latest second-generation eGaN FET provides performance advantages over the first-generation EPC1007 device, since it is fully enhanced at a lower gate voltage and has greater immunity to fast switching transients.

Compared with a state-of-the-art silicon power MOSFET with similar on-resistance, the EPC2007 is much smaller and has many times superior switching performance, says EPC. Applications that benefit from eGaN FET performance include hard-switched and high-frequency circuits such as isolated DC-DC

power supplies, point-of-load converters, and class D audio amplifiers.

EPC's eGaN FET portfolio provides power design engineers with the opportunity to increase the efficiency and reduce the size of their power conversion systems compared with

silicon-based MOSFETs, claims co-founder & CEO Alex Lidow.

The EPC2007 eGaN FET is lead free, RoHS-compliant and halogen free. In 1000-piece quantities, it is priced at \$1.31, available via Digi-Key Corp.

www.epc-co.com

Development board for systems using EPC2007

EPC has introduced the EPC9006 development board, which it says will make it easier for users to start designing with its 100V eGaN 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 EPC9006 development board is a 100V maximum device voltage, 5A maximum output current, half bridge with onboard gate drives, featuring the 100V EPC2007 eGaN FET. The board's purpose is to simplify the evaluation process of the EPC2007 eGaN FET by including all the critical components on a single board that can be easily con-

nected into any existing converter.

Measuring 2" x 1.5", the EPC9006 development board contains not only two EPC2007 GaN FETs in a half-bridge configuration with gate drivers, but also an on-board gate drive supply and bypass capacitors. The board contains all critical components and layout for optimal switching performance. There are also probe points to facilitate simple waveform measurement and efficiency calculation.

EPC9006 development boards are priced at \$95 each via Digi-Key. A 'Quick Start Guide' is included for reference and ease of use.

http://epc-co.com/epc/documents/guides/EPC9006_qsg.pdf

EPC achieves ISO 9001 certification for quality management

EPC has received the International Organization for Standardization's ISO 9001:2008 certification for its quality management system after passing an assessment conducted by Det Norske Veritas, an ANSI-ASQ National Accreditation Board (ANAB)-certified auditor.

EPC claims to be first to introduce enhancement-mode eGaN FETs as power MOSFET replacements.

"Our quality management system is dedicated to continuous improvement, our processes are well documented and controlled, changes are made in a considered way, and we listen systematically to our customers," comments co-founder & CEO Alex Lidow.

www.iso.org/iso/iso_9001_2008

EPC9005 development board introduced for systems using 40V EPC2014 eGaN FETs

EPC has introduced the EPC9005 development board for users to start designing with its 40V eGaN-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 EPC9005 development board is a 40V maximum device voltage, 7A maximum output current, half bridge with on-board gate drives, featuring the EPC2014 40V eGaN FET (launched in August). The board's purpose is to simplify the evaluation process of the EPC2014 eGaN FET by including all the critical components on a single board that can be easily connected into an existing converter.

Measuring 2" x 1.5", the EPC9005 development board contains not only two EPC2014 GaN FETs in a half-bridge configuration with gate drivers, but also an on-board gate drive 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.

EPC9005 development boards are priced at \$95 each and are available from Digi-Key Corp. A 'Quick Start Guide' is included for reference and ease of use.

http://epc-co.com/epc/documents/guides/EPC9005_qsg.pdf

Accel-RF announces university collaboration program for GaN RF reliability test

Firm to provide RF equipment, software and services for device characterization

Accel-RF Corp of San Diego, CA, USA,, which produces turn-key RF reliability testing systems for compound semiconductor devices, has announced a university collaboration program that involves providing universities with RF equipment, software and other services for the reliability testing and characterization of compound semiconductor devices such as gallium nitride (GaN). The goal is for professors and their research teams to use these resources for research into compound semiconductor RF physics, reliability prediction, and test method improvement.

"Accel-RF is pleased to support our participating universities by providing leading-edge reliability test equipment to a team of researchers," says president & founder Roland Shaw. "Our equipment, software and support engi-

neering services allow researchers and manufacturers to collect in-situ performance degradation data on RF/microwave devices, and use that data to move forward the understanding of reliability drivers in advanced semiconductor technologies," he adds.

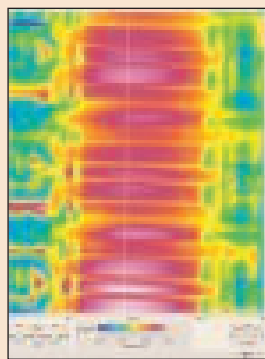
The university collaboration program bolsters Accel-RF's Cooperative Research and Development Agreement (CRADA) with the US Air Force Research Laboratory (AFRL) announced in August 2010.

"The relationship between Accel-RF and our academic partners has and continues to be a win-win situation," says Shaw. "The work already completed has born insights into development of more rugged GaN transistor technology that can be deployed in many applications throughout the semiconductor industry," he adds.

Accel-RF launches self-contained RF characterization platform

At the 22nd European Symposium on Reliability of Electron Devices, Failure Physics and Analysis (ESREF 2011) in Bordeaux, France (3-7 October), Accel-RF and its distributor Peritest of Voglans, France exhibited Accel-RF's new self-contained RF characterization platform, which incorporates RF source and measurement on board.

This is said to enable the easy RF characterization for pseudomorphic high-electron-mobility transistor (pHEMT), field-effect transistor (FET), heterojunction bipolar transistor (HBT), monolithic microwave integrated circuit (MMIC) and micro-electro-mechanical system (MEMS) devices.



Thermal image of a power FET channel measured under RF drive using Accel-RF test platform and SMART Fixture.

Typical applications for the platform include thermal imaging of GaN FET structures under RF stress and at elevated temperature.

Units are shipping in fourth-quarter 2011.

<http://esref2011.ims-bordeaux.fr>
www.peritest.com
www.accelrf.com

IN BRIEF

Low-profile split dual Si/SiC hybrid IGBT modules

Combining its NFH-Series silicon-based insulated-gate bipolar transistor (IGBT) with a Zero Recovery silicon carbide (SiC) Schottky diode, Powerex Inc of Youngwood, PA, USA is offering split dual Si/SiC hybrid IGBT modules (the QID1210005 and QID1210006) designed for high-frequency applications (upwards of 30kHz for hard switching and 60-80kHz for soft switching).

In January, the US Department of Energy's Advanced Research Projects Agency-Energy (ARPA-E) awarded a \$5.15m, three-year grant to fund SiC power device development, with the bulk going to project leader Cree Inc of Durham, NC (which makes SiC power devices), along with partners Powerex, high-power semiconductor maker ABB Ltd of Zurich, Switzerland, and North Carolina State University (NCSSU).

Each module includes two IGBTs, each having a reverse-connected Zero Recovery free-wheel SiC Schottky, yielding a 30% cut in switching losses. All components and interconnects are isolated from the heat-sinking baseplate, allowing simplified system assembly and thermal management.

The modules have a very low profile and can be easily reconfigured. In total, five configurations are possible: independent; as a dual; in parallel; common collector; and common emitter.

Rated at 100A/1200V, the modules feature: a low ESW (turn-off loss); aluminum nitride isolation; and a low internal inductance. The QID1210005 has a copper baseplate and the QID1210006 has an AlSiC baseplate for extended thermal cycle life.

The modules can be used with standard Powerex NFH gate drivers.
www.pwr.com

SETi wins STTR Phase II to develop AlInN/GaN HFETs

Phase I demos AlInN epitaxial growth on bulk GaN

Sensor Electronic Technology Inc (SETi) of Columbia, SC, USA says that it has been awarded an STTR (Small Business Technology Transfer) Phase II program to further develop aluminum indium nitride/gallium nitride (AlInN/GaN)-based heterojunction field-effect transistors (HFETs) on free-standing bulk GaN substrates.

The Phase II program was awarded via the US Missile Defense Agency (MDA) following successful demonstration of the epitaxial growth of an entirely strain-free HFET structure, consisting of lattice-matched AlInN on bulk GaN substrates in the Phase I program. During Phase I, AlInN/GaN heterostructures were deposited on bulk GaN substrates with indium compositions ranging

from 0–25%, with minimum sheet resistances of $\sim 235 \Omega/\text{square}$.

The new program will target further reductions in defect density in the epitaxial GaN and AlInN layers and aims to demonstrate increased device reliability over conventional AlGaIn/GaN HFETs. SETi says that increased reliability in GaN HFETs is essential in the defense and satellite markets, which account for more than a quarter of the entire GaN RF device market.

Known for its UVTOP and UVClean deep-UV LED products (emitting light at wavelengths shorter than 365nm), SETi specializes in Al(In)GaIn material technologies, and has a patented process MEMOCVD (migration-enhanced metal-organic chemical vapor dep-

osition) process for defect reduction in AlGaIn-based epitaxial structures on sapphire substrates. It says that the application of MEMOCVD in UVLED structures has enabled it to become the first UV LED firm to offer LEDs with wavelengths shorter than 365nm on the commercial market.

SETi adds that it has now demonstrated the benefits of its Al(In)GaIn materials growth technologies on bulk nitride substrates and, through further development from programs such as the MDA-funded program, aims to push AlInN material technology further to the development of next-generation high-power, very high-frequency RF components.

www.s-et.com

NMIC launches aluminum diamond heat spreader material for GaN devices

Nano Materials International Corp (NMIC) of Tucson, AZ, USA has launched what it claims is the first commercial device-level solution for dissipating the heat generated by high-density semiconductor devices such as gallium nitride RF power transistors.

When used as a heat spreader integrated with a device, NMIC's new aluminum diamond metal matrix composites (MMCs) have demonstrated their ability to reduce junction temperatures by up to 25%, allowing the devices to generate their full power output at their highest efficiency and potentially extend their operating life, says NMIC. The firm claims that it is the first aluminum diamond MMC material to be economically viable in high volume at a cost that adds minimally to each GaN device.

GaN can generate high levels of RF power over broad frequency ranges well into the millimeter-wave range. GaN devices therefore have much



higher power density than other technologies such as GaAs, silicon and SiGe, as measured by the amount of power they can generate in a given amount of device gate periphery.

However, this power density also results in the production of large amounts of waste heat that must be removed from the device, a challenge that must be met effectively if GaN technology is to achieve its full potential, NMIC says.

Diamond has the highest thermal conductivity of any substance on Earth. When made as an aluminum

diamond composite and used as a heat spreader material, this property remains about 80% higher than its nearest competitor copper-molybdenum-copper, which is widely used for this purpose. Aluminum diamond also has a coefficient of thermal expansion (CTE) close to that of silicon carbide, which is essential as most GaN devices employ SiC as their substrate material. NMIC says that its aluminum diamond also has metallization properties well suited for die attach, along with excellent dimensional tolerance and material stability.

The MMC material, with nickel-gold electrolytic or electroless plating, is available in thicknesses, shapes, and sizes required by GaN transistors or MMICs. It can be supplied as MMC material alone or incorporated within a package in order to serve the needs of device manufacturers and package suppliers.

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IQE's first-half 2011 growth driven by smartphones and diversifying optoelectronics business

Including £1.1m from US-based Galaxy Compound Semiconductors (acquired in September 2010), for first-half 2011 epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK has reported revenue of £38.3m, up 16% on £33m a year ago due to continued strong sales performance in key markets (with wireless up 14% and optoelectronics up 25%). However, on a constant currency basis, revenue grew 23% (19% organically), with wireless sales up 21% and optoelectronic sales up 32% (or 16% organically).

"The continued growth in demand for our wireless products driven by strong global smartphone adoption [and other mobile computing devices such as tablet PCs], coupled with increased revenues from our optoelectronic wafers, have enabled us to maintain our momentum in the first half of 2011 with a diversifying revenue stream," says chief executive Dr Drew Nelson. "Our core wireless markets [comprising 75% of total sales] continue to grow rapidly whilst the new markets around energy efficiency and consumer communications are also developing well," he adds.

IQE's gallium arsenide (GaAs) based products are in most top-tier smartphones, yielding a broad customer base and growing market share (over 30%). The firm says that it is currently engaged in more than 20 new significant product

qualifications. In addition, IQE has seen more than 100% growth in gallium nitride (GaN)-based high-power RF business, as well as significant growth in optoelectronics.

Significant organic growth has been driven by emerging technologies, including concentrator photovoltaic (CPV) solar, infrared materials and vertical-cavity surface-emitting lasers (VCSELs) for finger navigation and optical interconnects. In particular, infrared materials growth has been supported by the acquisition of Galaxy. IQE has also submitted several patent applications across a broad range of technology.

Gross margin was 22% (level with a year ago). Selling, general & administrative expenses rose by £0.8m from £4.6m to £5.4m. But, despite the adverse impact of foreign currency exchange, earnings before interest, tax, depreciation and amortization (EBITDA) rose from £5.4m to £6.1m, down on second-half 2010's £13.1m but up from £5.4m in first-half 2010. Operating profit rose from £2.7m to £3m. Cash inflow from operations rose from £1.9m to £5.9m.

Smartphones represent a fundamental structural shift in mobile communications and will still only account for 28% of the total handset marketplace in 2011, says IQE. Industry analysts predict continued growth in smartphone shipments

for several years to come. In addition, the rapid roll-out of LTE and 4G communications in 2012 and beyond, and the proliferation of wireless applications (such as with smart meters and point-to-point communications) will add further demand for IQE's wireless products, the firm reckons.

Demand for wireless products is also strongly supported by accelerating growth of optoelectronic devices across a range of new technologies and applications, including optical communications, finger navigation, lasers for projection, high-efficiency LEDs and CPV materials for solar energy generation.

"The end markets for our products continue to look attractive and offer sustainable high growth," Nelson says. "Our overall upbeat outlook is tempered by recent growing uncertainty in the global economy. This has the potential to impact inventory levels downstream in the supply chain or of individual customers, although we have not seen any evidence of this at this time," he notes. "Given IQE's strategic positioning, the board remains confident of meeting current market expectations and of the group's exciting longer-term growth prospects." IQE is therefore continuing to invest in further production capacity to address growing demand in 2012 and beyond.

www.iqep.com

IQE appoints head of sales & marketing for Asia Pacific

IQE has appointed Norio Hayafuji as head of sales & marketing for the Asia Pacific region.

Hayafuji has more than 27 years of experience in manufacturing, business development, sales & marketing and general management within compound semiconductor technology firms including Mitsubishi Electric, Procomp and Century Epitech.

Based at IQE's Singapore facility, he will coordinate sales & marketing activities and provide a technical focus for wireless, optoelectronic and photovoltaic products across the Asia Pacific customer base.

"We confidently expect China, Taiwan, Korea and Japan to become major global powers in emerging technologies over the next decade," says CEO & presi-

dent Dr Drew Nelson. "We already have a considerable presence in the Far East, with a solid customer base and state-of-the-art manufacturing facility. The appointment of an acknowledged industry expert with extensive knowledge and experience of our industry in the region will help ensure that IQE is well positioned to exploit this growth potential," he adds.

Voltaix opens Shanghai office

Voltaix LLC of Branchburg, NJ, USA, which makes specialty materials that enhance the performance and manufacturability of semiconductors and photovoltaics, has established a sales and technical/customer support office in Shanghai, China.

Yun Liu, Asian business manager and Voltaix's first employee in China, will be responsible for executing regional sales & marketing initiatives. With an MBA from the University of Ottawa as well as Bachelor Degree in Mechanical Engineering from Shanghai University, over the past 5 years he has driven growth in solar, semiconductor and TFT applications at a large industrial gas firm.

The new office will allow expanded sales & marketing staffing. "Sustainable growth of Voltaix chemistries in China for solar and semiconductor applications is expected to continue well into the future," says Greg Muhr, director, global sales & marketing.

With expertise in silicon, germanium and boron chemistry, Voltaix makes

electronics products including germane, diborane, trisilane, and trimethyl boron, using proprietary synthesis, purification, and packaging technology developed in-house, as well as designing and building its own equipment for use in its manufacturing operations. Products are custom designed for applications including advanced DRAM computer memory; silicon germanium (SiGe) transistors for wireless communications chips; strained silicon for high-speed logic chips (CPUs); copper-enabling low-k dielectrics for computer chips; and high-efficiency thin-film silicon solar cells. Voltaix claims that its materials improve manufacturability by minimizing defect formation and increasing machine throughput.

"We felt the need to bring resources closer to our distribution partners and end users to provide timely technical and customer support," says Muhr.

www.voltaix.com

GeO₂ supply deal with Sparton's China mine

Voltaix has executed a memorandum of understanding (MOU) with mineral exploration development & production firm Sparton Energy Inc of Toronto, Ontario, Canada for the purchase of all germanium production from the Huajun Mine in Yunnan Province, China. The MOU involves Voltaix investing \$4.2m in a series of advance payments related to milestones in developing operations at Huajun.

"As the world's leading germane producer, securing our germanium supply is critical. This relationship allows us to continue to provide our customers with the highest levels of supply chain security by giving Voltaix an exclusive source of significant germanium reserves," says executive VP Mark Wilkinson.

"Sparton is delighted to establish this unique long-term relationship with Voltaix," comments Sparton's president Lee Barker. "Local ger-

manium concentrate prices at Lincang have almost doubled within the past year, and we look forward to resuming production of this specialty metal."

The MOU contemplates deliveries of germanium dioxide (GeO₂) over the life of a strategic supply agreement (SSA) to recoup the advance payments. Product pricing is based on a blended formula related to processing and refining costs and local market pricing for GeO₂. The advances are to be used for safety upgrades and efficiency improvements to boost production rates.

The mine is in the final stages of having a new licence issued after completing safety and security upgrades to meet new Chinese regulatory requirements. After licencing, reactivation will begin and local workers re-employed. At full capacity, staffing is about 400.

www.spartonres.ca

IN BRIEF

Umicore and INER introduce 8" Ge wafers for CPV

At a III-V compound solar cells advanced technology seminar in Taipei, Taiwan's Institute of Nuclear Energy Research (INER) and Belgium-based Umicore Electro-Optic Materials have announced the introduction of 8" germanium (Ge) wafers for concentrated photovoltaic (CPV) cells.

Earlier this year INER's research team achieved a cell efficiency in excess of 37% at a concentration of 500x, based on 5.5mm cells from Umicore's 8" germanium wafers (cut from dislocation-free Czochralski crystals). The result has also been shown to be reproducible in a volume production environment.

The increased wafer size used in production offers the potential to reduce the processing cost of CPV solar cells. One 8" wafer yields 640 pieces of 5.5mm size for use in a CPV cell. INER development indicates that 8" wafers can increase throughput by up to 30% and generate production cost savings in excess of 30% compared to processes using 4" germanium wafers. "The era of the 8" germanium wafer is coming," says Dr Edward Yang of INER.

"Dislocation-free germanium has been the cornerstone of the success of III-V solar cells," says Umicore technology manager Dr Ben Depuydt. "It is today the most widely adopted technology in triple-junction solar cells, and our 8" wafer technology is a real enabler for the development of CPV cells," he adds.

Last year Umicore opened up a dislocation-free germanium wafer production plant in North America (in Quapaw, OK, USA), doubling its production capacity.

www.substrates.umicore.com

Dow Electronic Materials forms LED Technologies business targeting solid-state lighting

MOCVD precursors grouped with photoresist, lithography ancillaries and CMP pad & slurry supply

Dow Electronic Materials, a business unit of The Dow Chemical Company, has formed a new LED Technologies business segment to capture current and future demand for light-emitting diodes in the global solid-state lighting (SSL) market.

"Dow is in a unique position to capitalize on this rapidly growing market because we offer the broadest technology today and we bring a deep knowledge of LED materials processing," claims Jim Fahey, global general manager for Dow Electronic Materials' Growth Technologies business. "For more than 35 years, Dow has been an important player in the SSL market as a leading supplier of metalorganic CVD precursors, so we understand the technology needs,"

he adds. "Our long history with semiconductor materials, processing and methodologies allows us to meet the exacting needs of semiconductor companies — many of which are Dow's existing customers — as they migrate into the SSL market."

Solid-state lighting — especially for general illumination — is in many ways in its infancy

As well as the MOCVD precursors used to make the active light-emitting areas in LEDs, the new LED Technologies business will supply photoresists, related ancillaries for lithographic processing, and pads and slurries for CMP (all of which are used in manufacturing LEDs).

"SSL — especially for general illumination — is in many ways in its infancy," says Rick Hemond, global business director for LED Technologies. "The current market growth is largely driven by back-lighting for displays, mobile devices and HDTVs, but wider adoption of LEDs into commercial and residential lighting is expected to expand market growth over the next decade and beyond," he adds. "There are many opportunities for materials suppliers, and we look forward to expanding our portfolio and capabilities — in some cases by leveraging Dow's core materials and competencies — to make further inroads in the SSL market," Hemond concludes.

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Sumitomo investing \$52m in expanding GaAs epiwafer compound semiconductor materials business

Tokyo-based Sumitomo Chemical is to expand compound semiconductor materials production facilities at its Chiba Works in Sodegaura, Chiba Prefecture, Japan, in order to strengthen the business and the stable supply of materials to customers.

Sumitomo Chemical says that, with gallium arsenide being widely adopted for high-frequency devices used in mobile phones and other equipment due to its signal processing at high frequencies as well as low power consumption, in recent years demand has been growing rapidly for applications in antenna switches and power amplifiers in multi-function mobile phones (as typified by smartphones). The firm expects demand to continue to grow in future, so it aims to expand production of GaAs epitaxial wafers.

Until now Sumitomo Chemical has been manufacturing GaAs epi-

wafers at its Chiba Works and at its US subsidiary Sumika Electronic Materials Inc of Phoenix, AZ, with production capacity expanded stepwise in the past. Given the expectations of a continued increase in demand for GaAs epiwafers, the firm has decided to double compound semiconductor materials production capacity at the Chiba Works through investing about ¥4bn (US\$52.2m), with the aim of not only expanding the business but also establishing a fully secured system for stable supply.


In addition, capitalizing on its technology cultivated through the GaAs epiwafer business, Sumitomo Chemical is developing new compound semiconductor materials. Specifically, it will participate in the government-private sector joint project for next-generation power semiconductors at the Nagoya Institute of Technology, where it

undertakes R&D on gallium nitride. Such next-generation power semiconductors are capable of being operated at high voltage and high temperatures, and are expected to contribute to improved performance of home electrical appliances and personal computers, as well as electric vehicles, solar cells, and equipment for wind power or geothermal power generation etc (all of which can contribute to energy saving, and are likely to show market expansion in the future).

Positioning the compound semiconductor materials business as one of the priority areas of its IT-related Chemicals Sector, Sumitomo Chemical says that it aims to enhance its existing operations through expanding production capacity as well as seeking to further expand its business by focusing efforts on developing new materials.


www.sumitomo-chem.co.jp/english

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IN BRIEF

Riber wins order from China for GaN MBE research reactor

Riber has sold a Compact21 GaN MBE reactor to a State Key Laboratory in China. The system will enable the laboratory to increase its research capabilities for nitride optoelectronic materials and technology design and to develop new industrial applications.

Riber says that it has previously commissioned a large number of MBE systems for GaN deposition, and that the new order strengthens its position in the Chinese market and more generally in the Far East (the most rapidly expanding region of the compound semiconductor industry).

www.riber.com

Riber reports 142% revenue growth for first three quarters of 2011

Full-year forecast raised to €29m

For third-quarter 2011, Riber S.A. of Bezons, France, which makes molecular beam epitaxy (MBE) systems as well as evaporation sources and effusion cells, has reported revenue of €5.5m, up 72% on €3.2m a year ago. Following €5.7m in Q1 and €7.2m in Q2, revenue for the first three quarters of 2011 was €18.5m (55% from Asia, 35% from Europe, 10% from North America), up 142% on just €7.6m a year ago.

During the first three quarters, growth was driven mainly by sales of evaporation sources, up 14-fold year-on-year from just €0.6m to €9.1m, reflecting the delivery of major orders for investments in the organic LED (OLED) flat-screen markets. Systems sales doubled, from €2.8m to €5.7m, as five MBE

systems were delivered, versus four research systems a year ago (with a marked improvement in unit value). However, revenue from services and accessories fell by 12% from €4.2m to €3.7m due to demand slowing, particularly in the USA.

The order book totaled €19.3m at the end of September (compared with €19.1m a year ago), including three production systems and seven research systems (to be delivered between 2011 and 2013).

In view of the delivery schedule for the end of the year, Riber is targeting about €29m in full-year 2011 revenue, up 40% on 2010's €20.7m (compared with July's forecast of €27–29m, up 35%), combined with operating margin of more than 15%.

IN BRIEF

5N closes CDN\$250m credit facility

5N Plus has closed a CDN\$250m senior secured multi-currency revolving credit facility to replace its existing CDN\$50m two-year facility with National Bank of Canada. It will be used to refinance existing indebtedness and for corporate purposes, including capital expenditures and growth opportunities.

The new credit facility has a four-year term and bears interest at either prime rate, US base rate, LIBOR or EURO LIBOR plus a margin based on 5N Plus' senior consolidated debt to EBITDA ratio. 5N Plus also has a US\$35m credit facility in Asia.

At any time, 5N Plus has the option to request that the new facility is expanded to CDN\$350m through the exercise of an additional CDN\$100m accordion feature, subject to review and approval by the lenders.

5N Plus and Rio Tinto Alcan discuss developing primary gallium source

5N Plus Inc of Montreal, Canada, a producer and provider of high-purity metals, compounds and wafers for electronic applications, has signed a memorandum of understanding (MOU) with Rio Tinto Alcan, a global provider of bauxite, alumina and aluminium. The MOU will allow 5N Plus and Rio Tinto to pursue discussions regarding a project to recover gallium from an alumina production stream at Rio Tinto Alcan's Vaudreuil alumina facility in Quebec.

"We are very pleased with the scope of our discussions with Rio Tinto, and have good reason to believe that we will shortly be in a position to develop a new primary source of gallium," says 5N Plus' president & CEO Jacques L'Écuyer. "In light of anticipated strong growth in the demand for gallium, this new source will enable us to both strengthen our supply chain and forge a strategic partnership with Rio Tinto," he adds.

Founded in 2000, 5N Plus focuses on specialty high-purity metals such as tellurium, cadmium, selenium, germanium, indium, antimony and bismuth and also produces related II-VI 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. 5N Plus owns four material subsidiaries: 5N PV GmbH (Eisenhuttenstadt, Germany), Firebird Technologies Inc (Trail, BC, Canada), 5N Plus Corp (DeForest, WI, USA) and Sylarus Technologies LLC (St George, UT, USA). Also, in April, 5N Plus acquired MCP Group SA of Tilly, Belgium (the world's leading producer and distributor of bismuth and bismuth chemicals, and a supplier of specialty metals including gallium, indium, selenium and tellurium).

www.5nplus.com

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IN BRIEF

Epistar qualifies MaxBright for high-volume production

Epistar Corp of Hsinchu Science-based Industrial Park (Taiwan's biggest LED chip maker) has qualified Veeco's TurboDisc MaxBright multi-reactor gallium nitride MOCVD system for high-volume production of high-brightness (HB) LEDs.

"Veeco's MaxBright multi-chamber system enables us to ramp production quickly on the industry's most productive platform," comments Epistar's president Ming Jiunn Jou PhD. "We will continue to rely on Veeco for technological innovation and process expertise as a strong strategic partner. Veeco's commitment to providing best-in-class MOCVD equipment, as well as enhanced local support with their new technology center in Hsinchu, will help Epistar to achieve our future expansion goals and success," he believes.

"The MaxBright system is the ideal solution for the lowest cost-of-ownership LED production, and we are pleased that Epistar, a clear leader in high-quality LED manufacturing, has adopted the MaxBright for their production ramp," comments William J. Miller PhD, Veeco's executive VP, LED & Solar. "Our long-standing partnership is a key factor in the mass adoption of LEDs for general lighting."

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

www.epistar.com.tw

www.veeco.com/maxbright

Veeco celebrates opening of Taiwan Technology Center Hsinchu site to provide process support for LED industry

Epitaxial deposition, process, and metrology equipment maker Veeco Instruments Inc of Plainview NY, USA, which makes metal-organic chemical vapor deposition (MOCVD) equipment for manufacturing LEDs, has celebrated the opening of its new Taiwan Technology Center (TTC) in Hsinchu, Taiwan, which will provide process support for the rapidly growing LED industry.

Guests at the opening ceremony included several of Veeco's key customers in Greater China as well as key local government officials.

"Our goal is to ensure customer collaboration and enhanced responsiveness to build a long-term strategic partnership with our key Greater China customers," declared CEO John R. Peeler. "We selected Hsinchu as the location for our new Taiwan Technology Center because of its strong history of LED industry leadership and the large number of local LED manufacturers. This center provides excellent access to some of the world's best technology and engineering talent, and is strategically located for convenient access by other Asian customers," he added.

"By opening the TTC, we are bringing Veeco's leading technology closer to our customers," notes Peter Collingwood, Veeco's senior VP, sales & service. "While we have always supported this region around the clock, this new site takes our commitment to the next level. We are able to easily demonstrate our latest technology and newest MOCVD systems to help our customers to ramp their production of high-efficiency, low-cost LEDs."

The TTC site, which has about 40 Veeco staff, is equipped to conduct process demonstrations, arrange rapid start programs to transfer best known methods (BKM), provide early access to evaluate

system upgrades, and support joint technology development programs. The TTC is equipped with Veeco's MOCVD systems, including a multi-chamber TurboDisc MaxBright MOCVD system.

"We are committed to satisfying our customers and helping them to accelerate their production," commented Justin K. Wang,

We selected Hsinchu as the location for our new Taiwan Technology Center because of its strong history of LED industry leadership and the large number of local LED makers. This center is strategically located for convenient access by other Asian customers

general manager, Veeco Greater China region.

"Our goal is to be the preferred supplier with the best products on the market, as well as having a local presence to expedite our customers' time-to-market," he adds.

"The TTC is the newest part of our significant expansion in Asia that we announced last fall [at the 7th China International Forum for Solid State Lighting in Shenzhen, 14-16 October]," notes Peeler.

"Veeco will invest over \$30m to dramatically expand our Asia footprint to help

customers continue to accelerate the pace of adoption of LEDs for consumer electronics and solid-state lighting, including additional new R&D/demo and process support sites in Shanghai, China (opened May 2011) and Seoul, Korea (opening in 2012)," he adds.

www.veeco.com

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IN BRIEF

Power+Energy appoints director of global sales

Power+Energy Inc of Ivyland, PA, USA, which provides palladium-membrane-based hydrogen purifiers for the compound semiconductor and energy industries, has appointed Stuart Bestrom as director of global sales, responsible for direct sales and management of the worldwide distributor network to promote P+E purifiers.

"Stuart joins Power+Energy with extensive experience in hydrogen purification technologies including palladium, regenerable catalytic and getter used in semiconductor and related markets," says VP sales & marketing Al Stubbmann. "His knowledge of the industry and technology will be a valuable resource as P+E gains growing acceptance of its revolutionary, quality-driven technology to provide high-flow, reduced-cost hydrogen purification systems to support large LED fabs requiring parts-per-billion gas purity."

Most recently, Bestrom was sales manager at Johnson Matthey, where he managed sales & marketing. "P+E's modernization of the traditional palladium purifier, with research funded by the US Department of Energy, provides a durable, high-flow capability in a compact design that will serve the increasing needs of the semiconductor and energy industry," he comments.

● Power & Energy is exhibiting at the International Conference on Silicon Carbide and Related Materials (ICSCRM 2011) in Cleveland, OH (11–16 September). P+E says that its micro-channel purifiers are widely used for SiC processes because they eliminate trace nitrogen, a dopant that must be tightly controlled for effective device fabrication.

<https://icscrm2011.org>

EpiLEDs boosts blue HB-LED capacity with CRIUS II-L MOCVD system

In Q2/2011 Taiwan-based LED maker EpiLEDs Technologies Inc ordered an Aixtron CRIUS II-L MOCVD system in 69x2"-wafer configuration.

Delivery in Q3/2011 was followed by installation and commissioning by a local Aixtron service team in EpiLEDs' facility in Tainan, and used for volume production of GaN-based blue high-brightness (HB) LEDs.

"This is not our first CRIUS II system but it is our first of the enlarged new-generation CRIUS II-L," says EpiLEDs' president Steve Ku. "I see it as the foundation for our capacity expansion plans," he adds. "We are very proud to be amongst the first to receive the latest-generation CRIUS II-L system, the world's most capacious MOCVD reactor for blue LED production. It will give us an enormous advantage as we strive to meet the challenges of the world's solid-state lighting marketplace on price and performance."

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

The CRIUS II-L was launched this summer and is said to be the world's largest-capacity MOCVD reactor available (16x4" or 69x2" wafers). Based on the market-proven CRIUS II platform, the enlarged system provides seamless transfer of qualified LED processes, says Aixtron. The CRIUS II-L reactor is design optimized for wafer sizes from 2" to 8", and offers the potential for further productivity enhancements.

www.epileds.com.tw

Forepi orders multiple CRIUS II reactors

In Q1/2011 Aixtron won an order for multiple 55x2" CRIUS II MOCVD systems from existing customer Formosa Epitaxy Inc (Forepi) in Taiwan, for the volume production of blue HB-LEDs. Delivered over Q2–Q4/2011, the reactors are being installed and commissioned by one of Aixtron's local support teams.

"The CRIUS II will give us much needed enlarged production capacity," says Forepi's president Dr Fen Ren Chien. "Since the CRIUS II has grown from 31x2" to 55x2" wafers, the new reactors will play a key role in our future expansion plans for blue HB-LED production," he adds.

"I have been extremely pleased with the performance of our existing Aixtron MOCVD production systems and the high quality of service the local team has given us," Chien notes. "Once we had built up experience with our single

CRIUS II, we quickly decided to ramp up production with further CRIUS II reactors so as to benefit from the technical advantages of the Aixtron next-generation Close Coupled Showerhead (CCS) technology. The CRIUS II gives us the highest growth rates and growth pressure as well as zero particle generation and minimized maintenance," he continues.

"Unique CCS reactor chamber technology only requires the application of area-scaling factors for simple process transfer, which is particularly useful for customers like Forepi," says chief operating officer Dr Bernd Schulte. "CRIUS II can, if required, be upscaled to larger wafer sizes, which is crucial for control of GaN LED manufacturing costs. Alternatively, the reactor chamber can accommodate as many as 13x4" wafers."

www.forepi.com.tw

Aixtron lowers full-year 2011 guidance

Deposition equipment maker Aixtron SE of Herzogenrath, Germany has issued new guidance for full-year 2011 of €600–650m in revenue (revised from €800–900m), with an EBIT (earnings before interest and taxes) operating profit of 25–30% (rather than 35%). Management has also reviewed its existing equipment order backlog and has decided, as a matter of prudence, to reduce the previously published order backlog by €100m (from €373.5m).

The firm says that this new guidance and backlog adjustment reflects the perceived increase in conversion risk, purchase order delays and deferred system delivery requests into 2012 by several customers, specifically in Asia.

Whilst in the opinion of management, the mid- to long-term LED market opportunities remain very positive, recent discussions with

Asian customers have revealed increasing concern about the short-term fragility of the economic recovery, leading to investment caution, the firm says. Coupled with evident margin pressures from rapidly dropping end-market prices for LEDs, several customers are delaying new purchase order placements and deferring system deliveries into 2012.

However, with the very positive customer response to the firm's new CRIUS II-L MOCVD system (launched in July), Aixtron's management continues to believe that the imminence of an emerging LED lighting industry — in conjunction with initiatives such as the Chinese 5-year plan — continues to support the positive outlook for the LED industry, despite short-term demand adjustments driven by market uncertainty.

www.aixtron.com

Jiangsu Canyang to boost blue HB-LED capacity with Aixtron CRIUS II reactors

Aixtron says that in second-quarter 2011 it received an order for four CRIUS II MOCVD systems in 55x2"-wafer configuration from China's Jiangsu Canyang Optoelectronics Ltd, a joint venture with Taiwan-based LED chipmaker Formosa Epitaxy Inc (FOREPI). The firm is seeking a smooth process transfer from their existing CRIUS MOCVD reactors to Aixtron's new-generation platform.

After delivery between the second and fourth quarters of 2011, one of Aixtron's local support teams will install and commission the reactor in the Jiangsu Canyang's production complex in China. All systems will be dedicated to the growth of blue high-brightness LEDs.

"We are embarking on a whole new era of high-volume blue LED production at Jiangsu Canyang," says FOREPI president Dr Fen-Ren Chien. "To minimize risk and interruptions we have once again chosen Aixtron equipment. The outstand-

ing performance of our existing CRIUS and G4 systems as well as the excellent design concept of the Showerhead technology I am confident will give us the proven fastest time-to-market," he comments. "While these will be Jiangsu Canyang's first CRIUS II systems, I am convinced that the new systems will demonstrate the expected results as well as easy production process handling and excellent compatibility," Chien continues.

Jiangsu Canyang Optoelectronics specializes in R&D and industrialization of LED epitaxial wafers and chips. Its core business covers the production of ultra-high-brightness InGaN LED epiwafers and LED chips, and its capacity is expected to reach 50 MOCVD systems within the next two years. In April 2010, the firm placed a multi-tool order for Aixtron Planetary and Showerhead HB-GaN LED MOCVD systems.

www.forepi.com.tw

IN BRIEF

LG receives Aixtron G5 HT reactor for GaN/Si applications

Aixtron says that in first-quarter 2011 existing customer LG Electronics Woomyeon R&D Campus (LG Electronics Advanced Research Institute) in South Korea ordered an AIX G5 HT MOCVD reactor in 8x6"-wafer configuration. Following delivery in third-quarter 2011 the reactor will be installed and commissioned by a local Aixtron service support team alongside the firm's existing Aixtron MOCVD systems.

LGE will use the system to develop gallium nitride on silicon (GaN-on-Si) power electronics in partnership with Aixtron. The contract also includes a cooperation agreement to optimize LGE's GaN/Si processes and to accelerate its proprietary device-oriented production. LGE aims to develop power electronic devices offering the best combination of performance and cost demanded by markets such as home appliances and electric vehicles.

Aixtron says that its equipment is particularly suited to customers such as LGE who plan to transition from R&D to mass production. LGE's application will also benefit from the thickness uniformity across the wafers and across the pattern, as well as run-to-run dependability.

Overall, the AIX G5 can fulfil the needs for LGE's special process parameters and device structure, says Aixtron. It will also directly address the requirements for large-wafer process developments from the beginning. The mutual trust arising from many years of cooperation between LGE and Aixtron will continue through the new partnership on this GaN-on-Si project, which will involve expertise in installation and process development, say the firms.

Infinera to scale next-gen InP PICs with Aixtron MOCVD tool

Aixtron says that in first-quarter 2011 it received an order for an AIX 2600G3 IC MOCVD system from new customer Infinera Corp of Sunnyvale, CA, USA, a vertically integrated manufacturer of digital optical network systems incorporating its own indium phosphide-based photonic integrated circuits (PICs). Capable of growing 49x2", 12x4" or 7x6" wafers, the reactor will be used for next-generation InP PICs following delivery in third-quarter 2011 and commissioning by Aixtron's local support teams.

"We were looking for the world's foremost MOCVD system to provide a foundation for the fabrication and scaling of our next-generation PICs," says Dr Fred Kish, senior VP, Optical Integrated Circuit Group at Infinera. "The Aixtron MOCVD system will be of significant importance not only in development but also in production of these challenging indium phosphide circuits," he adds. "Their systems have the highest reputation and capabilities and include precise epitaxy control, excellent run uniformity as well as scalability for guaranteed future proofing. Couple that with the excellent support service and we were certain the AIX 2600G3 IC deposition system uniquely suited our needs."

Infinera's PICs integrate more than 60 functions on two chips for use in the long-haul dense wavelength division multiplexed (DWDM) optical transport network (OTN) market. The firm says that its systems and PIC technology currently provide customers with simpler and more flexible engineering and operations, faster time-to-service, and the ability to rapidly deliver differentiated services. Most recently, it has demonstrated next-generation PICs capable of both 500Gb/s and 1Tb/s data rates, implemented on two monolithic InP chips that integrate more than 600 functions.

www.infinera.com

Azur Space expands terrestrial CPV cell production with Aixtron reactor

Deposition equipment maker Aixtron SE of Herzogenrath, Germany says that its metal-organic chemical vapor deposition (MOCVD) system technology has been implemented at Azur Space Solar Power GmbH of Heilbronn, Germany, which has expressed satisfaction with the performance capabilities and Aixtron service for the production of concentrator photovoltaic (CPV) solar cells for terrestrial applications. Aixtron Europe's support team recently carried out commissioning of the reactor at Azur's production complex.

Azur Space develops, produces and supplies bare solar cells for both space and terrestrial CPV customers. Based on more than 40 years of experience in space solar cell technology, its range of products covers several types of silicon and III-V solar cells on germanium.

"We have worked with Azur for many years so there is a strong mutual confidence with Aixtron as

an experienced technology partner," says Aixtron's chief operating officer Dr Bernd Schulte. "This will be continued with the new-generation system. Azur is highly capable of exploiting the process performance that is built-in with Aixtron equipment," he adds.

"We selected Aixtron's MOCVD technology due to its outstanding system-to-system reliability," says Azur Space's Dr Klaus-Dieter Rasch. "Aixtron MOCVD technology is the best choice for our application, not the least being because of the straightforward installation, commissioning and support service," he adds. "The company has repeatedly demonstrated their flexibility to react promptly and efficiently to customer production capacity expansion needs. Excellent energy efficiency and high yield are amongst the other notable characteristics that have impressed technical staff at Azur."

www.azurspace.com

www.aixtron.com

China's NEDI orders MOCVD systems to develop power devices and LEDs

Aixtron says that existing customer Nanjing Electronic Devices Institute (NEDI), a manufacturer of electronic components in China, has ordered an AIX 2600G3 IC MOCVD system in 12x4"-wafer configuration plus a VP2400HW CVD system with 6x4"-wafer capacity.

Following delivery in the third and fourth quarters of 2011, the systems will be installed and commissioned by a local Aixtron service support team alongside NEDI's existing Aixtron MOCVD systems at its facility in the Jiangning Economic & Technological Development Zone, Nanjing, China.

"These are not our first Aixtron MOCVD systems but they will play

a vital part in our planned development of materials for power devices and LEDs," says NEDI's professor Kun Chun Mao, who is in charge of purchasing the systems. "My team is very familiar with the technology and they trust Aixtron's advanced technology with its ease of use, versatility as well as process compatibility with our existing recipes and procedures," he adds.

"We have also been very satisfied with the first-class local support provided by the Aixtron service office and the enlarged spare parts stock in Shanghai," Mao continues. "This partnership will serve us well when we begin operations with the new reactors."

www.ndsaw.com

LayTec acquires ORS

ORS' technologies to be integrated into EpiCurve TT and EpiTT products

LayTec AG of Berlin, Germany (which makes in-situ metrology systems for MOCVD processes, focusing on compound semiconductor and photovoltaic applications) has acquired the majority of tangible and intangible assets of Optical Reference Systems Ltd (ORS), a former competitor that entered liquidation in August after an extended period of difficult trading conditions.

"The R&D team of ORS did a great job during the last three years in developing complementary metrology technologies," says LayTec's CEO & president Thomas Zettler. "These technologies now will be integrated into LayTec's EpiCurve TT and EpiTT product families.

Specifically, combining the full range of in-situ technologies with our brand new software platform EpiNet2.0 will enable all our industry customers to meet the current challenges of yield enhancement and LED performance improvements for solid-state lighting related manufacturing," he adds.

"The R&D team is very happy to have joined forces with the LayTec organization in Berlin," says former ORS managing director Neil Gerrard (now president of LayTec UK Ltd). "We have been welcomed as partners into this excellent organization supplying both global industry and academia, with cutting-edge integrated metrology products," he adds.

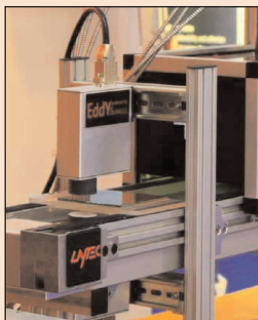
www.laytec.de

LayTec launches Eddy for high-resolution sheet resistance measurement

At the 26th European Photovoltaic Solar Energy Conference & Exhibition (EU PVSEC 2011) in Hamburg, Germany in September, LayTec AG of Berlin, Germany (which makes in-situ metrology systems for MOCVD processes) launched a new system for high-resolution sheet resistance measurements, powered by the firm's Dresden-based partner Suragus GmbH, which provides eddy-current-based testing technology.

Eddy offers contact-free real-time monitoring of deposition processes for thin-films, e.g. transparent conductive oxides (TCOs), using high-speed eddy current measurement. The system provides comprehensive conductivity/sheet resistance analysis.

Eddy can be integrated in any solar cell production line as an in-line metrology tool, allowing 100% coverage of conductivity properties. It enables fast feedback of layer homogeneity and absolute



sheet resistance values with direct feedback to the deposition process. Tight coverage of each glass sheet (or other

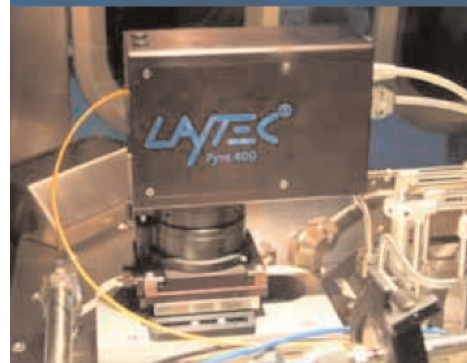
substrate) with several measurement points per sheet allows precise process control and statistical process control (SPC). The results enable the user to recognize short-term deviations and long-term trends, the firm says.

LayTec says that Eddy offers quality control of low- and high-conductive thin-films, especially TCO sheet resistivity monitoring from 0.01–1000Ω/square and thickness measurements from 5nm. The firm adds that it can easily adapt the system to a customer's needs for specific measurement ranges and dynamics.

www.photovoltaic-conference.com

Real GaN surface temperature

LayTec's groundbreaking new product Pyro 400 finally makes real wafer surface temperature measurements of GaN possible. It offers deep insight into surface temperature changes caused by carrier gas, rotation speed and reactor pressure variations as well as wafer bowing effects. This quantum leap in GaN temperature measurement provides immediate access to emission wavelength variations and thereby provides huge benefit for yield enhancement in future GaN-based LED production.



The Pyro 400 in-situ system can be used in combination with the EpiCurve® TT for simultaneous bowing control.

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IN BRIEF

CVD doubles size by buying new facility

CVD Equipment Corp (a designer and manufacturer of equipment for developing and manufacturing electronic components, materials and coatings) has signed a contract to buy a 120,000ft² plant in Central Islip, NY to expand its Engineering, Manufacturing, Administrative and Application Laboratory. The facility is about 15 minutes from CVD's existing two buildings in Ronkonkoma, which total 63,275ft², and are being offered for sale.

"The virtual doubling of the size of our Long Island facilities allows us to increase staff and capabilities in multiple product areas," says president Leonard Rosenbaum. "The planned expansion includes First Nano R&D equipment, CVD Production equipment and, through our Application Laboratory, process development and material manufacturing programs, which will advance the state of the art in 1D, 2D and 3D Nanotechnology beyond the traditional limits of the chemical vapor deposition field."

CVD Equipment forms CVD Materials subsidiary

CVD Equipment Corp of Ronkonkoma, NY, USA has announced the expansion of the materials part of its business. The materials will be marketed through the subsidiary CVD Materials Corp.

"We believe that now is the right time to build on the processing capability, material manufacturing, marketing and business growth success of our Application Laboratory, which continues to open new business opportunities in both traditional and non-traditional chemical vapor deposition related markets," says president Leonard Rosenbaum. "We will further develop our in-house next-generation material manufacturing capabilities and capacities and expand our marketing and sales efforts directly to researchers and innovators at universities, government and Industrial R&D facilities that are working on application development for tomorrow's next generation products in semiconductors, solar, batteries, capacitors, water filtration, catalysts composites, and other traditional and non-traditional chemical vapor deposition applications through CVD Materials," he adds.

"These applications will primarily utilize graphene, carbon nanotubes (CNT), nanowires (NW), and other 1D, 2D and 3D surface and surface-area-enhanced materials," Rosenbaum continues. CVD Materials Corp will primarily focus on (1) contract CVD-related process development, (2) research material manufacturing, (3) CVD and other nano-enabled material manufacturing licensed from third parties, and (4) on CVD Equipment Corp's proprietary materials and material processing platforms.

"We expect that this business model extension will help to accelerate the commercialization of tomorrow's technologies and will bring future equipment, material manufacturing and joint venture business opportunities to CVD Equipment Corp," says Karlheinz Strobl, VP of business development. "This expansion of the Application Laboratory will further accelerate the commercialization of tomorrow's technology and our 'Sustainable Growth with Low Risk' business strategy."

www.cvdequipment.com

SPTS ships 600th AVP vertical thermal processing system

SPTS Technologies Ltd of Newport, Wales, UK has shipped its 600th Advanced Vertical Processor (AVP) vertical batch thermal processing system to Cypress Semiconductor Corp, to be used for its S8 technology platform, which supports its TrueTouch, PSoC 3, PSoC 5, CapSense and NVSRAM products.

Manufactured at SPTS' Thermal Products Division in San Jose, CA, USA, the AVP furnace is used for a diverse range of diffusion and low-pressure chemical vapor deposition (LPCVD) applications in the semiconductor, power management, MEMS and compound semiconductor markets. The division maintains

development capability on the common wafer sizes for all these markets, from 100mm to 300mm.

The AVP system is available in a single- or dual-boat configuration, providing flexibility and a low cost-of-ownership (CoO) solution for all process types. SPTS says. In-situ clean technology enables the AVP to run LPCVD processes for up to two years between quartz change, improving system uptime and maximizing productivity. Key processes include wafer annealing from 100°C to >1200°C and the deposition of low-temperature silicon germanium (SiGe), thick doped polysilicon and stress-controlled silicon nitride (SiN).

"SPTS is a key partner in enabling our high-performance SONOS (Silicon-Oxide-Nitride-Oxide-Silicon) technology," comments Cypress' executive VP Shahin Sharifzadeh. "Its expertise in thermal processing technology and commitment to customer service are invaluable in helping us to deliver our products to market," he adds.

"This shipment demonstrates both the success of the AVP product line and pays testament to the strong partnerships we develop with our customers," says Vivek Rao, VP & general manager of SPTS' Thermal Products Division.

www.spts.com

SPTS takes 900th order for DRIE module

Plasma etch, deposition and thermal processing equipment maker SPTS Technologies of Newport, Wales, UK has received an order for its 900th DRIE (deep reactive ion etching) process module. The module will be shipped to an Asian foundry for use in micro-electro-mechanical system (MEMS) manufacturing.

DRIE is a highly anisotropic etch process used to create structures in silicon, and is the cornerstone of modern MEMS production, says SPTS. The use of DRIE has expanded to also include applications for power (in deep trench isolation) and through-silicon-via (TSV) in 3D-IC production. SPTS' DRIE module is hence used worldwide across a variety of device production applications, including MEMS, advanced packaging, and power devices.

SPTS shipped its first Bosch-licensed DRIE system in 1995 through its partnership with Robert Bosch GmbH, the inventors of the 'Bosch process'. SPTS has steadily

expanded its DRIE product offerings through strategic merger and acquisition activity. In 2009, the two DRIE providers Aviza Technologies Inc and Surface Technology Systems plc (STS, a subsidiary of Sumitomo Precisions Products Co Ltd) merged to form SPP Process Technology Systems Ltd (SPTS). This February, SPTS consolidated on this further by acquiring Tegal Corp's DRIE division (formally AMMS), which included key intellectual property (IP) for future product development. SPTS now supports what is reckoned to be the world's largest installed base of R&D and production DRIE systems. In August, SPTS completed a management buyout from SPP.

"DRIE is the foundation of the MEMS market and we have supported customers in this space from the very beginning, from the development of inductively coupled plasma processes, followed by high-power decoupled plasma sources, to our

latest generation, the Pegasus Rapier system," says executive VP & chief operating officer Kevin Crofton. "The growth of the MEMS market has been enormous in the past 5–10 years — each of us now comes into contact with a MEMS-enabled device every day," he adds.

SPTS' Omega etch systems comprise a suite of single-wafer etch process modules for a variety of applications. The Omega DRIE modules provide production-worthy process capability, with high throughputs and tilt control for Bosch process silicon etching used in MEMS and 3D-IC/TSV manufacturing. The Omega inductively coupled plasma (ICP) process modules offer compound semiconductor etch processes including GaAs, GaN and GaP for LEDs and high-frequency RF devices, and the Omega APS is focussed on etching dielectric and low-volatility materials, relevant to MEMS, LED and TSV applications.

www.spts.com

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RASIRC doubles manufacturing and development space

Steam purification firm RASIRC Inc of San Diego, CA, USA, whose products deliver ultra-pure water vapor for semiconductor, photo-voltaics, nano-technology and other manufacturing applications, has relocated its global operations to a larger facility at 7815 Silverton Avenue. The new 19,500ft² space includes a class-1000 cleanroom for manufacturing products for the PV industry.

"Rapid growth in RASIRC products required a new facility to handle higher volumes," says founder & president Jeffrey Spiegelman. "This expansion allows us to handle the increased production and doubles our R&D lab space," he adds.

RASIRC says that it is experiencing continued growth in demand for its products, particularly Steamers for photovoltaic passivation films for the



RASIRC's new global operations facility.

solar industry and humidity control for semiconductor manufacturing. In the solar industry, RASIRC's products deliver ultra-pure steam that is needed to form oxidation layers that improve solar energy capture efficiency. In addition, steam can be used in conjunction with phosphorous or boron doping to improve the emitter profile. For the semiconductor industry, ultra-pure steam is used for generating oxide films on wafers in diffusion and rapid thermal processing.

Additional uses include wafer cleaning of next-generation films and atomic layer deposition (ALD) for high-k layers. RASIRC claims that its products reduce costs, improve quality and dramatically improve safety associated with these applications.

"RASIRC has grown rapidly over the last five years," says Spiegelman. "The transition from an R&D to a manufacturing company is demonstrated by the increase in our orders from both new and repeat customers," he adds. "The market validation of our products has enabled us to move into a new and larger facility, significantly increase staffing levels, and enabling us to fund development of further innovation."

www.rasirc.com

SENTECH launches plasma-enhanced ALD system

Based on many years of experience in developing and manufacturing plasma-enhanced chemical vapor deposition (PECVD) and inductively coupled PECVD (ICPECVD) systems (including the proprietary planar triple spiral antenna ICP source), SENTECH Instruments GmbH of Berlin, Germany has launched its first PEALD (plasma-enhanced atomic layer deposition) system.

PEALD is a method of extending the capabilities of ALD by applying radical gas species rather than

water as an oxidizer during the deposition process.

The new ALD system enables both thermal and plasma-assisted operation and deposition monitoring using SENTECH's ellipsometers. The firm offers ultra-fast in-situ ellipsometers for monitoring layer-by-layer film growth, applying laser ellipsometry as well as wide range spectroscopic ellipsometry.

The first PEALD system has already started operation at Germany's Technische Universität

Braunschweig (TU Braunschweig) for the deposition of extremely uniform and dense thin oxide films such as Al₂O₃ and ZnO. For the deposition of Al₂O₃, TMA (C₃H₉Al) and plasma-generated atomic oxygen (O) were used at substrate temperatures of 80-200°C.

SENTECH says that the PEALD films exhibit excellent thickness uniformity and very small variation in refractive index (measured with spectroscopic ellipsometers).

www.sentech.de

Plasma Etch launches PE-100 Convertible combined anisotropic/isotropic etching/cleaning system

Plasma Etch Inc of Carson City, NV, USA has launched a new plasma system that incorporates two individual plasma etching/cleaning type/mode technologies into a single complete stand-alone plasma etching/cleaning system.

The PE-100 Convertible allows the user to switch back and forth

between reactive ion etch (RIE) anisotropic-type etching mode applications and isotropic-type etching/cleaning-mode applications. Traditionally, two separate stand-alone plasma systems were necessary to achieve this capability.

Plasma Etch says that the PE-100 Convertible system can be used for

research and development, medical devices, solar cells, nanotechnology, optics, printed circuit boards, micro-electro-mechanical systems (MEMS), wafer-level packaging, and laboratory applications as well as other related semiconductor processes.

www.plasmaetch

Applied Energy Systems breaking ground on new ultra-high-purity gas system manufacturing plant

On 5 October, Applied Energy Systems Inc, which makes ultra-high-purity gas source and distribution systems, broke ground on its new Semiconductor Equipment Manufacturing and Technology (SEMAT) Center in order to expand its current operation Malvern, PA, USA, where the firm has resided since 1985.

The new center will manufacture the next generation of gas source and distribution systems for world-

wide customers of Applied Energy Systems and its SEMI-GAS Systems Division. The 16,000ft², two-storey facility, adjacent to the current facility, will house a new Class 100 cleanroom and engineering center as well as incorporate 'green' materials into the construction, including LED lighting and solar panels.

The projected \$2.5m building will not only facilitate the expansion of Applied Energy Systems but also

increase the growth of business in the greater Philadelphia area, says the firm. "This new building will usher in a new chapter in the company's life by providing the extra space we need to develop better products and more jobs in the community," says president Steve Buerkel. "The construction of the new facility will also help generate jobs in the area during this downturned economy," he adds.

www.semi-gas.com

SEMI-GAS upgrades semi-automatic valve manifold box design with PLC controller for emergency shutoff

SEMI-GAS Systems, a division of Applied Energy Systems Inc of Malvern, PA, USA, has launched a new line of semi-automatic valve manifold boxes that facilitate pressure-regulated gas delivery to multiple points-of-use and feature a compact design and new PLC-based controller. The new valve manifold boxes (VMBs) reduce cost, space requirements, high-purity piping, utility demands and points of toxic gas monitoring when gas usage does not justify multiple gas cabinets, says the firm.

Each new valve manifold box features a new GSM series controller. Four-line semi-automatic VMBs include the new GSM-VS4 controller, which replaces the now obsolete GSM 1x4 controller. Benefitting from modern PLC-based technology, the GSM-VS4 independently operates emergency shutoff valves, monitors input from the excess flow switches, and displays delivery pressures. Local emergency shutdown via an emergency off (EMO) button and remote shutdown capabilities are standard, as well as other networking and communication signals.

Available in 4-, 6- and 8-stick designs, as well as customized mini and expanded versions, the new valve manifold boxes incorporate



SEMI-GAS' upgraded semi-automatic valve manifold box with PLC control.

an automatic emergency shut off (ESO) valve on each distribution stick. This ensures that each process gas is safely and continuously distributed from the gas source to various tools and points-of-use, as needed in semiconductor, LED or wafer production and R&D environments.

SEMI-GAS Systems says that its upgraded semi-automatic valve manifold boxes feature a rail-

mounted stick design for easy maintenance and expansion to accommodate fab plant additions, process changes and new tool installations. Individual process sticks are pressure regulated and the lines are isolated for localized gas control. Pressure can be monitored using gauges, indicating pressure switches, or transducers.

The system is continually monitored for alarms to ensure the safest operating conditions. The GSM-VS4 controller will automatically shut the system down in the event of an alarm. The valve manifold boxes also feature an ergonomically positioned color touch screen interface to display the system schematic and relevant operating conditions. LED lights provide constant system status.

The valve manifold box enclosure is constructed of welded 11 Ga steel with a 1/4"-thick safety glass window and a self-closing, self-latching door. The 4-stick model is 44" tall, 22" wide and 15" deep. A UL-approved fire sprinkler is also included. Each valve manifold box also features integrated wall- or rack-mount attachment points.

A wide array of features and options are available to create custom VMBs for specific application requirements, notes the firm.

InnoLas appoints technical director

Laser processing system maker InnoLas Semiconductor GmbH of Krailling, Germany, which makes wafer laser marking and sorting equipment, says that, Michael Kölbl (former head of customer support) is now technical director, responsible for technology, development, production and service.

Since his degree dissertation in 1997, Kölbl has developed expertise in laser marker and sorter systems for the semiconductor and LED wafer markets. In 2007 he took over the project leadership for the integration of new InnoLas systems in a newly constructed wafer fab in Singapore, and in 2009 he became managing director of subsidiary InnoLas SEA (South East Asia), where he expanded business opportunities for InnoLas in the South East Asia area. He remains a member of InnoLas SEA's board of directors since his return to Germany in 2011.

"Of particular concern to me are all aspects of internal and external communication, which constitute the foundation for a high level of satisfaction of our customers," Kölbl says. ● InnoLas strengthens software team Automatic and machine-readable marking of LED wafers — for subsequent reading of marking while conforming to the SEMI standards — is not a trivial undertaking, says InnoLas. However, it simplifies product quality control and tracking. To fulfil the various requirements of different manufacturers, InnoLas says that it is continually developing its fully automatic systems. An example is the marking and subsequent reading on either or both sides of a wafer of any size and material and the consequent sorting.

To consolidate this commitment, InnoLas has strengthened its software team with the addition of two computer engineering specialists. "With this move we can offer our customers a wide range of possibilities on a standard system," notes general manager Andreas Behr.

www.innolas.com

Linde starts up UHP nitrogen/oxygen plant in Hillsboro, Oregon

Linde North America of Murray Hill, NJ, USA, through one of its US affiliates, has expanded the capacity of its plant in Hillsboro, OR to supply ultra-high-purity (UHP) gaseous nitrogen and oxygen to semiconductor manufacturers in the Pacific Northwest.

As a member of Germany-based gases and engineering firm The Linde Group, Linde North America supplies products and services to the semiconductor and electronics industries through its electronics and specialty gases business.

Linde says the new capacity is required to meet the growing needs of semiconductor manufacturers in the greater Portland area, which Linde has been serving since the

early 1990s. The use of UHP nitrogen and oxygen in the manufacturing process is essential to ensure products meet their extremely tight design specifications, adds the firm.

"The expansion of the Hillsboro facility represents Linde's commitment to focus on key global customers and be a valued supplier to them no matter where they expand," says Linde North America's president Pat Murphy. "As technologies advance, the purity of the gases that touch the surface of the wafer becomes even more critical and the latest Linde generation of high-purity Spectra plants is at the industry forefront of the supply of UHP nitrogen and oxygen," he claims.

www.lindeus.com

Edwards' new iXH500H dry pump series cuts CoO by 30%

Vacuum and exhaust-abatement equipment maker Edwards Ltd of Crawley, UK has expanded its iXH family of harsh-process dry pumps by introducing the iXH500H series, optimized for flat-panel, solar and semiconductor processes requiring high gas flows (up to 500m³/h) and flexible pump temperature profiles.

The iXH500H series temperature flexibility suits such harsh processes, the firm claims. Running at low pump temperatures, the iXH500H series is beneficial for processes that use high flows of corrosive gases (e.g. FPD PECVD, thin-film solar PECVD, semiconductor MOCVD) or for processes that use thermally sensitive pre-cursors (e.g. ALD) that could 'plate out' by-products within the pump. High operating temperatures can be used where the risk is the condensation of by-products within the pump (e.g. high-k dielectric deposition).

"This new series in the iXH family is designed to address the varying pumping challenges encountered in

flat-panel, solar and advanced semiconductor processes that can significantly reduce a pump's MTBS [mean time between servicing]," says Dr Allister Watson, drypump product manager-FPD & Solar Sectors. "Until now, the industry lacked a single harsh-process dry pump with the flexibility to address these different challenges," he adds. "The iXH500H series, with its increased pump temperature flexibility, addresses this need, while also reducing pump energy consumption by up to 15%."

The firm claims that, due to lower energy consumption and enhanced MTBS, the iXH500H series pumps can yield a 30% lower cost of ownership (compared with previous-generation iXH dry pumps) while delivering the small footprint and hydrogen pumping capabilities of the existing iXH450 series.

Also available are service upgrades to convert existing iXH450 series pumps to the new iXH500H series.

www.edwardsvacuum.com

Ultratech achieves ISO 9001 and 14001 certification for Singapore operations and recertification for US facility

Ultratech Inc of San Jose, CA, USA, which designs and manufactures photolithography and laser-processing systems used to make semiconductor devices and high-brightness LEDs (HB-LEDs), has earned ISO 9001:2008 and 14001:2004 certification from the DQS-UL Group for its international operations headquarters in Singapore as well as recertification for its San Jose facility.

Last December, Ultratech opened its Singapore operation, which includes engineering and manufacturing of its lithography systems and other related products, in addition to housing international sales and service operations. Also, recertification of the San Jose facility enables Ultratech to provide global customers with the same standards across both of its manufacturing sites, the firm says.

"Ultratech is committed to the highest standards of quality management and environmental sustainability," says senior VP of operations Tammy Landon. "Now, the same processes, procedures, work instructions, systems and methodologies that have been effective at our corporate headquarters in San Jose have also been implemented in our Singapore operations — creating a seamless transition of systems and processes between our two manufacturing sites," he adds. "This transition provides our customers the confidence that any system manufactured in Singapore will have the same high standards of quality, performance and sustainability as a system built in San Jose."

ISO 9001:2008 is the latest edition of the ISO 9001 standard, which has become the global benchmark for assuring a quality management system is operational that satisfies quality requirements with the aim of enhancing customer satisfaction in supplier-customer relationships. Likewise, ISO 14001:2004 is the latest edition of the ISO 14001 standard, one of a series of internationally recognized standards designed to build a company's environmental management system (EMS) and manage the performance of that system to continually improve its environmental performance.

"Ultratech had outstanding results for a first-site assessment of its Singapore facility," comments the lead auditor for DQS-UL. "Particularly noteworthy was the fact that extensive quality and environmental awareness training programs for both regular and contract employees had been well established and implemented. In addition, excellent housekeeping had been maintained throughout all areas of the site."

www.ultratech.com

Ultratech had outstanding results for a first-site assessment of its Singapore facility, says the lead auditor for DQS-UL

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Keithley products to be distributed by Metric in Baltic States

Keithley Instruments has signed an agreement for the distribution of its products in Finland and the Baltic states (Estonia, Latvia and Lithuania) with Metric Industrial Oy of Espoo, Finland (part of Nordic MI Group, a business unit of Swedish public company Addtech), which specializes in distributing components and test equipment for the industrial automation, fiber-optic networks, and electronics industries.

Metric will sell the full line of Keithley instruments geared to the specialized needs of electronics manufacturers for high-performance production testing, process monitoring, and product development solutions, including: digital multimeters and systems; switching and control; power supplies; source and measure products; low-level measurement and sourcing, including low-current/high-resistance measurements and low-voltage/low-resistance measurements; semiconductor test; optoelectronics test; and data acquisition products.

"By working as a team, Keithley and Metric will be able to deliver superior test & measurement solutions in the region," says Keithley's VP of business management Mark Hoersten. "In this way, we can offer our customers efficient access to our products, coupled with the superior local support that Metric's technical sales engineers and service organization can provide," he adds.

"Metric is the biggest independent test & measurement equipment supplier in Finland, with a product portfolio that includes some of the world's leading suppliers," says Mika Joutsila, business unit manager at Metric. "We are focusing strongly on the electronics industries market and, when combined with the Tektronix product line, Keithley products fit very well," he adds. "Our aim is to provide the best possible local support for Keithley customers and to help them improve their productivity."

www.metric.fi

Keithley expands Series 2400 SourceMeter family for low-voltages

Keithley Instruments of Cleveland, OH, USA has launched a low-cost addition to its Series 2400 SourceMeter instrument family. Like all the firm's source measurement unit (SMU) instruments, the new Model 2401 SourceMeter is optimized for high-precision test applications such as current versus voltage (I-V) characterization of photovoltaic cells, high-brightness LEDs, low-voltage materials, and semiconductor devices, as well as resistance measurements. However, it now provides these source and measurement unit capabilities at 20V and 1A signal levels and at what is claimed to be an unprecedented low price.

"The Model 2401 is priced at \$2995 (€2280/£2016), making it the test & measurement industry's lowest-cost standalone source-measurement instrument with a complete set of measurement ranges, features, and programmable operating modes," claims marketing manager Charles Cimino. It offers an economical alternative to test systems configured with separate programmable power supplies and digital multimeters or applications for which precision programmable power supplies lack sufficient accuracy, signal range, or resolution he adds.

The Model 2401 operates and is programmed in exactly the same way as the other Series 2400 family member units within its 1A/20V range boundaries. Like the rest of the family, the Model 2401 integrates a highly stable DC power source with a true instrument-grade 5½- or 6½-digit multimeter in a single enclosure.

In operation, the Model 2401 can act as a voltage source, a current source, a voltmeter, an ammeter, and an ohmmeter, and provides four-quadrant bipolar and automatic source/sink operation. Referring to Keithley SMU convention, operating in I vs V quadrants



Keithley Instruments' Series 2401 SourceMeter.

1 or 3, it operates as a source, delivering power to a load. In quadrants 2 or 4, it operates as a sink, dissipating power internally from an external source such as a PV cell or other energy source.

The Model 2401's combination of low cost, tightly integrated sourcing and measurement, and wide dynamic range suits a variety of both benchtop and system applications with low-voltage requirements and with limited test hardware budgets, says Keithley:

- HB-LED forward/reverse I-V and LIV (light-current-voltage) testing;
- Solar cell efficiency test (source and sink current); and
- Precision DC load characterization, replacing readback supplies or supply/DMM (digital multimeter) combinations, which typically provide insufficient accuracy (IDDQ testing).

Other applications include: active/passive component test and voltage/current/resistance measurements; battery operation validation for portable electronic devices; characterizing implantable medical devices (pacemakers etc); characterizing low-leakage electronic device/circuits (forward/reverse, transistor gain/leakage); and calibrating 3½- to 4½-digit data acquisition boards, meters, and DMMs.

www.keithley.com

Epistar adopts KLA-Tencor's Candela inspection system

Process control & yield management solutions provider KLA-Tencor Corp of Milpitas, CA, USA says that Taiwanese LED chip maker Epistar has adopted its Candela substrate and epitaxy wafer inspection system. KLA-Tencor says that the order marks the growing adoption by LED device makers worldwide of the inspection system for wafer defect detection and classification at production-grade throughputs.

The introduction of the Candela tool to Epistar's manufacturing process provides automated inspection methods for sapphire substrates to ensure vendor quality, and provides greater visibility into the GaN epi process to help detect root-cause defectivity and early prediction of process excursions. "Adoption of KLA-Tencor's Candela inspection has provided Epistar with improved sapphire quality control

and MOCVD process control," says Epistar.

Substrate defects are known to impact epi process yield, and the Candela system provides increased sensitivity to these yield-limiting defects, says KLA-Tencor. With its proprietary optical design and detection technology, the Candela system detects and classifies sub-micron defects, including micro-cracks and micro-scratches, polishing and brushing streaks, and chemical residues.

As LED makers transition production to larger wafer sizes and introduce new patterned sapphire substrate (PSS) processes, the economic impact of resulting process-induced defects is significant. For defects occurring during the epi process steps, the Candela tool can detect hexagonal pits and bumps which can lead to electrical

failure and epi cracks that can adversely impact field reliability, says KLA-Tencor.

"The Candela system allows LED manufacturers to conduct root-cause analysis to speed process development, quickly fine tune production processes to minimize process excursions, and ultimately achieve higher yield per wafer," says Jeff Donnelly, group VP, Growth and Emerging Markets (GEM) Group at KLA-Tencor. "We are pleased to add Epistar to the growing list of Candela adopters."

The Candela tool is now installed in Epistar's Taiwan facility, adding to the hundreds of Candela tools currently installed around the world. Candela is part of KLA-Tencor's integrated LED portfolio, which includes the ICOS WI-series and Klarity LED.

www.kla-tencor.com

Jordan Valley Semiconductors named one of the 'Deloitte Israel Technology Fast 50'

For the 4th time in the last 6 years, x-ray and vacuum ultraviolet (VUV) metrology tool maker Jordan Valley Semiconductors Ltd (JVS) of Migdal Haemek Israel has been named one of the '2011 Deloitte Israel Technology Fast 50', the ranking of the 50 fastest-growing technology companies in Israel. Rankings are based on the percentage of fiscal year revenue growth over five years.

"Since the Deloitte Brightman Almagor Zohar Fast 50 award measures sustained revenue growth over five years, being one of the 50 fastest growing technology companies in Israel is an impressive achievement," comments Tal Chen, partner in charge of the Deloitte Brightman Almagor Zohar Israel Technology Fast 50 Program.

The growth is a testament to the wide adaptation of the firm's x-ray metrology into advanced semiconductor manufacturing processes as

well as emerging markets such as the LED and compound semiconductors, says says Jordan Valley's founder & CEO Isaac Mazor.

The JVX6200i x-ray metrology system is a high-throughput, high-uptime and low-CoO (cost of ownership) production multi-channel metrology tool for front- and back-end-of-line (FEOL and BEOL) processes as well as wafer-level packaging (WLP) applications. The popular configuration combines x-ray fluorescence (XRF) and x-ray reflectance (XRR). Typical applications are: FEOL (high-k/metal gate, SiON and ACL hard masks), BEOL (Cu seed/barrier, Cu electroplating & CMP) and WLP (UBM stack, Sn/Ag micro bumps and Cu pillars).

The JVX7200 x-ray metrology system is claimed to be the first in-line production control tool for epitaxial SiGe and Si:C applications. It combines fast HR-XRD and

fast XRR channels, capable of measuring SiGe composition, thickness, density, strain and relaxation of single- and multi-layer stacks on product wafers with high throughput, accuracy and repeatability. Unlike optical or spectroscopic tools, HR-XRD and XRR are first-principles techniques that deliver accurate and precise results without calibration, says JVS.

The QC3/QC-Velox are high-resolution x-ray diffractometers (HR-XRD) especially designed for production in-line quality control for the compound semiconductor markets such as LEDs, photovoltaics, CPV, power transistors, and RF. The tools are designed for epitaxial thin-film materials analysis, measuring thickness, composition and relaxation of epilayers such as GaN, GaAs, InP, MQW, Si and Ge.

www.jvsemi.com

www.deloitte.com/view/en_IL/il/industries/tmt/fast50/index.htm

IN BRIEF

Chief operating officer named a 'Mover and Shaker'

Kyma's chief operating officer Dr Heather Splawn has been named a 2011 Triangle Mover and Shaker.

Sponsored by Business Leader Media (which publishes Triangle Business Leader magazine), the award recognizes "leaders who are inspirational and devoted to both their co-workers and the community".

Splawn joined Kyma as director of business development in early 2010, when she was awarded a Corporate Research Postdoctoral Fellowship for Engineers (sponsored by the National Science Foundation and the American Society for Engineering Education). She became VP of operations in late 2010 then chief operating officer this August.

www.kymatech.com

Conductive and semi-insulating GaN templates provide added flexibility

Kyma Technologies Inc of Raleigh, NC, USA, which provides crystalline gallium nitride (GaN), aluminum nitride (AlN) and aluminum gallium nitride (AlGaIn) materials and related products and services, has added two new products to its growing product portfolio.

The firm's new semi-insulating (SE) GaN-on-sapphire template features a 5 μ m-thick layer of SE GaN grown on Kyma's AlN-on-sapphire template. Typical resistivity ranges from $\sim 1 \times 10^6 \Omega\text{-cm}$ to more than $1 \times 10^9 \Omega\text{-cm}$; a product resistivity specification of $R_s > 10^5 \Omega\text{-cm}$ has been established.

Kyma's new highly n-type conductive (n^+) GaN-on-sapphire template features a 5 μ m-thick layer of n^+ GaN grown on its AlN-on-sapphire template. Typical resistivity ranges from 5m $\Omega\text{-cm}$ to 10m $\Omega\text{-cm}$; a product resistivity specification of $R_s < 20\text{m}\Omega\text{-cm}$ has been estab-

lished.

Kyma has been supplying GaN templates for several years but, until now, without electrical conductivity specifications. "Our previous GaN templates served as a great nucleation surface for advanced materials and device development efforts, but presented some limitations to the customer for certain device endeavors," notes chief technology officer Ed Preble. "These new additions to our GaN template product line provide the customer with added flexibility in terms of what epilayer designs and device topologies can be used to achieve their goals," he adds.

"We are pleased to respond to our customers requests to be given a choice in the conductivity of the GaN layer in our GaN-on-sapphire templates," says technical sales engineer Tamara Stephenson.

www.kymatech.com

Kyma reports thermal conductivity analysis on GaN materials

Kyma Technologies has announced the results of an analysis of the thermal conductivity of several of its GaN materials products, carried out over the past three years by researchers in the group led by professor John Muth of the Materials Science and Engineering Department of North Carolina State University (NCSU).

Muth's group has published many of the results during this three-year period for bulk and template single-crystal GaN materials. More recently it also measured the thermal conductivity of Kyma's high-purity polycrystalline GaN. The results include two record numbers:

1. bulk GaN has been measured to have thermal conductivities of $260 \pm 5\text{W/mK}$;
2. high-purity polycrystalline GaN has been measured to have thermal conductivities of $165 \pm 5\text{W/mK}$.

Additionally, the thermal conductivity of Kyma's GaN-on-sapphire templates is found to vary from 180W/mK to 220W/mK for thicknesses between 100 μ m and 400 μ m, respectively (a result of declining dislocation density from about $8 \times 10^8 \text{cm}^{-2}$ to $3 \times 10^7 \text{cm}^{-2}$, respectively). Kyma's more typical GaN template product has 5 μ m of GaN and was not measured but is expected, based on NCSU's analysis of the literature, to have a thermal conductivity of about 130W/mK ($\sim 20\%$ higher than typical values for a 2 μ m-thick MOCVD GaN buffer layer grown on sapphire).

While defect density clearly impacts bulk GaN thermal conductivity, there is no significant dependence on doping density for intentional doping levels between 10^{16}cm^{-3} and 10^{18}cm^{-3} , says Kyma.

"We are enjoying incremental improvement in our bulk GaN materials properties, which is being born out in their thermal conductivity, as well as in other properties," says chief technology officer Dr Ed Preble. "Our polycrystalline GaN is also a pretty good thermal conductor," he adds. "This is not extremely surprising: the grains are relatively large (10–40 μ m) and relatively low in extended defect density, plus the material density is close to its theoretical value, and the chemical purity level is 6N's (<1ppm impurities by weight) or better."

Kyma's polycrystalline GaN is available in customer-defined shapes, ranging from 1cm-wide cubes to round wafers with diameters of 1", 2", 3" and 100mm and thicknesses of 0.5–5mm. The round form factor can be polished to an optically flat level, the firm

Kyma's chief scientist Paskova joins advisory board on return to academia

Kyma Technologies Inc of Raleigh, NC, USA, which provides crystalline gallium nitride (GaN), aluminum nitride (AlN) and aluminum gallium nitride (AlGaN) materials and related products and services, has announced the departure of Dr Tanya Paskova who, after serving as chief scientist since 2007, is returning to academia to continue her career, focusing on crystal growth and characterization of III-V semiconductor materials and devices. Her relationship with Kyma will continue in a new form, as she is joining the firm's Technical Advisory Board.

Kyma says that Paskova has helped it to better understand the materials properties and improve the manufacturability of its bulk and template nitride semiconductor products, including bulk GaN substrates with different surface orientations, GaN templates, AlN templates and, most recently, aluminum gallium nitride (AlGaN) templates. She has also served as principle investigator (PI) on a number of government R&D projects, focused mostly on the development of bulk GaN substrates, as well as their application for a number of homoepitaxial nitride devices. She was also one of the major contributors to the growth of Kyma's intellectual property portfolio. While at the firm, she has authored or co-authored a number of key scientific publications, in partnership with several academic groups and government laboratories.

"Tanya has contributed to Kyma's progress at a very high level, and her understanding of the III-N materials system is unsurpassed," comments president & CEO Keith Evans. "We are extremely supportive of the next chapter in her career, and are especially hopeful we will be able to continue to benefit from her talents and interests as her key strategic industry collabor-

ation partner," he adds.

"Being chief scientist with Kyma for four years has been a tremendous professional opportunity and a much valued experience," says Paskova. "I look forward to maintaining a close relationship with the Kyma team and pursuing new avenues for collaboration in the future."

As a new member of Kyma's Technical Advisory Board, Paskova joins Dr Jeffrey T. Glass (professor of Electrical and Computer Engineering and Hogg Family Director, Engineering Management & Entrepreneurship, Duke University) and Dr John F. Muth (associate professor of Electrical and Computer Engineering, North Carolina State University).

Paskova has held the position of adjunct professor in Materials Science and Engineering at North Carolina State University since 2009. After obtaining her academic degrees from Bulgaria's Sofia University and Sweden's Linköping University, she held posts as an assistant professor at Sofia University, and a visiting lecturer and an associate professor at Linköping University and Germany's University of Bremen. She spent most of her career working in the group of professor Bo Monemar, focusing on the development of GaN epitaxial growth and the study of basic properties of nitride materials and structures.

Paskova is an editor of two scientific books and author of more than 220 scientific papers, reviews and chapters in journals and books. She has also given several invited talks at international conferences and seminars at universities, national laboratories and large industrial companies. Paskova is an associate editor for the Journal of Crystal Growth and a member of several referee boards for research foundations and physics journals.

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GT Advanced Technologies releases case study on impact of sapphire material quality on LED wafering

GT Advanced Technologies Inc of Merrimack, NH, USA (a provider of polysilicon production technology as well as sapphire and silicon crystalline growth systems and materials for the solar, LED and other specialty markets) has released a case study 'Yields Matter: The Impact of Sapphire Material Quality on the LED Wafering Process' that details the findings of a blind material study on the effects of sapphire material quality on the epi-ready wafer manufacturing process for high-brightness (HB) LEDs. The study demonstrates that sapphire material quality has a direct impact on LED wafer yields and that, of the materials from four suppliers that were tested, GT's Advanced Sapphire Furnace (ASF) grown sapphire material delivers the highest wafer yields, it is claimed.

"GT has been supplying sapphire to the LED industry for over 12 years. We initiated this evaluation project in order to validate the positive observations that we have heard from materials customers on the superior quality of ASF-grown sapphire material and its favorable impact on wafer yields," says Cheryl Diuguid, VP & general manager Sapphire Material and Equipment. "Wafer yields are especially critical to wafer manufacturers as they directly impact their economics," she adds. "The data illustrates that there are differences in wafer yields for various sapphire material sources, and that GT's ASF material performed the best."

The study evaluated 25 core samples from GT ASF and three other sapphire suppliers. GT says that, to obtain unbiased data, it worked

through an independent wafer manufacturer and provided blind, unmarked material sources. Data was collected on key wafering parameters that drive yield and cost including wafer geometry (surface roughness or Ra, total thickness variation or TTV, warp and bow) and the rate of wafer rejections.

The wafering analysis is part of a larger comprehensive material characterization project initiated by GT to study the effects of sapphire material properties on the entire manufacturing processes in the HB-LED value chain.

The firm presented the findings of the study at the LED Japan Conference & Expo/Strategies in Light trade show in Yokohama (28-30 September). The paper is also available on the firm's web site.

www.gtat.com

Rubicon begins on-site processing of aluminum oxide for sapphire crystal growth

Rubicon Technology Inc of Bensenville, IL, USA, which makes monocrystalline sapphire substrates and products for the LED, RFIC, semiconductor and optical industries, has begun the transition to on-premise processing of aluminum oxide used for the production of sapphire wafers.

Using a customized in-house method, Rubicon converts raw aluminum oxide powder into a form usable in its ES2 crystal growth process, which enables the firm to reduce its manufacturing costs while increasing control of the quality of its raw materials.

Rubicon says that, in addition to providing greater control of quality and cost, the new process developed by the firm's crystal growth engineers forms the powder into different shapes which can optimize the space in the crucibles in its crystal growth furnaces, resulting

in larger crystals.

"As the LED industry transitions to larger-diameter substrates, ensuring a steady supply of raw material becomes increasingly important," says president & CEO Raja Parvez. "Large-diameter wafers are as much as three times thicker than two- to four-inch wafers and require more aluminum oxide," he adds. "It is important that our new on-site processing capability brings us a reliable supply of raw material that we can process into large-diameter sapphire wafers for LED manufacturers."

Advances in raw material handling combined with the recent company-wide installation of enhancements to its proprietary crystal growth furnaces (Rubicon Furnace Version ES2-XLG3.0) delivers cost efficiencies for the production of large-diameter sapphire, says the firm. The next-generation ES2-XLG3.0

furnaces provide automation for vacuum monitoring and crystal growth rates for greater yield consistency, and require less operator intervention (five staff per 100 furnaces at any given time). The ES2-XLG3.0 furnaces operate in Rubicon's US crystal growth facilities in Batavia and Bensenville, Illinois.

The transition to larger-diameter wafers in LED production has started, with several key LED chip makers having announced plans to migrate to and/or test large-diameter wafers in 2011/2012, says Rubicon. The firm claims that its robust process platforms for large-diameter sapphire wafers and its ability to scale to commercial volumes can create superior performance factors for the LED industry. To date, Rubicon has shipped more than 150,000 six-inch sapphire wafers.

www.rubicon-es2.com

Ammono launches high-transparency n-type GaN substrates

Ammono S.A. of Warsaw, Poland, which produces bulk gallium nitride (GaN) using ammonothermal technology, has introduced a new range of high transparency n-type substrates.

During the last 12 years Ammono has developed technology allowing the manufacture of GaN wafers with carrier concentrations between $2 \times 10^{17} \text{cm}^{-3}$ and $2 \times 10^{20} \text{cm}^{-3}$. The existing standard n-type product has a carrier concentration of 10^{19}cm^{-3} . Ammono says that, to respond to market needs, it is introducing new products based on n-type material that is characterized by both a higher transparency and a lower carrier concentration of $3 \times 10^{17} \text{cm}^{-3}$. The ammonothermal GaN substrates hence present additional advantages for the production of LEDs, UV LEDs and photovoltaic applications, the firm reckons.

The dislocation density in the material remains at a level of $5 \times 10^4 \text{cm}^{-2}$, which is currently the best commercially available, it is claimed. Initially, Ammono will offer high-transparency substrates in form factors of 10mm x 10mm square wafers and circular 1" wafers.

In 2012, besides its standard 2" n-type AMMONO-GaN substrate, the firm is targeting the introduction of a 2" product based on this new high-transparency material.

In 2012, besides its standard 2" n-type AMMONO-GaN substrate, the firm is targeting the introduction of a 2" product based on this new high-transparency material

IN BRIEF

Ammono discounts stock prior to launch of larger, 2" GaN substrates

As part of the buildup to a January 2012 launch of its new 2-inch c-plane n-type substrate, Ammono S.A. of Warsaw, Poland, which produces bulk gallium nitride (GaN) using ammonothermal technology, has introduced discount prices during fourth-quarter 2011 (from 1 October) for its smaller-size GaN wafers, which are currently in the company's stock.

For the special offer, Ammono has also introduced a simplified purchase procedure on its website in order to speed shipment. A quotation will follow within 48 hours of request.

www.ammono.com



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Optogan opens Europe's second largest LED chip production site

European LED chip and luminaire maker Optogan has opened its new LED chip production site in Landshut, Germany.

Founded in Helsinki, Finland in 2004 by three Russian physicists from Ioffe Institute in St Petersburg, Optogan is a vertically integrated developer and maker of HB-LEDs for applications including solid-state lighting. As well as having an R&D facility in Helsinki, since founding Optogan GmbH in Germany in 2005 it has established epitaxy and chip R&D plus a pilot line in Dortmund. Also, after founding CJSC Optogan in Russia in 2009, in 2010 it acquired an industrial facility in St Petersburg where, in late 2010, it opened what is reckoned to be the largest LED component and luminaire production site in Eastern Europe.

"In Landshut, we have discovered the ideal infrastructure for our



Optogan's LED chip production site in Landshut.

future high-volume production of efficient LED chips," states Hans Peter Ehweiner, managing director of Optogan GmbH. The foundation of the new site is the former Hitachi semiconductor factory, which has a cleanroom area of up to 4000m². Investment reaching double figures of millions of euros and up to 100 members of staff form the framework for production activities. With initial annual capacity of more than 1 billion LED chips combined with cost-effective manufacturing

processes, Optogan believes it is well equipped for the future.

The Landshut site is also the base for Optogan Group's international sales activities. The firm's core business is currently focused on European markets, but business is increasingly developing worldwide.

"I am delighted that Optogan has decided to use a site in Bavaria when expanding its operations in Germany," said Martin Zeil, Minister of Economic Affairs of the German Federal State of Bavaria, at the opening. "The site's proximity to Munich Airport and its access to highly qualified specialists and experts form an excellent foundation for the company to develop its international business."

Optogan launches 60W-replacement LED lamp bulb

Optogan Group has launched its first original domestic LED lamp on the Russian market. The E27 bulb was designed in cooperation with design studio art.lebedev to replace 60W incandescent bulbs.

"The vertically integrated manufacturing structure of Optogan allows us to control quality at every stage of production, from the German chip manufacturing to packaging and assembling the final product in St Petersburg," says president Maxim Odnoblyudov.

Consisting of German-Russian components, the new light source is claimed to be significantly less expensive than European counterparts. From September onwards, the first contingent of bulbs is available for 995 Rubles in both Moscow and St Petersburg. In early 2012 the bulb will be introduced to the global market, when the target price should be about €30.



Optogan's E27 lamp.

With a luminous flux of 720lm, the lamp's power consumption is 11W (about six times lower than that of an incandescent lamp). Its life-span exceeds 50,000 hours

(corresponding to 6 years of continuous illumination). Used 3-4 hours per day, the E27 is designed to operate for more than 46 years. LED light sources are not affected by turning them on or off frequently, which does not affect their life as drastically as it does with incandescent, or worse still, fluorescent lamps.

Optogan claims that its E27 solves the problem of light fluctuations

(which adversely affects human health when working long-term under artificial lighting), since it provides a smooth, warm-white light (with a correlated color temperature of 3050K). Also, unlike incandescent and fluorescent lamps, it does not contain dangerous substances such as mercury or lead.

Currently, the market share of LED light sources in Russia is 5-6%. Experts estimate that by 2015 the share of LEDs in the domestic market will exceed 25%. Global acceptance too is about 3%, but the addition of late adopters is expected to push this up to about 20% by the middle of this decade. Today, strong growth in the LED market is generated by the industrial, administrative and office sector, but a further increase in figures during 2013 via the retail sector is expected, says Optogan.

www.optogan.com

Optogan and Atlantik Elektronik sign distribution agreement

European LED chip and luminaire maker Optogan and Atlantic Elektronik GmbH of Planegg, Germany (part of Atlantik Networxx Group) have signed a distribution agreement for the pan-European market.

The aim of the new collaboration is to market energy-efficient lighting solutions and the latest 'Made in Germany' LED applications. The focus is on the sale of white LEDs, chips, and components such as driver ICs, specifically chip-on-board (COB) solutions in the high-power range (5–500W), via modular component technology combined with sophisticated control systems.

The focus of the new partnership is on mutual assistance in supporting customers' new projects in the regions DACH (Germany, Austria and Switzerland), Benelux (Belgium, The Netherlands and Luxembourg), and Eastern Europe. Joint activities will also be extended to regions and countries such as Scandinavia and southern Europe.

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

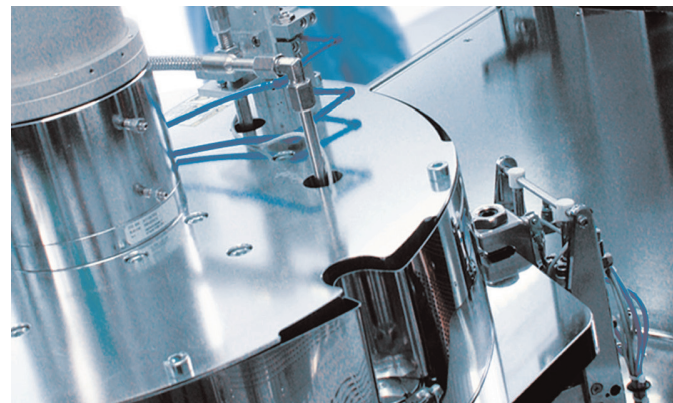
Optogan says that, due to its depth of experience in new design, Atlantik Elektronik has the expertise to provide customers with quick access to the latest solutions in the field of LED components, bulbs and LED lights for high-performance applications.

"Optogan is the ideal partner to focus on customers demanding innovative LED solutions whilst at the same time requesting a short time-to-market with these products," says Atlantik Elektronik's CEO Ottmar Flach. Fast market access can be achieved through the intense long-term customer relationship and sales experience of Atlantik Elektronik, Optogan reckons.

"We have teamed up with Atlantik Elektronik because we not only recognize the technical competence of the LED technology but also from adjacent areas of Atlantik products that help our customers to implement the latest technologies in their products," says Ove Sørensen, Optogan's director of sales & business development. "This partnership will accelerate the design process of the customer, which of course, in return, leads to faster market presence," he adds.

www.atlantikelektronik.com

www.optogan.com



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Lextar goes public on Taiwan stock exchange

Lighting reaches nearly 40% of LED maker's revenue

Lextar Electronics Corp (LEC) of Hsinchu Science Park, Taiwan has gone public on the Taiwan Stock Exchange (TWSE), claiming to be the only firm in the Taiwanese LED industry with vertical upstream-to-downstream integration.

Lextar was established in May 2008 as a subsidiary of display panel maker AU Optronics (AUO), and specializes in manufacturing high-brightness LED epiwafers, chips and packages, as well as energy-saving and smart lighting products. After acquiring domestic packaging firm LightHouse Technology Co Ltd in March 2010, Lextar has experienced rapid growth. Lextar has manufacturing plants in Hsinchu Science Park, Hukou Industrial Park and Chunan Science Park in Taiwan, and is establishing a new plant in Suzhou, China. Total staffing is now more than 2200.

Revenues in 2010 were US\$255m (NT\$8bn). Lextar's chairman Dr David Su says that, with stable output for LCD backlight applications, Lextar has built up its production and technology capacities in a very short time and secured its niche in the lighting market

(with products for applications including professional lighting sources, consumer lighting sources and various lighting products). Currently, Lextar's lighting business constitutes nearly 40% of total revenue, and the firm has now entered the supply chains of the top three international lighting brands, it adds. Based on its vertical integration, Lextar says that it has been able to maximize market opportunities and create added value for international brands via their total solutions.

Since it was founded, Lextar has positioned itself in full-spectrum lighting products as well as photometric, electrical, mechanical and thermal technologies. Its full series LED light tubes (with lengths of 1-5 feet and a variety of options for brightness, socket and color temperature) are being shipped to customers at a volume of 200,000-300,000 units per month. The firm has also started mass delivery of GX16 tubes which are compliant with Japan's latest JEL801 certification. Meanwhile, LED bulbs and panel lights are already being received by international brand owners. This year,

Lextar has also started receiving large orders for LED lighting projects and has started shipments. COB (chip-on-board) and LED light modules with various powers have also been launched. For the COB product line-up, the low-wattage products (4-7W, 8-15W, 15-21W) meet the requirements for light bulbs while the high-wattage products (30-50W) can be used for downlights and floodlights.

Lextar reckons that, with its Lighting Solutions and Value Provider (LSVP) strategy (introduced at the beginning of this year) and its technology and production capacity base in epitaxy and chips, it has entered the integrated services arena for lighting markets while simultaneously penetrating ODM/OEM brand owners in the European Union, USA and Japan. The firm says that it is determined not only to capture lighting channel markets around the world but also to adopt strategic partners in order to provide customers with quality products and services as well as improving added value by means of multiple channels and multiple brands.

www.lextar.com

Sharp to launch LED with luminous efficacy of 93.3lm/W in 50W input power class

Tokyo-based Sharp Corp says that it has developed and will introduce the GW5DME30MR5 high-power LED lighting device, which incorporates an LED chip with high emission efficiency combined with a proprietary blend of phosphors.

Luminous efficacy is 93.3lm/W (claimed to be the industry's highest in the 50W input power class) at the 3000K color temperature commonly used in downlights for retail stores. Sharp says that, in the future, lighting sources for applications such as downlighting

and spotlights in retail stores are expected to shift to higher-power LEDs.

Joining the 3000K GW5DME30MR5, the range also includes the 2700K GW5DME27MR5 and the 4000K GW5DME40MR5.

Also, the color rendering index (Ra) of the GW5DME30MR5 is 83. Proprietary package technology provides greater color consistency, contributing to higher quality in the design and development of lighting fixtures, Sharp says.

In addition, in order to meet the

need for light sources that require higher color rendering properties, the product lineup also includes high-performance models (the 2700K GW5DGE27MR5, the 3000K GW5DGE30MR5 and the 4000K GW5DGE40MR5) that feature a color rendering index of more than 90.

Sample price for the LEDs is ¥4000. Volume production is scheduled to start on 1 November. Monthly output should be 50,000 units.

www.sharp.co.jp



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Extra \$15m to speed Bridgelux's GaN-on-Si development GaN-on-Si LED chip technology targeted for commercialization in 2013

LED chip and lighting array maker Bridgelux Inc of Livermore, CA, USA (which claims to be the only vertically integrated maker of LED solid-state light sources specifically for the lighting industry) has closed an additional \$15m in financing, raised specifically to further accelerate research, development, and scaling of its GaN-on-silicon LED chip technologies, targeted for commercialization in 2013.

Bridgelux says that the financing round, which was oversubscribed, was quickly filled out by existing financial and strategic investors in response to company reports indicating that additional capital could further accelerate its GaN-on-Si program. Included in the round are VantagePoint Capital Partners, DCM, El Dorado Ventures,

Novus Energy Partners, IFA, Chrysalix, Harris & Harris Group, Craton Equity Partners, Jebsen Asset Management, and Passport Capital.

Previously, in early August, Bridgelux raised \$60m in a Series E financing round led by Los Angeles-based Craton Equity Partners. This took the total amount of venture capital raised to about \$180m.

"By continuing to drive down the cost of solid-state solutions for general lighting, Bridgelux is helping to expand the market for these solutions, which we expect to grow from \$3bn in 2011 to more than \$25bn in 2015," says CEO Bill Watkins. "This additional capital will further accelerate our breakthrough development efforts in producing commercial-grade LEDs

on silicon while we continue to deliver the industry's leading GaN-on-sapphire array solutions," he claims.

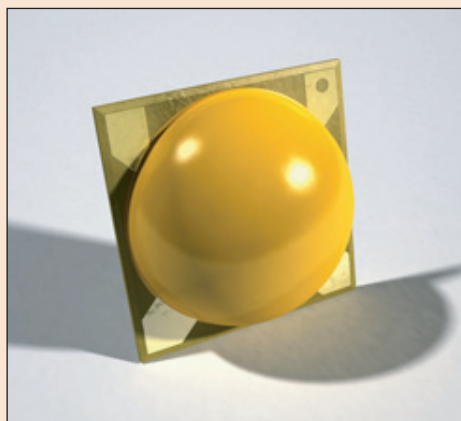
After originally focusing on designing and making its power LED chips based on ITO/InGaN (indium tin oxide/indium gallium nitride), Bridgelux launched its first LED array product line in January 2009, followed that May by a Lighting Services Group to offer a range of solid-state lighting design and support services, and in March 2010 by the 'plug-and-play' Helieon Sustainable Light Module (jointly developed with Molex Inc of Lisle, IL, USA) for industrial and commercial building owners. In May 2011, Bridgelux launched the third generation of its LED Arrays.

Micro SM4 LED launched for 20–40W replacement lamp market

Bridgelux has expanded its portfolio of solid-state light sources to address the requirements of the \$1bn 20–40W lamp replacement market. Leveraging Bridgelux's array technology into a surface-mountable LED component, the Micro SM4 delivers high flux density in a smaller footprint, suiting applications where discrete LEDs are preferred.

Bridgelux says that the Micro SM4 can reduce the component count, cost, complexity and size of the lighting system, enabling a cost-effective, high-performance LED solution for diffuse and directional lighting, such as 20–40W incandescent, 20–35W halogen, B10-style (candelabra), and low-wattage compact fluorescent lamp (CFL) replacements.

Using only 4.6W of input power, the Micro SM4 LED can deliver 330–520 lumens in both warm-white (2700K and 3000K) and cool-white (5600K) color temperatures. Minimum 80 CRI and 90 CRI



Bridgelux's new Micro SM4 LED.

(color rendering index) options, with 3-step MacAdams Elipse color selections, will be offered for warm-white products. Production shipments will be available in first-quarter 2012.

"The Bridgelux Micro SM4 delivers comparable efficacy and performance to some of our smaller-form-factor arrays in the size of a miniaturized discrete component," says VP of marketing Jason Posselt. "The ability to use

high-volume surface-mount assembly methods will open up new design integration options and help our customers to improve both cost-to-market and time-to-market," he adds.

Bridgelux says that the Micro SM4 features the latest technical advances in epitaxial gallium nitride (GaN) layer growth, LED chip design and packaging technologies. The products are configured so that they align with industry-standard drive currents to simplify the electronic driver selection process for new lamp and luminaire product development, and are offered in both 6V and 12V design configurations to enable driver design flexibility. As with all Bridgelux light sources, the Micro SM4 LED is offered with a five-year warranty.

Bridgelux's products were exhibited at the Hong Kong International Lighting Fair (27–30 October).

www.bridgelux.com

Ultrahigh-CRI LED arrays launched for retail and hospitality lighting

Bridgelux Inc of Livermore, CA, USA has launched its Decor line of ultrahigh color rendering index (CRI) LED arrays. Leveraging the firm's ES and RS array technology and developed in collaboration with luminaire designer and maker Martini Lighting (a division of Martini SpA of Milan, Italy), Decor is optimized for demanding applications such as retail, hospitality, museums and high-end architectural lighting.

With a CRI of 97 and a 3-step MacAdams Elipse color control option, the Decor arrays enable lighting designers to truly render a full palette of colors over a wide range of light levels, says Bridgelux. Delivering 1200–2500 lumens, the new arrays have been spectrally engineered to closely replicate the light quality of halogen and incandescent light sources. The arrays deliver R9 and R15 values of 98, to both enhance reds and represent skin tones accurately, ensuring clean and natural lighting. The firm says that the Decor series expands lighting options available to the

lighting designer, complementing its existing standard minimum 80 and minimum 90 CRI products.

The Decor arrays deliver output equivalent to a 75–150W halogen bulb, while using only 25–50W of power. They also have the same form factor as previous Bridgelux Array product generations, allowing a simple upgrade path for existing users while minimizing design efforts.

"The new Decor arrays take us to the next level, enabling very high-end lighting design," says Giorgio Martini, vice president at Martini Lighting. "These new arrays have allowed us to rethink lighting and luminaire design in fresh and innovative ways," he adds. "We can design precision lighting effects and striking contrast ratios, enhancing the presentation of retail merchandise. The Decor arrays now permit us to deliver the highest-quality light, brilliantly rendering colors and textures. These are the elements that allow us to present our shops and restaurants in living color."

www.martinilight.com

Bridgelux a 'GoingGreen Global 200' winner for creating new opportunities in green tech

Bridgelux has been chosen by the editorial team of AlwaysOn and industry experts worldwide as a GoingGreen Global 200 winner (a "leader among green-tech companies and a player most likely to disrupt markets").

Selected from thousands of domestic and international green-tech firms, the Global 200 were judged against five criteria: innovation, market potential, commercialization, stakeholder value, and media buzz. The winners were honored at AlwaysOn's GoingGreen Silicon Valley event on 27 September in San Francisco.

"Inclusion in the GoingGreen Global 200 list validates our commitment to leading innovation

and speeding market adoption for LED lighting," says Bridgelux CEO Bill Watkins. "Recognition from influencers and experts in the greentech industry further confirms our efforts and LED lighting's vast market potential," he adds.

"Picking this year's GoingGreen Global 200 was a very competitive process, as literally dozens of great green-tech companies are emerging out of the pack, raising big money, and gaining significant market traction," says AlwaysOn's founder & editor Tony Perkins. "This year's winners clearly represent some of the highest-growth opportunities we've seen in the private company marketplace."

www.aonetwork.com

IN BRIEF

Bridgelux's 792% growth during 2006–2010 yields Deloitte 'Technology Fast 500' ranking

LED chip and lighting array maker Bridgelux Inc of Livermore, CA, USA has been ranked number 135 on Deloitte's 2011 Technology Fast 500 list.

The Technology Fast 500, which was conducted by Deloitte's subsidiary Deloitte & Touche LLP, ranks the fastest-growing technology, media, telecoms, life sciences and clean tech firms — both public and private — in North America, based on percentage of fiscal year revenue growth from 2006 to 2010.

To be eligible, companies must own proprietary intellectual property or technology that is sold to customers in products that contribute to a majority of its operating revenues. Firms must have base-year operating revenues of at least \$50,000 (USD or CD), and current-year operating revenues of at least \$5m (USD or CD). Companies must also be in business for a minimum of five years and be headquartered in North America.

Bridgelux grew its revenue 792% during the 2006 to 2010 period. CEO Bill Watkins attributes this to both strong growth in the general illumination market, and the adoption of the firm's LED array architecture.

"Bridgelux's ranking in the Technology Fast 500 is a not only a reflection of our success in delivering leading technology and products, but in our ability to leverage numerous strategic partnerships with global leaders in materials technologies, embedded wireless communication and control technologies, as well as Energy Service Providers," he adds.

www.deloitte.com

Cree launches TEMPO testing services for lighting makers

LED chip, lamp and lighting fixture maker Cree Inc of Durham, NC, USA has announced the commercial availability of TEMPO Services, a set of quantitative and qualitative tests and analyses for LED-based lighting fixtures and lamps. The firm says that TEMPO (Thermal, Electrical, Mechanical, Photometric and Optical) Services represent the accumulated advantage of its experience with customer LED systems combined with the use of calibrated test equipment to give LED lighting makers and end users confidence in LED product designs.

Third-party labs currently provide testing services such as IES LM-79 (regarded as the industry's most comprehensive LED luminaire test). However, through years of experience with component LEDs and its LED-based lighting systems, Cree says it has identified many other aspects of end-product quality that are not and cannot be examined by third parties. These include chemical compatibility between materials used in the luminaire and the LEDs, the effectiveness of mixing slightly different color LEDs for enhanced color consistency, and TM-21 LED lifetime projections.

"At Cree, we've really 'seen it all' when it comes to LED components, and successful LED designs don't just happen — they are methodically constructed," says Mark McClear, director of applications engineering. "TEMPO Services can give manufac-

turers competitive advantages by helping them avoid costly design mistakes and by providing access to a broad range of test environments that are, in many cases, cost-prohibitive for them to build and operate."

Cree offers a range of TEMPO Services to LED luminaire makers, depending on their product development needs. The flagship service is the TEMPO 21 Service (claimed to be the most comprehensive LED luminaire test available), which measures and analyzes a final product design before submitting it for LM-79 certification. TEMPO 21 examines all the aspects of quality that Cree has identified as critical. The firm then provides the testing results and performance data in an easy-to-read format through the TEMPO report, which can comprise product sales collateral for TEMPO customers.

"I applaud Cree for recognizing the inherent difficulties faced by both end users and specifiers when evaluating an LED luminaire," comments Steve Walczak, director of product engineering at Sternberg Lighting. "As a lighting manufacturer, we found the Cree TEMPO testing to be a valuable asset, which helps to shorten our sales cycle by giving customers an added level of confidence in the way our fixtures are designed and built," he adds.

"The TEMPO report provides Sternberg with an additional layer of credibility because it identifies that

we are not designing solely on the recommendations of the DOE, IES and other lighting authorities, which are important, but that we're also working very closely with the chip manufacturer, which we consider key to proper luminaire design," says Walczak. "It's a great tool that provides an extremely thorough fixture analysis that confirms our fixtures are engineered to the intended performance criteria and specifications."

The TEMPO 21 Service also includes consultation time with a Cree application engineer to review the testing results and highlight possible areas for improvement in the design.

Cree is also offering two quick turnaround testing services so that LED system designers do not have to procure, calibrate and operate their own testing equipment during the design validation stage of development. The TEMPO SPOT Service provides measurements of flux, efficacy and chromaticity for luminaires and replacement lamps. The TEMPO FLASH Service provides measurements of flux, chromaticity and throw for torches and other portable lighting designs.

Cree is providing TEMPO Services out of its Cree Technology Centers in Research Triangle Park, NC and Santa Barbara, CA. Future TEMPO Services locations will include Munich, Shanghai and Taiwan, for lighting designers and manufacturers on three continents.

<http://tempo.cree.com>

Cree boosts XLamp XP-G LED efficiency to 140lm/W in production

Cree has boosted its XLamp LED family with new levels of performance for its XLamp XP-G LEDs.

The cool-white XP-G provides brightness of up to 148lm and luminous efficiency of 141lm/W, while the outdoor-white (4000K) delivers up to 139lm and 132lm/W and the warm-white (3000K) offers up to 122lm and 116lm/W, all at a drive current of 350mA. The firm says that the XP-G can

help lighting manufacturers to reduce system cost and complexity as well as making existing designs brighter and more efficient.

Cree says that, by leveraging the XP-G form factor, the increases in brightness and efficacy can shorten the LED fixture design cycle and improve customer time to market, with drop-in-ready performance enhancements. XP-G LEDs also have the longest projected lifetime

data published, it is claimed.

Cree says that its XP-G LEDs are optimized for directional lighting, in applications from street and area lighting to PAR replacement lamps to high-output flashlights. The firm says it is also the first LED supplier to publish 10,000 hours of lifetime data, allowing users to project TM-21 reported lifetimes of over 60,000 hours (nearly 7 years).

www.cree.com



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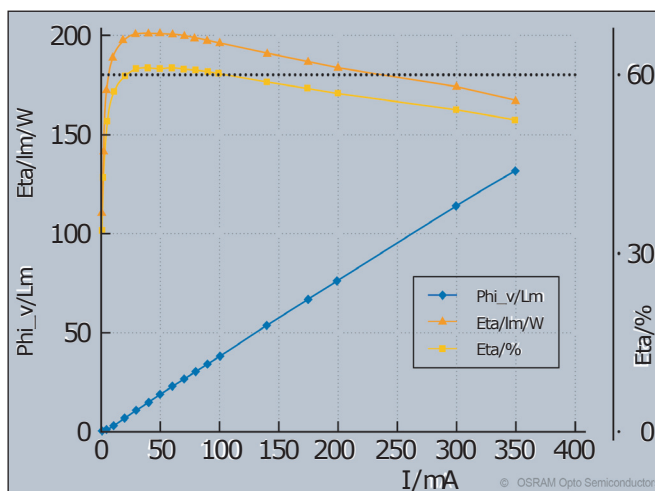
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Osram red LED prototype breaks 200lm/W barrier

Osram Opto Semiconductors GmbH of Regensburg, Germany says that its R&D lab has achieved a record electro-optical efficiency of 61% for a red high-power LED. The 1mm² chip housed on a laboratory package emits at a wavelength of 609nm (λ -dom) and has achieved a record luminous efficacy of 201lm/W at an operating current of 40mA. At a typical operating current of 350mA its luminous efficacy is still 168lm/W, so even at this high wattage more than half of the electrical energy is converted into light.

The increase in output was achieved using a chip with the latest generation of the firm's own thin-film technology.

Osram says that LED color mixing systems such as the firm's Brilliant Mix concept are the latest trend, particularly for general illumination applications. Such systems enable any kind of white light to be produced, from warm white through neutral white to daylight white. The overall system performance is as good as the individual components



Luminous efficacy and wall-plug efficiency.

will allow. Osram says that its new red high-power LED promises a further improvement in the quality of light with lower power consumption, especially in warm white. This should benefit not only color mixing concepts but also all applications that use high-efficiency red LEDs — in the general illumination, projection and automotive sectors.

Higher efficiency means more light from the same amount of electricity,

which in turn means lower power consumption for a particular application. Because fewer chips are needed to produce the same brightness, designers will have greater freedom, says Osram Opto. Light sources can be made smaller while still producing the same brightness.

"The results of this project can be extended to all the wavelengths in AlIn-

GaP chip technology, so we anticipate a boost in efficiency in these light colors — even at 660nm, which is the wavelength needed for plant lighting for example," says Dr Martin Behringer of Osram Opto's LED development team. "Probably we will be introducing the results of this development project across the entire wavelength spectrum into production in about a year's time."

www.osram-os.com

OSTAR Compact 2x2 LED doubles projection brightness

Osram Opto Semiconductors has added another LED to its OSTAR Compact series for projection applications. With twice the brightness in all colors and near-record green values, the OSTAR Compact 2x2 is claimed to be the brightest LED of its type on the market, suiting high-power projectors for the commercial and domestic sectors.

With the new 2x2 version, the OSTAR Compact series now offers greater flexibility. With just one set of red, converted green and blue LEDs, it is now possible to achieve a luminous flux of 400lm from the projector. The new version has been designed specifically for imager diagonals of 0.4–0.55". If multiple sets of LEDs are combined for larger imager diagonals, the high brightness levels needed for office projector applications can be achieved.

Osram Opto claims that the OSTAR Compact 2x2 LED offers the best ratio of light to size available. With dimensions of 5.8mm x 4.6mm and an output of 85lm per mm² of footprint, it is claimed to be the brightest LED in this package class on the projection market (measured in pulse mode for green at an operating current of 6A). Containing two 2mm² chips, it produces twice the output of the standard Compact LED with one chip.

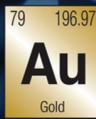
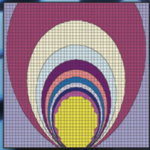
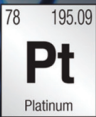
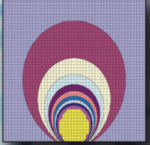
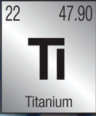
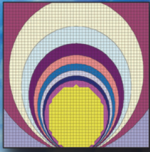
The package is available in red, converted green and blue. In converted green the LED has what is claimed to be record typical luminous flux of 2400lm in pulse mode at an operating current of 6A. The increase in output is based on the two integrated blue chips using ThinGaN technology and the green phosphor converter. Since a

greater proportion of green than red or blue is needed to produce white light, the increase in brightness has a significant effect on the overall system brightness of the projector, says Osram Opto.

"Each chip in the new Osram OSTAR Compact 2x2 can be individually controlled, which means that the drivers can be individually designed — either for high voltage and low currents or vice versa," says Wolfgang Schnabel, product manager for the OSTAR Compact series. "If high-voltage LED drivers are used the new LEDs not only provide greater system brightness but also greater system efficiency," he adds. "The two chips can be connected in parallel or in series, with the latter providing higher efficiency and more readily available standard drivers."

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IN BRIEF

Osram Opto appoints new chief operating officer

Frank Tillner has succeeded Elke Eckstein as chief operating officer of Osram Opto Semiconductors, taking over responsibility for the chip and LED production plants at its headquarters in Regensburg, Germany and in Penang, Malaysia. Tillner, 51 and a native of Aachen, Germany, has many years of experience in semiconductor processes and production. He was last employed as senior VP at solar system maker Conergy AG.

"With his long-standing experience in the sector, he not only has an immense specialized knowledge but also the management expertise required to meet the demands of the various processes at Osram Opto Semiconductors," comments Osram Opto's CEO Aldo Kamper.

Tillner's career began 26 years ago in the semiconductor sector. Following studies in physics engineering, his first post was with Siemens AG, where he was a process engineer for lithography in the Semiconductor Memories division. Tillner has since held various positions at the firm, including six years in Essonnes, France. He has also worked with Texas Instruments GmbH, Infineon Technologies AG and Qimonda AG.

Executive posts included chief operating officer for Infineon AG's Secure Mobile Solutions Group; senior VP, production & purchasing at Qimonda AG, and senior VP, solar components & global large projects at Conergy AG. Osram Opto says that, due to his expertise in product and technological development, marketing, logistics, quality and finances, along with his worldwide responsibility for production plants, Tillner brings a wealth of experience and a holistic view of organizational structures to his new position.

Osram combines IR LED emitter with proximity and ambient light sensors to cut crosstalk in smart-phones

Osram Opto Semiconductors GmbH of Regensburg says that its new SFH 7773 digital sensor makes it easier to install both proximity and ambient light sensing in smart-phones and similar devices by combining the functions of a digital ambient light sensor and a digital proximity sensor in a single compact unit.

Combining the emitter and detector chips together — three devices in all — also simplifies the elimination of crosstalk in many applications, reducing design requirements, since designers no longer have to install a separate IR emitter to enable the proximity sensor function.

The SFH 7773 detects objects up to a distance of 15cm (5.9 in.) while simultaneously measuring the intensity of the ambient light. Measuring just 5.3mm x 2.5mm x 1.2mm, its black package is barely noticeable behind the transparent covers of smart phones, says Osram Opto. Due to highly efficient chip technology, power consumption is low (a maximum of 5mA flows in stand-by mode and 300mA in operational mode) suiting portable devices.

Proximity sensors detect objects by receiving the reflection of an emitted light signal. But the cover of a smart-phone, for example, also reflects light back to the sensor. This crosstalk is usually intercepted by installing an optical barrier or placing the emitter at a sufficient distance from the cover to prevent the cover reflections from reaching the detector. However, both methods are rather complex and cumbersome. Osram Opto says that, with the SFH 7773, designers



SFH 7773 is a combined proximity and ambient light sensor with IR LED emitter in one package for unprecedented design versatility and ease of use.

no longer have to worry about crosstalk because, inside the device, the emitter and the detector chip are located sufficiently far apart from each other and apertures are integrated into the package to prevent crosstalk, or at least to significantly reduce it.

Now, to a large extent, designers are free to select the integration time of the detector and thus the detection range of the proximity sensor via the I²C interface. That way, the ambient light sensor can also adjusted to the transparency of the smart-phone cover. A variety of sensitivity levels is available, ranging from 3 to about 65.500 lux and 0.03 to 655 lux.

"This means that now, for the first time, our customers can optimize the device for their respective application — from the operating distance to the sensitivity of the ambient light sensor," notes product marketing manager Bianka Schnabel. "Due to this considerably simplified design and flexibility of use, combined ambient light and proximity functions become more attractive for the mid-price segment of smart-phones and other portable devices," she adds.

www.osram-os.com

Osram Opto launches smallest 1W-class IR LED

Osram Opto Semiconductors GmbH claims that its new IR OSLOM SFH 4715S is the smallest infrared LED with more than 1W of optical power. The device measures just 3.75mm x 3.75mm and hence can facilitate very compact illumination units for CMOS and CCD cameras.

The IR OSLOM typically provides 1070mW of optical power at 1A operating current, and has a typical thermal resistance of only 6.5K/W. A lens with $\pm 45^\circ$ emission angle is integrated into the device. Due to this adapted outcoupling lens, the IR OSLOM delivers 15% more output power than components without lens. Also, with a wavelength of 850nm, the IR OSLOM is well matched to the sensitivity of CMOS and CCD camera sensors. The small package allows compact configurations, enabling high power density. In particular, 3D cameras benefit from improved power since the IR LED can be modulated up to very high operating currents of 5A at 10MHz.

To achieve the record-breaking ratio of device size to power, Osram has combined its nanostack chip technology with its temperature-stable OSLOM Black Series package. The highly efficient stack chips have two p-n junctions connected in series and generate nearly twice the optical power of conventional emitters, it is claimed. The OSLOM Black Series package is based on a metal lead frame, and its thermal expansion matches exactly the thermal behavior of circuit boards. Thus good cycle stability is achieved, even at heavily fluctuating temperatures, as may occur outdoors. The IR OSLOM also complies with quality standards such as automotive standard AEC-Q101. Together, the latest chip technology and the package properties ensure an operating lifetime of up to 50,000 hours.

The IR OSLOM is fully compatible with its counterpart for the visible spectral range. Makers of street lighting or CCTV systems combining visible and IR LEDs can hence use their experience with OSLOM Black

Series LEDs and apply existing designs and board layouts.

Osram says the IR OSLOM expands its position in infrared illumination and complements its product range with an additional power class. The device particularly addresses security applications, from spotlights for IR cameras and CCTV systems via machine vision solu-

tions to number-plate recognition.

"We plan a [longer-wavelength] 940nm version," says Dr Joerg Heerlein, marketing manager for infrared devices. "Since humans perceive intensive infrared light as a faint red glow, this IR OSLOM is especially tailored for light sources which should not be seen by people."

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Jenoptik to double production of GaAs laser bars

Jenoptik Group of Jena, Germany is investing about €10m to expand manufacturing of optoelectronic components (high-power laser bars) at its site in the Berlin-Adlershof technology park. The existing production facility has reached its capacity limit and is being expanded due to rapidly increasing demand (particularly from Asia), as well as for future projects, including internationalization of the firm's Lasers & Material Processing division.

The new facility will be equipped with manufacturing technology for automated production designed to process 4" gallium arsenide wafers. "We will also be reaching unit volumes that will enable us to not only achieve economies of scale but also a highly automated and state-of-the-art production process," says Jenoptik chairman Dr Michael Mertin. The new production facility should begin operation at the start of 2013.

Jenoptik has had production facilities in Berlin-Adlershof since 2006. The optoelectronic base material and its efficient production are being

developed by Jenoptik in close collaboration with the Ferdinand-Braun-Institute, Leibniz Institute for High Frequency Technology (FBH) in Berlin-Adlershof. JENOPTIK Diode Lab (spun off from FBH in 2002) is an example of expertise and technology transfer. Jenoptik says it is hence part of a network of research institutions at the Science and Technology Park Adlershof, and benefits from being located in close proximity to its technology partner. Currently Jenoptik employs 70 people at Berlin, mainly in the Lasers & Material Processing and Optical Systems divisions. As a result of the investment, staffing will rise by the year 2013 in accord with expected future growth.

The laser bars from Berlin form the basis of the high-power diode lasers developed and made in Jena, for which the main focus is on lifetime, beam quality, output power and efficient mass production, says Jenoptik. Since Jenoptik Group controls the entire manufacturing technology chain, including epitax-

ial processing (applying the optically active layers to the GaAs substrate), the laser bars are also sold to customers worldwide.

Jenoptik says that in recent years there has been a significant rise in demand for high-power diode lasers, due mainly to new laser applications. High-power diode lasers are increasingly conquering mass volume markets (e.g. direct laser material processing in industrial environments and in medicine/aesthetics). As an excitation source they are also needed for modern laser technologies such as thin-disk and fiber lasers as well as diode direct lasers. These types of lasers are already achieving high growth rates and will continue to do so in the future, reckons the firm. The main advantages of high-power diode lasers are their high efficiency, compact design and low operating voltage, it adds. The capacity range of the lasers can be adapted variably to the requirements of the respective field of application.

www.jenoptik.com

OPEL selects GrowthPoint as advisor for ODIS affiliate

OPEL Technologies Inc of Toronto, Canada, which makes high-concentration photovoltaic (HCPV) panels and solar tracker systems as well as developing semiconductor devices and processes, has chosen GrowthPoint Technology Partners as advisors.

GrowthPoint provides merger & acquisition, fundraising and strategic advisory services to a range of semiconductor, information technology, energy technology and defense contracting companies. For OPEL, it will help to identify and evaluate strategic options for value optimization of the proprietary Planar Optoelectronic Technology (POET) semiconductor process developed by the firm's US affiliate OPEL Defense Integrated Systems (ODIS Inc) of Shelton, CT. These options may include the full or partial sale of the technology.

"We were impressed with GrowthPoint's outstanding track record of guidance provided to other semiconductor, defense and clean-tech firms," notes OPEL Technologies' CEO Leon M. Pierhal.

POET creates high-performance devices by fusing optical and electronic functions together on a single chip. Specifically, POET is a semiconductor manufacturing process that enables the monolithic fabrication of GaAs integrated circuits containing both electronic and optical elements on a single wafer. Developed over 18 years by chief scientist Dr Geoff Taylor and his ODIS team, POET is protected by numerous patents and patents pending. OPEL says that, offering devices with dramatically lower costs and increased speed, density and reliability, POET could potentially

impact a broad range of mobile and server applications with reduced power consumption compared with conventional silicon-based devices.

OPEL says that US Government departments and agencies are developing specific devices using the POET platform (including image sensors and ultra-low-power random access memory), highlighting POET's potential to address high-speed and low-power applications for commercial and consumer applications, included servers, tablet computers and smartphones. Recently, POET technology was independently validated by BAE Systems (in their fabrication facility) when working transistors were created using the POET platform.

www.gptpartners.com

www.opeltechinc.com

3S Photonics acquired by Eurazeo Croissance

€37m to give private equity firm 83% stake

3S Photonics Group of Nozay, France, which makes chips, optical discrete modules and passive components for the laser, sensing and telecom markets, has been acquired by Paris-based private equity firm Eurazeo.

With a diversified portfolio of €4bn in assets, Eurazeo launched Eurazeo Croissance last year as part of its policy to support the development of French SMEs (small and medium enterprises). After its first investment in renewable energy firm Fonroche, 3S Photonics represents Eurazeo Croissance's second investment.

Eurazeo is purchasing the holdings of several 3S investors, including Fonds Stratégique d'Investissement (FSI) for which 3S was one of its first investments. Eurazeo will also invest in a capital increase of €10m to finance 3S' growth, making a total equity investment of €37m by Eurazeo. Following the equity increase, Eurazeo will hold close to 83% of 3S Photonics' capital.

3S was founded in 1994 as Alcatel Optronics S.A. (a subsidiary of the Alcatel group) and acquired in 2003 by Avanex Corp of Fremont, CA,

USA, becoming Avanex France S.A. In April 2007, it was bought by entrepreneur Alexandre Krivine (becoming president & CEO) and chief technology officer Didier Sauvage (former director of Avanex France) and renamed 3S Photonics. The firm designs and manufactures both active optoelectronic components (incorporating gallium arsenide and indium phosphide laser chips fabricated in-house at Nozay, France) and passive fiber-based optical components (made at what was formerly Avensys Inc of Montreal, Quebec, Canada, acquired in early 2010). 3S is active in two global markets: high-speed telecom networks (both the historical core business of submarine telecoms as well as, more recently, terrestrial telecoms) and fiber lasers (supplying products for industrial, medical and defense applications). With about 400 staff, 3S generated revenue of €51m in fiscal 2011 (to end June).

Eurazeo aims to help 3S consolidate its position in its traditional telecoms markets and broaden its presence in the industrial laser

market by supporting its external growth policy, including through future reinvestment.

"We will be supporting Alexandre Krivine and his team, continuing the work begun with the help of FSI to make 3S Photonics a true global leader in the optoelectronic components market," says Fabrice de Gaudemar, Eurazeo's executive board member responsible for Eurazeo Croissance.

"FSI's intervention in 2009 facilitated a first round of financing, helping to enable 3S Photonics' acquisition of Avensys," notes FSI's director of investment Thierry Sommelet. "We are pleased that 3S Photonics will be able to continue its development with the support of a recognized leader in France's private equity industry," he adds.

"We are gratified by Eurazeo's entry into our capital structure," says Krivine. "With their support, we look forward to accelerating our organic and external growth and seizing opportunities offered by the international consolidation of our industry."

www.3Sphotonicsgroup.com
www.eurazeo.com

nLIGHT raises \$17.5m in Series E venture funding

nLIGHT Corp of Vancouver, WA, USA, which makes high-power semiconductor lasers for material processing, defense and medical applications, recently raised \$17.5m in a fully subscribed Series E round of venture capital financing, bringing total equity funding to about \$110m.

Existing investors participating in the latest round included Oak Investment Partners, Mohr Davidow Ventures, and Menlo Ventures. All have been actively involved with the firm for more than 10 years and have a strong record of companies achieving initial public offerings, notes nLIGHT.

nLIGHT says that the new funding will help to fuel rapid growth in semiconductor-based laser products such as multi-kilowatt laser systems, high-peak-power pulsed fiber lasers, and diode-pumped solid-state laser range finders.

In particular, the new investment is being used to expand the firm's 65,000ft² headquarters and manufacturing facility by 11,000ft². Construction work has already started.

nLIGHT is also relocating its administrative functions out of its existing building to a second, 18,000ft² building in the same Vancouver industrial park.

"We founded nLIGHT with the vision that dramatic improvements in semiconductor lasers would transform the laser industry and enable disruptive new applications," says CEO Scott Keeney. "This funding will allow us to continue to fulfill this vision and support our accelerating growth," he adds.

The funding follows recent highlights including: continued growth in profitability; more than \$60m in orders booked in first-half 2011; the addition of more than 100 staff in the last year (bringing the total to over 400); and the launch of the nPower multi-kilowatt laser platform.

www.nLIGHT.net

Implementation agreement approved for 25G generation

Members of the Optical Internet-working Forum (OIF) have approved the Common Electrical I/O (CEI) 3.0 implementation agreement (IA), which defines electrical layer interfaces with signaling rates up to 28 Gbaud/s for next-generation systems (the next evolutionary step beyond the existing CEI IA, which addressed signaling rates up to 11.2 Gbaud/s). The CEI 3.0 electrical layers form the basis of future protocol interfaces developed by the OIF, and were developed in conjunction with the OIF's efforts to address 100 Gbaud/s networks.

"The CEI work is important to the networking industry because it paves the way to second-generation 100G systems and even beyond," says CEI author and OIF's Technical Committee vice chair Klaus-Holger Otto of Alcatel-Lucent. "Moving forward, these IAs will help to drasti-

cally reduce power and increase density of the system internal interconnects and therefore open the way for even higher integrated transmission systems in the near future," he adds.

Announced in early September, the Next Generation Interconnect Framework project will explore various application spaces for high-speed optical and/or electrical interconnect to build on the CEI work.

The OIF's Physical and Link Layer (PLL) Working Group has been working on the Common Electrical I/O 25 Gbaud/s (CEI-25) project, which includes electrical specifications for 28 Gbaud/s signaling for chip-to-chip applications, and 25 Gbaud/s signaling for backplane applications. The CEI-28G-SR clause supports chip-to-chip interfaces up to 300mm with one connector. The CEI-25G-LR clause supports back-

plane interfaces up to 680mm with two connectors. CEI-25 builds on the legacy of previous generations of CEI effort, which provided electrical signaling solutions in the 5–6 Gbaud/s and 10–11 Gbaud/s ranges.

The latest work will enable narrower interfaces for 100Gb/s applications, such as 100 Gigabit Ethernet, which will enable smaller package sizes, lower-pin-count components, connectors and optical modules, lower power dissipation and clockless interfaces.

"This is the industry's first published agreement for 25G generation of electrical interfaces," says PLL Working Group chair David Stauffer of IBM. "This represents a culmination of several years of work in the OIF to address the implication of 100Gb/s networks deployment."

www.oiforum.com

OIF next-generation interconnect and 100G projects to address growing pains for 100G and beyond

The OIF has initiated a Next Generation Interconnect Framework project that explores application spaces for high-speed optical and/or electrical interconnect and identifies the necessary elements for follow-on implementation agreements (IA). The OIF has also begun a new 100G project to address next-generation integrated coherent receivers, targeting lower-cost, higher-density applications. A third project addresses a Multi-Link Gearbox (MLG) for 100G client-side signaling.

"All three of these projects are critical to the industry to support 100G and beyond," says Rod Smith of TE Connectivity and the OIF Market Awareness & Education (MA&E) committee co-chair, PLL (Physical and Link Layer). "As the industry transitions to 100G and beyond, new agreements are needed to support the higher data rates through smaller form factors and reduced power consumption."

In the past decade, the industry

has developed high-speed electrical interfaces such as the OIF's CEI-11. New technologies and agreements will be needed to meet next-generation interconnect system solutions, says the OIF. Such interconnect solutions will be required for applications including very short reaches within the blade, longer reaches between blades (backplanes) and chassis-to-chassis. These applications will require interoperability between components from different vendors as well as significant investment across the ecosystem, adds the OIF.

"Electrical signaling over the required distances within a system is anticipated to be challenging at the higher data rates," says OIF board member Jeff Hutchins. "Both vendors as well as users will benefit from agreements that enable interoperability within the various applications spaces," he adds.

The second project, the Generation 2.0 Intradyn Coherence Receiver

(Gen-2 ICR), will define a smaller 100G coherent receiver to satisfy the need for size and cost reduction to support the evolving 100G coherent DSP-based module standards. The project follows the OIF's Gen-1 ICR IA (OIF-DPC-RX-01.0 IA), which enabled long-haul applications using line-card and large-form-factor transponder (e.g. MSA-100GLH) implementations.

The third project (MLG) will enable applications where a group of 10GBASE-R virtual links are transported by a 4x25G physical link. It will define a 10:4 Mux MLG function to convert multiple (up to 10) independent 10Gb/s links into 4x25G lanes, and a 4:10 DeMux MLG function to convert the 4x25G lanes back to multiple (up to 10) independent 10Gb/s links. Also, the project will define in-band coding that preserves 10GBASE-R physical lane-to-lane ordering and in-lane bit ordering to support synchronous and asynchronous 10G lanes.

HELIOS demonstrates first 40Gb/s optical modulator in silicon

European project presents results at Group IV Photonics Conference

Grenoble-based CEA-Leti (the French government's Laboratory for Electronics & Information Technology), which coordinates the pan-European consortium HELIOS (pHotonics ELectronics functional Integration on CMOS) to accelerate commercialization of silicon photonics, claims that a team of European researchers and companies has achieved a major milestone towards fabricating silicon photonics circuits in CMOS foundries.

By demonstrating for the first time a 40Gb/s optical modulator in silicon with a record extinction ratio of 10dB (the power difference between the 1 and 0 data levels), members of the European HELIOS Project have accomplished one of the key project goals necessary in building and optimizing the entire supply chain for fabricating complex functional silicon photonics devices, from design to the process level.

As well as the 40Gb/s modulator, HELIOS partners are building the fabrication supply chain through several other complex photonic ICs that address a variety of industrial needs, including a 16x10Gb/s transceiver, a photonic QAM-10Gb/s wireless transmission system, and a mixed-analog and digital-transceiver module for multifunction antennas.

Designed and characterized by staff in the Silicon Photonics Group at the Advanced Technology Institute, University of Surrey, UK, the modulator circuit was fabricated in a CMOS-compatible process by Leti, which is coordinating the project. HELIOS partners presented the results at the 8th International Conference on Group IV Photonics in London, UK (14–16 September).

"This result is a major step towards high-bandwidth optical systems on silicon because it makes 40Gb/s modulators viable for commercial applications," says

Graham Reed, professor of silicon photonics at the University of Surrey.

Silicon photonics, which Leti says is the only viable technology to meet the demand of high-volume markets, has generated growing interest in recent years, mainly for optical telecommunications or for optical interconnects in micro-electronic circuits. CMOS photonics may lead to low-cost solutions for a range of applications such as optical communications, optical interconnections between semiconductor chips and circuit boards, optical signal processing, optical sensing, and biological applications, it adds.

Launched by the European Commission in May 2008 within the Information and Communication Technologies (ICT) theme of its 7th Framework Program (FP7), the €8.5m, four-year HELIOS project is designed to drive European R&D in CMOS photonics and to pave the way for industrial development. Specifically, it aims to develop microelectronics fabrication processes for integrating compound semiconductor-based photonics with CMOS silicon circuits and to make the technology available to a wide variety of users.

Project partners include CNRS, Alcatel Thales III-V lab, Thales, University of Paris-Sud, 3S Photonics and Photline Technologies in France; IMEC in Belgium; Phoenix BV in The Netherlands; IHP and the University of Berlin in Germany; Austriamicrosystems AG and the University of Vienna in Austria; IMM and the University of Trento in Italy; the University of Valencia, the University of Barcelona and DAS Photonics in Spain; and the University of Surrey in the UK. The overall project cost is €12m.

www.helios-project.eu

www.leti.fr

IN BRIEF

Mitsubishi launches 1.3µm 40Gbps EML module for 10km

Tokyo-based Mitsubishi Electric Corp has launched a compact 1.3µm-band 40Gbps electro-absorption modulator laser (EML) module for optical signal transmission up to 10km by devices used for sending high-volume data. The FU-497SEA was presented at the 13th China International Optoelectronic Exposition (CIOE) in Shenzhen, China in September.

As online traffic continues to increase rapidly, 10Gbps optical interfaces for networks are giving way to faster 40Gbps interfaces, says Mitsubishi Electric. The firm's existing FU-697SEA 40Gbps EML module uses the 1.55µm band for transmission distances that are limited by wavelength dispersion to about 2km.

As chromatic dispersion at 1.3µm is almost negligible, the new 1.3µm-band EML chip can deliver high signal quality for 40Gbps optical transmissions over distances of up to 10km. Using single-mode fiber (via an LC connector), the transmission penalty is less than 1dB after 10km. The module also has a high extinction ratio (10dB, typical) and high mask margin (10%, typical) at 43Gbps operation.

With a package compliant with the XLMD-MSA (multi-source agreement), the RF signal input is via dual SMPM connectors for differential connection between modules and digital signal circuits (helping to simplify system design for transmission equipment).

Mitsubishi Electric says it plans to launch additional compact, power-saving EML modules in future.

www.MitsubishiElectric.com/semiconductors

NeoPhotonics acquires PIC firm Santur

Santur's active InP PICs for transmitters to complement NeoPhotonics' hybrid PIC-based receiver for 100G coherent systems

NeoPhotonics Corp of San Jose, CA, a vertically integrated designer and manufacturer of photonic integrated circuit (PIC)-based modules and subsystems, has acquired Santur Corp of Fremont, CA, USA.

Founded in November 2000, Santur is a vertically integrated designer and manufacturer focused on commercializing InP PIC-based tunable laser array and packaging technologies for communications applications. Its technology includes established telecom designs offering approaches to wide tunability as well as high-speed transceivers. Products are designed to provide reduced size, power consumption and cost for a wide range of DWDM, coherent line-side and client-side networking applications in 10G, 40G and 100G networks. Santur generated revenue of about \$21m for the six months to end-June 2011.

NeoPhotonics is paying an estimated \$39.2m in cash for Santur, after deductions for closing costs and other adjustments, plus up to \$7.5m extra contingent on the finan-

cial performance of Santur products subsequent to closing of the transaction through the end of 2012.

"Santur has developed innovative InP-based photonic integration products that are critical elements in 100G coherent transmitters and that complement the NeoPhotonics PIC-based 100G coherent receiver product line," says NeoPhotonics' chairman & CEO Tim Jenks.

"By combining active InP PICs from Santur with our hybrid [silica-on-silicon] PICs, we can provide our customers with new products for 100G coherent systems that feature higher levels of integration, higher performance and greater functionality. Furthermore, Santur's advanced tunable laser products also fit with our Speed and Agility product lines, enabling us to provide customers more complete solutions for reconfigurable networks," he adds.

Also, Santur is a provider of PIC-based 40 and 100G transceiver modules for client-side and data-center applications. NeoPhotonics recently entered this fast growing

market with its first products.

"By combining Santur's products, roadmap and strong customer positions with the NeoPhotonics portfolio of products, vertically integrated and high-volume manufacturing capabilities, and complementary customer set, we intend to further develop our 100G coherent line-side products and rapidly establish NeoPhotonics as a major vendor of client-side components for the cloud," says Jenks.

"Our InP PIC technologies form the foundation for our line of innovative products that we have successfully developed and sold to leading customers around the world," says Santur's president & CEO Paul Meissner. "The combination of our technology and products with complementary technology and products from NeoPhotonics can provide compelling value to our customers. This is a case of the sum being much greater than the parts... NeoPhotonics represents an excellent strategic fit for Santur," he adds.

www.santurcorp.com

NeoPhotonics adds 40km and 80km SFP+ transceivers for high-capacity metro networks

NeoPhotonics has added to its SFP+ transceiver portfolio with new versions that enhance its existing range of 6G SFP+ transceivers for Common Public Radio Interface (CPRI) and 10G SFP+ transceivers for 10G Ethernet and OC-192/STM-64 SONET/SDH transport.

The new SFP+ transceivers also address the 'green' transition in networking toward lower-power and smaller-footprint modules, which reduce overall power consumption in communication systems and support the increasing face plate port density needed to meet rapidly growing bandwidth demands. The SFP+ MSA allows for a maximum of 1.5W of power

consumption per module without clock and data recovery (CDR); the older XFP MSA allowed 3.5W (more than double the power) for an equivalent transceiver module. NeoPhotonics' portfolio includes several versions that cover both 40km (ER) and 80km (ZR) reach, supporting various protocols.

"We are pleased to support our customers in their green efforts to reduce the power consumption and carbon footprint of their broadband networks, and to meet their growing needs for higher optical port densities on their equipment shelves," says chairman & CEO Tim Jenks.

SFP+ transceivers without integrated CDR are designed to support

10G Ethernet transport and comply with IEEE 802.3-2005 and 802.3-2008. Transceivers with integrated CDR are designed to support OC-192/STM-64 SONET/SDH and comply with the ITU-T Recommendation G.709 for Optical Transport Network (OTN) at the OTU2 line rate. All of these transceivers are designed to meet Telcordia GR-468 CORE qualification requirements and cover the extended operating temperature range of -5°C to +85°C (E-Temp). Both RoHS5 and RoHS6 versions are available. The SFP+ ER and ZR transceivers are available in sample quantities.

www.neophotonics.com

Infinera unveils first multi-terabit P-OTN network platform based on 500Gb/s PICs

Infinera Corp of Sunnyvale, CA, USA has unveiled the DTN-X, the first multi-terabit packet-optical transport (P-OTN) network platform based on 500Gb/s PICs, and designed for global service providers facing increasing demands for bandwidth driven by video, mobile and cloud-based services.

The DTN-X is built to integrate switching with DWDM without trade-offs in capacity. Its architecture extends the ease of use and reliability of Infinera's DTN system in a new multi-terabit platform that scales for the future, is simple to operate, and efficiently reduces the number of elements in the network, says the firm.

Infinera says unabated growth in Internet traffic is driving operators to upgrade networks to 100Gb/s and higher-speed optical transmission. The firm is introducing third-generation 500Gb/s PICs that integrate more than 600 optical functions and deliver what are claimed to be the first 500Gb/s super-channels, giving a foundation for the DTN-X's scale, simplicity and efficiency. Infinera recently tested the fully functioning 500Gb/s PICs on the production network of pan-African telecoms provider SEACOM, demonstrating 500Gb/s of coherent transmission over 1732km, and earlier this year the firm presented test results for a 1Tb/s PIC.

Since most end-user services are 10Gb/s or less, global operators require integrated ITU G.709 Optical Transport Network (OTN) switching to groom traffic onto larger 100 and 500Gb/s pipes to maximize network utilization. The DTN-X will deliver 5Tb/s of non-blocking OTN switching in a single bay, and in later releases will be upgradeable to resilient multi-bay configurations providing 100Tb/s of non-blocking OTN and MPLS (multi-protocol label switching). Rather than integrating DWDM with switching as an after-thought, the DTN-X is designed to

combine three unique technology building blocks — PICs, custom switching ASICs, and intelligent GMPLS software — enabling it to be flexibly configured with up to 5Tb/s of DWDM or service interfaces in each bay, or any combination of the two, without any loss of capacity.

Infinera says that the combination of the 500Gb/s PICs and integrated switching will allow the DTN-X to deliver the following benefits to global service providers:

- *Scale for the future* — The DTN-X is designed to help operators face future bandwidth demands by delivering 500Gb/s super-channels, upgradeable to 1Tb/s super-channels yielding up to 24Tb/s per fiber in the future. Initially the DTN-X will offer 5Tb/s of OTN switching capacity, upgradeable in future to 100Tb/s (a fully equipped DTN-X is planned to have enough capacity to stream a movie to each of Netflix's 23.6 million members simultaneously).
- *Simple to operate for rapid service deployment* — The DTN-X is designed to converge layers of the network and support DWDM transmission, OTN switching and, in the future, MPLS switching in a single platform. The all-digital architecture, point-and-click automation and intelligent GMPLS software are designed to enable global service providers to rapidly deploy network capacity while lowering operational costs.
- *Efficiency for the bottom line* — Infinera says the disruptive nature of its 500Gb/s PIC will enable the DTN-X to consume 33% less space and 50% less power than alternatives in a typical configuration. In a recent white paper that modeled a large pan-North American optical network it was found that the DTN-X required 69% fewer modules and 67% fewer chassis than competing approaches ('The Evolving Economics of Optical Network Design', S. Ramasubramanian, University of Arizona, and S. Subramaniam, George Washington University).

"Our growth is continually driving the need for greater integration and efficiency within the network," comments Stu Elby, VP of technology at Verizon. "Innovations such as photonic integrated circuits that enable terabit scale while adding efficiency with integrated transport and switching will be essential to extracting long-term economic value as the network scales to hundreds of terabits," he believes.

Interoute, whose pan-European network was the first in Europe to deploy Infinera's 100Gb/s PICs more than four years ago, is planning to use the DTN-X to continue to invest in the scale and reach of its European network. In March, it completed the first successful subsea field trial of a 500Gb/s PIC. "Interoute successfully exploited the previous generation of PIC technology, revolutionizing how high-capacity services were delivered in Europe," says its chief technology officer Matthew Finnie. "We look forward to the DTN-X as the next evolution of the model that has consistently demonstrated cost and operational efficiency," he adds.

"The DTN-X is a multi-terabit class platform that enables service providers to build scalable, simple and efficient optical transport networks, ultimately making them more profitable," says Infinera's president & CEO Tom Fallon.

Infinera is introducing a full-rack, multi-bay-ready chassis and a half-rack chassis, both of which are planned for availability in first-half 2012. The DTN-X is interoperable with the DTN platform and is planned to support 10 Gigabit Ethernet (10GbE), 40 Gigabit Ethernet (40GbE), 100 Gigabit Ethernet (100GbE), 10Gb/s SONET/SDH/OTN, 40Gb/s SONET/SDH/OTN, 100Gb/s OTN, 8/10Gb/s Fibre Channel, and multiple-bit-rate clear-channel interfaces.

www.infinera.com

Thailand flooding to impact Fabrinet's contract manufacturing until end of 2011

Opnext, Oclaro, JDSU and Infinera affected this quarter

Thailand-based contract manufacturer Fabrinet Co Ltd has reported the impact of the flooding in Thailand on its plants, which has affected customers including Opnext, Oclaro, JDSU and Infinera.

On 22 October, flood waters infiltrated the offices and manufacturing floorspace at Fabrinet's Chokchai campus in Pathum Thani. The firm had taken precautionary measures to move or protect production and test equipment, inventory and tooling, but manufacturing buildings 1 and 2 were flooded with several feet of water, inflicting extensive damage and rendering the facility largely inaccessible. Production is unlikely to resume at Chokchai before the end of this quarter.

The flooding has not breached the firm's Pinehurst campus (about 7 miles north of Chokchai). However, production at buildings 3, 4 and 5 there was suspended due to the impact on local transportation and utilities (including power), which continues to affect both arterial and access roads to Fabrinet's factories and some employee residences.

Fabrinet is the primary contract manufacturer for optical module and component maker Opnext Inc of Fremont, CA, USA, which says that it expects the flooding at Chokchai to have a significant impact on its operations and its ability to meet customer demand for its products in the near future.

While Opnext is still assessing the likely impact on its financial results for the current and future quarters, it expects the loss of revenue in its fiscal third-quarter (ending 31 December) to be material. Multiple factors will affect revenue loss, including Opnext's ability to move production to other locations, existing inventory from which to meet customers' needs, the level of customer demand, and Opnext's ability to increase production at other facilities.

Fabrinet is also the primary contract manufacturer for Oclaro Inc of San Jose, CA, USA, which makes optical communications and laser components, modules and subsystems. Fabrinet manufactures about 30% of the firm's total finished goods in Chokchai and Pinehurst.

Oclaro said that its assessment of the damage to equipment and inventory on site is affected by the limited site accessibility. Oclaro and Fabrinet management are investigating alternative production locations and have enacted business continuity plans.

Shipments continue from Oclaro's manufacturing facility in Shenzhen, China and other locations. However, the firm is evaluating the broader supply chain implications of the flooding in Thailand across its entire manufacturing operations.

Due to the ongoing assessment of flood damage and recovery plans, Oclaro is postponing the announcement of its quarterly results.

"However, we are pleased to report that our preliminary results are within our previous guidance range and that our profitability was near the upper end of the range," says Oclaro's chairman & CEO Alain Couder. For fiscal first-quarter 2012 (ending 1 October 2011) Oclaro now expects revenue of \$106m (down on \$109.2m last quarter, but within the guidance of \$103–113m), non-GAAP gross margin of about 23% (towards the upper end of guidance of 18–24%, and up on last quarter's 22.9%), and adjusted EBITDA of –\$4.5m (compared with guidance of –\$8.5–2.5m, and a slight improvement on –\$4.7m last quarter).

Production is unlikely to resume at Chokchai before the end of this quarter. Flooding has not breached the firm's Pinehurst campus

Fabrinet is one of three primary contract manufacturing partners for the Communication and Commercial Optical Products (CCOP) business segment of JDSU of Milpitas, CA, USA, supporting a portion of its product portfolio from Pinehurst (but not Chokchai). JDSU personnel are on site working with Fabrinet.

"We are closely monitoring the situation and communicating with our customers, taking action to secure equipment and inventory at the site, and developing and preparing to execute contingency plans," said JDSU. "We are evaluating the impact of these events on our CCOP segment." JDSU's Communications Test & Measurement and Advanced Optical Technology (AOT) business segments anticipate little to no impact.

Fabrinet is also a contract manufacturer for Infinera Corp of Sunnyvale, CA, USA, a vertically integrated manufacturer of digital optical network systems incorporating its own indium phosphide-based photonic integrated circuits (PICs). Infinera says that it is executing business continuity contingency plans using existing inventory and moving to alternate contract manufacturers and second sources. However, it will likely not be possible to transition all components and subsystems quickly enough to avoid some supply chain disruption. The firm says that its priority is to invest the necessary resources to minimize the number of customers affected and limit any impact on their operations.

Infinera is still assessing the full extent of the impact on its financial results for the current and future quarters, but it currently estimates the potential negative impact to its December-quarter guidance to be 5–15% of revenue (depending on the level of competition for alternative sources for relevant components).

www.fabrinet.com

Opnext launches TXFP transceiver for 96 channels on full C-band, with flexibility to field re-tune any wavelength

At the European Conference and Exposition (ECOC 2011) in Geneva, Switzerland (19-22 September), optical module and component maker Opnext Inc of Fremont, CA, USA announced the introduction and availability of its integrated tunable XFP (TXFP) transceiver, involving a demonstration highlighting automatic wavelength tuning designed to deliver stable wavelength control while supporting a wavelength range of 1529–1567nm.

Developed in collaboration with Hitachi's Central Research Laboratory (CRL), the TXFP pluggable

transceiver is a hybrid design that combines the tunable laser and indium phosphide Mach-Zehnder (InP-MZ) chips to offer what is claimed to be superior optical shutter functionality. The TXFP transceiver delivers system performance to address mode-hopping for optimized wavelength stability in a variety of DWDM applications, says Opnext. In addition, the TXFP design can flexibly support negative-chirp or zero-chirp DWDM applications to replace DWDM-XFP or 300-pin tunable transponders.

"Opnext's tunable XFP transceiver

has been designed to provide our customers with wavelength control and reliability in a smaller form factor where high port density is valuable," says Tadayuki Kanno, president of Opnext's modules business unit. "Using our own, in-house designed compact tunable TOSA [transmission optical sub-assembly], we're bringing a TXFP module to market that can support the growing demand for tunable DWDM technologies," he adds.

Opnext expects its tunable XFPs to be in mass production in early 2012.

www.opnext.com

Next-gen 100G DP-QPSK coherent transponder module launched

After first demonstrating the technology over North American and European networks more than 18 months ago, at the ECOC show Opnext Inc of Fremont, CA, USA has introduced its 100Gbps DWDM MSA transponder module. Based on the latest second-generation coherent technology, the OTM-100 offers performance, power, size and cost advantages over first-generation technologies and other alternatives in a 5" x 7" industry-standard module, claims Opnext.

The OTM-100 is a fully integrated, 100Gbps optical transponder that enables network equipment vendors to build 100Gbps metro, regional, long-haul, ultra-long-haul and submarine transport solutions. The 100G Digital Coherent Signal Processing LSI (DSP-LSI) in the digital signal processor is made by NTT Electronics Corp and is the product of the 'R&D on High Speed Optical Transport System Technologies' project which was supported by Japan's Ministry of Internal Affairs and Communications. Using soft decision forward error correction (SD-FEC), the OTM-100 module improves reach (minimizing or eliminating the need for regenera-

tion points), simplifies network deployment rules and reduces operating costs.

The OTM-100 suits transport systems that are designed around 10Gbps engineering rules with inline dispersion compensation modules (DCMs) as well as newer systems without DCMs, says Opnext. It is built on coherent detection technology to tolerate linear fiber plant impairments such as chromatic dispersion (CD) and polarization mode dispersion (PMD). Also, the ability to apply digital signal processing techniques to remove channel impairments means that the new transponder modules will work in existing fiber plants designed for 10Gbps and, in some cases, even in fiber plants designed for 2.5Gbps, without any changes except for the transponder itself.

"Opnext has been leading the development of 100Gbps technology, including defining the ecosystem of the supply chain, for the past four years," claims Mike Chan, president of the subsystems business unit and Opnext's executive VP, business development & marketing. "Our strength is in leveraging our engineering

know-how to put key technologies like coherent to work to deliver best-in-class performance," he adds.

"Over the next three years, the WDM transmission market will rapidly transition from 40Gbps to coherent 100Gbps as carriers take advantage of the better cost-per-bit performance of 100Gbps," reckons Andrew Schmitt, optical directing analyst with Infonetics Research Inc. "The availability of 100Gbps coherent technology from module vendors like Opnext will help extend availability of this technology and drive the adoption of 100Gbps technology in carrier networks."

Opnext says that its plug-and-play technology will allow carriers to upgrade their existing line systems to 100Gbps without having to strand capacity or light new fiber. The technology eliminates the need for external dispersion compensation, which reduces cost, minimizes IP latency and allows for deployment over older installed fiber with poor transmission characteristics.

Opnext expects that the OTM-100 module will begin mass production in April 2012.

First 100GbE CMOS PHY solutions for 100G line-cards

Inphi Corp of Sunnyvale, CA, USA, a fabless provider of high-speed analog ICs for the communications and computing markets (using InP, GaAs, SiGe or silicon bipolar as well as CMOS), has announced the availability of what it claims is the first 100 Gigabit Ethernet (GbE) CMOS PHY solutions that support the IEEE 802.3ba standard and target next-generation high-density 100G line-cards. Based on Inphi's iPHY architecture announced in March, the IN112510 100GbE CMOS gearbox (GB) and IN012525 100GbE CMOS clock data recovery (CDR) chipsets aim to speed time-to-market for higher-aggregate-bandwidth systems while containing costs of next-generation 100GbE line-cards targeted for data center and enterprise networks.

Cost-effective, energy-efficient 100GbE links will soon become essential tools for data center and service provider networks, which are struggling to satisfy the global economy's hunger for more bandwidth, says Inphi. With service providers and data centers demanding technology with low power consumption, Inphi's latest iPHY CMOS PHY solutions aim to enable them to easily upgrade to 100GbE networks while retaining a lower carbon footprint. By integrating multiple channels along with transmit and receive functions on a single IC, Inphi says it can double the levels of integration available from existing 100GbE PHY and CDR offerings.

"Our industry-leading PHY design metrics — power, footprint, integration — position us to use these devices across data center, enterprise and service provider applications," says Siddharth Sheth, VP of marketing for Inphi's high-speed connectivity products. "As the market transitions away from the power-hungry and area-intensive SiGe-technology-based CFP modules towards lower-power, higher-density CMOS-based CFP and CFP2 line-cards, Inphi's PHY offerings will enable and lead that transition."

"Video, rich IP content, streaming media, and bandwidth-hungry mobile and cloud-based enterprise apps are driving massive upgrades of data-center and service provider networks," says John D'Ambrosia, chair, Ethernet Alliance and past chair, IEEE 802.3ba 40G/100G Ethernet Task Force. "With fat pipes needed to accommodate the tsunami of data generated by these applications, the demand for 100GbE is in the here and now." The announcement from Inphi is an key step in allowing system OEMs and optical module vendors to build next-generation 100GbE systems that are both 802.3ba-compliant and key to 100GbE's success in the market, D'Ambrosia reckons.

"We are expecting strong growth in the 100GbE market, especially in the enterprise and data-center segments, with the advent of smaller-form-factor, lower-power 100G optical modules," comments Jag Bolaria, senior analyst at The Linley Group. "Coupled with Inphi's low-power, highly integrated CMOS 100G PHY products, the market's move to high-density 100G systems will become a reality."

The iPHY IN112510 is a single-chip, low-power PHY for 10:4 gearbox applications for 100GbE and OTU4 high-density 100G line-cards with 25-28Gbps electrical interfaces. Other technical features include:

- support for 100G BASE-LR4/ER4 and OTU4 28Gbps operation for OTL4.4;
- optimized for extremely low-latency to allow use in ultra-low-latency applications;
- programmable transmit and adaptive receive equalization on all SerDes interfaces with fine granu-

larity and control, allowing performance to surpass IEEE CAUI, CEI-11G SR and CEI-28G VSR specifications;

- self-test and loopback modes that allow diagnostic monitoring of channel and system parameters;
- eye-scan and monitor on all SerDes receiver interfaces for link margin and stress testing in a lab or production test environment;
- innovative package design that allows denser line-cards;
- optimizations for next-generation CFP2-based line-card designs; and
- single-chip low-power solution that allows next-generation optimized CFP modules.

The iPHY IN012525 is a low-power CDR for 100GbE and OTU4 next-generation 100G modules. The CDR features:

- support for 100G BASE-LR4/ER4 and OTU4 28Gbps operation;
- programmable transmit and adaptive receive equalization on all SerDes interfaces with fine granularity and control, allowing performance to surpass CEI-28G VSR specifications;
- self-test modes that allow diagnostic monitoring of channel and system parameters;
- eye-scan and monitor on all SerDes receiver interfaces for link margin and stress testing in a lab or production test environment; and
- optimizations for next-generation CFP2 modules.

Inphi also launched the IN2841TA, a transimpedance amplifier (TIA)/limiting amplifier (LIA) for 100GbE receivers. Interoperable with Inphi's iPHY 100GbE CMOS SerDes solutions, the IN2841TA offers the lowest power, best sensitivity, and highest overload, it is claimed. Together, the IN2841TA and iPHY CMOS SerDes create a platform solution for 100GbE CFP and CFP2 modules.

Inphi showcased its latest next-generation products in at the European Conference on Optical Communication (ECOC 2011) in Geneva, Switzerland in September.

www.inphi.com

We are expecting strong growth in the 100GbE market... with the advent of smaller-form-factor, lower-power 100G optical modules

TriQuint launches 1st 32G SMT differential modulator driver with low power consumption for extended reach

TriQuint Semiconductor Inc of Hillsboro, OR, USA has released what is claimed to be first 32Gb/s surface-mount differential modulator driver amplifier with the lowest power dissipation available for ultra-long distance optical networks.

The new driver amplifier is designed to extend the reach of 40Gb/s optical networks; extended reach is a key benefit of the DP-BPSK (dual-polarization binary phase-shift keying) modulation format, employed for ultra-long-distance optical fiber networks, says TriQuint. The TGA4959-SL supports both DP-BPSK and the differential quadrature phase-shift keying (DQPSK) optical modulation formats.



TriQuint's TGA4959-SL surface-mount differential modulator driver amplifier

TriQuint claims to have set the standard for 40Gb/s and 100Gb/s optical modulator drivers with its TGA4943-SL, the first high-performance surface-mount driver amplifier

for metro and long-haul fiber networks. The TGA4959-SL extends TriQuint's portfolio to support new modulation formats while offering a modulator driver amplifier with differential output amplitude, adjustable from 6V_{pp} to 9V_{pp}. As well as low power dissipation (just 2.2W for V_{out} = 8V_{pp} at V_d=5V), the TGA4959-SL also provides system-critical benefits including low rail ripple, high-voltage capability and very low output jitter, says the firm. Additive RMA jitter is 580fs, gain is 24dB at 16GHz, and rise and fall times are 13ps. The package size is 10mm x 7mm x 3.2mm. Samples and evaluation boards are available. www.triquint.com

Oclaro unveils high-power 980nm pump lasers with smaller footprint and higher output power

Oclaro Inc of San Jose, CA, USA, which makes optical communications and laser components, modules and subsystems, has expanded its pump portfolio with a new high-power 500mW uncooled 980nm pump laser and what is claimed to be an industry-first 2 x 600mW dual chip pump in a single package (showcased at September's European Conference and Exhibition on Optical Communications (ECOC 2011) in Geneva, Switzerland.

"These new pumps build on Oclaro's heritage as a leading pump supplier and leverage more than two decades of proven design expertise in the pump industry," says Robert Blum, director of product marketing for Oclaro's Photonic Components business unit. "Customers are looking for greener designs that use lower power and come in smaller sizes, and Oclaro is able to meet these needs while also adding more functionality and features," he adds.

The new 500mW uncooled pump delivers a significantly smaller form factor with a SFF 10-pin butterfly

package that can also be used in existing 14-pin slots. With 500mW of kink-free power, the laser delivers what is claimed to be the lowest power consumption of any such pump solution. The pump operates across the entire -5°C to 75°C temperature range, and is wavelength stabilized, qualified to Telcordia GR-468-CORE, and RoHS 6/6 compliant.

Oclaro says that the new pump is a viable option to traditional cooled pumps for powers up to 500mW for use in metro, cross-connect, single- or multi-channel applications. It also specifically addresses the growing market demand for SFF single-channel and 40Gb/s per-channel amplifiers with higher power requirements.

The new dual chip pump is designed for dual-stage and mid-stage access amplifiers, reconfigurable optical add-drop multiplexers (ROADM) on-blade and amplifier-based line-cards. It leverages Oclaro's integration expertise to deliver a smaller form factor by delivering a 1 x 14-pin

package that replaces two discrete pumps. The pump features two dynamically independent co-packaged lasers that are individually addressable and stabilized, delivers negligible cross-talk, and offers the full functionality of traditional 14-pin pumps. Besides the form-factor reduction, it also significantly lowers the total module power consumption versus two discrete pumps and enables users to reduce cost through simplified control electronics and reduced component count.

Both new pumps deliver high reliability by featuring the Oclaro OC2 alignment and packaging technology, which has been field proven since 2004. They also enable the pumping of multi-stage amplifiers with lower component count, reduced power consumption, smaller form factor and a lower-cost solution through the use of a single thermoelectric cooler (TEC), says Oclaro.

The pumps are sampling to customers, and are available in volume production later this year.

www.oclaro.com

ClariPhy & Oclaro launch 40G coherent reference design

Oclaro Inc of San Jose, CA, USA and ClariPhy Communications Inc of Irvine, CA, USA, a fables developer of ultra-high-speed, mixed-signal digital signal processing (MXSP) system-on-chip (SoC) ICs for coherent optical networks, have announced the availability of a 40Gbps coherent reference design that includes a broad portfolio of commercially available high-volume coherent components.

The reference design features Oclaro's complete set of 40Gbps coherent optical transmission components — including a narrow-linewidth ITLA (integrated tunable laser assembly), 40G coherent receiver and 40G lithium niobate modulator — as well as the ClariPhy LightSpeed CL 4010 coherent SoC (claimed to be the first single-chip CMOS coherent SOC manufactured in a standard 40nm CMOS). It is an open platform design that has already achieved interoperability with Cortina's Optical Transport Network (OTN) Processor families

and can be leveraged by other coherent component companies to address the growing need for coherent-based networks. The new reference design was demonstrated by ClariPhy at the European Conference and Exhibition on Optical Communications (ECOC 2011) in Geneva, Switzerland in September.

"ClariPhy and Oclaro are leading the development of an entire coherent ecosystem that delivers flexible and agile high-bit-rate solutions that service providers are demanding," claims Reza Norouzian, ClariPhy's VP of business development & sales. "With a coherent-based network, service providers can easily and cost-effectively transition from 10Gbps to 40Gbps coherent networks while paving the migration to 100 Gbps coherent networks in the future. These advantages are driving the rapid deployment of coherent-based technology, as demonstrated by the volume shipments that Oclaro and ClariPhy are making into this space," he adds.

"The availability of a coherent reference design is another milestone in driving the successful proliferation of coherent technology into the core optical network," says Oclaro's chief commercial officer Yves Le Maitre. "Coherent networks have already proven to deliver the flexibility and scalability service providers need to continually deliver higher bandwidth at affordable price points, and this announcement highlights the fast pace at which the industry is moving to this advanced technology."

Oclaro and ClariPhy say that, driven by its 55,000ps/nm chromatic dispersion tolerance, the reference design can deliver up to 3000km of optical reach performance, enabling module and line-card designers to deliver what is claimed to be leading optical signal-to-noise ratio (OSNR) performance and low power consumption with high chromatic and polarization-mode dispersion tolerance.

www.clariphy.com

Oclaro shipping 40Gbps coherent modules in volume

Oclaro has announced volume shipments of its MI 5000XM 40Gbps coherent modules (launched at March's OFC/NFOEC 2011 event).

Oclaro says that the announcement strengthens its high-speed optical networking coherent roadmap, which features a full range of component and module solutions designed to enable service providers to deploy highly scalable and flexible future-proof architectures.

Bandwidth-intensive applications such as cloud computing, video, file transfer and online gaming are driving a transformation in the core network, says Oclaro. Service providers must cost effectively deliver the increased bandwidth and low latency needed for these new services, and they must be capable of provisioning new services quickly and with high

resiliency to meet evolving consumer and business needs.

To accomplish this, service providers are transitioning to richer mesh network topologies with a photonics core, and adopting digital coherent transponder technology as a single scalable technology for core network applications, the firm says. Coherent transponders such as the MI 5000XM are critical components of these mesh networks, Oclaro claims, because they offer a reliable and cost-effective way of encoding large amounts of data into light signals needed to flow through the photonics core and then decoding the light signals at the connection end point.

"Volume shipments of our 40Gbps coherent modules put Oclaro in an even stronger technology position for helping our customers deliver flexible and agile high-bit-rate

solutions for next-generation networks that utilize coherent detection," says Per Hansen, VP of product marketing for Oclaro's ONS business unit.

The MI 5000XM delivers what is claimed to be leading OSNR (optical signal-to-noise ratio) performance, low power consumption and high chromatic and polarization mode dispersion (PMD) tolerance. The transponder is designed to work both in dispersion-managed and unmanaged solutions, and can support reach up to 3000km without optical dispersion compensation.

As part of Oclaro's high-bit-rate portfolio, the MI 5000XM can be used directly on blades designed for an Oclaro 40Gbps transponder module, uses an industry-standard i2c interface, and provides fully autonomous set-up and control.

www.oclaro.com

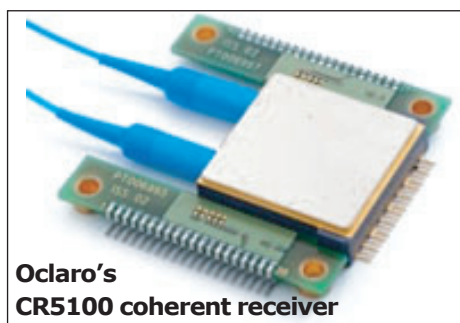
Oclaro adds 100Gbps coherent receivers for transmission networks using PM-QPSK modulation

Oclaro Inc of San Jose, CA, USA, which makes optical communications and laser components, modules and subsystems, has launched the CR5100 series of 100Gbps coherent receivers.

The firm claims that the new receivers provide a compact and cost-effective solution to implement coherent communication using the polarization multiplexed quadrature phase-shift keying format (PM-QPSK, or DP-QPSK), which is the modulation scheme of choice for metro and long-haul optical transmission. Oclaro previewed the new receivers at the European Conference and Exhibition on Optical Communications (ECOC 2011) in Geneva, Switzerland in September.

“By leveraging our expertise in indium phosphide integration and our proven track record in developing coherent solutions for high-speed networks, we’ve been able to significantly lower the footprint of these receivers, which frees up valuable space for adding more functionality to customers’ modules and line cards,” says Yves Hardy, senior director of Transmission Product Management.

The new 100Gbps coherent receiver is used in transmission networks that employ the PM-QPSK modulation format. The CR5100 series (together with the CR5040 Series for 40Gbps PM-QPSK) is designed to be compliant with the OIF Implementation Agreement OIF-DPC-RX-01.0, a collaborative forum to which Oclaro has been a key contributor. The receiver is also available in a much reduced form factor for users that want to benefit from this next-generation footprint. Oclaro says that the design provides a compact and cost-effective solution for implementing coherent transponders using PM-QPSK, minimizing chromatic dispersion impairments and improving the spectral



Oclaro's CR5100 coherent receiver

efficiency of existing fiber infrastructure.

The CR5100 100Gbps coherent receiver uses Oclaro's indium phosphide (InP) technology to implement the optical hybrid phase mixers with integrated waveguide photodetectors, and employs high levels of functional integration on InP to minimize cost and enable high-volume manufacture. The electrical outputs of the balanced waveguide photodetectors are then coupled to a pair of dual-input linear transimpedance amplifiers (TIAs). The coherent receiver has several electrical control features to optimize the performance of the TIAs, such as bandwidth control and manual gain adjustment. The 32 GBaud output from the receiver is then coupled to the input of the subsequent ADC/DSP IC.

The functional components of the receiver are assembled in a miniature ceramic package, which is less than a half of the minimum footprint defined by the OIF. InP-based photonic integration enables a significant increase in density on the module or line card, says Oclaro. The miniature package is also available with an adaptor PCB for users that prefer compliance to the form, fit and function defined by the OIF Implementation Agreement.

Oclaro is sampling the CR5100 series of 100Gbps coherent receivers to tier-one systems and module manufacturers, with production release scheduled for later this year.

www.oclaro.com

IN BRIEF

Oclaro expands tunable portfolio with zero-chirp TXFP

Oclaro has announced the production release of a zero-chirp full-band tunable XFP (TXFP) that delivers full 300-pin equivalent performance in a small, pluggable MSA footprint with low power consumption.

The firm showcased its tunable laser portfolio at September's European Conference & Exhibition on Optical Communications (ECOC) in Geneva, Switzerland. “Our customers need tunable lasers in a variety of formats, and our goal is to be the one-stop shop with the solutions that match their evolving product requirements,” says Jim Haynes, president & general manager of Oclaro's Photonic Components business unit.

Oclaro's tunable laser portfolio includes continuous-wave tunable laser assemblies, tunable transmitter assemblies, MSA 300-pin 10Gbps SFF transponders, 40Gbps tunable transponders, tunable pluggable transceivers, and tunable XFP transceivers in both negative-chirp and zero-chirp form for the C- and L-bands.

Oclaro offers the zero-chirp TXFP in various configurations, including APD or PIN Rx options. Along with the firm's negative-chirp TXFP and its first-generation tunable pluggable transceivers, users now have the option to migrate all 10Gbps DWDM links to a pluggable form factor without compromising on system performance. The new zero-chirp tunable XFP is fully qualified and released to production.

Oclaro notes that it continues to enhance 10Gbps DWDM links by announcing high-efficiency versions of TXFPs for low power dissipation and high-temperature environments, as well as preparing for the next generation of small-form-factor pluggable formats.

GigOptix unveils ultra-low-power 10Gb/s SFP+ transceiver for datacenter interconnects

At the 37th European Conference on Optical Communications (ECOC 2011) in Geneva, Switzerland (19–22 September), GigOptix Inc of San Jose, CA, USA (which supplies semiconductor and optical components for high-speed information streaming) unveiled an ultra-low-power 10Gb/s SFP+ transceiver designed for power conscious datacenter interconnects.

The SFP+ transceiver was implemented using GigOptix's ultra-low-power HXT/R4101 vertical-cavity surface-emitting laser (VCSEL) driver and transimpedance amplifier (TIA) chipset. The firm claims that the solution's unique system-level architecture enables power savings of more than 60% for power-hungry data-center interconnects. The SFP+ transceiver

(now shipping in production volume) was designed in partnership with Hong Kong-based Energeia Innovations Co Ltd (which acted as the program manager) and with high-volume ODM/OEM manufacturer PCL Technologies (which designed the product for manufacturability). The transceiver program was executed through the GigOptix's Virtual-Vertical alliance approach, in order to provide the best cost-performance solution to customers.

At ECOC, GigOptix will showcase the 10G SFP+ module dissipating less than 275mW running a full 10Gb/s link over 100m.

"We implemented this highly innovative product to address data-center customer demand not only for high-performance but also for low-power-consumption applications,"

says GigOptix's chief technical officer Andrea Betti-Berutto. "Together with our partners in what we call a Virtual Vertical Model, we re-evaluated how SFP+ transceivers are architected and we identified optimization that could be leveraged across the value chain," he adds.

"We utilized the latest process and design technologies to define a chipset design that not only improves performance but also reduces power consumption, effective footprint and system cost," Betti-Berutto continues. "We will continue to execute the Virtual Vertical model in working with value-add partners to bring more products to not only the communications market, but also to other markets and industries, in order to enhance our customers' benefit."

www.gigoptix.com

GigOptix to supply 4-channel 10G VCSEL drivers & receivers to Delta for AOC and pluggable products

GigOptix Inc of San Jose, CA, USA has agreed to supply 4-channel 10Gb/s VCSEL driver and receiver amplifier chip-sets to enable the active optical cable (AOC) and pluggable product offerings of Taiwan-based Delta Electronics Inc.

GigOptix's HXT/R5 chip-set has been designed to support multiple applications ranging from 1Gb/s to 10Gb/s per channel. Its feature set enables users to optimize the trade-off between power dissipation and performance of the optical link, says the firm. Chip performance improvements have been made, such as 30% less power dissipation at 10Gb/s than the previous chip generation, 2.0dB better receiver sensitivity under typical operating conditions, and the addition of advanced monitoring and power-reduction functions.

"Our partnership with Delta Electronics will bring an entirely

new level of data speeds and broadband access — Delta's implementation of our HXT/R5004 chipsets for their QSFP AOCs and pluggables will enable their customers' systems with lower power dissipation, simpler design, and better overall performance," says Dr Raluca Dinu, general manager & VP of the GigOptix Optics Product Line.

"GigOptix components will enable Delta Electronics to quickly get to market with competitive AOCs and pluggable products," reckons Ted Kuo, director, Broadband Module business unit, for Delta Electronics' Component Business Group (CPBG). "We selected GigOptix as our trusted partner because they bring years of experience in the parallel optical market, and our integration of their HXT/R5 solution is only the beginning of what will be a very profitable relationship," he reckons.

GigOptix's chip-set consists of 4-channel and 12-channel VCSEL drivers and receiver amplifier chip-sets. These are designed to enable ultra-low power consumption of less than 450mW for a 40G link over 100m as well as to minimize the number of components required to implement a transceiver, resulting in lower costs. The HXT/R5 family incorporates programmable equalization and pre-emphasis circuitry to facilitate various trace lengths in addition to providing full programmable control via fully integrated analog-to-digital convertors (ADCs) and digital-to-analog convertors (DAC) through an industry-standard 2-wire interface.

Samples of the HXT/R5 Series are available with an evaluation board for evaluation with vertical-cavity surface-emitting lasers (VCSELs) and photodiodes (PDs).

www.delta.com.tw

Integrated modulator drivers for 100G DP-QPSK applications

M/A-COM Technology Solutions Inc of Lowell, MA, USA (which makes semiconductors, components, and subassemblies for RF, microwave and millimeter-wave applications) showcased its expanded Optomai optoelectronics product line at the 37th European Conference on Optical Communications (ECOC 2011) in Geneva, Switzerland in September.

Two new modulator driver amplifiers for 100G DP-QPSK applications are now available in small-form-factor packages:

- The MAOM-003104 is a quad-channel driver in a 25mm x 40mm x 6.5mm package with GPPO connectors.

- The MAOM-003106 is a dual-channel driver in a 10mm x 10mm x 2.3mm surface-mount package. Both devices have ultra-low jitter, says the firm, as well as output voltage up to $8V_{pp}$ and gain of more than 30dB. Rise and fall times are better than 11ps, with data rates up to 32Gbps.

M/A-COM Tech offers an extensive

portfolio of modulator drivers and transimpedance amplifiers (TIA) for high-speed optical communications. The optoelectronics products for 10, 40 and 100Gb/s have been developed using the firm's proprietary IC design. The packaging technology offers high-performance solutions with small size and low cost. The drivers and TIAs are compatible with industry-leading optical modulators and photodiodes, and have been developed to comply with industry standards as stated by the OIF, IEEE, and industry multi-source agreements (MSAs).

M/A-COM Tech offers Optomai products for both line-side and client-side applications, including:

- electro-absorption modulated laser (EML) drivers for 10, 28 and 40G;
- indium phosphide Mach-Zehnder (MZ) drivers for 10G and 22.3G;
- lithium niobate MZ drivers for 10G, 22.3G and 32G; and
- single- and dual-channel TIAs for 10G, 22.3G, 28G and 32G.

www.macomtech.com

IN BRIEF

GigOptix files amended complaint

GigOptix Inc of San Jose, CA, USA has filed a Second Amended Complaint in the lawsuit that it initiated in Santa Clara County Superior Court in April against five former employees, Silicon Valley-based firm Optomai Inc, and M/A-COM Technology Solutions Inc of Lowell, MA, USA (which acquired Optomai Inc in April).

The amended complaint asserts claims against the former employees for breach of loyalty and breach of employment-related contracts, and asserts claims against all defendants for violation of California's Trade Secrets Protection Act.

GigOptix seeks damages and injunctive relief. Although the defendants deny the claims, GigOptix says that it intends to vigorously pursue the litigation to protect its intellectual property and proprietary information.

40G DQPSK driver-modulator Bundled Solution

At the 37th European Conference on Optical Communications (ECOC) in Geneva, Switzerland in September, GigOptix Inc launched its 40G DQPSK Bundled Solution.

GigOptix claims that, with the productization of its Thin Film Polymer on Silicon (TFPS) modulators, this is the first time that a transimpedance amplifier (TIA), a modulator and a driver can be supplied by a single vendor, while offering complete inter-operability for its reference design and for production delivery.

The 40G solution includes: a GX62255 dual-channel 32G Mach-Zehnder modulator (MZM) driver; a LX8220 DQPSK TFPS MZM; and two GX3220 linear TIAs.

"Today's supply chain requires customers to buy a modulator from

one vendor, a driver from a second and a TIA potentially from a third vendor. Ensuring that all these components are correctly matched is critical for the optimal performance of the system and can pose a great challenge when designing," says Dr Raluca Dinu, VP & general manager of Optics at GigOptix.

"Our strategic plan all along was to design and supply all the key components to the transceiver industry. Our bundled offering of TIA, driver and modulator — the first of its kind in the industry — is optimized to achieve the best performance, optimized power efficiency, and smallest footprint, while reducing customers' R&D costs and development cycles," he adds. "Our TFPS modulator product line offers a unique approach to enable higher

levels of integration in various packaged solutions, and we are committed to continue working with our valuable customers to extend our bundled product family."

The Bundled Solutions represent what GigOptix believes is an industry first for a firm providing a complete solution set consisting of a TIA and a TFPS MZM with a matched driver for an optical application. The firm claims that the Bundled Solution reduces customer engineering expenditure, accelerates time-to-market for new products, and enables customers to leverage GigOptix's low-power solutions with enhanced cost efficiencies. GigOptix Bundles will address 40G DPSK, 40G RZ-DQPSK as well as coherent 40 and 100G DP-QPSK applications.

www.gigoptix.com

Finisar's quarterly revenue falls 3.7% to \$228.2m

Drop driven by soft demand from Chinese telecom customers

For its fiscal first-quarter 2012 (to end-July 2011), fiber-optic communications component and subsystem maker Finisar Corp of Sunnyvale, CA, USA has reported revenue of \$228.2m, up 9.8% on \$207.9m a year ago but down 3.7% on \$236.9m last quarter, driven mainly by continued softness in demand from telecom customers, particularly Chinese OEMs. Revenue included \$7m from acquiring a controlling stake in Norway-based Ignis ASA (which provides optical components and network solutions for fiber-optic communications) on 18 May through end-June (the end of Ignis' fiscal quarter).

Compared to last quarter, sales of LAN/SAN products rose by 0.2% (\$143,000), sales of metro/telecom products (including WSS/ROADM line cards) fell by 6.7% (\$9.3m), and sales of products for analog and CATV applications rose by 12.7% (\$400,000). Sales of 10Gbps or faster products rose by 1.2% (\$1.3m), sales of less than 10Gbps products rose by 6.1% (\$5.5m), and sales of WSS/ROADM line-card products fell by 47% (\$15.9m).

On a non-GAAP basis, gross margin has fallen from 35.2% a year ago and 34.2% last quarter to 32.1%, driven by lower overall revenue and by Ignis' products (for which gross margin is lower than Finisar's average). However, gross margin still exceeded guidance of

30.7–31.7%, due to lower-than-expected manufacturing costs.

Operating expenses have risen from \$44.2m a year ago and \$48m last quarter to \$52.4m, driven by the addition of \$2.4m of Ignis operating expenses and by R&D expenses rising by \$2.5m (from \$32.9m to \$35.4m) due to the development and qualification of new products (including the tunable XFP transceiver). Nevertheless, operating expenses were still lower than expected.

Compared with \$29m a year ago and \$33.1m last quarter (operating margin of 14% of revenue), operating income was \$20.9m (9.2% margin, but at the top end of the expected range of 7.3–9.3%). Income from continuing operations was \$19.5m, down from \$25.8m a year ago and \$32.1m last quarter.

"During the first quarter we continued to invest in our new product development programs, including our tunable XFP transceivers, 40Gbps and 100Gbps products, 16Gbps fiber channel transceivers and our edge or access ROADMs," says executive chairman Jerry Rawls. "We are currently qualified at multiple OEM customers for our tunable XFP transceiver and are in qualification with more than 15 additional customers," he adds.

"We expect production of this product to start to ramp during the second quarter of fiscal 2012," notes CEO Eitan Gertel.

During the quarter, capital expenditures were \$16.3m (down from \$19.4m last quarter). Also, on 29 June, Finisar closed its cash tender offer for the remaining outstanding shares of Ignis ASA, and now holds 100% of the shares. The total cost of the acquisition during the quarter was \$76.7m. In addition, on behalf of Ignis, Finisar repaid debt equivalent to \$8.2m. Cash and cash equivalents hence fell from \$314.8m to \$238.1m. However, excluding the impact of the uses of cash with respect to the Ignis acquisition, repayment of debt, and payout of previously accrued bonus amounts, cash reserves would have risen by \$15.2m. During the first quarter, accrued compensation expense fell by \$7m, due mainly to the pay out of employee bonuses previously accrued during fiscal 2011.

Including the impact of the consolidation of Ignis (involving about \$14m of revenue at a gross margin of 23–24%, additional operating expenses of \$5m and dilution to earnings per share of about \$0.02), for fiscal second-quarter Finisar expects revenue of \$235–250m and non-GAAP operating margin of 8.5–10.0%.

Finisar expects the Ignis acquisition to be accretive to non-GAAP earnings per diluted share within one year following the closing of the tender offer (subject to the achievement of anticipated synergies).

WaveShaper range expanded with C+L-band optical processors

Finisar has added to its WaveShaper programmable optical processor family with the 1000S/X and 4000S/X, offering an extended wavelength range covering both the C- and L-bands in a single instrument and designed for testing of reconfigurable optical networks as well as for laser pulse shaping in metrology and medical systems.

In metrology, broader-bandwidth ultrafast pulses can now be accurately manipulated, enabling new applications in super-continuum generation and optical atomic clocks. In communications, system testing of new reconfigurable network structures covering the extended C-band and even the C+L-band is enabled.

Finisar has also launched version 2.0 of the WaveManager Application Suite software package, which supports new functions including accurate prediction of a filter shape and emulation of a comb of laser channels. Its emulation algorithm for creating DWDM spectra helps to cut system testing cost.

www.finisar.com/instruments

Finisar demonstrates first multi-rate serial CFP-FR optical module with error-free operation at 40Gb/s

At the European Conference on Optical Communications (ECOC) in Geneva, Switzerland in September, fiber-optic communications component and subsystem maker Finisar of Sunnyvale, CA, USA demonstrated several new products, including what is claimed to be the first CFP-FR module offering error-free operation at 40Gb/s.

Designed for 40G client-side applications, the 40Gb/s multi-rate serial CFP-FR optical module has an MSA pluggable form factor that integrates Finisar's optical technology and offers power consumption below 8W. The demonstration used EXFO's FTB-8140 Transport Blazer, which provides SONET/SDH and OTN test functions at 40/43Gb/s transmission rates to show the CFP-FR module's error-free performance when transmitting and receiving at full rate plus interoperability with a 300-pin module. The CFP-FR is also plug-in compatible with SR4 and LR4 CFP modules.

Finisar also demonstrated its 10Gb/s DWDM 80km SFP+ transceiver technology in conjunction with EXFO's FTB-880 Netblazer Multiservice Tester on the FTB-1 Handheld Modular Platform. The results showed error-free operation at 10.7Gb/s over 80km of single-mode fiber. The new transceiver extends Finisar's 10Gb/s multi-rate SONET/SDH SFP+ product family, enabling telecoms systems vendors to deploy next-generation high-density 10Gb/s platforms over a variety of reaches. Designed as an alternative replacement for DWDM XFP transceivers, the new SFP+ transceiver delivers the same performance with lower power consumption and a smaller footprint. Features include internal dual CDRs for enhanced jitter performance, a limiting electrical interface APD receiver, and an XFI-compliant interface.

Finisar also showcased its new GPON Stick for passive optical net-

work (PON) applications. Instead of deploying a GPON ONT (optical network terminal) in a bulky box (as has been needed previously), the Stick provides complete GPON ONT functionality in a compact SFP package. Due to its efficient size, lower power consumption, and standard-compliant pluggability, it is designed to enable telecom service providers and equipment vendors to support many new applications, including wireless backhaul and business services. Finisar claims to be the first firm to offer a product based on this technology.

"These new products and demonstrations span a wide variety of segments including access, transport and intra-central office applications," says VP of marketing Rafik Ward. The firm's growing portfolio of technologies not only drives the leading edge of the market but also creates new opportunities within established markets, he believes.

www.finisar.com

First 1x20 high-port-count WSS with Flexgrid technology launched

Finisar has introduced its latest reconfigurable optical add-drop multiplexers (ROADM) product, a 1x20 high-port-count WSS (wavelength selective switch) with Flexgrid technology, demonstrated at the European Conference on Optical Communications (ECOC) in Geneva, Switzerland in September.

The 1x20 WSS with Flexgrid aims to enable telecom carriers to migrate to higher data rates (400Gb/s+), interconnect more fiber directions at each node, and offer colorless, directionless and contentionless (CDC) ROADM operation.

Finisar says that, in rapidly expanding telecom networks, the 1x20 WSS high-port-count device is designed to enable carriers and service providers to increase the level of meshing within the network

through higher nodal capacity while offering better performance across express (through traffic) ports. This helps to minimize end-to-end system penalties and maximize the number of ports available for CDC add/drop modules. Enhanced filter bandwidth technology integrated into the products is designed to enable high-speed signals to travel longer distances and through more ROADM nodes. The benefit should be increased network flexibility and lower cost per gigabit per second per mile.

Finisar says its proprietary Flexgrid technology enhances the WSS by enabling carriers to dynamically change channel spacing to precisely match the required signal bandwidth with minimal wasted optical spectrum. Specifically, current ROADM deployments concentrate

on fixed 50GHz channel spacing, which can support data rates up to 100Gb/s. By leveraging adjustable channel spacing from 50GHz to 200GHz in increments of 12.5GHz, Flexgrid is designed to enable carriers to efficiently carry all future transmission formats up to 1Tb/s per wavelength on existing ROADM infrastructure, at whatever bandwidth these signals may require.

"The introduction of Finisar's 1x20 WSS with Flexgrid results from Finisar's ongoing commitment to provide the solutions our customers need to address the next generation of ROADM and wavelength cross-connects," says CEO Eitan Gertel. "These important enhancements to our WSS product portfolio are fully compatible with Finisar's Flexgrid capabilities introduced earlier this year," he adds.

IN BRIEF

JDSU appoints test & measurement expert Barnes to board of directors

JDSU of Milpitas, CA, USA, which serves the Communications Test & Measurement, Communications & Commercial Optical Products, and Advanced Optical Technologies sectors, has appointed Keith Barnes to its board of directors.

"We welcome Keith to JDSU's board of directors and look forward to drawing on the expertise he has built over the last 35 years as a global technology business leader," says chairman Martin Kaplan. Barnes complements JDSU's board with extensive test & measurement industry knowledge and global operations expertise spanning North America, Europe and the Asia-Pacific region, he adds.

Barnes has held senior executive positions in semiconductor, manufacturing and test & measurement companies, including serving as chairman and CEO for three public companies. Most recently he was chairman of Verigy, a semiconductor equipment company focused on lab and manufacturing test solutions for firms in the communications, consumer electronics, computers and memory industries. He also served as division president of the Agilent Technologies test business which was spun out to become Verigy. Earlier in his career, Barnes served in executive positions with Electroglas, IMS, Cadence and Kontron. He is also on the board of Spansion Inc and is a director of the San Jose State University Foundation Board.

With Barnes' election, JDSU's board now consists of 10 members, including nine independent directors.

www.jdsu.com

JDSU demonstrates QSFP+ modules for 40G transmission in enterprise, LAN and SAN networks

At the European Conference and Exhibition on Optical Communications (ECOC 2011) in Geneva, Switzerland (19–21 September), optoelectronic chip and module maker JDSU of Milpitas, CA, USA demonstrated quad small-form-factor pluggable plus (QSFP+) transceiver modules for 40G optical transmission up to 10km in enterprise, local-area (LAN) and storage-area networks (SAN). Leveraging key building blocks from JDSU's optical communications portfolio, the QSFP+ modules are much smaller and provide lower power dissipation compared to older solutions.

JDSU says that the increasing use of cloud computing, online video, voice over IP (VOIP) and other internet applications are driving large amounts of content through enterprise, LAN and SAN, and telecom networks. Network operators are under pressure to deploy high-performance and high-density optical products to support 40G and 100G bit rates while continuing to drive down operating expenses.

Alan Lowe, president of JDSU's Communication & Commercial Optical Products (CCOP) segment, says that the new modules exemplify the firm's commitment to providing a complete range of client-side and line-side optical solutions that are affordable and efficient for 40G networks and beyond.

The new modules for both short-reach and long-reach applications are currently being sampled with network equipment makers and firms focused on high-speed computing solutions. JDSU expects the products to be commercially available by first-quarter 2012.

The QSFP+ long-reach module generates and modulates four different wavelengths of light at 10G speeds and combines them into a single optical fiber for client-side

network transmission. It is also capable of receiving the four light channels and reconstructing the 40G signal, providing full transceiver capability at 40G for distances up to 10km.

The QSFP+ short-reach module supports shorter distances of less than 100m. It uses JDSU's vertical-cavity surface-emitting laser (VCSEL) technology to generate four different optical signals, each modulated at 10G and transmitted

Leveraging key building blocks from JDSU's optical communications portfolio, the QSFP+ modules are much smaller and provide lower power dissipation compared to older solutions

over ribbon fiber. The module is also able to receive this incoming light and reconstruct the 40G data stream to provide a full transceiver solution. It is designed to support both 40GE and OTU3 protocols.

JDSU notes that the benefits of QSFP+ include: compact size (compared with older and much larger CFP modules, saving value real estate in data centers); hot pluggable ability (network operators can add new QSFP+ modules as more bandwidth is required without interruption to service); lower power dissipation (less than 3.5W, compared with 8W in older CFP modules); high performance (leveraging JDSU's optical communications technology portfolio and photonic integration expertise); and long reach (up to 10km for client-side optical transmissions in enterprise, LAN, SAN and telecom networks).

www.jdsu.com

Baja Sun partners with Arima on Mexico's first integrated solar firm

During a visit by Governor Osuna of Baja California to Arima's operations in Taipei, Taiwan, Baja Sun Energy SRL announced the formation of the first integrated solar business in Mexico.

Baja Sun Energy will construct a concentrated photovoltaic (CPV) solar module manufacturing plant and use the panels produced for a utility-scale solar generation facility, all sited in Silicon Border Science Park, a 2000-hectare 'CleanTECH Park' in Mexicali, Mexico (strategically located at the crossroads of the power grids of the USA and Mexico) that caters to the specialized needs of the renewable energy sector (including wind, solar, algae harvesting and smart grid companies looking for factory sites and energy generation sites).

The announcement took place as Baja Sun and Arima Solar completed agreements making Arima a stakeholder and supplier of CPV technology, GaAs semiconductors and other materials to Baja Sun. The governor met with Arima's chairman Stephen Lee as well as executives of Baja Sun Energy and Silicon Border.

Initial plans include investing over \$500m in the next four years. Baja Sun's factory will break ground later this year, and will be outfitted by Arima with a turnkey CPV manufacturing equipment line to make cells, modules and dual-axis tracking systems. The firm has already secured a top-tier customer for a 10MW solar farm.

Annual capacity will be built out to over 100MW, with more than 4240 direct employees. Inclusion of the State University (UABC) Campus on the Silicon Border CleanTECH Park and a collaboration with University of California San Diego should ensure that the location's human resource needs are met, it is reckoned. Mexican staff will be trained at the Arima Eco factory in Taiwan. The total supply chain should ultimately create over 8000 jobs for the Baja California/San Diego Mega Region.

The factory will ultimately also have its own 150MW utility-scale power plant (the balance of the capacity will be sold to both users and utility companies in Mexico and the USA).

Baja Sun reckons that, as an integrated CPV enterprise, it will be able to provide the lowest-cost solar energy solution for North America. With manufacturing plants on the border of Baja California, the firm will also establish sales & marketing operations in San Diego, CA.. Arima Eco, Grupo Maiz (of Monterrey, Mexico) and Silicon Border will own the new company.

"We are at the center of a huge market for solar, wind and other kinds of renewables, including the energy warehousing project we recently announced," says Silicon Border's CEO DJ Hill. "From our park you can reach most of the western USA in less than a day by truck. Talent and tax incentives make this location very competitive to China. Further, products made here can be used for stimulus projects such as 'Buy American' because of the NAFTA [North American Free Trade Agreement] treaty. We also have green infrastructure including water, waste treatment and LED lighting, more eco-friendly than anywhere else in North America," he adds.

"Mexico has more sunshine per capita than most countries in the world, and it is only fitting that we start a Mexican company to capture the sun for our own use in the State of Baja California," says Governor Osuna. "The solar market is expected to grow from the currently installed 2.1GW at the end of 2009 (according to the Solar Energy Industries Association) to 44GW by 2020 in North America over the next 10 years. Mexico can be one of the world's largest players in this process, given our cost and location advantages," he reckons.

"We are very optimistic about this new venture that will expand our product reach to the Americas while

IN BRIEF

Emcore wins solar cell contract for four Mitsubishi Electric satellites

Emcore Corp of Albuquerque, NM, USA, which makes compound semiconductor-based components and subsystems for the broadband, fiber-optic and solar power markets, has been awarded a contract by Japan's Mitsubishi Electric Corp to manufacture, test and deliver space-qualified multi-junction solar cells for the TURKSAT 4A, TURKSAT 4B, Himawari-8 and Himawari-9 satellites.

Mitsubishi Electric is under contract with TURKSAT A.S. to manufacture the 4A and 4B commercial telecom satellites based on its DS-2000 satellite platform. It is also under contract to build the Himawari-8 and Himawari-9 geostationary satellites for the Japan Meteorological Agency.

"Emcore has successfully delivered solar cells to Mitsubishi Electric under several previous contracts for other satellite missions, and we look forward to supporting Mitsubishi Electric with their future space power requirements," says Emcore's chief operating officer Christopher Larocca.

www.emcore.com

<http://global.mitsubishielectric.com>

we cover Asia and the rest of the world," says Arima Group chairman Steven Lee. "While we are confident that the experienced team of Baja Sun can do the job with our support, we find that the Government support for this project and Arima Eco ensures success," he comments. "We also had great support from the Mayor of Mexicali and the Federal Government's ProMexico Organization, from the local Commissioner of Trade here in Taiwan to the Director General himself."

www.arimaeco.com

www.siliconborder.com

OPEL raises \$10m from Kodiak Capital to fuel expansion

OPEL Technologies Inc of Toronto, Ontario, Canada, which makes high-concentration photovoltaic (HCPV) panels and solar tracker systems through its subsidiary OPEL Solar Inc and develops semiconductor devices and processes through US affiliate OPEL Defense Integrated Systems (ODIS Inc) of Shelton, CT, has entered into a financing arrangement for New York-based Kodiak Capital Group LLC to provide up to \$10m of funding capacity in the form of an equity line of credit, in exchange for up to \$10m of the common shares of OPEL Technologies.

OPEL may draw-down funds from time to time, at its sole discretion, over a period of two years after the common shares have been qualified for distribution. All shares will be issued at a price equal to the market price on the TSX Venture Exchange, based on the five consecutive trading days immediately after a draw-down notice has been delivered minus a discount of 10%.

The amount that OPEL will be entitled to request from each of the draw-downs shall be equal to the greater of (i) \$1m or (ii) up to 200% of the average daily volume (US market only) (ADV) multiplied by the average daily trading volume of the shares for the three trading days prior to the delivery of a draw-down notice.

The arrangement is subject to the approval of the TSX Venture Exchange, and distribution of the common shares is subject to the issuance of a receipt for a prospectus (final) which is required to be filed OPEL with the appropriate Canadian securities regulatory authorities. The firm has agreed to issue to Kodiak 2.5% of the facility amount payable in newly issued common shares upon the issuance of a receipt for a prospectus plus 2.5% at the time of the first draw-down of funds by OPEL.

OPEL says that it will use the funds for its growth and expansion plans and to meet its contractual

obligations stimulated by its accelerated sales and to address further R&D efforts of OPEL Technologies (including its subsidiaries and affiliate companies).

"This \$10m comes at the perfect time to help fulfill the rapid growth and expansion we have been enjoying for the past several years," says chief financial officer Michael McCoy. "The scope of this investment by a premier US financial investment firm underscores our belief in OPEL's future," says CEO Leon M. Pierhal. "Kodiak has a deep industry background in semiconductors, clean technologies and communications infrastructures," he adds. "Kodiak's expertise and experience certainly is a perfect fit for OPEL Technologies' businesses because Kodiak has a keen understanding of our business segments and the financial requirements it takes to become first a dominant force then maintain that position within the markets."

www.kodiak-capital.com

OPEL Technologies appoints VP of North American sales

OPEL Technologies Inc (formerly OPEL Solar International Inc until 29 August), has appointed Jeffrey 'Jay' Johnson as VP of North American sales, responsible for leading the sales process for the USA and Canada. Johnson has been with OPEL Solar Inc (formerly OPEL Inc) since 2009, as director of sales for the Western Region of the USA.

"Jay's broad experience in utility sales and renewable energy sales has already proven to greatly add to the capabilities of our sales team," says CEO Leon M. Pierhal. "Through his sales results thus far in his tenure with OPEL, we welcome him to the management team, adding specific focus on the accelerating sales growth OPEL has been experiencing," he adds.

Johnson has over 15 years of experience in sales, marketing and management, generally involving

emerging utility markets. Expertise includes marketing of new product development, creating new service offerings and expanding markets within developing and mature industries. Prior to OPEL, Johnson held director and senior management level positions in sales and management with CETX Energy Agency in Houston, TX and Akeena Solar in Los Gatos, CA. He began his career at SNK Realty, where he held positions of increasing responsibility over a period of 11 years as the firm grew from three staff to just over 200. Johnson has a Bachelor of Science degree in Finance from California State University, Chico and an MBA in Technology Management from the University of Phoenix.

In his compensation package, Johnson was granted incentive stock options, included in the following.

OPEL Technologies has granted additional incentive stock options under its stock option plan to certain directors, officers and key consultants to purchase up to 2,153,000 common shares (2.3% of the outstanding voting shares). Options granted to officers are 46.5% of the total grants, and options to independent members of the board are 34.8%. The remainder were granted to key consultants and employees. The stock options are exercisable at a price of CA\$0.51 per share expiring 28 September 2021. There are currently 9,587,250 options outstanding and 92,158,421 voting shares outstanding.

Options will vest and be exercisable on the basis of 25% on the date of grant and 25% every 6 months thereafter.

www.opeltechinc.com

Soitec launches fifth-generation CPV systems for large-scale solar plants

Soitec of Bernin, France, which makes engineered substrates including silicon-on-insulator (SOI) wafers (as well as III-V epiwafers through its Picogiga International division), has introduced its fifth generation of concentrator photovoltaic (CPV) systems, with enhanced features and performance characteristics designed to benefit large-scale utility power plants. The new product configuration delivers higher efficiency and lower cost of electricity, the firm adds.

Designed to improve the levelized cost of electricity (LCoE) for very large solar power plants, the new CPV system includes a 28kW tracker with a module area of more than 100m² (the optimum size to deliver high performance while drastically reducing the cost of installation and maintenance, the firm claims). Soitec says that, while using the same proven materials as the previous generation, the new system's configuration improves on its previous CPV products, boosting energy-generating efficiencies to as high as 30% by introducing evolutionary improvements to the firm's Concentrix technology. Soitec adds that its two-axis-tracking CPV systems are well suited to installation sites with high direct solar radiation, producing a high, constant power output curve throughout the day and able to match peak-load demands.

The new system consists of 12 CPV modules, each generating more than 2kW of peak power. For this new product, Soitec has reconfigured its Concentrix modules to reduce the number of parts per CPV system, making installation in the field simpler and faster. By leveraging the field-proven CPV cells, high concentration ratio and silicone-on-glass Fresnel lens construction used in previous generations of Concentrix products, the new system delivers the same high reliability and life expectancy.



Soitec's Concentrix CPV systems.

Soitec is also offering power companies a path to lower costs and faster installation times by using a 'building block' approach developed by the firm together with its partners. The new CPV systems are designed to be clustered into blocks of more than 1MW, each using a pair of centralized inverters. This design strategy significantly reduces construction and maintenance costs, says the firm.

"We are ready now to provide very cost-effective deployment of CPV solar power plants capable of

Soitec has begun shipping demonstration units to project sites. Plans call for volume production to ramp in Q2/12

generating hundreds of megawatts of electricity," says Hansjörg Lerchenmüller, senior VP, customer group for the solar energy business unit.

Soitec has begun shipping demonstration units to project sites. Plans call for volume production to ramp in first-quarter 2012 at the firm's manufacturing facility in Freiburg, Germany, and later at Soitec's planned new factory in San Diego, CA, USA.

Soitec exhibited at the Solar Power International trade show in Dallas, TX, USA (17-20 October).

www.soitec.com/en/solar-energy

DOE finalizes \$90.6m Cogentrix loan guarantee

The Department of Energy (DOE) has finalized a \$90.6m loan guarantee to Cogentrix of Alamosa LLC.

Announced as an offer of a conditional commitment in May, the loan guarantee will support the Alamosa Solar Generating Project, a 30MW high-concentration photovoltaic (HCPV) power generation facility in south-central Colorado near the city of Alamosa.

The project represents one of the first utility-scale HCPV energy generation facilities in the USA and, when completed, the largest of its kind in the world, it is reckoned. Founded in 1983, power generation project developer Cogentrix Energy LLC of Charlotte, NC (a subsidiary of The Goldman Sachs Group Inc) estimates that the project will support up to 100 construction jobs.

The facility will use HCPV systems designed and made by Amonix Inc of Seal Beach, CA, USA consisting of concentrating optics and multi-junction solar cell panels controlled by a dual-axis tracking system that rotates and tilts the cells throughout the day so the surface of the solar panel maintains an optimal angle with respect to the sun.

Cogentrix estimates that the multi-junction solar cells are nearly 40% efficient (about double that of more traditional PV panels), making CPV technology advantageous in areas with high amounts of direct sunlight, such as Alamosa County.

The facility is expected to produce enough energy per year to power over 6500 homes and will avoid the emissions of over 43,000 metric tons of carbon dioxide per year. The project is supported by a power purchase agreement (PPA), under which the Public Service Company of Colorado will buy the power generated by the facility for the next 20 years. The project is also expected to source more than 80% of its components from the USA.

www.lpo.energy.gov

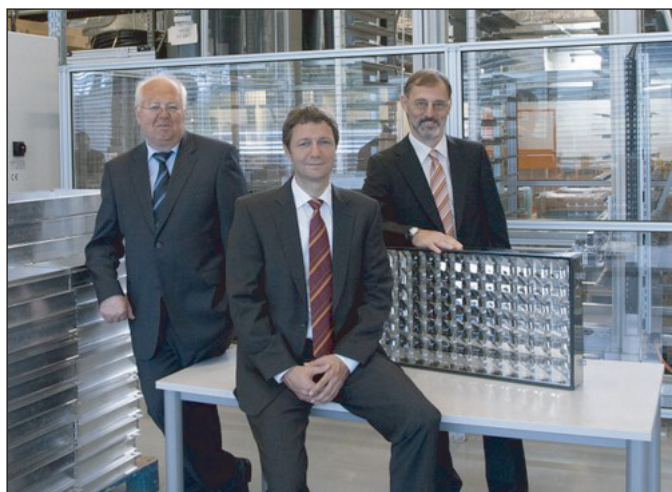
Multi-junction CPV technology of Soitec, AZUR SPACE and Fraunhofer ISE nominated for German Future Prize

Hansjörg Lerchenmüller (senior VP at Soitec of Bernin, France), Dr Andreas Bett (deputy director of Fraunhofer Institute for Solar Energy Systems ISE in Freiburg and director of its Materials – Solar Cells and Technology Division) and Dr Klaus-Dieter Rasch (managing director of AZUR SPACE Solar Power GmbH in Heilbronn) have been nominated for the German Future Prize 2011. Together they have developed multi-junction concentrator photovoltaic (CPV) solar cells, modules and systems that capture different ranges of the solar spectrum, converting twice as much sunlight into electrical energy as silicon-based photovoltaic systems.

Each year, the jury of the German Future Prize nominates three teams that, due to excellence in research, have introduced new products to the market. The Federal President of Germany, Christian Wulff, attended the official nomination ceremony on 27 August at the IdeenExpo in Hannover and will present the award to the winning team on 14 December.

Currently, 85% of all photovoltaic modules are made using crystalline silicon. However, this only converts a specific range of the solar spectrum into electrical energy, so efficiency is limited. Hence, 15 years ago, researchers at Fraunhofer ISE targeted finding a new approach: depositing several layers of various semiconductors — specifically, the III-V semiconductors gallium indium phosphide (GaInP), gallium indium arsenide (GaInAs) and germanium (Ge) — on top of each other in one solar cell, just 3mm in diameter. “Each semiconductor captures a different range of the solar spectrum and the energy yields add up,” says Bett.

Multi-junction solar cells were initially developed for space applications. The III-V solar cells developed at Fraunhofer ISE are manufactured industrially by AZUR



Nominated for the German Future Prize 2011, from left to right: Dr Klaus-Dieter Rasch (managing director of AZUR SPACE Solar Power), Hansjörg Lerchenmüller (senior VP at Soitec), and Dr Andreas Bett (director of the materials – Solar Cells and Technology Division and deputy director of Fraunhofer ISE).

SPACE and used to supply energy for telecom satellites. However, the firm also produces multi-junction solar cells for terrestrial applications. Fraunhofer ISE’s III-V solar cells have an efficiency of 41.1% (a record in 2009) and are currently being transferred to series production by AZUR SPACE. “Within a very short period of time we were able to show that efficiencies of 40% are possible in the solar industry, and we believe that those around the 50% mark are also entirely feasible,” says Rasch.

To exploit the potential of multi-junction solar cells for terrestrial use, researchers at Fraunhofer ISE focused on optical concentration. Lenses that concentrate sunlight by a factor of 500 were placed in front of the multi-junction solar cells, and cells and lenses were then combined into one module. “We have replaced expensive semiconductor materials and added low-cost lenses. Thanks to these newly developed concentrator modules, we are able to produce a higher output per area,” says Bett.

After developing the module in the laboratory, in order to develop production-ready concentrator modules and convert them into high-per-

formance systems, staff at Fraunhofer ISE founded the spin-off Concentrix Solar GmbH under the direction of Lerchenmüller. The company continued to drive the industrial processing technology that had been initiated at Fraunhofer ISE and, after a few years, launched Concentrix modules on the market. The firm was acquired in December 2009 by Soitec Group, which manufactures engineered substrates including

silicon-on-insulator (SOI) wafers (as well as III-V epiwafers through its Picogiga International division).

“Our concentrator modules convert 28% of sunlight into electricity, that’s twice as much as in conventional photovoltaics,” says Lerchenmüller. In addition to their lower energy-generation costs, concentrator systems have further advantages: Due to their modular design they can be used in power plants with energy outputs ranging from less than 1MW to more than 100MW. The energy needed to manufacture the modules is paid back after just a few months of operation, and the investment costs required to set up mass-production facilities are comparatively low, it is claimed.

Concentrator technology is well suited to large-scale solar power plants in sunny regions. Soitec Solar has already installed more than 3MW of capacity in power plants in Southern Europe, South Africa and the USA, and will soon build another module factory in the USA.

www.deutscher-zukunftspreis.de

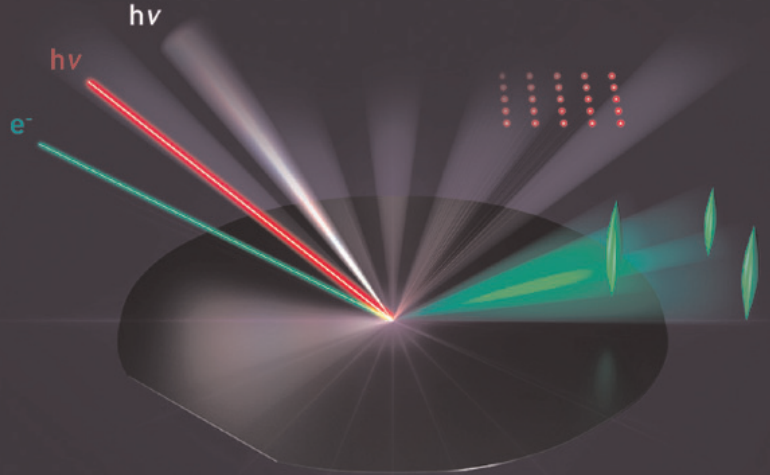
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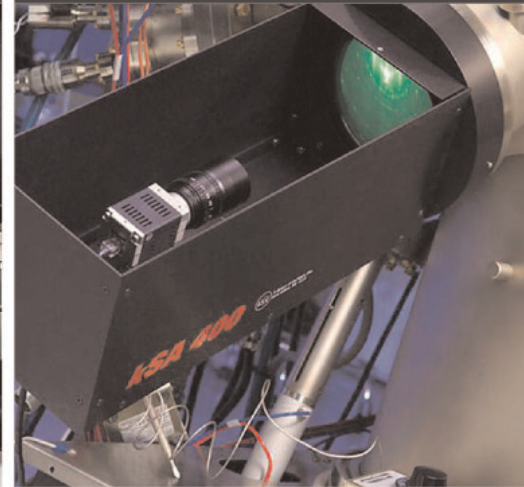
kSA BandiT Wafer Temperature



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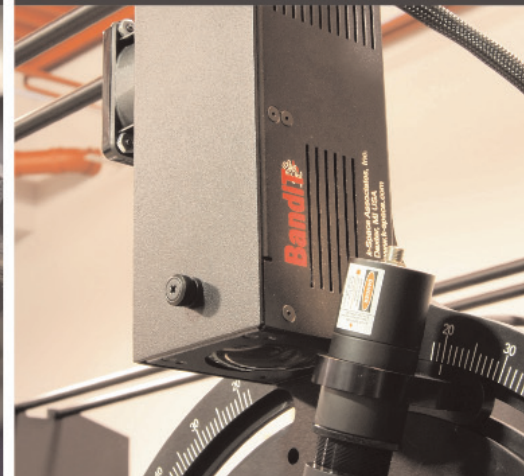
kSA MOS Ultra-Scan and
Thermal-Scan Stress Mapping



kSA Rate Rat Pro Thickness &
Deposition Rate



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US Ex-Im Bank providing \$455m in project funding for First Solar exports to Canada

First Solar Inc of Tempe, AZ, USA, which makes CdTe-based thin-film photovoltaic (PV) modules, says that, at a tour of its manufacturing facility in Perrysburg, OH, Fred P. Hochberg, chairman & president of the Export-Import Bank of the United States (Ex-Im Bank), announced its authorization of two loans totaling \$455.7m to support First Solar's exports to solar energy projects in Ontario, Canada.

On the tour, Hochberg and Senator Sherrod Brown (D-OH) and met with workers and outlined efforts to create and sustain jobs by increasing exports.

The loan guarantees constitute Ex-Im's largest ever financings supporting US solar energy exports. The support was needed because viable long-term financing for these projects was not otherwise available in the commercial marketplace.

In fiscal 2011, Ex-Im is providing a record level of support for US exports related to solar energy production. Through 1 September, it has approved about \$650m to support sales of US goods and services to solar energy projects.

Ex-Im has authorized nearly \$573m in fiscal 2011 to support First Solar's exports to solar energy projects in not only Canada but also in India collectively. Its total authorizations on behalf of First Solar are supporting an estimated 550 jobs at the Perrysburg facility.

"It is critical that we encourage more American companies to compete in the global marketplace," says Hochberg. "These two transactions will boost Ohio's economy, create hundreds of local jobs and move us closer to President Obama's goal of doubling US exports by the end of 2014," he adds.

"Ex-Im Bank's support strengthens First Solar's competitiveness and enables us to sustain US renewable-energy manufacturing and the jobs that go with it," says James Brown, president of First Solar Utility Systems Business Group. "Financing costs represent a major part of any solar project, so this support helps accelerate the deployment of renewable energy worldwide."

In two separate transactions, Ex-Im is providing guarantees supporting commercial loans to project borrowers for the purchase of First Solar's and other US exports:

1. a \$236.7m (CDN\$226.1m) loan to support First Solar's exports for the construction of a 50MW project consisting of five 10MW systems in three facilities in the Ontario townships of Amerherstburg, Belmont and Walpole (connected to the grid through the Hydro One, Erie Thames Power and Haldimand Hydro distribution systems).
2. a \$219m (CDN\$184.3m) loan to support First Solar's exports for the construction of a 40MW project in St. Clair, Ontario, consisting of the

Moore facility and the Sombra facility, on separate sites near St. Clair Lake (connected to the grid through the Hydro One distribution system).

Electricity produced by the projects will be sold under multiple 20-year power-purchase agreements to the Ontario Power Authority under Ontario's Renewable Energy Standard Offer Program. In both transactions, Ex-Im Bank is guaranteeing Canadian-dollar-denominated loans made with the proceeds of two Canadian market bond issuances with repayment terms of 18 years.

First Solar is also the parent firm of First Solar Development Canada Inc (FSDCI), which is the project developer and engineering, procurement & construction (EPC) contractor.

The transactions are supporting First Solar's export of these services in addition to its Series 3 thin-film CdTe solar-PV modules. Also supported are exports of power inverters from Xantrex Technology USA Inc of Elkhart, IN (a subsidiary of Schneider Electric).

As well as the Ontario projects, in fiscal 2011 Ex-Im Bank has authorized financing for First Solar exports to three projects in India: \$18m for the 15MW ACME Solar Technology project in Gujarat; \$15.7m for the 5MW Azure Power project in Rajasthan; and \$84.3m for the 40MW Dahanu Solar Power project (Reliance Power Ltd) in Rajasthan.

www.exim.gov

First Solar to supply 100MW of CdTe PV modules to India's Reliance

First Solar has announced India's largest PV module supply agreement to date: 100MW for Mumbai-based Reliance Power Ltd.

First Solar will deliver 40MW of modules to Reliance by the end of 2011 for its project in Jaisalmer in Rajasthan state, which will supply renewable electricity to Mumbai. Delivery of the remaining 60MW is expected to be completed in 2012.

On 25 August, the US Export-Import Bank approved an \$84.3m direct loan to Reliance Power's Dahanu Solar Power Pvt. unit to purchase First Solar panels for the first 40MW of the project.

"We are delighted to collaborate with Reliance Power, one of India's leading independent power producers," says Jim Brown, president of First Solar's Utility Systems

Business Group. "India is expected to become one of the world's major solar markets, due to its abundant solar resource and significant energy demand," he adds. "This agreement with Reliance Power continues First Solar's momentum in India, helping develop the country's long-term, sustainable solar market."

www.reliancepower.co.in

Solar Chile and First Solar to co-develop photovoltaic projects in Northern Chile

Solar Chile, a subsidiary of Fundación Chile, and First Solar have signed a strategic alliance to co-develop PV projects in Chile. First Solar will provide its CdTe thin-film PV modules and engineering & procurement (EPC) services to future development projects, subject to execution of definitive project agreements.

As a joint venture between Fundación Chile and a group of local private investors, Solar Chile is a developer and operator of utility-scale solar plants that aims to accelerate the timeframe required to make solar energy competitive in Chile. "Together we will transform Chile into the first country in Latin America to generate solar energy at competitive prices," says Solar Chile's CEO Cristián Sjögren.

At the signing ceremony at Fundación Chile in Vitacura, Kathleen Weiss, VP of federal government & corporate affairs, and Kim Oster, director of business development, Latin America for First Solar, gave presentations on solar's rapidly declining costs and provided a global perspective on the development of a sustainable solar industry in Chile. "With strong growth projections, significant energy demand and abundant solar resource, Chile represents a tremendous opportunity to generate clean, renewable solar electricity cost effectively," said Oster.

Northern Chile has a solar resource that is among the most abundant in the world, and Fundación Chile has been exploring its

potential by implementing measurement services and pilot projects and by working in conjunction with the regional government on initiatives such as the Atacama Solar Platform, which has the goal to convert the plentiful solar resource in the Atacama Desert into a source of competitive and sustainable energy.

Fundación Chile works to support this and several other initiatives, including Solar Chile, related to developing the solar cluster, an industry ecosystem that will bring together technology and service companies, promote R&D, and support human capital development related to the broader solar energy sector.

www.solar-chile.com

First Solar cuts carbon emission intensity by 21% from 2008 to 2010

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 participated in and received a score on its inaugural response to the Carbon Disclosure Project (CDP), an organization that gathers and reports greenhouse-gas emissions for corporations around the world. First Solar says that it is the first company solely focused on solar development to have its response scored by CDP and included in CDP's 500 and Global 500 report.

First Solar's Disclosure Score was in the top quartile of the 339 S&P 500 respondents. For 2010, its global operations generated greenhouse-gas emissions totaling about 194 metric tons of carbon dioxide emission equivalents (CO₂e) per megawatt of modules produced, illustrating a reduction in carbon intensity of about 21% from 2008 to 2010. Also, the

3.3GW of modules produced by the firm through 2010 are being used globally to displace more than 2 million metric tons of CO₂e emissions per year for their 25+ year product life.

The CDP was launched in 2000 to accelerate solutions to climate change by putting relevant information at the heart of business, policy and investment decisions, and it encourages companies to measure and manage their direct and indirect carbon emissions and broader environmental footprint in order to accelerate solutions to climate change. About 3000 organizations in 60 countries around the world now measure and disclose their greenhouse-gas emissions and climate change strategies

First Solar's Disclosure Score was in the top quartile... illustrating a reduction in carbon intensity of about 21%

through CDP so that they can set reduction targets and make performance improvements.

"Like CDP, we at First Solar are focused on accelerating solutions to climate change and have taken a leadership role in measuring and reporting our carbon footprint," says Lisa Krueger, First Solar's VP of sustainable development. "We encourage other solar power companies to help accelerate solutions to climate change by measuring and disclosing their life-cycle carbon footprint."

First Solar claims that its thin-film PV technology has, on a life-cycle basis, the smallest carbon footprint and the fastest energy payback time of commercially available PV technologies, allowing PV to scale rapidly while achieving carbon reductions. Its product life-cycle management approach also led to the development and implementation of what it says is the solar industry's first pre-funded module collection and recycling program.

www.cdproject.net

NRG, El Paso Electric and First Solar dedicate opening of New Mexico's second-largest PV plant

NRG Solar LLC (a subsidiary of power generation firm NRG Energy Inc of Princeton, NJ), regional utility El Paso Electric and CdTe thin-film PV module maker First Solar Inc of Tempe, AZ hosted New Mexico state and local officials at their 20MW Roadrunner Solar Generating Facility to dedicate the start of energy production from what is the state's second-largest PV project.

It is also the third large-scale solar generation plant that NRG has brought online to date — totaling more than 86MW — and its first outside California. NRG Solar has over 2000MW of PV and solar thermal projects under development or in construction across the southwestern USA.

"Today marks another step towards American energy independence with the completion of the Roadrunner Solar Generating Facility," says John Sanchez, Lieutenant Governor of New Mexico. "This 20MW photovoltaic project is diversifying New Mexico's economy and creating good paying jobs for our state," he adds.



NRG's 20MW Roadrunner Solar Generating Facility.

The facility is sited on a 210-acre privately owned parcel of industrial-zoned land near Santa Teresa, NM, about 10 miles from El Paso, TX. First Solar provided engineering, construction and procurement (EPC) services for the project (which uses its modules mounted on single-axis trackers) and will also be the operations and maintenance contractor for the facility. The system rotates the PV solar panels to follow the sun throughout the day, increasing electricity production compared with a fixed-tilt installation. The project created

more than 200 jobs during its construction over the past nine months and is now generating electricity to supply thousands of homes.

"Our 20-year contract to purchase the power from this facility marks our largest commitment to solar energy research, education and utilization in our area," notes El Paso Electric's CEO David Stevens. With a net dependable generating capability of 1791MW, El Paso Electric provides generation, transmission and distribution service to about 379,000 retail and wholesale customers in a 10,000 square mile area of the Rio Grande valley in west Texas and southern New Mexico.

"The completion of the Roadrunner solar facility is a major milestone for the New Mexico border region," comments Secretary of Economic Development Jon Barela. "This builds on all the momentum taking place in the region due to the coming together of many entities for the economic development success of Santa Teresa, including NRG Energy, El Paso Electric and First Solar."

www.nrgsolarenergy.com

'Made in EU' modules qualify for Italian feed-in tariff premium

PV modules made by First Solar in its factory in Frankfurt (Oder), Germany have satisfied the requirements for a 10% feed-in tariff premium in Italy after passing a factory inspection.

This follows an official Factory Inspection certification by VDE, the German Association for Electrical, Electronic & Information Technologies, on the basis of guidelines established by the Italian government as part of its 'Conto Energia 4' (CE4) feed-in tariff program. CE4 aims to encourage the use of components 'made in Europe', rewarding projects that contain at least 60% local content with a 10% premium over normal feed-in tariff (FIT) rates.

"This certification provides an added value to our customers in Italy by increasing the attractiveness of investments in commercial PV systems," says Stephan Hansen, VP of sales for First Solar in Europe, the Middle East and Africa. "It also validates our commitment to manufacturing in Europe, which remains one of our most important markets globally."

First Solar has operated a thin-film solar module manufacturing plant in Frankfurt (Oder) since 2007. The firm is currently doubling annual manufacturing capacity at the plant to about 500MW. First Solar employs more than 1200 people in Frankfurt (Oder) and more than 1400 in the

European Union overall, and was recently recognized as a Great Place to Work by Germany's Great Place to Work Institute for the second year in a row.

In addition, most of the raw materials that First Solar uses for its German production are sourced within the European Union.

First Solar's modules also recently received the International Electrotechnical Commission's IEC 61701 certification, demonstrating their resistance to corrosive salt mist in coastal environments. All modules are covered by a 25-year performance warranty, and the firm offers a pre-funded module collection and recycling program.

Australia's first utility-scale PV project to use First Solar modules

First Solar Inc of Tempe, AZ, USA, which makes thin-film photovoltaic modules based on cadmium telluride (CdTe), together with Western Australian state-owned power utility Verve Energy and GE business unit GE Energy Financial Services of Stamford, CT, have announced that Australia's first utility-scale solar power project is under way. Output from the 10MW AC project on 80 hectares of cleared land 50km southeast of Geraldton will contribute to offsetting the energy requirements of the Southern Seawater Desalination Plant.

Verve Energy (which owns and operates power stations and renewable energy systems with a total capacity of 2967MW) and GE Energy Financial Services will each own 50% of the Greenough River Solar Farm, with the Western Australian Government providing A\$20m (including A\$10m from the WA Royalties for Regions program). No debt will be raised to fund the project.

The WA Water Corp (Western Australia's primary supplier of water, wastewater and drainage services) is building the Southern Seawater Desalination Plant, and has committed to purchase 100% of the solar farm's output under a 15-year contract. Western Australia requires new desalination plants to use power generated from renewable sources. The plant will produce about 50 gigalitres of potable water per year.

First Solar has agreed to supply the 10MW project with more than 150,000 PV modules and to provide engineering, procurement and construction (EPC) services, in addition to operations and maintenance support after the solar farm is operational. The agreement is subject to the satisfaction of certain statutory requirements.

The solar farm will be the first utility-scale PV project in Australia, 10 times larger than any other

operating solar project in the country. Taking advantage of the area's vast dry, flat and sunny conditions, it is expected to be fully operational mid next year.

"This announcement demonstrates the significant potential for renewable energy generation — especially utility-scale solar in WA and throughout Australia," says

First Solar has agreed to supply the 10MW project with more than 150,000 PV modules and to provide engineering, procurement and construction (EPC) services

investment in Australia, adding to its global portfolio of more than US\$400m of solar power equity and debt investments in 42 projects.

"This transaction enables us to apply our renewable energy investment expertise to a new market, add to our portfolio of projects with First Solar, and to GE's broader work with Verve Energy," says Jason Willoughby, GE Energy Financial Services' Australia business leader.

Providing affordable and sustainable energy to partially power the Southern Seawater Desalination Plant (near the town of Binningup), the project is expected to create more than 50 construction jobs. Producing energy when it is most needed (during the day), the project should displace 25,000 tonnes per year of greenhouse-gas emissions (equivalent to taking 5000 cars off the road). It will also boost Western Australia's share of the Federal Government's renewable energy target of 20% by 2020.

www.verveenergy.com.au
www.geenergyfinancialservices.com

Jim Brown, president of the Utility Systems Business Group of First Solar.

The project represents GE Energy Financial Services' first renewable energy

North County Watch and Carrizo Commons dismiss lawsuit against First Solar's Topaz Solar Farm

Topaz Solar Farms LLC, a subsidiary of First Solar Inc of Tempe, AZ, USA, has reached an agreement for North County Watch and Carrizo Commons to dismiss their lawsuit against the 550MW Topaz Solar Farm project that First Solar is developing in San Luis Obispo County, CA, USA.

Topaz has committed to the decommissioning and restoration of habitat at the project site after 35 years of operation. It will also place a conservation easement on the land and provide an endowment for managing the land in perpetuity. In addition to providing a timeframe for decommissioning and restoration, the agreement provides enhanced communication, collaboration, research and monitoring measures, including a Biological Working Group.

Combined with other off-site lands that Topaz is conserving, the agreement will support the preservation of about 22,000 acres to be protected in perpetuity following the end of project operations.

First Solar said on 22 September that the Topaz Solar Farm project would not meet the 30 September statutory deadline to receive a federal loan guarantee from the US Department of Energy (DOE). The firm also said that it was in advanced talks regarding the sale and financing of the project with potential buyers utilizing a different transaction structure that does not require a DOE loan guarantee.

Topaz is expected to create an average of 400 jobs during the three-year construction process and use modules from First Solar's Perrysburg, OH, and Mesa, AZ factories. Upon completion, it should generate enough electricity to power about 160,000 average California homes (displacing about 377,000 metric tons of CO₂ per year).

www.topazsolar.com
www.firstsolar.com

Nanosolar hits 17.1% aperture efficiency using printed, non-vacuum CIGS deposition process

Nanosolar Inc of San Jose, CA, USA, which makes thin-film photovoltaic panels based on printing copper indium gallium diselenide (CIGS) and nanoparticle inks (using the industry's first roll-to-roll solar cell printing factory, together with an assembly plant in Luckenwalde, Germany), says that the US Department of Energy's National Renewable Energy Laboratory (NREL) has certified an aperture efficiency of 17.1% for a

solar cell fabricated using Nanosolar's non-vacuum, low-cost printing on flexible foil technology.

"This achievement demonstrates that a non-vacuum CIGS deposition process can deliver world-class efficiency," says CEO Geoff Tate. "At the same time, Nanosolar's unique roll-to-roll printing process delivers substantial manufacturing cost benefits," he adds.

Nanosolar says that its aim is to become the lowest-cost solar cell

and panel manufacturer, independent of subsidies.

The firm claims that this is possible because its unique thin-film printing process enables significant cost savings compared with conventional vacuum-based deposition techniques. Its high-throughput roll-to-roll printing method also delivers higher capital efficiency and better materials utilization, Nanosolar adds.

www.nanosolar.com

CIGS PV utility panels installed in US National Guard camps

Nanosolar has announced the installation of 538kWp of its utility panels at the Camp Perry Ohio National Guard Base in Port Clinton, OH. Nanosolar partner Romanoff Electric Co LLC of Toledo, OH oversaw engineering, procurement and construction of 2750 Nanosolar Utility Panels as part of the project.

The panels were pre-assembled into cartridges by mounting system vendor AP Alternatives at its fabrication facility in Ridgeville Corners, OH, and then delivered and inserted into pre-driven and laser-guided piers at the project site. AP Alternatives' pre-assembly enables quicker and more cost-effective installation with far less panel breakage than with traditional mounting systems, it is reckoned.

"The Nanosolar Utility Panel delivers a low-cost, easy to install solar power alternative for America's military bases," says Jerry Heminger, VP of Alternative Energy at Romanoff Electric. "Nanosolar's utility-scale thin-film panel design allows us to install equivalent power with fewer panels and less equipment, cabling and people than conventional thin-film solar technologies," he adds.

Nanosolar also says that, together with engineering, procurement & construction (EPC) partner Belectric Inc of Newark, CA,



it is on schedule to construct its 1MWp ground-mount thin-film solar installation at Camp Roberts California National Guard Base near Paso Robles, CA. The project is funded by the US Department of Defense's Environmental Security Technology Certification Program (ESTCP) in order to showcase a low-cost, secure renewable energy alternative to fossil-fired power generation. Groundbreaking is scheduled for early January 2012 and system construction is due to take less than three months.

"Solar power is an affordable, reliable and responsible source of energy for America's military," says Nanosolar's CEO Geoff Tate. "Nanosolar is delivering a stable power source to Camp Perry and other military installations that is

independent of supply shortages, grid interruptions, and price fluctuations."

The firm says that its roll-to-roll printing process and utility-scale panel design enables the Nanosolar Utility Panel to reduce both manufacturing costs and balance of systems costs in multi-megawatt installations. It is also the first solar panel to be certified to operate at up to 1500 system volts. These system design features allow for balance of systems cost savings of up to 30% over competing thin-film solar panels in utility-scale power plants, it is claimed. Nanosolar adds that its panels can also be assembled close to market demand in order to leverage local resources and minimize logistics costs.

Korea's SK invests \$50m in CIGS PV maker HelioVolt Alliance to drive global manufacturing expansion

SK TIC (Technology Innovation Company) and SK Innovation (members of Seoul-based energy, chemicals and telecoms firm SK Group, which is Korea's third largest conglomerate) have agreed to collaborate with HelioVolt Corp of Austin, TX, USA, which makes copper indium gallium diselenide (CIGS) thin-film photovoltaic modules for the commercial rooftop and utility markets, on technology development and global manufacturing expansion.

HelioVolt was founded in 2001 by Dr Billy J. Stanbery based on his proprietary FASST manufacturing process for rapid printing of thin-film CIGS material, either directly onto glass substrates for solar modules or onto flexible plastic substrate for embedding in building-integrated photovoltaic (BIPV) products (e.g.

architectural glass and roofing tiles).

SK Group has now invested \$50m to expand HelioVolt Austin's manufacturing operations and has begun collaboration to develop the CIGS PV maker's global capabilities. In connection with the transaction, Bank of America Merrill Lynch acted as exclusive placement agent to HelioVolt. To date, the firm has raised more than \$200m in total to fund its move to volume production and international expansion.

"We are happy to be able to leverage SK leadership across our many complementary industries in order to create an outstanding global partnership with the HelioVolt team," says SK TIC's CEO Dr SH Park. "SK's technical and engineering expertise will provide HelioVolt with tremendous market,

manufacturing and supply chain access," reckons SK Innovation's chief technology officer Dr DS Kim.

HelioVolt says that, through the new partnership, its technical progress and rapid module cost reduction are providing SK an opportunity to play a key role in the rapidly growing global renewable energy market.

"The solar energy market is going through a transition period — one that is creating unprecedented opportunities," says HelioVolt's chairman & founder Dr BJ Stanbery. "We welcome SK's manufacturing, engineering and operational expertise in order to accelerate commercialization of our technology and business expansion," he adds.

www.heliovolt.com

Avancis raises monolithic thin-film PV module efficiency Reduction in CIGSSe absorber thickness and optimized in-line selenization boosts record again from 15.5% to 15.8%

At the European Photovoltaic Solar Energy Conference (EU PVSEC) in Hamburg, Germany in September, Avancis GmbH of Torgau, Germany (a subsidiary of Saint-Gobain of Courbevoie, France) reported that it has raised the efficiency of its copper indium selenide (CIS) thin-film PV modules again, from the record of 15.5% that it set in January to a new record of 15.8% for monolithic thin-film solar modules. The firm had previously set a record of 15.1% in January 2010.

The latest aperture efficiency for the fully encapsulated and framed champion module has already been confirmed by TÜV Rhineland. The result represents a new, independently certified efficiency record for a thin-film PV module measuring 30cm x 30cm, according to the August issue of the journal Progress in Photovoltaics vol19 (2011) p565.

"The renewed efficiency improvement can be traced back to the reduction of the layer thickness of the CIGSSe absorber by approximately 10% and an optimized in-line selenization process for the thinner absorbers," says chief

technology officer Franz Karg. "In addition, the P1 laser structuring was optimized and the structuring process between P1, P2 and P3 improved, with the aim of further enlarging the active surface."

Avancis says that it is important for future application of the new technology that the efficiency improvement is not achieved at the expense of impaired long-term stability. Its R&D department has

The P1 laser structuring was optimized and the structuring process between P1, P2 and P3 improved

hence performed climate tests (damp heat tests, in accordance with the IEC) with several of the efficiency-optimized modules. All tests demonstrated long-term stability comparable with that of the firm's previous products.

Also, so that the findings of the research department can be implemented in industrial applications as quickly as possible, the development department is working only with processes and materials that are actually in use in series production. For example, with the most recent record modules, the same series-identical float glass substrates with a SiN/Mo back electrode were used as for Avancis' PowerMax products.

At EU PVSEC, Avancis presented the complete findings of its efficiency program in a presentation 'Towards module efficiencies of 16% with an improved CIGSSe device design'.

www.avancis.de

Stion opens 100MW CIGSSe PV factory in Mississippi Record 14.1% efficiency for production-scale monolithically integrated thin-film circuit

Stion Corp of San Jose, CA, USA, which makes nanostructure-based CIGSSe (copper indium gallium sulphur-selenide) thin-film photovoltaic panels, has opened its first mass-production factory in Hattiesburg, MS with a ribbon-cutting ceremony attended by Mississippi Governor Haley Barbour and other state and local officials.

Founded in 2006 as Nstructures, Stion raised \$15m in June 2007 in a Series B financing round led by Lightspeed Venture Partners and joined by General Catalyst Partners along with previous investors Khosla Ventures and Braemar Energy Ventures. In June 2010, these added \$20m to \$50m invested by the world's largest semiconductor foundry Taiwan Semiconductor (TSMC) — via its affiliate VentureTech Alliance — in a \$70m Series D round of fundraising to help scale production (boosting the total raised since 2006 to \$114.6m). Stion also formed a strategic partnership with TSMC covering technology licensing, supply, and joint development.

Stion's existing 10MW-capacity product line in San Jose makes modules using what is claimed to be a simple, low-cost monolithically integrated circuit design. With a form factor of 65cm x 165cm and

energy conversion efficiencies of at least 11% and power ratings of 110–120W, the glass-glass CIGSSe PV panels are designed for use in major market segments including commercial/government, residential, utility and off-grid. Stion received its UL 1703 and IEC 61646 product certifications in January.

Also, the US National Renewable Energy Laboratory (NREL) has verified an efficiency of 14.1% for Stion's circuits, a record for production-scale monolithically integrated thin-film circuits. "Achieving 14.1% efficiency over a large area is indicative of the exceptional process control and uniformity delivered by Stion's technology, and also speaks to the continued improvement potential for CIGS-based technologies to meet the DOE SunShot goal of price parity by the end of this decade," comments Rommel Noufi, NREL's lead researcher for thin-film solar cells.

Stion says that its unique approach to CIGS leverages proprietary materials and device expertise along with a robust, high-volume manufacturing process based on readily available, standardized equipment. Using a monolithically integrated circuit design instead of assembling individual cells into a module enables a

lower bill of materials and more streamlined manufacturing process, it adds.

"Manufacturing high-efficiency, large-area CIGS modules with an inherently low cost structure and repeatable, scalable process is critical to driving the fundamental product economics," says Stion's president & CEO Chet Farris.

The new facility in Hattiesburg, which is the first thin-film solar factory in the Southeastern US, should deliver more than 1000 jobs and \$500m of investment over the next six years. The first phase includes a 100MW production line which will entail over \$100m of investment and 200 direct jobs in 2011 and 2012.

Since announcing the Hattiesburg site in January, Stion has hired 100 staff locally and implemented recruiting and training programs with Pearl River Community College and the University of Southern Mississippi. First-phase production will begin later this year.

"Our partnership with the state of Mississippi and the city of Hattiesburg has been a tremendous driving force behind our manufacturing scale-up," says Farris. "Our local employees and partners have worked hard to start up this facility on an extremely fast timeline."

www.stion.com

Eyelit's MES software implemented at Stion's PV panel facilities

Stion has implemented Eyelit's Solar Edition manufacturing software to support the production ramp-up at its facilities in San Jose and in Hattiesburg, MS.

Eyelit Inc of Toronto, Canada provides manufacturing execution software (MES) for visibility, control and coordination of manufacturing operations.

Deployment at Stion (completed in just 12 week) included the following features:

- traceability of solar panels from thin-film processing to fully assembled panel;
- WIP tracking with integrated SPC and data collection;
- user interfaces tailored without writing code for each production-line area;
- equipment state tracking for managing preventative maintenance;
- automated data collection from factory tooling; and
- input of data by barcode scanning.

"It provides us with a comprehensive set of modules built on a simple, but scalable architecture," says Stion's director of IT Vijay Mani. "Eyelit's quick implementation uses fewer resources than other MES solutions I've worked with," he adds. "Eyelit's targeted software bundle enables PV manufacturers such as Stion to quickly scale from a pilot stage to high-volume commercial production," says Eyelit.

www.eyelit.com

Global Solar starts production at Berlin module plant 35MW plant adds to 40MW plant at Arizona HQ

Global Solar Energy Inc, which makes copper indium gallium diselenide (CIGS) thin-film photovoltaic cells and modules at its 40MW-capacity plant in Tucson, AZ, USA, has commissioned its new production facility in Berlin-Adlershof, Germany.

Founded in 1996, Global Solar's solar modules are lightweight and flexible, suiting building-integrated photovoltaic (BIPV) applications and solar power plants or foldable charging devices.

The Berlin factory has a production area of 2100m² and processes solar cells fabricated in-house. The latter are laminated between a number of films to ensure durability. High module efficiencies of up to 12.6% (claimed to be the most efficient of their kind) are achieved due to a

"unique mixing ratio" of copper indium gallium diselenide. Also, several of the factory's machines are custom-built, ensuring that series production is optimized, it is reckoned. Global Solar commissioned and installed equipment in the new factory in just five months, says Jens Mühling, managing director of the firm's German branch.

After starting pilot operation in August, more than 60 vacancies were filled at the Berlin plant (taking total company staffing to 300). With an annual production capacity of 35MW, the module manufacturing plant moved from two-shift to three-shift operation in third-quarter 2011. A further 100 jobs are due to be created by the end of 2012.

Weighing just 3.5kg/m², Global Solar's PowerFLEX BIPV modules are suited to use on flat industrial roofs, as the structural design of such buildings often prevents the use of heavy, thick-film modules, says the firm. After being rolled onto the roof surface, the flexible thin-film modules are affixed in position and require no support frames or stands. The roof membrane is not pierced and no additional wind loads are produced.

Measuring 5.74m x 0.5m, PowerFLEX modules offer a power density of up to 300W, and are therefore roughly twice as efficient as flexible amorphous silicon solar modules, the firm claims.

www.globalsolar.com

Global Solar forms partnerships and expands manufacturing to deliver flexible CIGS PV roofing modules worldwide

Global Solar Energy says that it has achieved several key milestones, including new strategic partnerships and an expansion at its manufacturing plant in Berlin, Germany, that enable the high-volume production and delivery of its PowerFLEX BIPV modules (which it claims to be the most powerful solar roofing solution) to commercial buildings worldwide.

Global Solar says that, offering what is reckoned to be twice the power per module than competing offerings and a simple, lightweight design that requires no roofing hardware, the capabilities of PowerFLEX BIPV have been recognized by leading roofing and building companies around the world, which have signed multi-year, multi-megawatt agreements with Global Solar. The firm has partnered with ENERGYKA, ISCOM SPA and BA Energy in Italy, and it is finalizing agreements with other channel partners in Europe, the USA and Asia.

"Since introducing PowerFLEX BIPV, there has been a surging interest in its simple and cost-effective way of increasing the value of a rooftop with solar energy generation," says Jean-Noel Poirier, senior VP of business development & marketing. "There is a lot of demand for laminates on roofs with weight limitations throughout the world," he adds. "The high efficiency of CIGS brings a huge advantage to this market segment, which was limited by the low efficiency of existing flexible laminates."

Earlier this year, the PowerFLEX BIPV roofing module received certification from both the International Electrotechnical Commission (IEC) and Underwriters Laboratories (UL).

"Our UL and IEC certifications, as well as the scale up of our plant in Berlin, allow us to start delivering the product in high volume," says Poirier. "Our customers are well positioned in their markets and are

developing innovative roofing systems using our module," he adds. "We are gearing up to announce several commercial rooftop and landfill projects in Europe."

Global Solar says that its PowerFLEX BIPV roofing panels are a more powerful and cost-effective alternative to traditional heavy and rigid glass solar modules, as well as other flexible PV products. Designed specifically for roofs, they maintain the integrity of a building structure, requiring no mounting systems and no penetration of the roofing membrane, while its large format and high power density deliver lower installation and balance of system (BOS) costs, it is claimed. Also, since the module rolls out flat onto the roof, wind load concerns are eliminated.

Global Solar showcased its PowerFLEX BIPV module at the Solar Power International 2011 event in Dallas, TX, USA (17-20 October).

First Chinese Ka-band nitride semiconductor MMIC

Researchers look to higher frequency of ~30GHz for microwave device construction.

Chinese Academy of Sciences (CAS) researchers have extended their work on gallium nitride (GaN) high-electron-mobility capability in the Ka-band (26.5–40GHz) to monolithic microwave integrated circuits [Wang Dongfang et al, J. Semicond., vol32, p085011, 2011]. The researchers from CAS' Institute of Microelectronics say: "This is, to the best of our knowledge, the first demonstration of domestic [i.e. to China] Ka-band GaN amplifier MMICs."

The Ka-band is used in satellite communications (telecoms and data links, e.g. in Kepler telescope), military high-resolution close-range targeting radar, vehicle speed detection, etc. Chinese MMICs have previously been focused on the C (4–8GHz) and X (8–12GHz) bands.

MMICs integrate microwave transistors, impedance matching and bias elements on one wafer. The researchers used an aluminum gallium nitride (AlGaN) high-electron-mobility transistor (HEMT) with 0.25 μm gate length and 2 μm x 75 μm width. In previous work, the saturated drain current for this device reached 1030mA/mm, and in the Ka-band the maximum stable gain (MSG) was 10.5–11.5dB.

The researchers used a coplanar waveguide (CPW) design (Figure 1) for the MMIC rather than micro-strips, since this made it easier to create the circuit, with fabrication requiring fewer process steps. However, the initial design process is more difficult with CPW circuits. In addition, CPW designs can have a lower thermal resistance, which is important for reducing the operating temperature of devices.

The researchers were unable to use power-matched impedances, since they have been unable to obtain optimal load and source values due to restrictions on measurement capabilities in the Ka-band. Instead the CPW setup was designed to maintain the S-parameter matrix of the HEMT in a suitable state with a drain voltage of 30V and a gate potential of -1.5V.

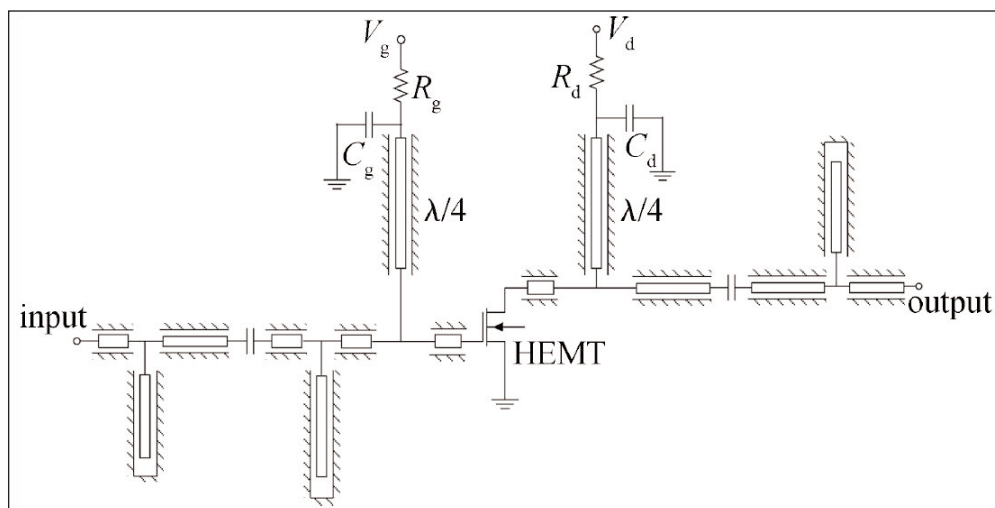


Figure 1. CPW amplifier circuit diagram.

The flip-chip MMIC also had thermal bumps at the ground-plate for heat removal. The use of flip-chip technology for high-power amplifiers has been estimated to give cost savings of up to 40%.

The CPW transmission lines were designed with 50 Ω impedance with a 46 μm -wide center conductor and a 15 μm -wide ground plate. The target frequency was 32GHz. The quarter-wavelength lengths of transmission line used to feed in the bias potentials were 1.2mm long. ▶

Barrier	Al _{0.2} Ga _{0.8} N	25nm
Spacer	AlN	1nm
Buffer	GaN	2-3 μm
Substrate	SiC	200-300 μm

Figure 2. Structure of the GaN epitaxial wafer.

► The circuit also needed stabilizing, since just using the transistor with a bias circuit was predicted to be unstable in the range 8–33GHz. This was achieved by adding decoupling capacitors and a stabilizing resistor for both gate and drain, rather than just the gate. Although adding resistance at the drain can reduce power efficiency, the researchers estimate that, under the given bias condition, the power consumed is less than 11mW.

Series and shunt CPW transmission lines were then added to conjugate match the source and drain impedances simulated for the transistor, bias and stabilizing elements. Electromagnetic simulation of the MMIC performance predicted a maximum gain of 8.1dB at 31.5GHz, which is lower than the 9.1dB at 32GHz for the schematic circuit simulation. The difference is attributed to losses in the passive components.

The MMIC was constructed at the CAS' Institute of Microelectronics on an epitaxial wafer (Figure 2) provided by the CAS' Institute of Semiconductors. The sheet resistance of this material was 370Ω/square.

The processing steps were similar to those used for creating standalone HEMTs: photolithography, etch, titanium-aluminum-nickel-gold ohmic contact metal evaporation, rapid thermal anneal, silicon nitride passivation, electron-beam lithography, dry etch, and T-shaped gate formation. Further processing involved CPW metallization, passivation and electroplating.

The final device (Figure 3) contained the designed MMIC, along with two test HEMTs and two test capacitors for verification/characterization of the discrete device performance. The whole chip measured 2.26mm x 2.36mm.

The researchers found that the gain and return-loss characteristics of the actual device were better at a source–drain bias (V_{ds}) of 10V, rather than the 30V of the design. Also, there was a shift in the optimum operation frequency, based on S-parameters, from the design's 32GHz to the range 26–27.5GHz. The peak gain at 26.5GHz was 6.38dB, about 1.7dB lower than that of the design.

The researchers give a number of possible reasons for the discrepancy between the device's actual and expected performance such as: the structure of the HEMT being different from the group's previous device on which the design was based (e.g. a 0.2μm larger gate head leading

Chinese Academy of Sciences researchers have extended their work on GaN high-electron-mobility capability in the Ka-band (26.5–40GHz) to monolithic microwave integrated circuits. "This is, to the best of our knowledge, the first demonstration of domestic Ka-band GaN amplifier MMICs."

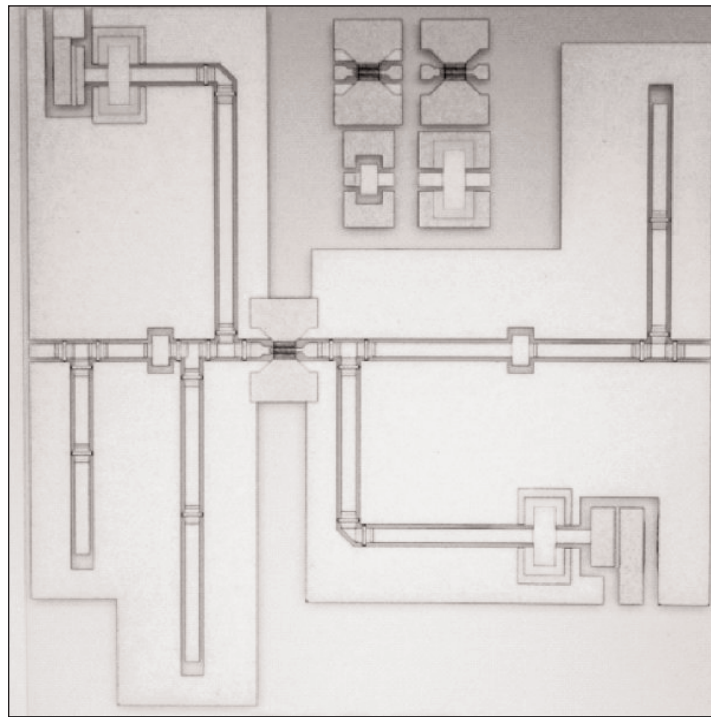


Figure 3. Photo of the Ka-band GaN amplifier MMIC.

to parasitic capacitance); the epitaxial structure was also somewhat different due to immaturity of the nitride semiconductor growth process (accuracy and stability need to be improved); losses due to metal–SiN insulator–metal capacitances; and finally the simulation software that was used is known to be inaccurate in the Ka-band.

Characterization of the test HEMT showed the cut-off frequency (f_T) to be only slightly lower than expected, but the maximum oscillation frequency (f_{max}) decreased from 120GHz to 91GHz. Also, the maximum stable gain was some 2dB down on the expected performance, with the degradation attributed to the larger gate head size.

Using a V_{ds} of 10V, a continuous-wave 26.5GHz signal showed linear gain of 6.3dB, maximum output power of 22dBm (158mW), and peak power-added efficiency (PAE) of 9.5%. The 'ultra-low' PAE is blamed on the lower operating voltage of 10V. This clearly needs to be improved, since a US Army Research Lab team reported in 2006 a peak PAE of 23% and a maximum output power of 4W for a nitride semiconductor MMIC operating at 35GHz.

The new results allowed the researchers to overcome their previous measurement limitations and estimate the maximum output power density in the Ka-band for their HEMTs: 158mW/150μm at 10V and therefore more than 3W/mm at 30V is expected.

The researchers comment: "For future Ka-band GaN MMIC fabrication, it is necessary to improve the consistency of the GaN epitaxial wafer, the stability of the process and the accuracy of the layout simulation." ■

<http://iopscience.iop.org/1674-4926/32/8/085011>

Author: Mike Cooke

InGaN/GaN DHBTs achieve cut-off of more than 5GHz

Georgia Tech researchers use graded emitter–base and base–collector to reduce V-defects and band discontinuity.

Georgia Institute of Technology has reported n-p-n indium gallium nitride/gallium nitride (InGaN/GaN) double-heterostructure bipolar transistors (DHBT) with relatively high collector current and frequency performance [Shyh-Chiang Shen et al, IEEE Electron Device Letters, vol32, p1065 August 2011]. The researchers comment on their work: “To the best of our knowledge, this letter is the first RF demonstration of GaN/InGaN HBTs with $f_T > 5\text{GHz}$.”

While nitride semiconductor high-electron-mobility field-effect transistors (HEMTs) have achieved kiloVolt breakdown voltages and cut-off frequencies of more than 200GHz, III-nitride bipolar transistors have shown less useful performance. Some progress has been made in producing reasonable DC characteristics such as high voltage, current gain and temperature performance in various n-p-n heterostructure transistor (HBT) and DHBT systems, for example, aluminum gallium nitride/gallium nitride (AlGaIn/GaN), InGaIn/GaN or pure GaN.

However, results published so far show particular weakness in terms of frequency and collector current performance. In efforts to improve this, the Georgia Tech researchers used techniques previously developed by some of themselves to reduce dislocation and V-defects in graded InGaIn DH structures. In particular, a graded base–emitter junction was used to avoid

Emitter	n-GaN, (n) $\sim 1 \times 10^{19}/\text{cm}^3$	70nm
Base-emitter junction	Graded InGaIn	30nm
Base	p-In _{0.03} Ga _{0.97} , (p) $\sim 1 \times 10^{18}/\text{cm}^3$	100nm
Base-collector junction	Graded InGaIn	30nm
Collector	n-GaN, (n) $\sim 1.0 \times 10^{17}/\text{cm}^3$	500nm
Sub-collector	n-GaN, (n) $\sim 3.7 \times 10^{18}/\text{cm}^3$	1000nm
Buffer	u-GaN	2500nm
Substrate	c-plane sapphire	

Figure 1. Epitaxial layer structure for DHBT.

While nitride semiconductor HEMTs have achieved kiloVolt breakdown voltages and cut-off frequencies of more than 200GHz, III-nitride bipolar transistors have shown less useful performance

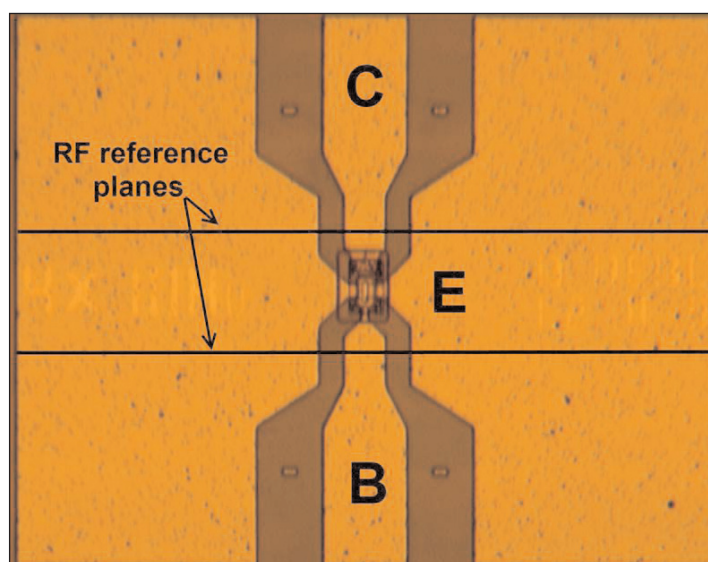


Figure 2. Microscope picture of fabricated GaN/InGaIn DHBT with emitter area $4\mu\text{m} \times 10\mu\text{m}$. The device is designed in common-emitter ground–signal–ground (G–S–G) coplanar waveguide (CPW) configuration for RF measurement.

V-defects. A graded base-collector junction was designed to eliminate the conduction band discontinuity between InGaN and GaN.

The InGaN DHBT structures (Figure 1) were grown on c-plane sapphire substrates using metal-organic chemical vapor deposition (MOCVD). A three-step mesa was etched with inductively coupled plasma (ICP) consisting of chlorine/helium to create emitter, base and isolation structures. Etch-induced surface damage was removed using dilute potassium hydroxide (KOH)/potassium persulfate ($K_2S_2O_8$) solution under ultra-violet illumination.

The base contact consisted of nickel-gold, while the emitter and collector contacts were titanium-aluminum-titanium-platinum and titanium-aluminum-titanium-gold, respectively. Benzocyclobutene (BCB) was used for passivation.

To access the emitter, base and collector contacts, holes were etched in the BCB using ICP. Device interconnects and RF probe pads consisted of titanium-gold (Figure 2).

Common-emitter DC characteristics of the $3\mu\text{m} \times 5\mu\text{m}$ emitter area device include a collector current of 2.4mA ($16\text{kA}/\text{cm}^2$) at a base current of $100\mu\text{A}$, giving a current gain of 24. The open base breakdown voltage was 95V at $1\mu\text{A}$ collector current.

RF measurements were performed on a $4\mu\text{m} \times 20\mu\text{m}$ emitter device, giving a 20dB extrapolation for the cut-off frequency (f_T) of 5.3GHz, at collector current density of $4.7\text{kA}/\text{cm}^2$ and collector-emitter voltage of 7V. Further study of the RF performance showed deviation from the usual 20dB fall-off at high frequency, partly due, it is thought, to capacitive coupling between emitter and collector.

The researchers comment: "This para-

Possible RF performance improvements for GaN/InGaN HBTs could include further reduction in the base resistance and growing these structures on substrates with better thermal conductivity to achieve higher-current operation. Sapphire is a poor base for devices that need to dissipate generated heat due to its very low thermal conductivity compared with silicon carbide, GaN, or even silicon

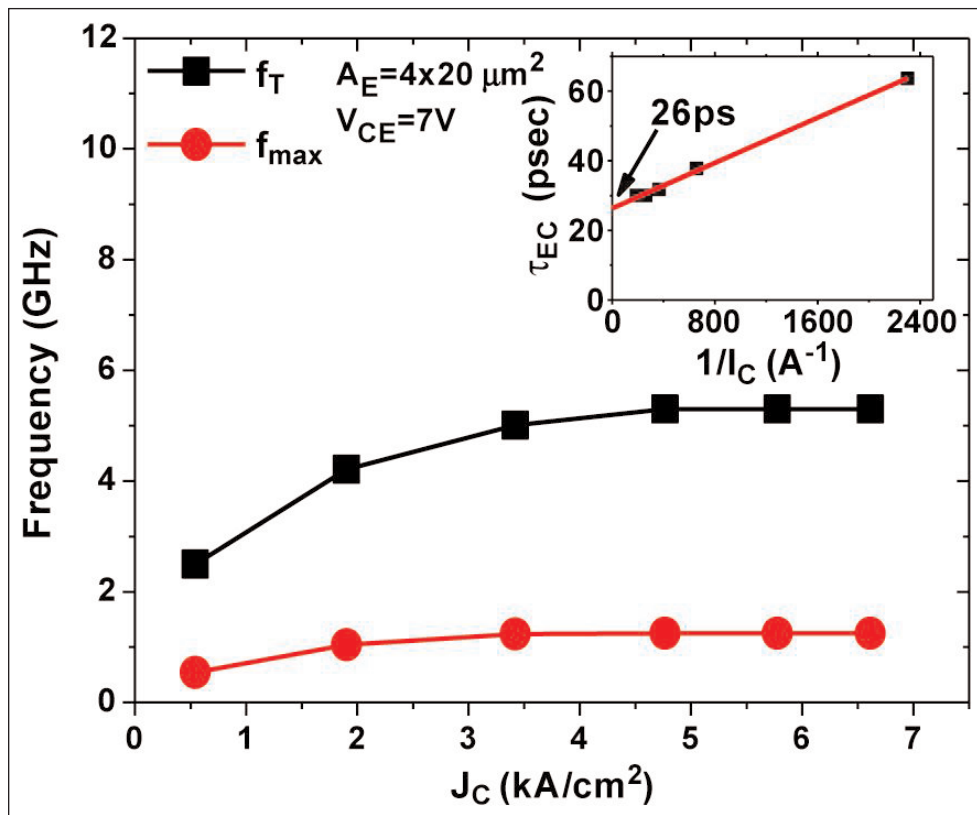


Figure 3. f_T and f_{max} of GaN/InGaN DHBT with emitter area $4\mu\text{m} \times 20\mu\text{m}$ at different collector current densities (J_C).

sitic component comes from the extensive overlay of the emitter ground-plane metal and the underlying thick (2500nm) unintentionally doped ($n \sim 10^{16}/\text{cm}^3$) GaN buffer layer that electrically connects to the sub-collector in the common-emitter CPW design."

The parameter (Mason's unilateral gain, U) used to determine a maximum oscillation frequency (f_{max}) of 1.3GHz also did not roll-off at the standard 20dB/dec, "because the curve is still transitioning from the low-frequency gain region to the high-frequency roll-off region before it reaches the unit-gain frequency".

The dependences of the cut-off/maximum oscillation frequencies on collector current were also explored (Figure 3). The values trend up with current, saturating after densities of around $5\text{kA}/\text{cm}^2$ and $3\text{kA}/\text{cm}^2$, respectively. The emitter-collector transit time (τ_{EC}) was derived from $1/(2\pi x f_T)$. The devices could only be run up to $7\text{kA}/\text{cm}^2$ due to thermal runaway effects and catastrophic damage at higher current.

The researchers say that possible RF performance improvements for GaN/InGaN HBTs could include further reduction in the base resistance and growing these structures on substrates with better thermal conductivity to achieve higher-current operation. Sapphire is a poor base for devices that need to dissipate generated heat due to its very low thermal conductivity compared with silicon carbide, GaN, or even silicon. ■

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Author: Mike Cooke

More positive threshold with Al_2O_3 and m-plane nitride semiconductors

UCSB/Rohm produce HFETs with +3V threshold voltage and on/off ratio of 4 million.

The University of California Santa Barbara (UCSB) and Japan's Rohm Co Ltd have produced enhancement-mode (E-mode) nitride semiconductor heterojunction field-effect transistors (HFETs) with a threshold voltage of +3V and on/off current ration of 4×10^6 [Tetsuya Fujiwara et al, Appl. Phys. Express, vol4, p096501, 2011]. Enhancement-mode, or 'normally-off', operation is seen as being particularly important for power switching devices because one wants such devices to switch off if they fail.

Nitride semiconductor HFETs (also known as high-electron-mobility transistors, HEMTs) usually operate in depletion-mode ('normally-on' at zero gate potential). A number of techniques have been used to shift the threshold in a positive direction, but the threshold voltage has fallen short of the +3V or more needed to choke off leakage currents at zero gate potential.

Most previous devices have used c-plane oriented crystal nitride semiconductor material where the difference in the c-direction polarization field between the gallium nitride (GaN) buffer and the aluminum gallium nitride (AlGaN) barrier layers creates a two-dimensional electron gas (2DEG) at the AlGaN/GaN interface that carries current at zero gate potential.

In 2009, UCSB researchers created an HFET with +2V threshold by using instead non-polar m-plane nitride crystal material to avoid these polarization fields. Now, the UCSB/Rohm group has added a layer of aluminum

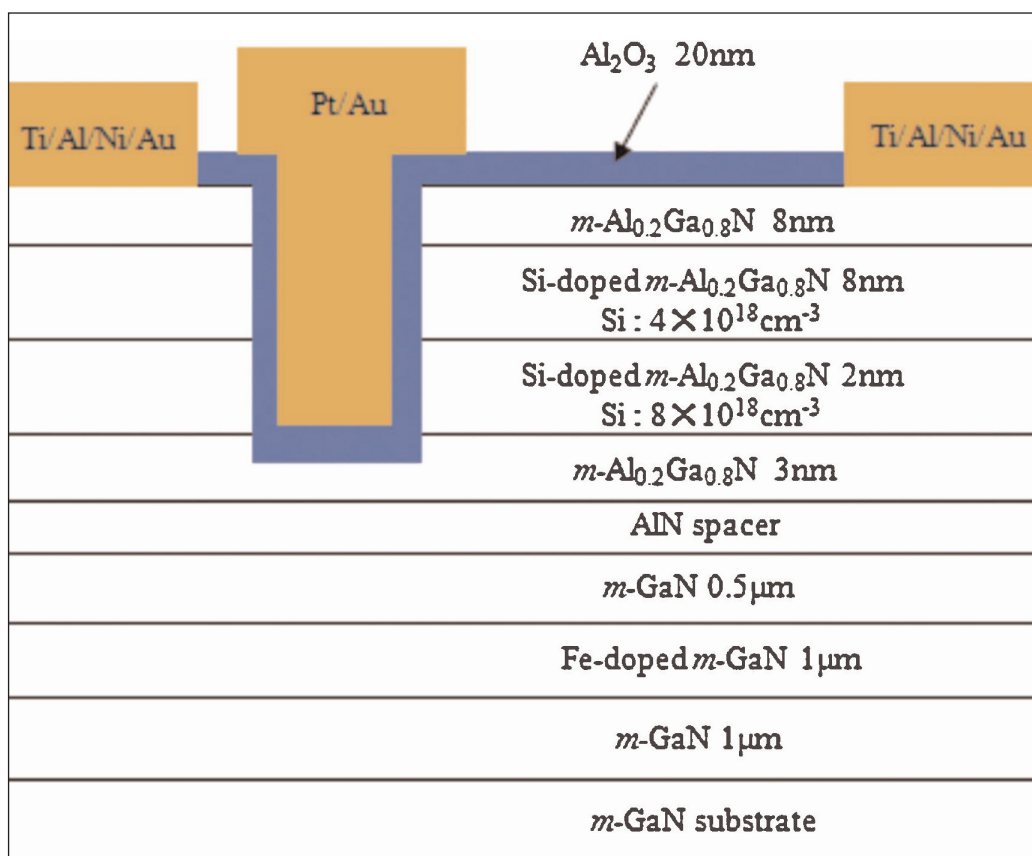


Figure 1. Schematic structure of UCSB/Rohm E-mode m-plane AlGaN/GaN HFET.

oxide to insulate the recessed gate from the channel region (Figure 1).

The devices were grown on m-plane GaN substrates using metal-organic chemical vapor deposition (MOCVD) and atomic layer deposition (ALD). Mitsubishi Chemical supplied the substrates. The semi-insulating iron-doped layer was achieved using the metal-organic bis(cyclopentadienyl)-iron. The ohmic titanium/aluminum/nickel/gold source-drain contacts were applied with electron-beam evaporation and subjected to rapid thermal annealing at 870°C for 30 seconds in nitrogen.

The recess for the gate was achieved with boron tetrachloride plasma etching. The Al_2O_3 dielectric was

then deposited. The platinum-gold gate metal was applied using e-beam evaporation. The dielectric was removed from the source-drain contact regions using a wet etch. The gate was $1\mu\text{m}$ long and $150\mu\text{m}$ wide. The source-drain spacing was $3.4\mu\text{m}$.

The contact resistance of $3\Omega\text{-mm}$ and sheet resistance of $2000\Omega\text{/square}$ were characterized using transmission line structures on the epitaxial material.

DC characterization (Figure 2) showed a threshold voltage of $+3\text{V}$ and maximum drain current ($I_{\text{ds(max)}}$) of 138mA/mm at a gate potential (V_{gs}) of $+7\text{V}$. The maximum transconductance of 45mS/mm occurred at V_{gs} of $+5\text{V}$. The researchers attribute the high positive threshold to the use of non-polar m-plane GaN, Al_2O_3 dielectric, and a recessed gate.

The sub-threshold performance was assessed at a source-drain potential (V_{d}) of 10V . The device is described as being completely off at V_{gs} of 0V with a leakage current (I_{off}) of $3.46 \times 10^{-8}\text{A/mm}$. The on/off ratio ($I_{\text{ds(max)}}$ / I_{off}) is thus 4×10^6 . The researchers say that this value is higher than that reported for other E-mode m-plane AlGaIn/GaN HFETs.

The on/off ratio is attributed to the use of m-polar GaN, the high dielectric constant of Al_2O_3 , and a low interface trap density.

The UCSB/Rohm researchers say that no data had been previously presented on the interface properties of Al_2O_3 and m-plane nitride semiconductor material. Therefore, the team first carried out photo-assisted capacitance-voltage (C-V) measurements to assess the quality of the Al_2O_3 interface with m-plane GaN.

MOCVD was used to create $1\mu\text{m}$ of unintentionally doped GaN, $0.5\mu\text{m}$ $3 \times 10^{18}/\text{cm}^3$ silicon-doped n-GaN, and $0.3\mu\text{m}$ $3 \times 10^{17}/\text{cm}^3$ silicon-doped n-GaN.

Most previous devices have used c-plane oriented crystal nitride semiconductor material where the difference in the c-direction polarization field between the GaN buffer and the AlGaIn barrier layers creates a 2DEG at the AlGaIn/GaN interface that carries current at zero gate potential. In 2009, UCSB researchers created an HFET with +2V threshold by using instead non-polar m-plane nitride crystal material to avoid these polarization fields

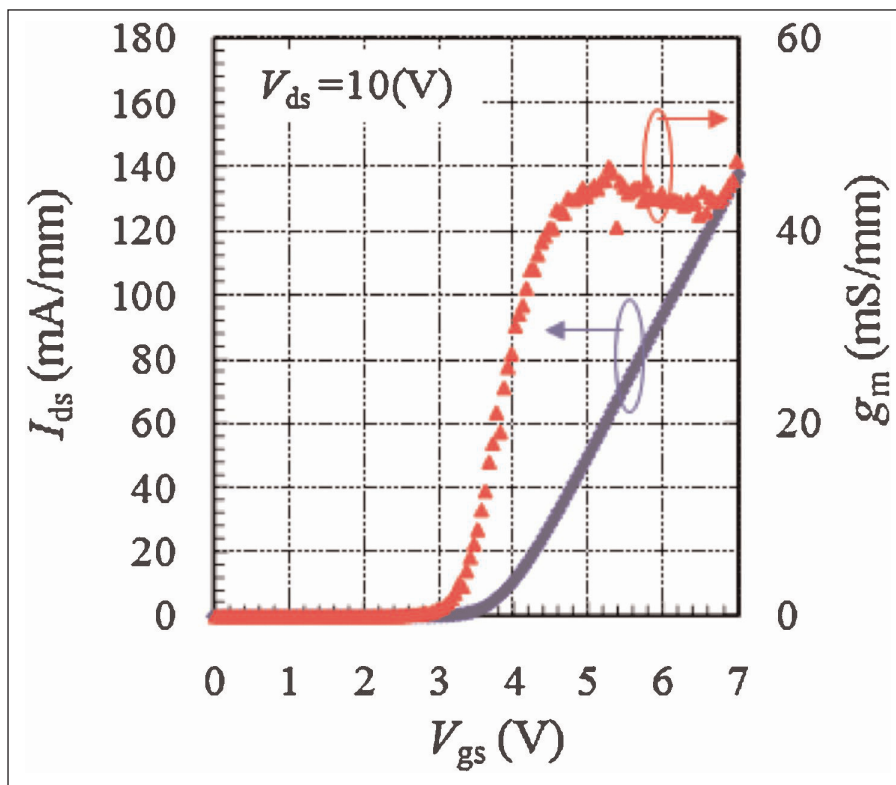


Figure 2. Transfer characteristics at a source-drain voltage of 10V for UCSB/Rohm E-mode m-plane AlGaIn/GaN HFETs.

The Al_2O_3 ALD (in both the interface characterization and in the final HFET) was preceded by a hydrochloric acid treatment at room temperature. The 20nm Al_2O_3 layer was deposited in two stages: 2nm at 200mTorr and then 18nm at 20mTorr . The higher-pressure step (with hydrogen/argon carrier) has been found to reduce the subthreshold slope properties of the structure from 270mV/decade to 170mV/decade . The lower pressure deposition used a pure argon carrier.

The sample was annealed at 400°C in $10\%/90\%$ hydrogen/nitrogen forming gas. A titanium-gold contact was used on the Al_2O_3 and an aluminum-gold contact was recessed into the n-GaN layers.

The density of traps between 0.2eV and 0.6eV from the conduction is estimated at $1\text{--}2 \times 10^{12}/\text{cm}^2\text{-eV}$. The researchers comment: "This value is almost comparable with reported values of $\text{Al}_2\text{O}_3/\text{c-plane GaN}$ ".

There is a peak of $5 \times 10^{12}/\text{cm}^2\text{-eV}$ around 0.9eV that is attributed to holes that can be generated by the ultraviolet (UV) radiation used in the C-V measurements. The UV light source had wavelength peaks at 365nm , 405nm , and 436nm . These peaks are the i-, h- and g-lines, respectively, of the mercury emission spectrum.

Financial and other support for the work came from UCSB's Solid State Lighting and Energy Center, US Office of Naval Research (ONR), DRIFT, and the UCSB nanofabrication facility (which is part of the US National Nanotechnology Infrastructure Network). ■

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Author: Mike Cooke

Passivated AlInN/GaN HEMT pushes past 200GHz cut-offs

Switzerland-based research characterizes 30nm-gate-length high-electron-mobility transistor with cut-off frequency of 205GHz.

Researchers in Switzerland report the first realization of fully passivated aluminum indium nitride on gallium nitride (AlInN/GaN) high-electron-mobility transistors (HEMTs) with cut-off frequencies in excess of 205GHz [Stefano Tirelli et al, IEEE Electron Device Letters, published online 15 August 2011]. The work was based at ETH Zürich's Millimeter-Wave Electronics Group and the Institute of Quantum Electronics and Photonics of École polytechnique fédérale de Lausanne (EPFL).

AlInN growth has been developed and improved as a promising barrier component in HEMT structures, allowing smaller devices compared with aluminum gallium nitride (AlGaN) barriers. AlInN allows higher electron densities to form at the barrier/buffer interface and has less surface depletion effects than AlGaN. This allows thinner barrier layers to be used, so that the need for recess etching to bring the gate contact closer to the channel region of the device is avoided. Etching can damage device performance and reliability.

Early work on AlInN/GaN HEMTs has tended to use unpassivated devices to show the possibility of the technology, since passivation increases parasitic capacitance effects. However, for long-term reliability and control of surface states, passivation layers are needed.

RF measurements were carried out up to 40GHz. De-embedding of the effect of the contacts was carried out to give cut-off (f_T) and maximum oscillation (f_{MAX}) frequencies of 205GHz and 220GHz, respectively, at drain and gate biases of 5V and -5.4V, respectively. Increasing the drain bias to 6V allowed an even higher

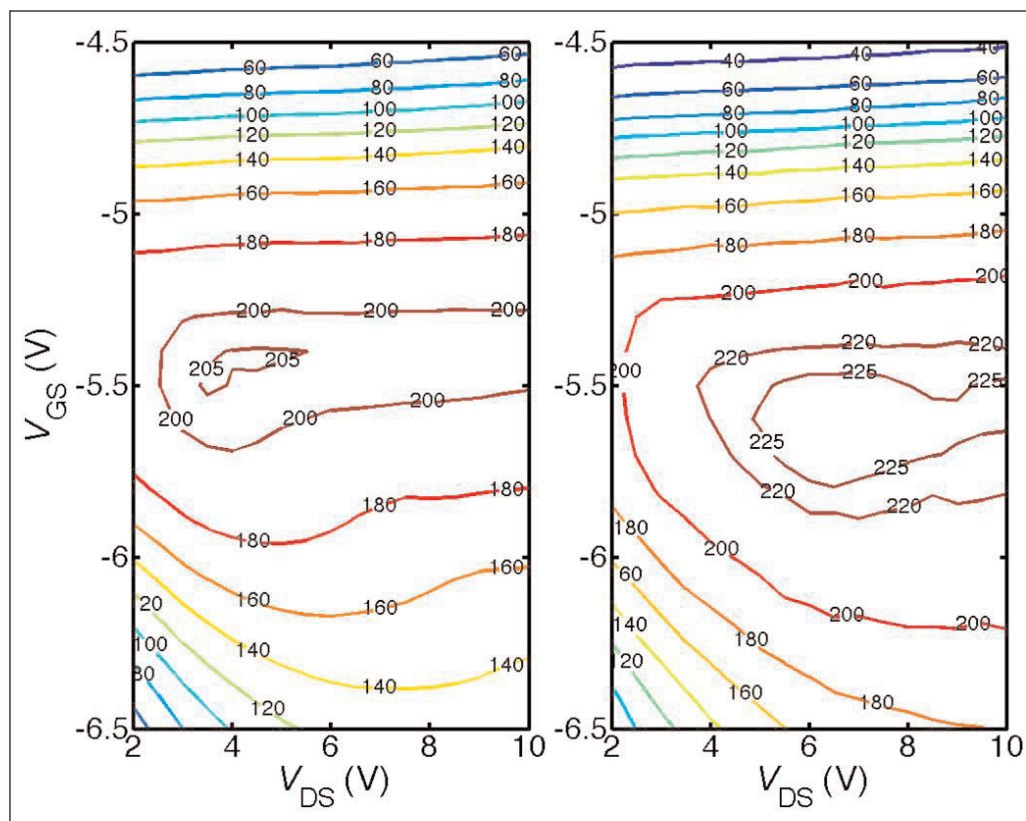


Figure 1. Drain (V_{DS}) and gate (V_{GS}) bias dependence of f_T (left) and f_{MAX} (right). The values are shown in gigahertz on the contour maps.

f_{MAX} of 230GHz with a gate potential of -5.6V. Around gate potentials of -5.5V, f_T and f_{MAX} remain above 200GHz (Figure 1) for a broad range of drain bias conditions (2.5–10V).

Previous work with 100nm-gate-length passivated AlInN/GaN HEMTs had f_T/f_{MAX} values of 144/137GHz. The researchers comment that, even with a thin passivation, the gate length (L_G) must nearly be halved compared with the 55nm unpassivated devices in their previous work to maintain f_T above 200GHz in a passivated HEMT.

MIT/Notre Dame recently produced unpassivated devices with 30nm gate that had f_T/f_{MAX} values of 245/13GHz.

Comparing their small-signal model with that of a device with low-resistance re-grown ohmic contacts resulting in f_T/f_{MAX} of 220/289GHz produced by

HRL Laboratories in the USA, the Swiss researchers believe that their device's f_T performance is limited by the relatively large gate-channel distance, resulting in restricted transconductance.

The HEMT epitaxial layers (Figure 2) were grown at EPFL on semi-insulating silicon carbide (SiC). The gate-to-channel distance was 11nm (1nm+8nm+2nm). The GaN cap was added to reduce gate leakage currents.

The ohmic source-drain contacts consisted of evaporated titanium-aluminum-molybdenum-gold, rapidly thermal annealed at 860°C. The contact resistance was measured at 0.3Ω-mm with a channel sheet resistance of 180Ω/square. The device regions were isolated using a phosphorus/helium ion implant.

T-shaped gates were formed using a three-layer electron-beam lithography process. The gate was 100μm wide with two fingers extending from a central contact (2x50μm). The gate was placed in the middle of the 1μm source-drain gap. The T-head of the gate was 400nm, while the base was 30nm. In fact, the actual cross-section of the gate was more Y-shaped (Figure 3). The metal structure of the gate was nickel-platinum-gold, giving a Schottky junction with the underlying semiconductor.

The device was then passivated with a 60nm layer of silicon nitride, deposited using plasma-enhanced chemical vapor deposition (300°C). The contacts were accessed using a sulfur hexafluoride plasma etch. The overlay wiring and measurement pads consisted of titanium-copper-gold.

DC measurements gave an extrinsic transconductance peak of 462mS/mm at drain bias 1V. The gate leakage with the gate at -7V was 4.4μA/mm at 0V drain, rising to 10μA/mm at 10V drain. These performance figures are comparable to those recently achieved by the group without passivation or GaN cap layer. The on-resistance was

AlInN allows higher electron densities to form at the barrier/buffer interface and has less surface depletion effects than AlGaN. This allows thinner barrier layers to be used, so that the need for recess etching to bring the gate contact closer to the channel region of the device is avoided. Etching can damage device performance and reliability

Cap	GaN	2nm
Barrier	AlInN (13.4% In)	8nm
Spacer	AlN	1nm
Buffer	GaN	2μm
Nucleation	AlN	70nm
Substrate	SiC	

Figure 2. Schematic of epitaxial layers used for HEMT.

1.1Ω-mm, with more than two-thirds of this coming from the contacts. The maximum drain current at 0V gate potential was 2.18A/mm.

Channel pinch-off is not achieved with higher drain bias. This is attributed to drain-induced barrier lowering associated with the gate-length/gate-channel-distance ratio of 2.7 (= 30/11). Pulse current-voltage (500ns) measurements at gate potentials of 0V and -6V show less than 30% current reduction. The 'quiescent' period corresponds to gate and drain potentials of -8V and 8V, respectively. The researchers comment: "Collapse is moderate, considering that the 30nm-gate devices are stressed with 16V of quiescent reverse GD bias." ■

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Author: Mike Cooke

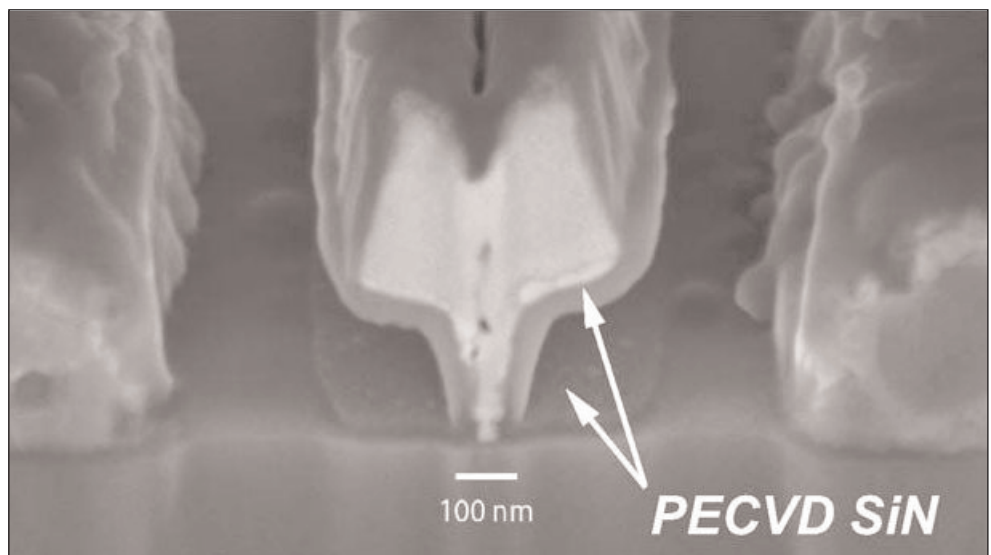


Figure 3. Micrograph of reported device after focused-ion beam (FIB) cut. Partial removal of SiN in proximity of ohmic contacts is an artifact of the FIB preparation process. HEMTs were fully covered for the measurements.

First noise assessment of AlN/GaN HEMTs on silicon

Researchers see results as being “highly favorable for circuit designs”, due to growth on low-cost silicon substrates.

France’s Institute of Electronic, Microelectronic and Nanotechnology (IEMN) has given the first evaluation of the noise performance of its aluminum nitride/gallium nitride (AlN/GaN) on silicon high-electron-mobility transistors (HEMTs) [F. Medjdoub et al, IEEE Electron Device Letters, published online 8 August 2011].

IEMN reported its novel approach to producing higher-performing nitride HEMTs on low-cost silicon substrates a couple of months ago (for further details, see Semiconductor Today reports in June 2011, for example, www.semiconductor-today.com/news_items/2011/JUNE/IEMN_210611.html).

In the new work, the noise performance was tested between 8GHz and 18GHz (Figure 1). At the optimum bias (drain-source V_{DS} , of 4V and gate-source V_{GS} , of 1.5V), the minimum noise figure (NF_{min}) was about 1dB with associated gain (G_A) of more than 11dB up to 12GHz. At 18GHz, NF_{min} was 1.8dB and G_A 10dB. The researchers comment: “These data are comparable to the best reported GaN-on-Si HEMT values”. The occurrence of the minimum noise figure under the same bias conditions as the maximum associated gain is “highly favorable for circuit designs”.

The equivalent noise resistance was 45–41 Ω in the range 8–18GHz, “even lower than the state-of-the-art 0.1 μ m GaN-on-Si HEMTs and indicates an excellent potential for broadband low-noise amplifiers”.

This performance is achieved despite the higher self-heating effects that are due to the lower thermal conductivity of silicon compared with silicon carbide (SiC) substrates. Also, SiC has a smaller mismatch in lattice parameter than silicon for growth of GaN. Lattice mismatch creates defects that can lead to parasitic electrical conduction at the substrate buffer interface.

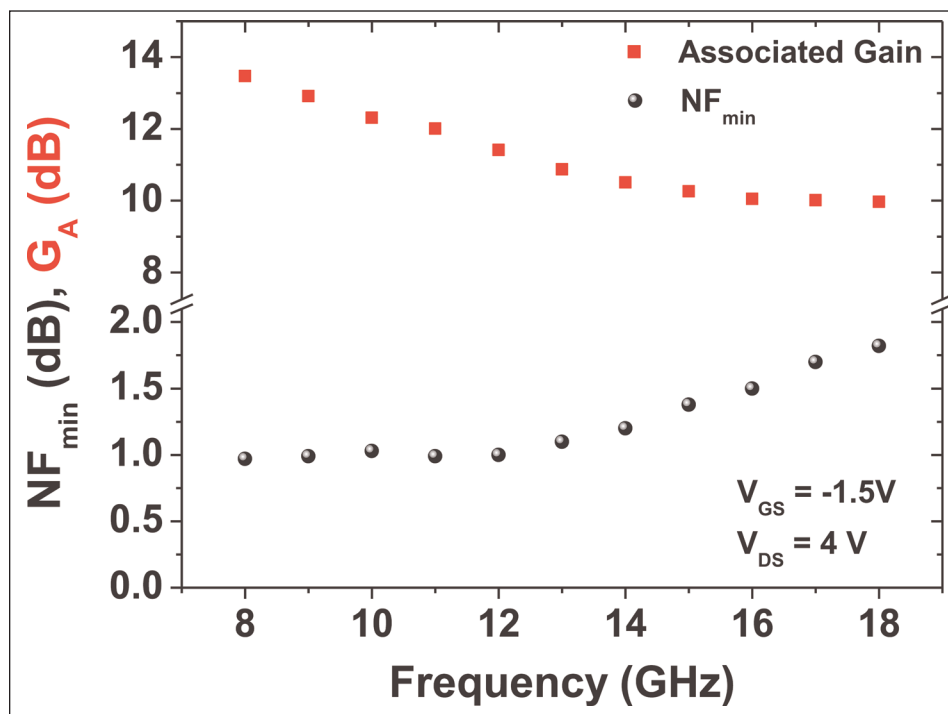


Figure 1. Associated gain and minimum noise figure as function of frequency biased at V_{GS} of -1.5V and V_{DS} of 4V at room temperature.

The researchers attribute its results to the high transconductance and the low gate leakage current found in its AlN/GaN/Si devices. They comment: “In addition, further improvement of the fairly high contact resistances and the reduction of the gate length should definitely enable sub-1dB microwave noise performance”. IEMN thus sees AlN/GaN HEMTs as being “an excellent candidate for the next generation of millimeter-wave monolithically integrated circuits”.

High-resistive silicon was used as substrate (5000 Ω -cm, 4-inch wafer). The device layers, up to and including the in-situ silicon nitride (Figure 2), were grown with metal-organic chemical vapor deposition (MOCVD) by EpiGaN. The titanium-aluminum-nickel-gold ohmic contacts were formed by etching down to the AlN barrier layer. The contacts were annealed in an 850 $^{\circ}$ C rapid thermal process in nitrogen. Nitrogen ion implantation was used to isolate devices. Plasma-enhanced chemical vapor deposition (PECVD) of silicon nitride was then performed. ▶

► The nickel-gold gate was formed by electron-beam lithography and etching through the SiN with sulfur hexafluoride plasma. A field-plate extension of $0.2\mu\text{m}$ toward the drain was used to modify the electric field in the device. The gate length was $0.16\mu\text{m}$. The gate-source and gate-drain distances were $0.3\mu\text{m}$ and $1\mu\text{m}$, respectively. The device width was $50\mu\text{m}$ ($2\times 25\mu\text{m}$).

The maximum current density at 2V gate potential was 1.97A/mm . The gate leakage was less than $100\mu\text{A}$ up to 80V reverse bias. This low value is attributed to the high barrier provided by the use of high-quality AlN and the presence of the in-situ SiN cap that gives a robust surface, avoiding gate tunneling at high field. The 1mA/mm gate-drain breakdown voltage is more than 100V.

The extrinsic transconductance peaks at 606mS/mm with the source-drain potential at 4V and the source-gate at -1.5V . This high value is credited on the short gate-channel distance and the high drain current density.

Extrapolation of the S-parameters at optimum bias measured between 1GHz and 50GHz give current gain extrinsic cut-off (f_T) and maximum oscillation (f_{max}) frequencies of 85GHz and 103GHz, respectively.

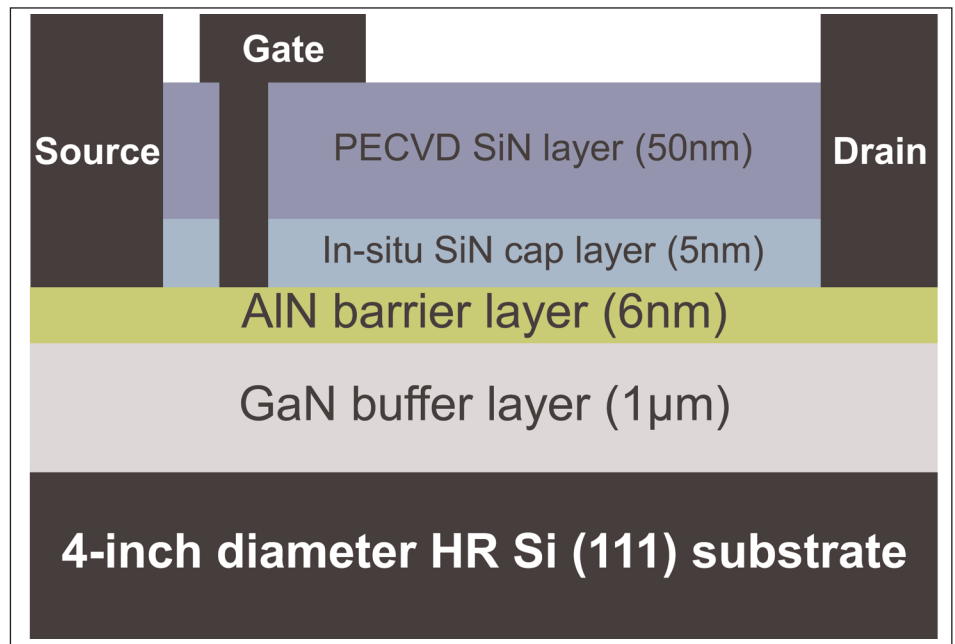


Figure 2. Schematic cross-section of fabricated AlN/GaN-on-Si HEMTs.

The field plate impacts the f_{max} value by increasing the gate-drain capacitance. The cut-off gate-length product ($f_T \times L_g$) value of $13.6\text{GHz}\cdot\mu\text{m}$ gives hope of very high-frequency operation with downscaling. The high current density and breakdown voltage should also enable the researchers to access high output power performance. ■

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Metal-nitride semiconductor avalanche for UV detection

Chinese group produces first MSM APDs on free-standing GaN with 400 μm x 400 μm effective area

Researchers in China have reported the first demonstration of a gallium nitride (GaN)-based planar metal-semiconductor-metal avalanche photodiode (APD) sensitive to ultraviolet light [F. Xie et al, *IEEE Electron Device Letters*, published online 14 July 2011]. The research group consisted of scientists from Nanjing National Laboratory of Microstructures, the Jiangsu Provincial Key Laboratory of Advanced Photonic and Electronic Materials, and Nanjing University.

The researchers used conductive free-standing bulk GaN substrates created via hydride vapor phase epitaxy (HVPE) to improve material quality. These substrates are much more expensive than the sapphire substrates used commercially as a base for nitride growth. However, as techniques develop it is to be hoped that free-standing GaN will drop in price. By using such substrates, the researchers were able to make devices with 400 μm x 400 μm effective device area, which is claimed to be the largest for GaN-based APDs so far reported.

Avalanche photodiodes work in a reverse-bias state, where a photon that is absorbed produces an electron-hole pair, the electron of which then accelerates in the high bias field and goes on to create further electrons by impact ionization. Gallium nitride has a wide bandgap of about 3.4eV that makes it sensitive to ultraviolet light with wavelengths greater than 365nm.

It is important in such devices that dark current and premature breakdown microplasma effects be reduced. As usual, these problems in nitrides are linked to material quality. The most commercial technique at present for producing nitride semiconductor devices is to grow the material on sapphire substrates. However, such growth results in many dislocations and other defects. The presence of defects restricts the area of devices that can be achieved, usually to less than 100 μm in diameter.

The free-standing substrates used for the Chinese research were 320 μm thick and had a room-temperature conductivity of $\sim 0.01\sigma\text{-cm}$. Metal-organic chemical vapor deposition (MOCVD) homoepitaxy

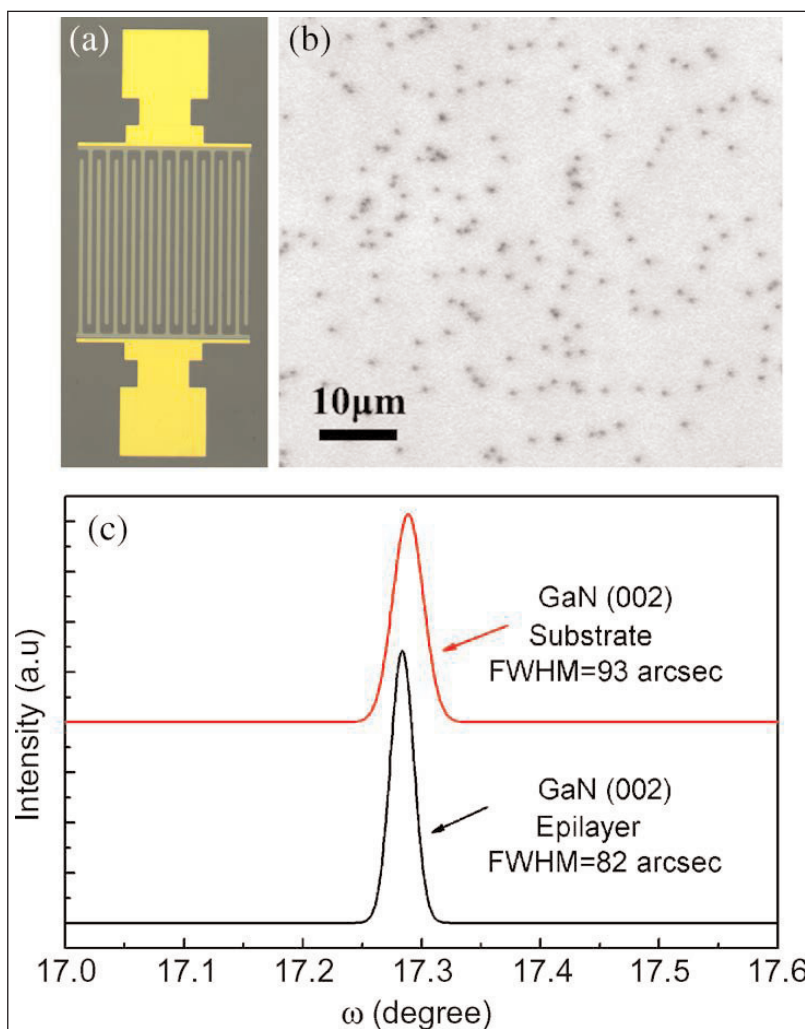


Figure 1. (a) Photograph of the GaN MSM APD. (b) Panchromatic CL mapping image of homoepitaxial GaN layer grown on bulk GaN substrate. (c) GaN (002) XRD rocking curves of the original bulk GaN substrate and the homoepilayer.

added a 1 μm heavily n-type GaN buffer layer, followed by a 3 μm n-type GaN active layer.

The dislocation density in the GaN layer was measured via cathodoluminescence (Figure 1b) as $5 \times 10^6/\text{cm}^2$, which compares very favorably with values of $10^8\text{--}10^{10}/\text{cm}^2$ normally found with GaN layers grown on sapphire and silicon carbide substrates (heteroepitaxy).

X-ray diffraction (XRD) rocking curves confirmed the material quality with low full-width at half maximum (FWHM) values for the (002) peak of the epilayer and

substrate (Figure 1c). The smaller FWHM of the epilayer indicates that it is of higher crystal quality than the substrate. Atomic force microscopy (AFM) measurements over a square region of $5\mu\text{m}$ gave a surface roughness of $\sim 5\text{nm}$.

Another problem with nitride diodes is producing p-type material, since the main technique for this — magnesium doping — is not that effective, compared with the silicon doping used to provide n-type material. Avalanche photodiodes that use p-type/intrinsic (i.e. no doping)/n-type (p-i-n) structures produced on free-standing GaN have achieved 10^4 multiplication gain. However, the presence of the acceptor levels in the p-type material leads to an enhanced red-shift of the absorption edge of the device at high reverse bias.

The Chinese group used metal–semiconductor–metal structures instead, depending on the Schottky diode rectifying effect that occurs at metal–semiconductor interfaces. Interdigitated Schottky electrodes were defined by photolithography and lift-off (Figure 1a). The electrodes used a semi-transparent nickel-gold (5nm/5nm) stack. The electrode fingers were $10\mu\text{m}$ wide and $400\mu\text{m}$ long. The spacing was $10\mu\text{m}$. An evaporated 200nm titanium-gold layer was patterned into contact pads.

Dark current and photocurrent under $6.5\mu\text{W}/\text{mm}^2$ 365nm UV illumination were measured (Figure 2). The dark current at 20V bias was 8.8pA ($1.4 \times 10^{-9}\text{A}/\text{cm}^2$ density). At higher bias there is a rapid increase in dark current that could be attributed to bulk dislocation defects or surface states that remain in the GaN crystal. The photocurrent tends to saturate around 20V.

Device simulations were used to estimate the critical electric field where breakdown begins, giving a value of 3.4MV/cm... The researchers believe they could improve the gain and stability of the avalanche breakdown with a new device design. Such a design would aim to create more uniform avalanche breakdown beneath the semi-transparent cathode, possibly using field-averaging schemes such as through adding a field-plate to modify the electric field pattern in the GaN material

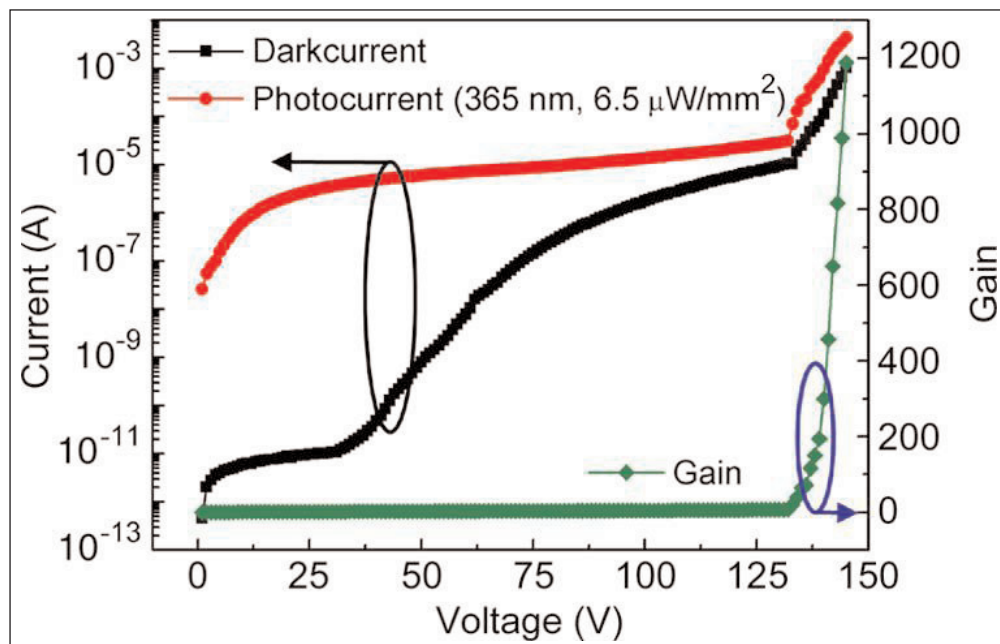


Figure 2. Current vs voltage (I–V) characteristics of APD measured under dark and under 365nm light illumination. Calculated avalanche gain of APD as function of bias is also shown.

At around 130V avalanche breakdown begins, as shown by increases in both photo- and dark-current. The gain was calculated based on the current values at 20V, where saturation of the unmultiplied photocurrent occurs. The gain at 145V is estimated to be 1188, which is a lower value than some GaN p-i-n APDs reported.

The cut-off of photo-response occurs around a wavelength of about 365nm that corresponds to the energy bandgap of the GaN material ($\sim 3.4\text{eV}$). As the bias increases, there is an undesired red-shift of the cut-off, probably due to the Franz–Keldysh effect where the electron and hole wavefunctions become modified by the electric field so they can overlap and couple with photons in classically forbidden areas. The rejection ratio of 360nm UV over 450nm blue light is $\sim 10^5$ at 20V bias. Variation of the performance with temperatures up to 425K was used to rule out other mechanisms for the photo-multiplication such as temperature-insensitive Zener tunneling.

Device simulations were used to estimate the critical electric field where breakdown begins, giving a value of 3.4MV/cm, agreeing with the theoretical breakdown field of GaN. The researchers believe they could improve the gain and stability of the avalanche breakdown with a new device design. Such a design would aim to create more uniform avalanche breakdown beneath the semi-transparent cathode, possibly using field-averaging schemes such as through adding a field-plate to modify the electric field pattern in the GaN material. ■

<http://dx.doi.org/10.1109/LED.2011.2160149>

Author: Mike Cooke

Record output for single-chip 262nm mid-UV LED

Crystal IS and US ARL approach power needed for specialized use.

Crystal IS Inc of Green Island, NY, USA and US Army Research Laboratory (ARL) claim record output power for single-chip ultraviolet (UV) LEDs with peak wavelength less than 265nm [James R. Grandusky et al, Appl. Phys. Express, vol4, p082101, 2011]. The researchers say that their measurement of 72mW at 1.7A of partial output power from a device emitting around 262nm corresponds to more than 100mW total when corrected for the fact that the set-up did not measure all the light coming out of the device.

The team comments: "The results presented in this letter are approaching the output power and efficiency needed to begin replacing current mid-ultraviolet sources in specialized applications."

LEDs for the mid-UV range of 250–275nm are being developed with a view to the replacement of mercury-lamp systems that are bulky, fragile, contain hazardous material, and have long warm-up times. The first application in sight is mid-UV disinfection systems, where the light is used to kill microbes in water and on surfaces.

Other possible uses include biological analyses and other instrumentation. Near-UV LEDs between 300nm and 400nm are presently used for bio-detection because they produce much more power than the mid-UV devices developed so far, but shorter wavelengths are more efficient in showing up biological particles through fluorescence techniques.

As usual, the challenges for producing efficient LEDs center on the need for high-quality nitride semiconductor material with low defect density and high hole carrier density, and on efficiently extracting the light that is produced. For devices emitting wavelengths shorter than 275nm, external quantum efficiencies (EQEs) have so far been limited to less than 2%.

The researchers used the same epitaxial material and fabrication techniques as in work carried out by Crystal IS in 2010 [James R. Grandusky et al, Appl. Phys. Express, vol3, p072103, 2010]. MOCVD was used on AlN substrates to create the pseudomorphic (strained) epitaxial material (Figure 1).

The multi-quantum well (MQW) light-emitting region consisted of a 5-period structure of n-Al_{0.7}Ga_{0.3}N barriers and Al_{0.55}Ga_{0.45}N wells. The electron-blocking layer (EBL) was Al_{0.8}Ga_{0.2}N. The large 2.4% lattice mismatch of the final p-GaN layer with the pseudomorphic AlGaIn was bridged by interrupting the growth and re-initiating

p-GaN	contact
Al _{0.8} Ga _{0.2} N	EBL
5x(Al _{0.55} Ga _{0.45} N/Al _{0.7} Ga _{0.3} N)	MQW
n-Al _{0.7} Ga _{0.3} N	contact
AlN	buffer
AlN	c-plane substrate

Figure 1. Epitaxial structure used in UV LED.

in a Stranski–Krastanov mode where the first islands of GaN form that coalesce to create thick layers. This last layer therefore had a higher dislocation density ($\sim 10^{10}/\text{cm}^2$) than the rest of the material.

An interdigitated mesa with an area of 0.0037cm² and a maximum width of 100μm was etched in the 820μm x 820μm square chips using inductively coupled plasma. The n-contact consisted of titanium-aluminum-titanium-gold and the p-contact consisted of nickel-gold. Further processing consisted of flip-chip bonding to a patterned AlN ceramic submount with gold-tin solder, mounting on a copper stud in a lead frame package, and wire bonding to form the electrical contacts. A 48-hour burn-in process at 100mA was performed to weed out unstable, short-lifetime devices.

The turn-on voltage of the device $\sim 5\text{V}$ was close to the ideal value of 4.7V. A quasi-continuous wave (CW) 400 millisecond measurement without heat-sink gave output powers of 2.1W at 20mA and 9.2mW at 100mA.

Further measurements in full CW and high current modes were made with a heat-sink. Unfortunately, the heat-sink was too big for the integrating sphere, so these measurements could not gather all the light emitted.

Comparing the output powers in CW on heat-sink operation with the quasi-CW at 20mA and 100mA gave ratios of 67.4% and 68.5%. The approximate constancy of this ratio suggests that the difference is due to light missing from the measurement without integrating

sphere rather than from self-heating effects. Also, calculations based on the emission pattern of such LEDs suggest that $\sim 73\%$ of light should be collected without integrating sphere, which is close to the 67–69% measured.

Spectral measurements show a peak at 262nm with a full-width at half-maximum of less than 10nm for currents as low as 5mA.

External quantum efficiency (EQE) and wall-plug efficiency (WPE) efficiency were also measured (Figure 2). The peak EQE was 1.48% at 20mA, falling off to 1.33% at 100mA. "The high EQE at low current densities is due to the low dislocation density in the material and the high IQE of the structures grown pseudomorphically on AlN substrates," the team comments. The WPE peaks at the lowest current, being above 1% at 20mA and falling to 0.8% at 100mA. "The decrease in the WPE efficiency is due primarily to the decrease in electrical efficiency as the current is increased."

Pulsed measurements (100 μ sec, 0.5% duty cycle) in the same configuration as in CW testing (with heat-sink) were carried out up to 1.7A (Figure 3). Output power at 100mA was 6.5mW, an increase of only 3% over the CW case. This indicates good thermal management of the device for CW operation at these current levels. Increased current leads to less output than expected from linear extrapolation (sub-linear). The researchers note that such decreases in efficiency (droop) are seen in visible nitride LEDs.

The highest output power was 72mW at 1.7A. Correcting for the absence of an integrating sphere would give an estimated output power of more than 100mW.

The researchers also measured thermal characteristics of the device by placing the LED on a thermoelectric cooler that was operated in reverse to heat the junction up to 50°C. The characteristic temperature (T_c) for the reduction of power output with heating was 983K. A high value of this parameter indicates a slower fall-off in performance with heating. InGaN LEDs have achieved values up to 1600K, but up to now AlGaIn LED devices emitting 265nm UV have been reported with values in the range 31–73K.

"The high T_c reported here is consistent with the fact that the pseudomorphic UV LEDs have both low dislocation density as well as good carrier localization in the quantum wells," the researchers say. "The high characteristic temperature of 983K was instrumental in achieving these record output powers for an

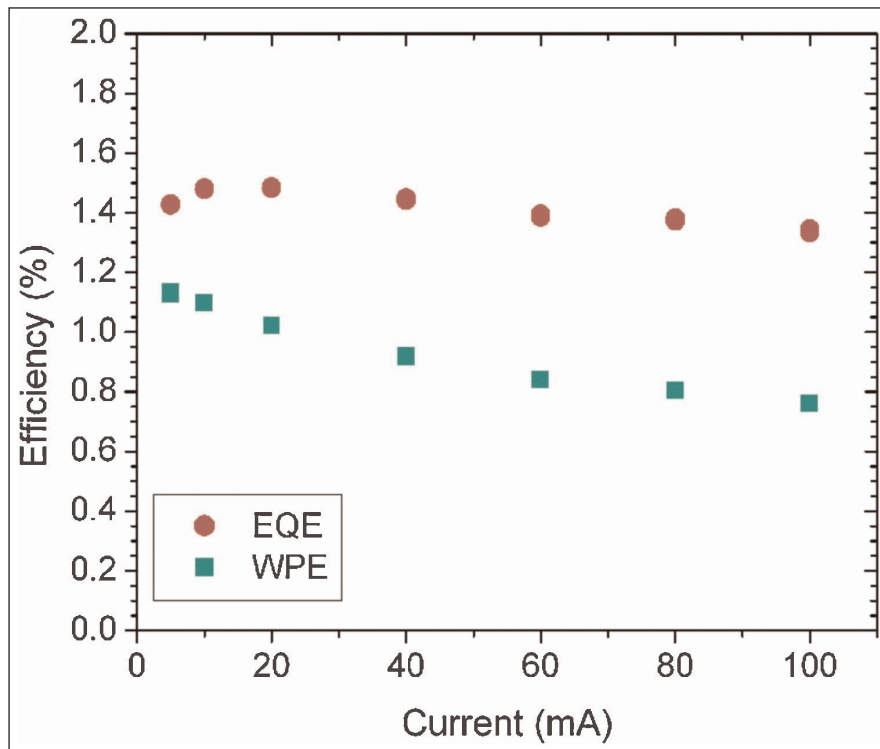


Figure 2. EQE and WPE from 5 to 100mA.

LED with wavelength shorter than 265nm."

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Author: Mike Cooke

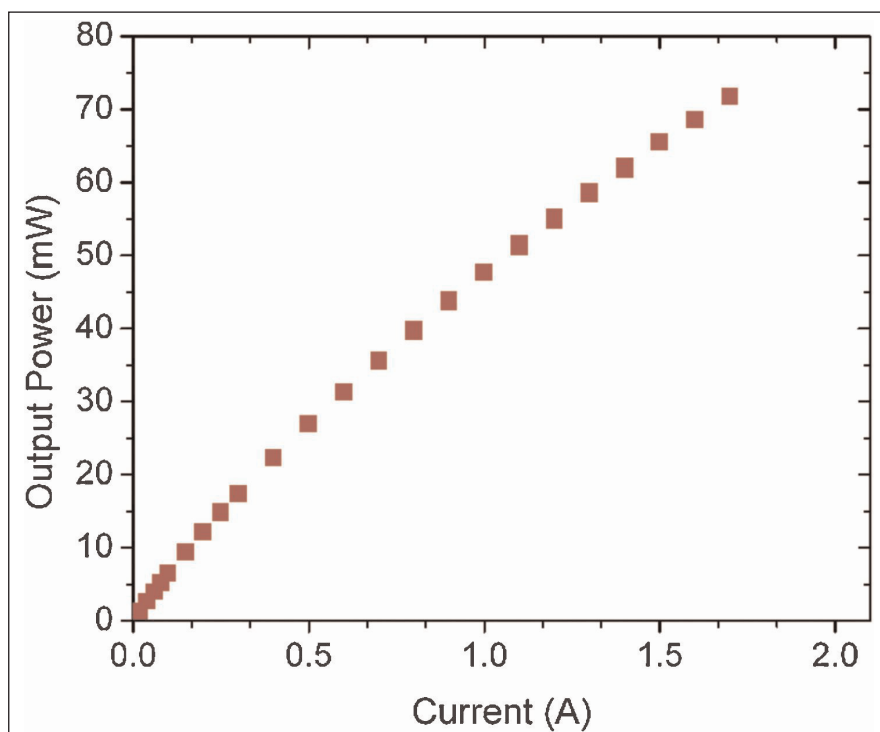


Figure 3. Output power as function of current for the device operated in pulsed mode with a 100 μ s pulse and 0.5% duty cycle.

Nitrogen/oxygen plasma improves p-type MgZnO for zinc oxide UV LEDs

LEDs produced with 35x the intensity of devices produced with nitrogen-only plasma at 20mA.

Stanley Electric Co Ltd. in Japan has reported double-heterostructure light-emitting diodes (DH-LEDs) using zinc oxide (ZnO) and magnesium zinc oxide (MgZnO) layers [Hiroyuki Kato et al, Appl. Phys. Express, vol4, p091105, 2011]. The researchers also developed an improved technique for nitrogen doping, involving a nitrogen/oxygen plasma, to increase hole carrier densities in the p-type layers.

At 20mA, the intensity of the nitrogen/oxygen LED was 35x that of a nitrogen-only device. The researchers estimated the output power at 20mA for the nitrogen/oxygen LED at 30 μ W, by comparing with a gallium nitride (GaN) semiconductor device. Clearly, much work is still needed, since GaN devices tend to be rated in milli-Watts, not micro-Watts.

Although ZnO is an attractive material in terms of cost, as a semiconductor material the major drawback is the lack of an effective technique for creating positively charged (p-type) 'hole' carriers. Bulk ZnO tends to be n-type with negatively charged 'electron' carriers due to the presence of aluminum and silicon impurities. The substrates used by the Stanley Electric researchers had an electron charge carrier density of about $10^{17}/\text{cm}^3$ and a resistivity of 0.1 Ω -cm.

ZnO has a wide bandgap energy of 3.37eV that suggests ultraviolet emissions around 370nm. The exciton (electron-hole states) binding energy of about 60meV has allowed the development of optically pumped exciton lasers. Recently, single-heterostructure LEDs have been developed by Stanley using layers of MgZnO.

The researchers have now produced double-heterostructure p-MgZnO/ZnO/MgZnO LEDs (Figure 1) with the p-type conduction achieved through doping with nitrogen. The p-layers were deposited using plasma-enhanced molecular beam epitaxy (PAMBE). Since ZnO and MgZnO tend to be n-type conducting, there is no need for special doping to achieve n-layers. The hydrothermally grown (0001) ZnO substrates were supplied by Tokyo Denpa. The undoped ZnO/MgZnO layers were grown at 900°C. The MgZnO layers consisted of 30% Mg and 70% Zn.

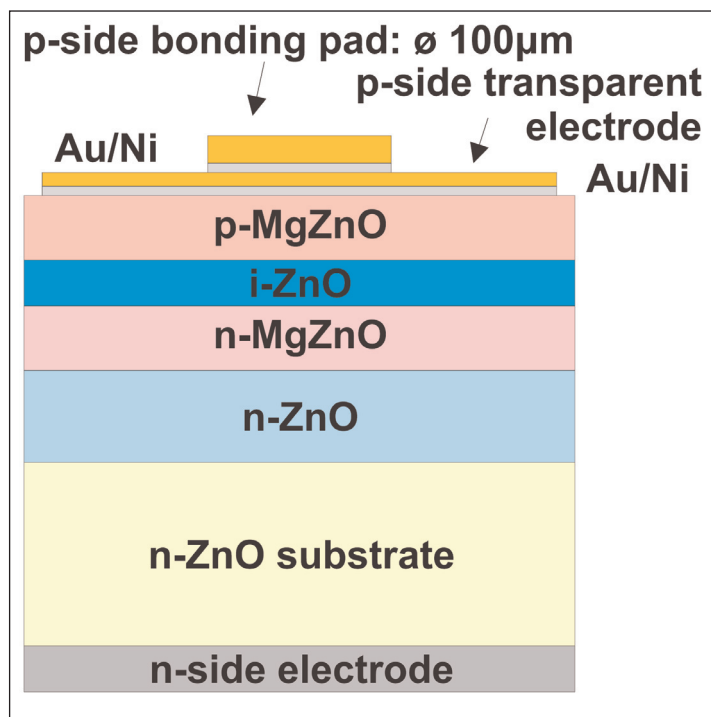


Figure 1. Schematic of ZnO-based DH-LED.

Although ZnO is an attractive material in terms of cost, as a semiconductor material the major drawback is the lack of an effective technique for creating positively charged (p-type) hole carriers. Bulk ZnO tends to be n-type with negatively charged 'electron' carriers due to the presence of aluminum and silicon impurities

The p-MgZnO was grown at the lower temperature of 700°C. The doping was carried out according to two different recipes. In the more traditional method, pure nitrogen gas was used with a flow of 1.0 standard cubic centimeter per minute (sccm). The new method consisted of a mixture of nitrogen (1.0sccm) and oxygen (0.2sccm). Both methods incorporated $2 \times 10^{20}/\text{cm}^3$ of nitrogen atoms in the

MgZnO structure.

The p-electrode consisted of a $300\mu\text{m} \times 300\mu\text{m}$ transparent square region of thin layers of nickel-gold and a thicker circular nickel-gold pad $100\mu\text{m}$ in diameter.

The turn-on voltage of the devices was 4–5V. The sharp emission peak occurred at about 380nm (Figure 2). The new p-doping method with nitrogen/oxygen source had much improved emission and lower leakage current under reverse bias.

The peak shifted to longer wavelengths under higher drive currents (Figure 2). Between 2mA and 20mA, the nitrogen/oxygen plasma LED red-shifted from 276nm to 378nm. The nitrogen plasma LED moved its peak wavelength from 377nm to 382nm between 10mA and 80mA.

On the basis of first-principles theory and characterization of the nitrogen/oxygen plasma doping, the researchers believe that the effect of adding oxygen gas to the doping plasma is to reduce the number of oxygen sites that are replaced by nitrogen molecules (N_2) and nitrogen-acceptor- N_2 complexes. The presence of oxygen in the plasma is thought to assist in the plasma activation. The characterization included secondary-ion mass spectroscopy and optical emission spectroscopy. ■

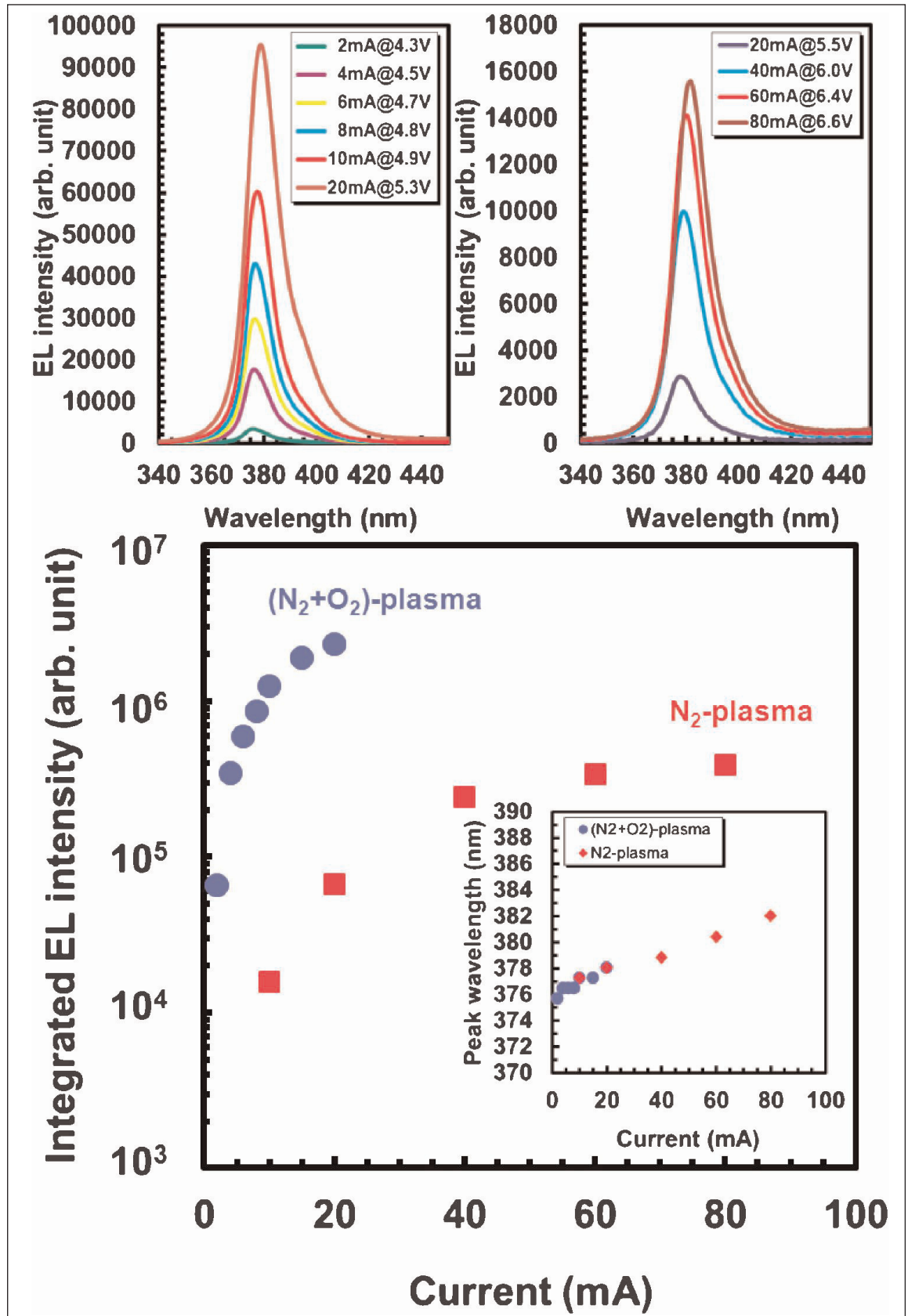


Figure 2. Effect of operating current on: near-band-edge EL spectra of LEDs fabricated using (N_2/O_2) -plasma (a) and pure N_2 -plasma (b); integrated EL intensity in range 360–420nm (c); and, peak wavelength of EL spectra (inset).

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Author: Mike Cooke

Deep ultraviolet goes deeper on silicon

Epitaxial lateral overgrowth used to improve the quality of aluminum nitride templates for deep UV LEDs.

Japan-based researchers have produced 256–278nm deep ultraviolet (DUV, shorter than 300nm or 350nm, according to taste) light-emitting diodes on silicon substrates [Takuya Mino et al, Appl. Phys. Express, vol4, p092104, 2011]. The organizations involved were Japan's Institute of Physical and Chemical Research (RIKEN), Panasonic Electric Works Co Ltd, and the University of Tokyo.

Potential applications for DUV devices include sterilization, water purification, medicine, and biochemistry. Advantages of growing devices on silicon substrates include low-cost, large-diameter wafers, electrical conductivity control, and good thermal conductivity. The Japan-based researchers also see possibilities for low-cost AlGaN-based DUV LEDs on Si substrates to be integrated with Si-based electrical circuits on the same chip.

To maximize the amount of light produced by LEDs, one has to increase the internal quantum efficiency (IQE) of electricity in producing photons, along with optimizing the light extraction efficiency (LEE) to give high external quantum efficiency (EQE), the desired final product.

The Japanese research focused on improving IQE through improved crystal quality, in particular, of the initial aluminum nitride (AlN) template layer, since IQE is adversely affected by the presence of threading dislocations. For DUV devices using nitride semiconductor layers, one of the key factors is the large lattice mismatch of about 19% between (0001) AlN and Si oriented with a (111) surface. The mismatch is even worse — about 43% — between AlN and the (100) Si used in most CMOS production.

Lattice mismatch increases the number of threading dislocations (TDs). Another problematic factor is the difference in thermal expansion between AlN and Si that leads to cracking of the crystal material when layers are cooled from growth (1300°C) to room temperature (~20°C).

The Japanese DUV LEDs were grown on (111) silicon wafers using metal-organic chemical vapor deposition

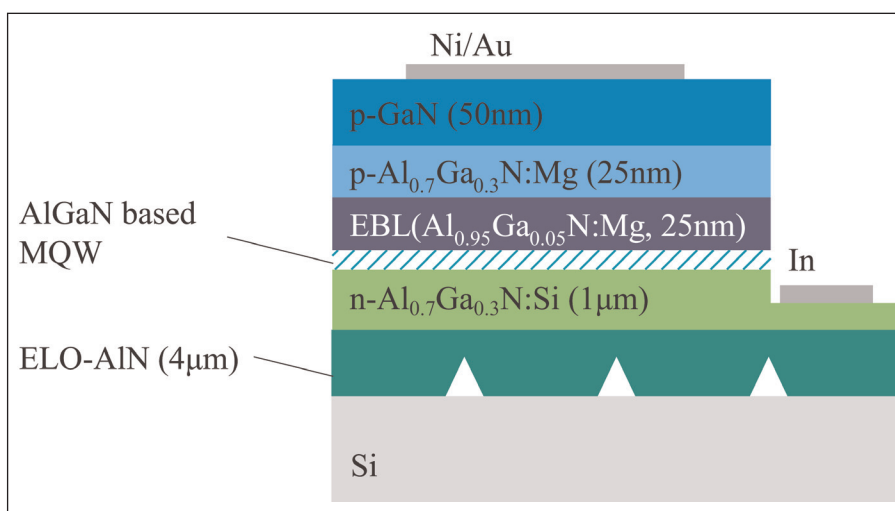


Figure 1. Schematic of AlGaN-based DUV LED fabricated on $\langle 10\bar{1}0 \rangle$ -trench-patterned ELO-AlN/Si template on a Si substrate.

(MOCVD) with trimethyl-metal and ammonia sources for the gallium/aluminum and nitrogen, respectively.

AlN template layers were grown at 1300°C in two steps: first, using a pulsed ammonia flow, and then a continuous flow. The second step relaxes the tensile stress in the AlN. When the second step is not used, one finds cracked surfaces.

The first step produced 300nm AlN layers that were then patterned for epitaxial lateral overgrowth (ELO) by etching with inductively coupled plasma down to the silicon with 2μm wide linear grooves separated by 8μm-wide terraces. ELO reduces the area from which subsequent nitride crystal material is seeded for further growth, hence reducing stress and the number of TDs. Different directions for the grooves were tried along the $\langle 11\bar{2}0 \rangle$ and $\langle 10\bar{1}0 \rangle$ directions.

The ELO layer consisted of continuous-flow AlN growth performed at 1300°C to give a total thickness of 4μm with the 300nm seed layer.

A series of optical and electron microscopic examinations were performed, along with x-ray diffraction. It was found that the $\langle 11\bar{2}0 \rangle$ material from adjacent strips did not coalesce well, so further work focused on the $\langle 10\bar{1}0 \rangle$ material that did coalesce successfully. Although some cracking was observed on the surface of the $\langle 10\bar{1}0 \rangle$ material, the researchers comment that "ELO-AlN is effective for relaxing the tensile stress

generated by the mismatch in the lattice and thermal expansion coefficients between AlN and Si, because a 4 μm -thick AlN layer on Si would crack heavily without the ELO-AlN layer."

Transmission electron micrography (TEM) was used to estimate the threading dislocation densities as $2 \times 10^8/\text{cm}^2$ for screw-type and $9.5 \times 10^8/\text{cm}^2$ for edge-type. X-ray diffraction rocking curves confirmed improved crystal quality with full-width at half maximum (FWHM) values of 780arcsec and 980arcsec for the (0002) and (10 $\bar{1}$ 2) peaks, respectively. These compare, respectively, with the values for the initial 300nm AlN layer of 3500arcsec and 3750arcsec. The researchers comment that the (10 $\bar{1}$ 2) FWHM value of 980arcsec "is lower than that of AlN templates on Si reported so far".

One of the researchers, Hideki Hirayama, had previously worked on the pulsed-flow technique for producing AlN on Si at RIKEN with Sachie Fujikawa, producing 280–300nm devices on silicon using InAlGaN active light-emitting layers. The produced AlN was 200nm after pulsing and 2 μm in total after the second step. In this previous work, no ELO patterning was used and the (10 $\bar{1}$ 2) rocking curve FWHM was 2000arcsec.

The DUV LEDs (Figure 1) were produced using LP-MOCVD on AlN templates on Si with <10 $\bar{1}$ 0> trenches. The three-layer multi-quantum well (MQW) active region consisted of undoped AlGaIn 1.5nm wells and 6nm barriers. The aluminum content of the wells varied between 40% and 55%, while the barriers had 70%, like the n-AlGaIn region. An electron-blocking layer (EBL) was used to avoid IQE losses from overshoot of electrons into the p-type contact region.

Continuous-wave emission was measured using bare wafers at room temperature in an integrating sphere (Figure 2). The forward voltages at 1mA and 20mA were 7V and 16V, respectively. The relatively high voltages are attributed to series resistance from lateral injection in the n-type layer. The researchers comment: "The forward voltage will be significantly reduced by using a flip-chip packaged device or by using a vertical LED structure by removing the Si substrate and AlN buffer".

The output powers are three orders of magnitude lower (i.e. a factor of a thousand) than those found for DUV devices grown on sapphire. At 500mA, a typical device produced 10 μW , compared with more than 10mW found for some sapphire-based devices.

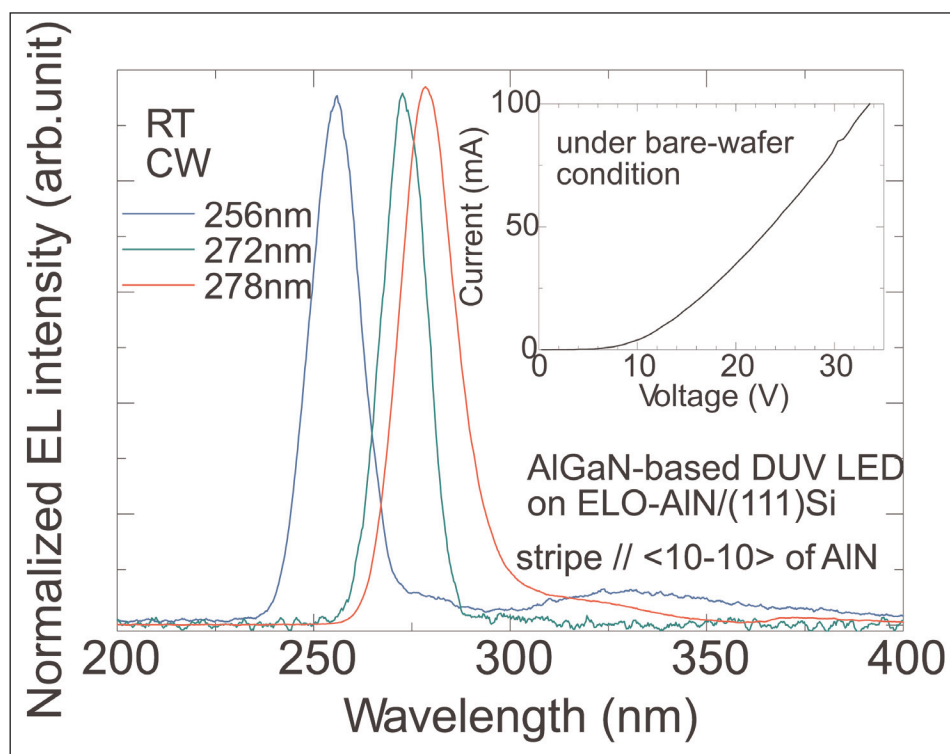


Figure 2. Electroluminescence spectra and typical current–voltage (I–V) curve of AlGaIn-based DUV LEDs on ELO-AlN templates on silicon at room temperature.

One problem with using silicon substrates is that silicon absorbs the DUV emission, so the emitted light can only be extracted from the top. Sapphire is transparent to DUV and most DUV LEDs use a flip-chip arrangement, extracting the light through the bottom of the device. A further loss occurs through absorption in the p-GaN contact layer. The researchers estimate that 85% of the light travelling in the upward direction is lost in this way.

Unfortunately, a p-GaN contact is needed at present in DUV devices because the magnesium doping used to create p-type conduction in nitride semiconductors has a high activation energy that increases with high Al-content. High activation energies lead to low hole concentrations. For example, the researchers estimate that the hole concentration in the p-GaN layers of their devices is about $10^{17}/\text{cm}^3$, compared with $10^{14}/\text{cm}^3$ in the p-AlGaIn EBL. By contrast, the silicon doping used to create n-type conduction has a low activation, resulting in an electron concentration in the n-AlGaIn layer of $10^{18}/\text{cm}^3$.

In addition to all these problems, more light is blocked by the nickel-gold p-electrode.

The researchers estimate that their present structure has a light extraction efficiency (LEE) of 0.01%. An improved LEE of 10% could result from removal of the Si substrate and the use of a vertical current-flow flip-chip structure. ■

<http://apex.jsap.jp/link?APEX/4/092104>

Author: Mike Cooke

Blocking and reflecting to boost nitride LED light output

Taiwan researchers use SiO₂/Al to avoid high current density and p-electrode light absorption.

National Cheng-Kung University and Kun-Shan University in Taiwan have used silicon dioxide/aluminum structures under the p-electrodes of nitride semiconductor LEDs to improve light output [Chun-Fu Tsai et al, *Semicond. Sci. Technol.*, vol26, p095013, 2011]. The silicon dioxide (SiO₂) was used to spread the current from the p-electrode over a wider area of the active region structure and the aluminum (Al) created a reflector to reflect light that would be absorbed by the p-electrode for extraction instead from the sapphire side.

Three devices were produced: one with no structure (reference); one with a SiO₂ current blocking/spreading structure (normal blocking); and a final one with a SiO₂/aluminum structure (reflective blocking). At 20mA injection current, the light output powers were 6.44mW, 7.45mW and 8.1mW, for the reference, normal blocking and reflective blocking devices, respectively. These represent improvements over the reference of 15.7% for the normal blocking LED and 25.8% for the reflective blocking device. Beyond 20mA, the blocking devices continue to show improved performance over the reference (Figure 1).

Nitride LEDs grown on insulating sapphire substrates usually have their p- and n-electrodes on the nitride side of the device. The electrodes tend to interfere with the ability to extract light from the structure. However, by reducing the electrodes to enhance extraction, one also increases the current density flowing through certain regions of the LED (e.g. under the p-electrode). Unfortunately, high current densities are a particular problem in nitride LEDs, where the efficiency can 'droop' drastically at high current. Also light produced directly beneath the p-electrode will more likely be absorbed by it.

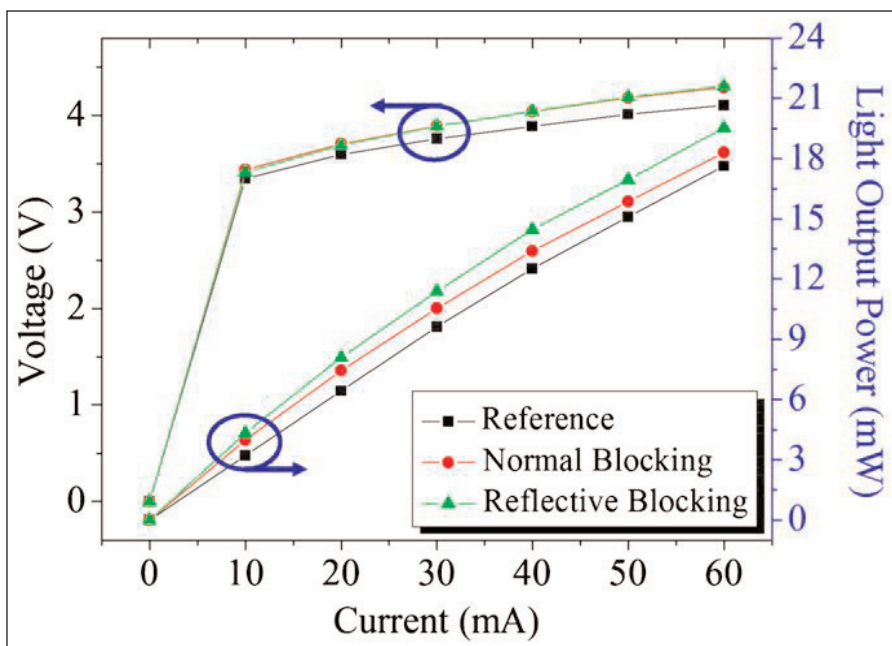


Figure 1. Light output power/current versus voltage (L-I-V) curves of reference, normal blocking and reflective blocking LEDs.

The nitride semiconductor epitaxial structures (Figure 2) were grown on c-face (0001) sapphire using metal-organic chemical vapor deposition (MOCVD) in a rotating-disk reactor with trimethyl-metal and

p-GaN	Mg-doped	$2 \times 10^{17} / \text{cm}^3$
Electron blocking	p-AlGaIn Mg-doped	
Multi-quantum well	10xInGaIn/GaN	
n-GaN	Si-doped	$3 \times 10^{18} / \text{cm}^3$
Nucleation	GaN	30nm
Substrate	c-plane (0001) sapphire	

Figure 2. Schematic cross-section of nitride semiconductor epitaxial structure used for LEDs.

ammonia sources. The silicon/n-type and magnesium/p-type doping came from silane and biscyclopentadienyl-magnesium, respectively. The mesa structure of the LED was patterned using photolithography and cut using inductively coupled plasma etch, before producing the different blocking designs for experimental tests.

The 'normal' blocking sample (Figure 3) consisted of silicon dioxide, deposited using plasma-enhanced CVD and patterned and wet etched with photolithography and a buffered oxide etch solution. The new 'reflective' blocking sample added aluminum with a reflectivity of 91% in 430–480nm blue light range. A 'reference' sample without blocking structure was also produced.

The 250µm x 580µm LEDs were completed with 250nm transparent conducting layers of indium tin oxide (ITO) on top of the current-blocking structures and chromium/platinum/gold metal p-/n-contact pads. The LEDs were all produced from epitaxial material grown on one substrate to ensure that improvements were caused by the current-blocking and reflection structures.

The electro-luminescence peaks of the three devices occurred around 454–455nm with full-width half-maxima (FWHM) of 18nm. The heights of the peaks went in lowest-to-highest order: reference, normal blocking, and finally reflective blocking.

Beam-profile/near-field images showed that the effect of the current-blocking structures

By reducing the electrodes to enhance extraction, one also increases the current density flowing through certain regions of the LED (e.g. under the p-electrode). Unfortunately, high current densities are a particular problem in nitride LEDs, where the efficiency can 'droop' drastically at high current. Also light produced directly beneath the p-electrode will more likely be absorbed by it

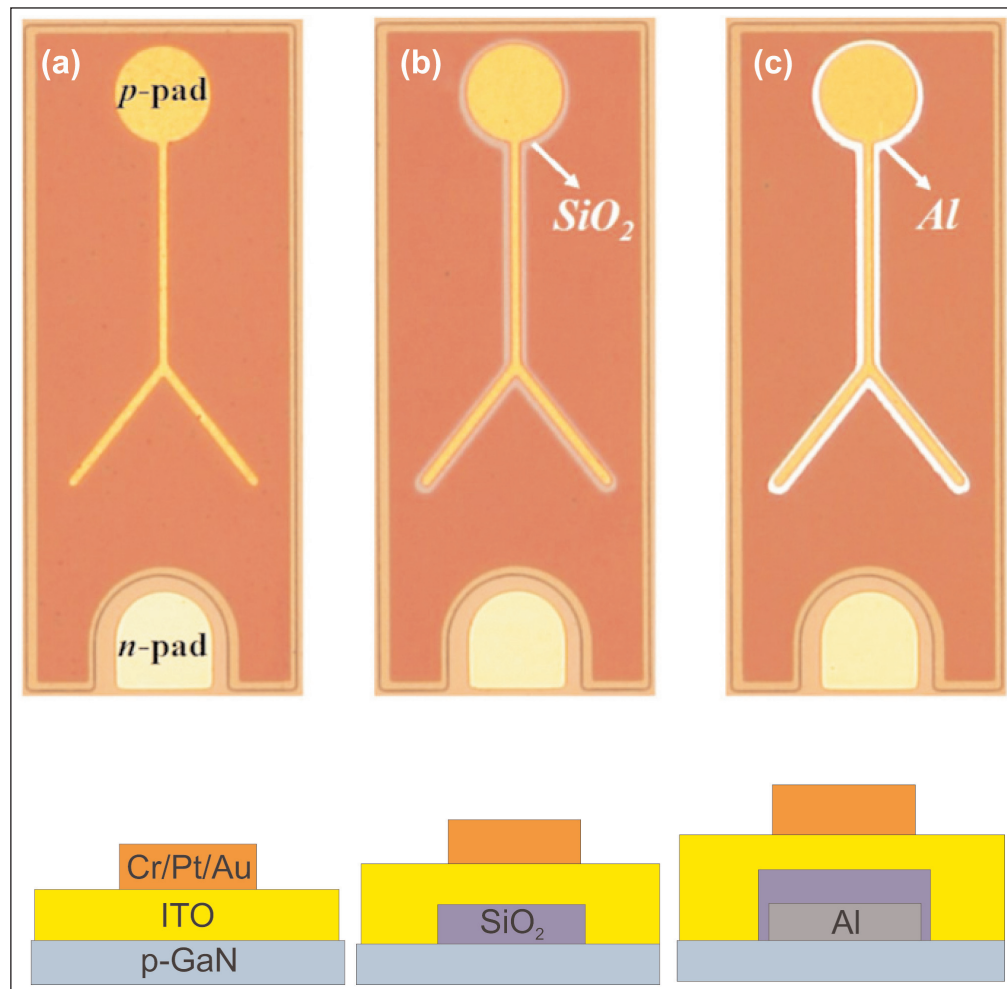


Figure 3. (top) CCD images of (a) reference, (b) normal blocking and (c) reflective blocking LEDs and (bottom) corresponding cross-sectional schematic views of the CBL structures.

was to spread out the current injection, reducing the current density in the active region to a level where photon production is more efficient.

The reverse-bias characteristics of the devices were also improved with the current-blocking structure. The reverse currents at 5V were 33.2nA, 20.7nA and 29.3nA, respectively, for the reference, normal blocking and reflective blocking devices. The researchers suggest that the improvement was due to the passivating effect on surface defects of the silicon dioxide blocking layer. There is less silicon dioxide in contact with the p-GaN contact in the reflective blocking case.

The forward voltages of the blocking devices (both, 3.7V) at 20mA were slightly higher than for the reference (3.6V). This is attributed to larger series resistance due to the smaller contact area between the p-GaN and transparent conducting indium tin oxide electrode. The reference also has a shorter average conduction path, since less spreading occurs. ■

<http://iopscience.iop.org/0268-1242/26/9/095013>

The author Mike Cooke is a freelance technology journalist who has worked in the semiconductor and advanced technology sectors since 1997.

EQE increased 2.4-fold with void-embedded cortex nano-patterned LED

External quantum efficiency reaches 58.3% at 20mA in Taiwan nitride semiconductor device.

Taiwan-based researchers have developed a sapphire nanopatterning technique that increases external quantum efficiencies (EQE) of nitride semiconductor LEDs by 2.4x over devices grown on conventional sapphire at 20mA drive current [Yu-Sheng Lin and J. Andrew Yeh, *Appl. Phys. Express*, vol4, p092103, 2011].

The researchers at National Tsing Hua University and National Applied Research Laboratories comment that the EQE of 58.3% at 20mA is comparable with that of other reported devices on nano-patterned sapphire substrates with values in the range 40–50%. The conventional device had an EQE of 24.5%. The output power measured from the top side of the devices at 20mA was 33.1mW for the patterned device and 13.9mW for the conventional LED.

Many researchers are seeking low-cost ways to enhance the performance of nitride semiconductor LEDs. One technique for this has been to pattern the sapphire substrate used before nitride growth. These nano-scale patterns can have two effects to improve the performance of the resulting LEDs.

First, the nanopatterned surface affects the growth process, reducing the number of dislocations in the nitride semiconductor crystal; such dislocations can degrade LED performance. Second, the growth process often creates air-voids at the interface between the sapphire and nitride semiconductor heterostructure; the voids can be used to alter the way the light generated by the

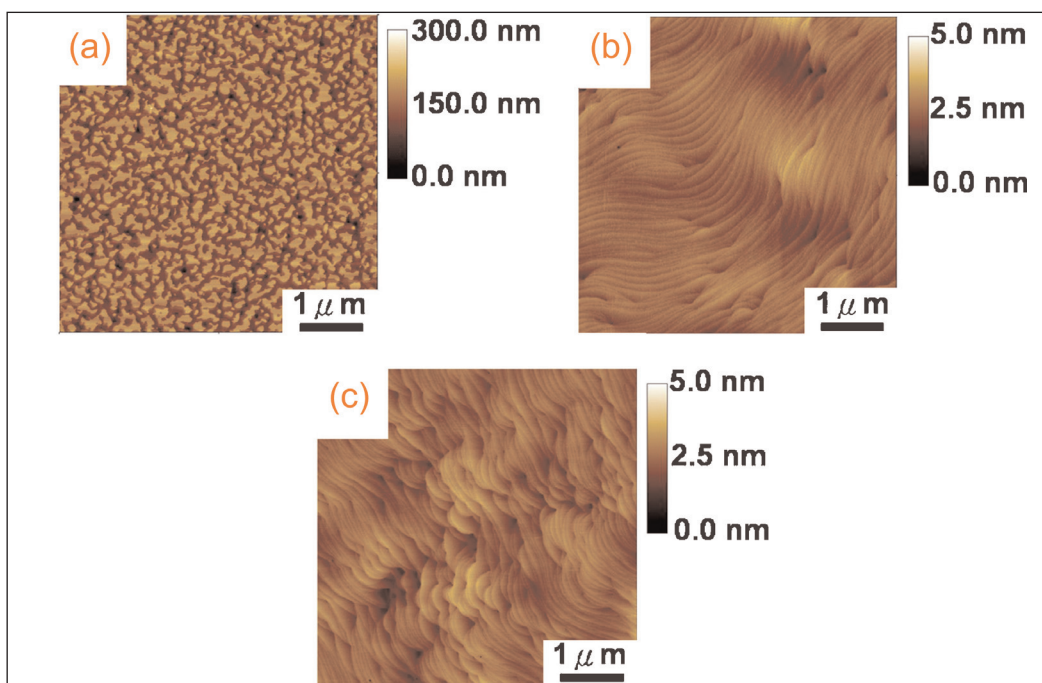


Figure 1. AFM images of surfaces of (a) sapphire with void-embedded cortex-like nanostructure (VECN), (b) undoped gallium nitride (u-GaN) on VECN sapphire, and (c) u-GaN on conventional sapphire. Scan area is $5\mu\text{m} \times 5\mu\text{m}$.

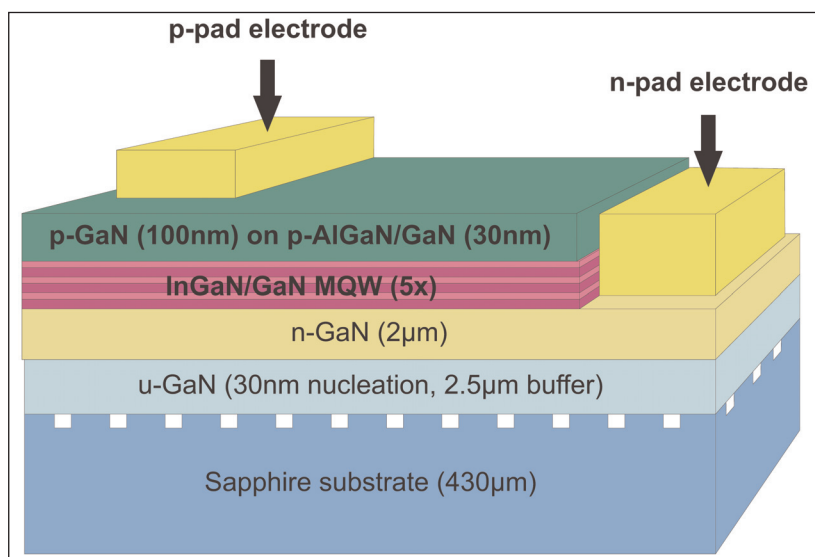


Figure 2. Schematic diagram of LED-VECN structure. The p-side layers consist of 30nm AlGaIn/GaN superlattice and 100nm p-GaN.

LED action leaves the device. Sometimes both effects operate to improve EQEs of nitride LEDs.

The Taiwan researchers used a random nano-patterning that they called 'void-embedded cortex-like nanostructures' (VECN). The team sees their method as being "a cost-effective solution to the wafer-level cortex-like nanostructures on sapphire for high-efficiency LEDs without implementation of an expensive semiconductor mask".

The nanopatterning of the sapphire wafer surface was achieved by creating a 2 μ m-thick hard mask of polysilicon and performing an inductively coupled plasma reactive-ion etch

with a boron tetrachloride and chlorine mix. The deposition of the polysilicon was through 640°C low-pressure chemical vapor deposition. The patterning for the hard mask was created by dipping the polysilicon-covered wafer in diluted Wright-etch solution for 30 minutes. Wright-etch solution is an acid mix developed in the 1970s to reveal defects in silicon crystal structures. The hard mask was removed by potassium hydroxide solution at 80°C. The resulting patterning of the sapphire wafer surface consisted of 10¹⁰/cm² 80–150nm deep structures spaced 50–150nm apart (Figure 1).

The LED structures were grown using low-pressure metal-organic chemical vapor deposition (Figure 2). Atomic force microscopy (AFM) of the buffer layer suggested a pit density of 10⁷–10⁸/cm². This is two orders of magnitude lower than pit density values for gallium nitride (GaN) grown on conventional sapphire substrates (CSS). Such pits are attributed to threading dislocations that propagate from the sapphire to the top of the GaN surface.

X-ray diffraction (0002) rocking curve full-width at half maximum (FWHM) values of 211 arcsec for the nanopatterned GaN/sapphire, compared with 294 arcsec for GaN/CSS, also suggest improved crystal quality. The further LED layers slightly increased the FWHM for

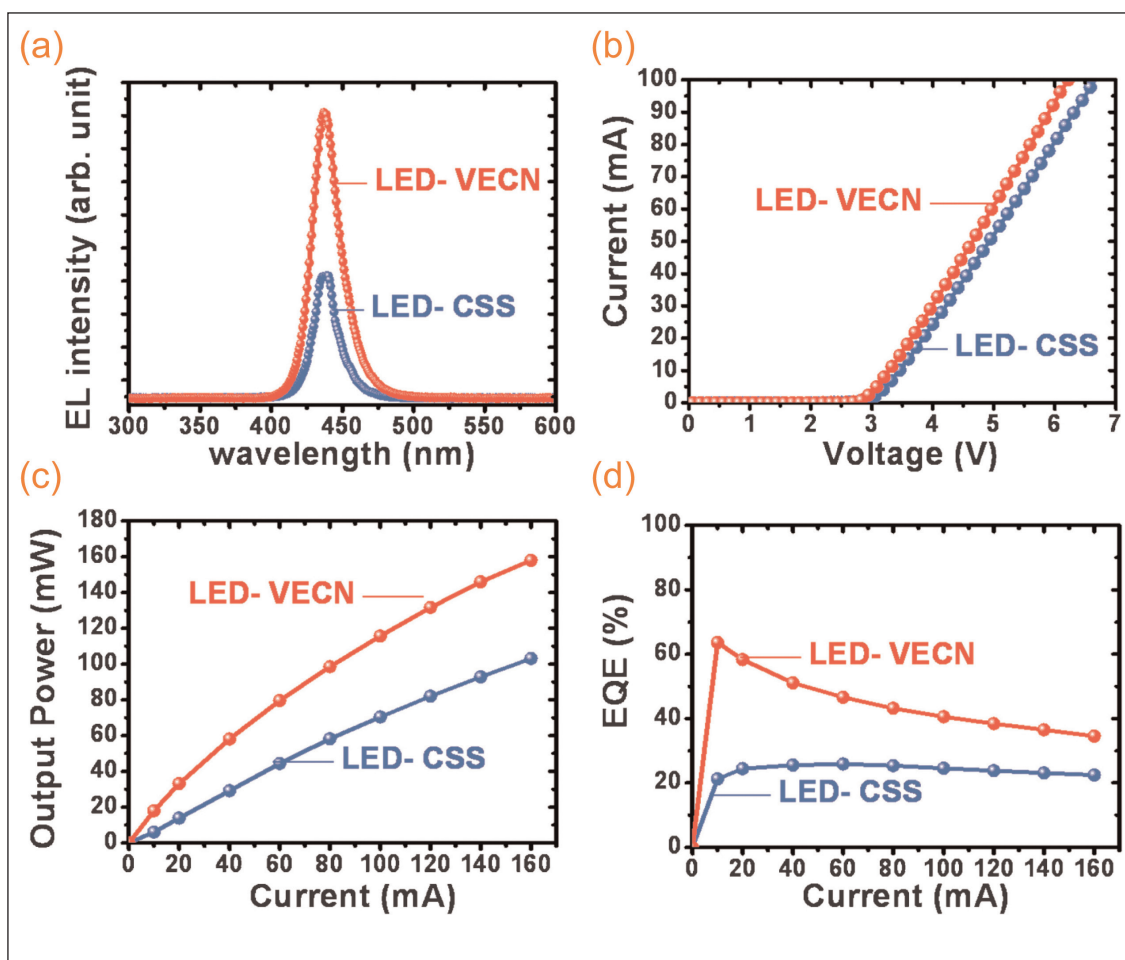


Figure 3. (a) Electroluminescence spectra for LED on VECN and conventional (CSS) substrate located at 438nm under an injection current of 20mA. (b) Current–voltage (I–V) curves of the LED-VECN and the LED-CSS, (c) light output power, and (d) EQE in relation to current characteristics of LED-VECN and LED-CSS, respectively.

the nanopatterned device structure to 216 arcsec, while the CSS device structure FWHM decreased to 256 arcsec. Satellite peaks up to fifth order were detected, suggesting good layer periodicity for the indium gallium nitride/gallium nitride (InGaN/GaN) multi-quantum wells (MQW), which made up the active region of the device.

The electroluminescent peak occurred at 438nm (violet) at 20mA drive current (Figure 3). At 20mA, the patterned LED had a lower forward voltage of 3.6V, compared with the conventional device's 3.8V. The reflection from the GaN/sapphire interface was 32.8% higher in the patterned device compared with that on conventional sapphire. The reflection is thought to occur at air voids formed during the GaN growth. Such reflection occurs due to the large difference in refractive index between GaN (2.45) and air (~1).

The characterizations of the crystal structure and light reflection suggest that the improvement results from both reduction in dislocation density, and improved light extraction through reflection. ■

<http://apex.jsap.jp/link?APEX/4/092103>

Author: Mike Cooke

Patterned sapphire for nitride enhancements

In the past few years, patterned sapphire substrates have been used to improve performance of nitride semiconductor light-emitting devices. Mike Cooke reports on some recent developments.

Many researchers are seeking low-cost ways to enhance the performance of nitride semiconductor light-emitting diodes (LEDs) and other devices. One technique for this has been to pattern the sapphire substrate used before nitride growth. These nano-scale patterns can have a number of effects to improve the performance of the resulting LEDs, affecting the ability to create photons from electron-hole recombination and the ability of these photons to be extracted from the device.

For example, the nanopatterned surface can affect the nitride semiconductor growth process, reducing the number of dislocations in the nitride semiconductor crystal; such dislocations can degrade LED performance. Also, the growth process often creates air-voids at the interface between the sapphire and nitride semiconductor heterostructure; the voids can be used to alter the way the light generated by the LED action leaves the device.

Another device type for which these improvements have been used is photovoltaic power generation from reversing the diode action. In principle, nitride semiconductors could cover a wide range of the solar spectrum from the infrared (InN, bandgap 0.7eV ~1800nm) to ultraviolet (AlN, 6eV ~200nm) wavelengths. In practice, the nitride semiconductor PV devices produced so far have tended to have low conversion efficiency, being restricted in the main to the ultraviolet region (less than 400nm) where there are fewer solar photons.

The problems in moving to longer wavelengths are similar to those in green LEDs and laser diodes — relatively poor material quality due to composition fluctuations arising from the tendency of the indium component needed for longer wavelength response not mixing well with other nitrides; and complications due to polarization fields arising spontaneously and due to the large piezoelectric strain-dependent effects in nitrides.

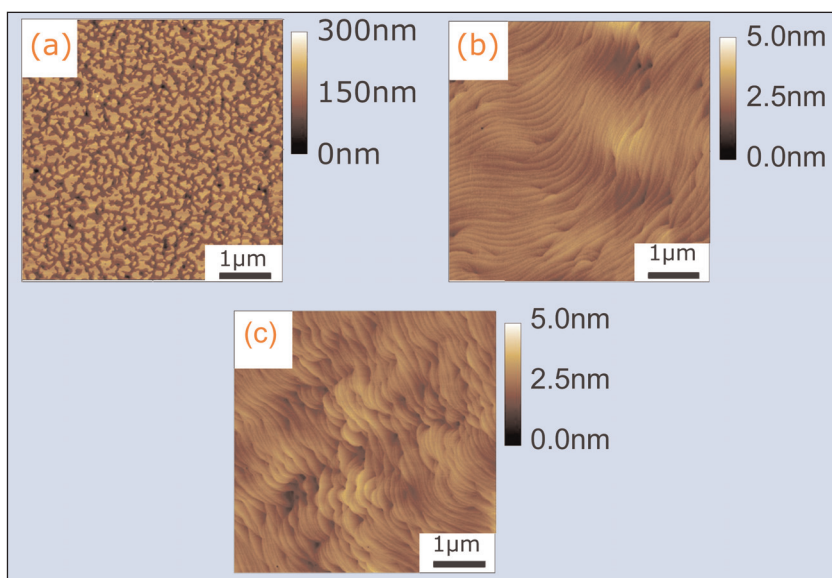


Figure 1. AFM images of surfaces of (a) sapphire with void-embedded cortex-like nanostructure (VECN), (b) undoped gallium nitride (u-GaN) on VECN sapphire, (c) u-GaN on conventional sapphire. Scan area is 5µm x 5µm.

Nanopatterning for light emission

Taiwan-based researchers have developed a sapphire nanopatterning technique that increases external quantum efficiencies (EQE) of nitride semiconductor LEDs 2.4x over devices grown on conventional sapphire at 20mA drive current [Yu-Sheng Lin and J. Andrew Yeh, *Appl. Phys. Express*, vol4, p092103, 2011].

The researchers at National Tsing Hua University and National Applied Research Laboratories comment that the EQE of 58.3% at 20mA is comparable with that of other reported devices on nanopatterned sapphire substrates with values in the range 40–50%. The conventional device had an EQE of 24.5%. The output power measured from the top side of the devices at 20mA was 33.1mW for the patterned device and 13.9mW for the conventional LED.

The Taiwan researchers used a random nanopatterning they called 'void-embedded cortex-like nanostructures' (VECN). The team sees their method as being "a cost-effective solution" for producing wafer-level cortex-like

nanostructures on sapphire for high-efficiency LEDs without the need for an expensive semiconductor mask.

The nanopatterning of the sapphire wafer surface was achieved by creating a $2\mu\text{m}$ -thick hard mask of polysilicon and performing an inductively coupled plasma reactive-ion etch with a boron tetrachloride and chlorine mix. The deposition of the polysilicon was through 640°C low-pressure chemical vapor deposition.

The patterning for the hard mask was created by dipping the polysilicon-covered wafer in diluted Wright-etch solution for 30 minutes. Wright-etch solution is an acid mix developed in the 1970s to reveal defects in silicon crystal structures. The hard mask was removed by potassium hydroxide solution at 80°C . The resulting patterning of the sapphire wafer surface consisted of $10^{10}/\text{cm}^2$ 80–150nm deep structures spaced 50–150nm apart (Figure 1).

The LED structures were grown using low-pressure metal-organic chemical vapor deposition (Figure 2). Atomic force microscopy (AFM) of the buffer layer suggested a pit density of 10^7 – $10^8/\text{cm}^2$. This is two orders of magnitude lower than pit density values for gallium nitride (GaN) grown on conventional sapphire substrates (CSS). Such pits are attributed to threading dislocations that propagate from the sapphire to the top of the GaN surface.

X-ray diffraction (0002) rocking curve full-width at half maximum (FWHM) values of 211 arcsec for the nanopatterned GaN/sapphire, compared with 294arcsec for GaN on conventional sapphire substrates (GaN/CSS) also suggest improved crystal quality. The further LED layers slightly increased the FWHM for the nanopatterned device structure to 216arcsec, while the CSS device structure FWHM decreased to 256arcsec. Satellite peaks up to fifth order were detected, suggesting good layer periodicity for the indium gallium nitride/gallium nitride (InGaN/GaN) multi-quantum wells (MQW), which made up the active light-emitting region of the device.

The electroluminescent peak occurred at 438nm (violet) at 20mA drive current (Figure 3). At

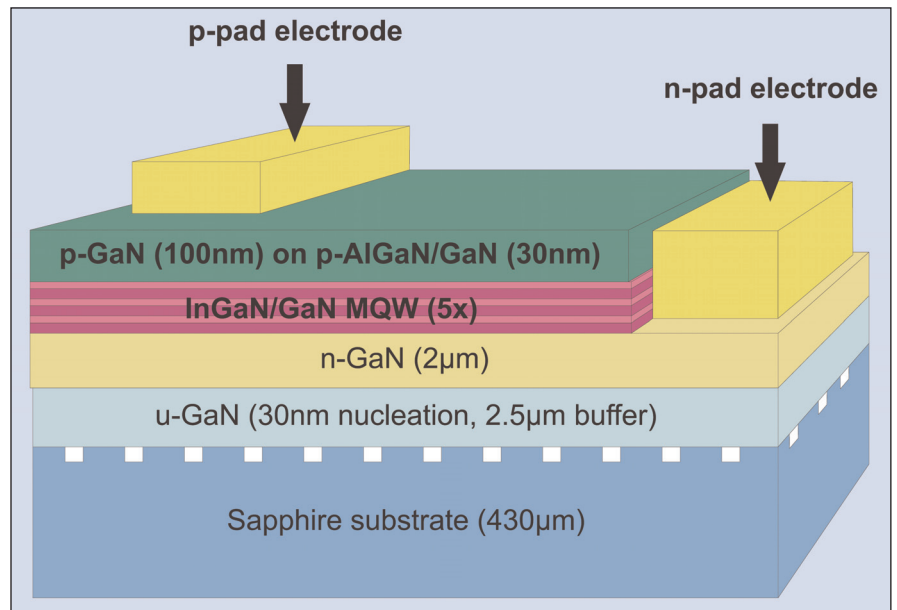


Figure 2. Schematic diagram of LED-VECN structure. The p-side layers consist of 30nm aluminum gallium nitride/gallium nitride (AlGaIn/GaN) superlattice and 100nm p-GaN.

20mA, the patterned LED had a lower forward voltage of 3.6V, compared with the conventional device's 3.8V. The reflection from the GaN/sapphire interface was 32.8% higher in the patterned device compared with that on conventional sapphire. The reflection is thought

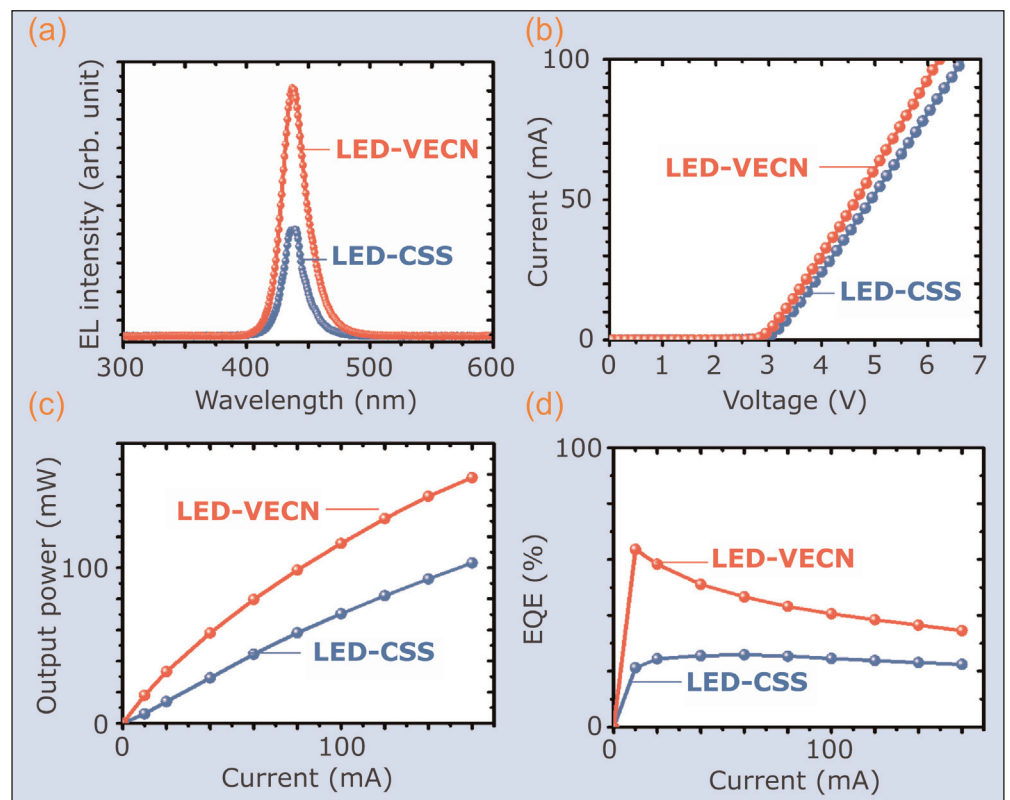


Figure 3. (a) Electroluminescence spectra for LED on VECN and conventional (CSS) substrate located at 438nm under an injection current of 20mA. (b) Current–voltage (I–V) curves of the LED-VECN and the LED-CSS, (c) light output power, and (d) EQE in relation to current characteristics of LED-VECN and LED-CSS, respectively.

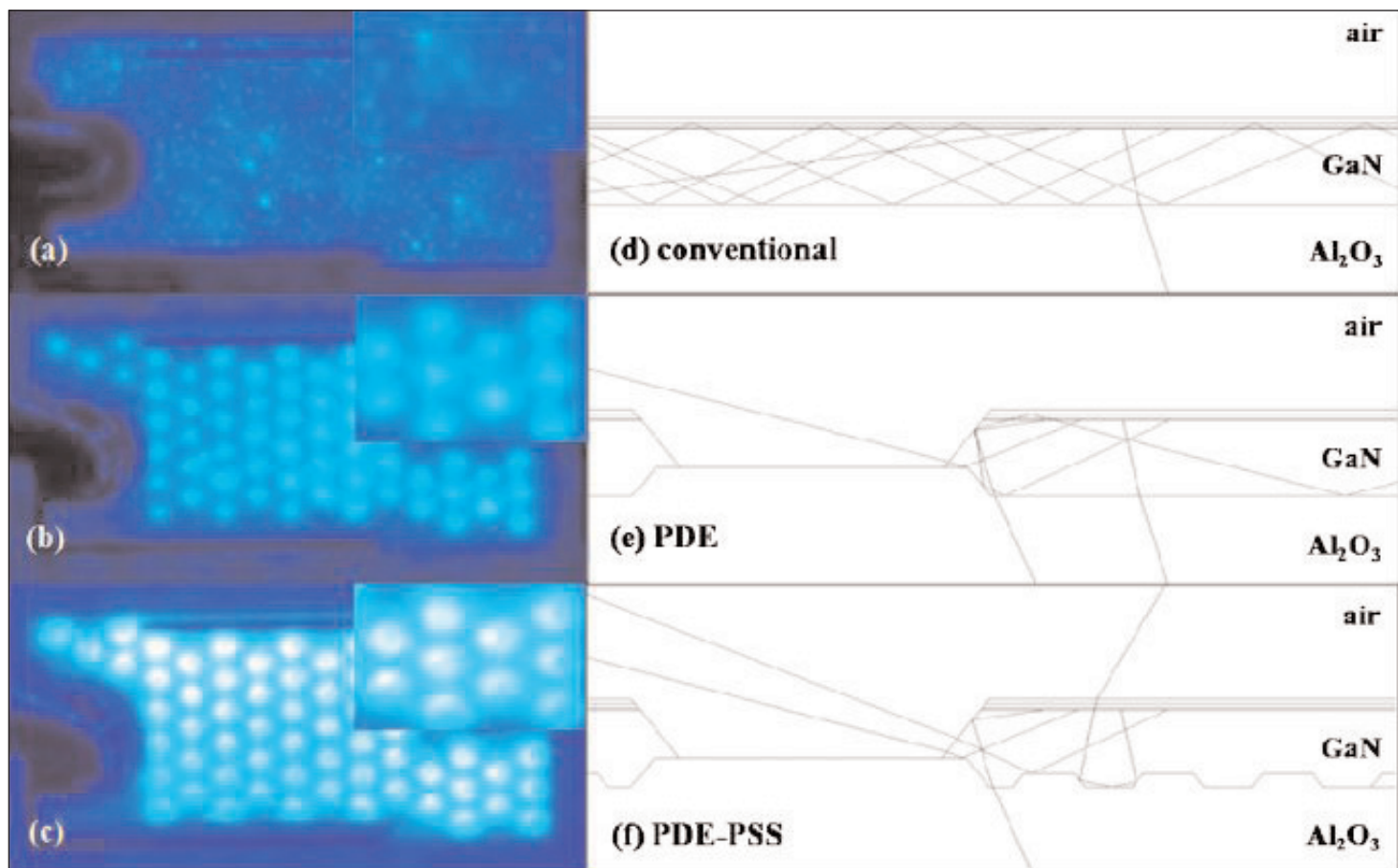


Figure 4. Electroluminescence images of (a) conventional, (b) PDE-only, and (c) PDE-PSS LEDs at low current. Figures (d)–(f): ray-tracing diagrams of the respective LEDs.

to occur at air voids formed during the GaN growth. Such reflection occurs due to the large difference in refractive index between GaN (2.45) and air (~ 1).

The characterizations of the crystal structure and light reflection suggest that the improvement results from both reduction in dislocation density, and improved light extraction through reflection.

In Korea, Chonbuk National University and LG Display [Hyun Kyu Kim et al, *Jpn. J. Appl. Phys.*, vol50, p042102, 2011] have combined a periodic deflector embedded on patterned sapphire substrates (PDE-PSS) to enhance light output. A 100nm-thick silicon dioxide mask was patterned and wet etched using photolithography and buffered sulfuric/phosphoric acid solution. The pattern consisted of hexagons that were either 15 μm diameter with 25 μm periodicity or 3 μm diameter with 15 μm periodicity. The advantage of a wet process is avoidance of damage that arises from plasma etches.

LED structures were produced that consist of 315 μm x 315 μm mesas with a nickel-gold transparent conductive layer, and chromium-gold n-type and nickel-gold p-type contacts.

The researchers attribute a lower forward voltage of 3.45V at 20mA in their LEDs grown on PDE-PSS substrates to the avoidance of plasma damage. LEDs grown on non-patterned sapphire — both conventional planar sapphire, and with PDE structures, but without PSS —

exhibited forward voltages of 3.6V at 20mA. Patterning also tightened the peaks of x-ray diffraction rocking curves from 368 arcsec (planar) and 300 arcsec (PDE-only) to 270 arcsec (PDE-PSS). For the final pay-off in terms of light output power at 20mA, the PDE-only device emitted 40% more than a conventional planar device, while the PDE-PSS LED produced 60% more light.

The researchers comment on the light extraction: "This result implies that the polygonal holes play a role as guided light deflectors, which facilitates the multiple chances for photons to escape from the LEDs. In addition, [Figure 4] shows that the light intensity around the polygonal holes of the PDE-PSS LEDs is brighter compared to the intensity around the polygonal holes in the PDE LED. We also observe a strong luminescence emanating in the perimeter of polygonal hole and in the polygonal hole inside as well."

Earlier this year, researchers from Rensselaer Polytechnic Institute (RPI) in the USA and SCIVAX Corp of Japan used patterned sapphire substrates to improve the efficiency of green (520–570nm wavelength) LED indium gallium nitride (InGaN) semiconductor structures [Yufeng Li et al, *Appl. Phys. Lett.*, vol98, p151102, 2011; reported in *Semiconductor Today* May/June 2011, p110].

Patterning the sapphire with a hexagonal array of cylindrical holes was found to improve the crystal quality of the nitride semiconductor material through reducing

threading dislocation (TD) densities in the quantum wells of the LEDs where the light is produced. Total internal reflection of light due to the patterning was also reduced, resulting in the enhancement of light extraction efficiency (LEE) by 1.58x.

A number of other groups have developed patterned substrates for improving LED performance. Taiwan's National Chung Hsing University used the air voids created in nitride growth on

patterned sapphire to create a method for removing the substrate in a wet chemical etch lift-off process [www.semiconductor-today.com/news_items/2010/SEPT/NCHU_030910.htm].

Again in Taiwan, National Central University (NCU) and Academia Sinica used a maskless wet etch to produce pyramid-shaped pits in sapphire to give a 37% increase in light output; meanwhile, National Chiao Tung University researched changes in crystal quality and LED performance brought about by changing the slant angle of pyramids produced with a mask and wet etch process [www.semiconductor-today.com/news_items/2010/FEB/NCU_100210.htm].

A different example of LED enhancement through patterning is Hong Kong University of Science and Technology and Taiwan National Chiao Tung University developing nano-patterning on silicon rather than sapphire to improve light output by 21% over micro-patterned silicon [www.semiconductor-today.com/news_items/2010/MAY/HKU_210510.htm]. The growth of high-quality nitride material on silicon is even more difficult than on sapphire due to a larger lattice mismatch ($\sim 17\%$ rather than $\sim 14\%$).

Solar cell development

Patterned sapphire substrates have also been used to enhance the performance of nitride-semiconductor photovoltaics. National Taiwan Normal University's Institute of Electro-Optical Science and Technology used a PSS to grow nitride semiconductors with more than 70% reduced threading dislocations, resulting in 60% increased short-circuit current in photovoltaic devices processed from the epitaxial material [Ya-Ju Lee et al, Appl. Phys. Lett., vol98, p263504, 2011].

The PSS was produced using a mixture of sulfuric and phosphoric acids to etch the c-plane sapphire substrate

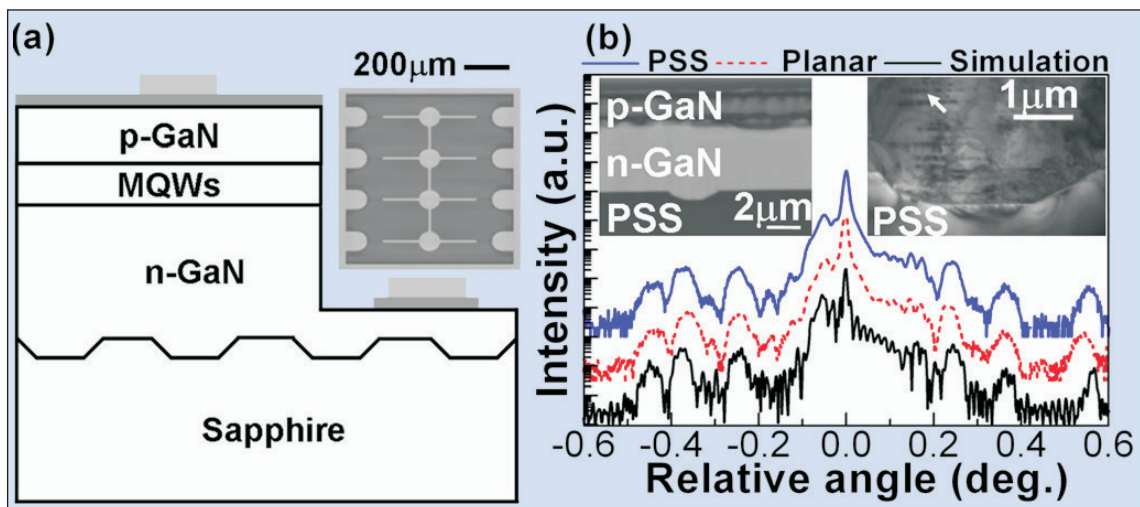


Figure 5. (a) Schematic of the InGaN-based MQW solar cell grown on PSS; inset: SEM image of the actual device. (b) XRD rocking curves of both solar cells; insets: cross-sectional SEM image of the solar cell grown on PSS (left-hand) and an enlarged TEM image focusing on the GaN/sapphire interface (right-hand).

at 300°C. The pattern consisted of triangular $\{0001\}$ c-plane depressions with side-walls consisting $\{1-102\}$ r-plane facets. The diameter of the depressions was about 3 μm, 0.5 μm deep, set at 7 μm pitch.

The nitride layers were grown using MOCVD (Figure 5). The light absorption layer consisted of a 10-period multi-quantum well of 2.5 nm $\text{In}_{0.23}\text{Ga}_{0.77}\text{N}$ separated by 12 nm GaN barriers. Square 800 μm x 800 μm mesas were etched down to the n-type layer. Indium tin oxide (ITO) was used as a 300 nm transparent conducting current-spreading layer on the contact, followed by chromium-gold electrodes. A device was also grown on standard planar sapphire and processed in a similar way.

Examination with scanning electron microscope showed that the GaN grew without air voids, unlike some of the work mentioned above. Cross-sectional transmission electron micrographs show a large number of stacking faults in the trench regions of the PSS that appear to interact with threading dislocations (TDs), preventing their penetration into the MQW region. Molten potassium hydroxide (200°C) was used to create etch pits that can be counted to give an estimate of dislocation density. For the planar substrate, the TD density was $1.28 \times 10^9/\text{cm}^2$; the use of PSS reduced the TD density to $3.62 \times 10^8/\text{cm}^2$.

Current-voltage measurements showed a significant reduction of about one order of magnitude (a factor of ten) in reverse bias current in the PSS device, "entirely due to a reduction in leakage paths associated with TD defects in MQW". The respective shunt resistances are estimated at 0.1 GΩ and 1 GΩ for the PSS and conventional devices, respectively. Operating the PV devices as LEDs gave 30% enhanced electroluminescence for the PSS component due to enhanced light extraction properties. ►

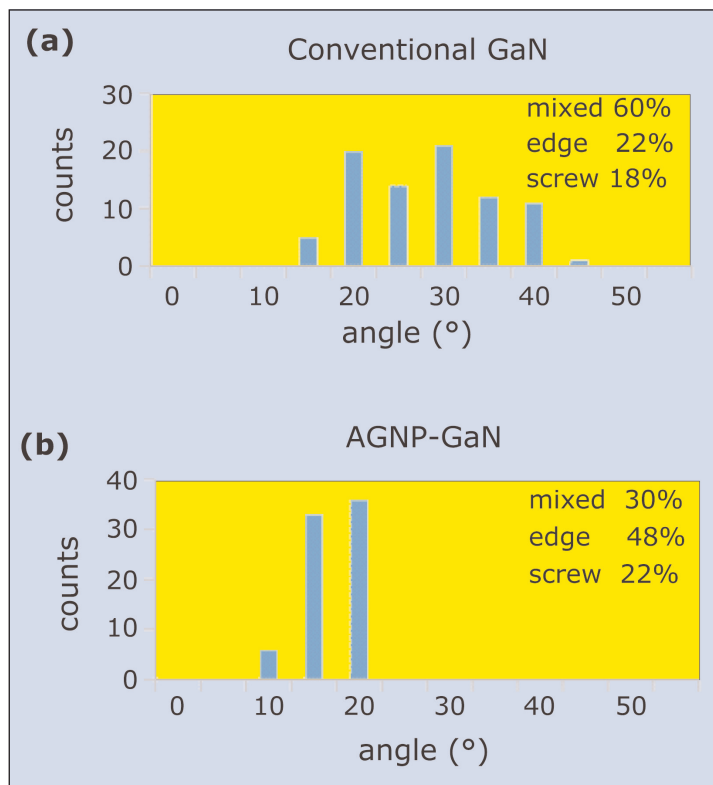


Figure 6. Distribution of dislocation bending angles and types for (a) conventional GaN and (b) AGNP-GaN.

- ▶ For PV operation under 100mW/cm² 1.5AM light, the open-circuit voltage of 2.05V was the same for both devices. However, the short-circuit current density was enhanced by 60% at 1.09mA/cm² for the PSS device, compared with 0.68mA/cm² for the conventional cell. The maximum power densities were 1.14mW/cm² (PSS) and 0.79mW/cm² (planar). However, the fill-factor was reduced from 57% (0.79/2.05x0.68) to 51% (1.14/2.05x1.09) for the conventional and PSS devices, respectively.

Earlier this year, another group of Taiwan-based researchers at National Cheng Kung University, National Chiao Tung University, and Southern Taiwan University also used epitaxy on PSS to improve the performance of nitride semiconductor solar cells [C.C. Yang et al, IEEE Electron Device Letters, published online 24 February 2011; reported ST April/May 2011 p76]. These patterned substrates had truncated cone structures created using photolithography and etch. The conversion efficiency of the patterned device was 1.71%, compared with 1.34% for the cell grown on planar sapphire. A conversion efficiency of 2.95% for nitride-based PV cells was achieved by Texas Tech University researchers last year (www.semiconductor-today.com/news_items/2010/AUG/TEXAS_240810.htm).

Characterization and tools

Lehigh University researchers in the USA have tried to look more closely at what goes on when GaN is grown on patterned sapphire [Wanjun Cao et al, J. Appl. Phys.,

vol110, p053505 p2011]. The researchers compared GaN quality resulting from a conventional GaN-on-sapphire method with an 'abbreviated growth mode' on nano-patterned c-plane sapphire (AGNP-GaN).

The conventional growth consisted of 30nm low-temperature (535°C) GaN buffer, hydrogen etch-back, and high-temperature (1080°C) GaN recovery and growth.

The nano-patterned sapphire substrate was created through a process of oxidation and epitaxial conversion of aluminum islands developed at Lehigh. This process results in a square array of 200–300nm diameter bumps with a pitch of about 1000nm. The square array of aluminum mesas was defined through electron-beam lithography. The height of the resulting Al₂O₃ bumps was about 100nm.

The AGNP-GaN growth consisted of a 15nm LT-GaN buffer and immediate HT-GaN deposition without etch-back/recovery.

The island growth phase created non-uniform, irregular features with conventional planar substrate; but in AGNP-GaN growth the islands had greater regularity in spacing, size and geometry, being located preferentially in the valleys between the sapphire bumps. Further, the AGNP-GaN islands had distinct inclined facets that have been associated with dislocation bending during coalescence. Dislocation bending is thought to be a major source of dislocation reduction in GaN.

Coalescence occurred after about 12 minutes of HT-GaN growth on the AGNP-GaN islands, giving a layer of 0.25µm. The conventional growth layer coalesced after 22 minutes with 0.66µm thickness.

While dislocation densities reduced five-fold between 2µm and 3.5µm thickness on conventional sapphire, the most dramatic reductions in dislocation density for AGNP-GaN occurred before 0.5µm. In the conventional GaN, dislocation bending occurred about 2.5µm, while in AGNP-GaN it is seen to occur before 1µm. After 4µm, the dislocation density in both types of material is estimated to be about 5x10⁸/cm². Dislocations included mixed, edge and screw types (Figure 6).

The researchers conclude: "These findings support earlier results showing that InGaN QW LEDs grown on nano-patterned sapphire showed enhanced output power and carrier lifetime compared with those grown on a planar template. The indication also is that AGNP-GaN may achieve equivalent or better performance than conventional GaN at much smaller thickness, saving time and expense in growth."

A number of companies are responding to the increased interest in patterned sapphire with tools such as atomic force microscopes (AFM, e.g. Bruker), wafer scribes (e.g. ESI), nanolithography (e.g. Eulitha) and automated defect inspection (e.g. KLA-Tencor). ■

Mike Cooke is a freelance technology journalist who has worked in semiconductor and advanced technology sectors since 1997.

Wet versus dry etching for sapphire wafers

Imtec Acculine's Derek Mendes discusses how wet etching of patterned sapphire substrates for GaN LED manufacturing can present cost savings over dry etching that multiply dramatically as throughput and wafer size scales up, even if polishing touch-up work is subsequently performed to increase light extraction efficiency.

According to a market research report published by Strategies Unlimited (SU), the high-brightness (HB) LED market experienced a 93% growth rate between 2009 and 2010. The global market for packaged HB LEDs was \$5.6bn in 2009 and grew to \$10.8bn in 2010. Strategies Unlimited is predicting that by 2015 the global market will be worth \$18.9bn, representing a compound annual growth rate (CAGR) of 11.8%.

Despite the positive forecast, there is one element that has the potential to stifle the growth of the LED market: high (and growing) production costs.

The US Department of Energy is expected to release a report stating that, in order to compete effectively with the fluorescent lighting market, solid-state lighting manufacturers need to cut the cost per lumen (currently at \$18/kilo-lumen) by eight-fold to \$2.20/kilo-lumen by 2015.

Gaining efficiencies during the manufacturing process is a key method to drive down costs. Larger-diameter sapphire wafers hold the promise of making the manufacturing process significantly more efficient, but they also present challenges to fabricators.

Transitioning from using of a standard 2-inch wafer to a wafer measuring 4-inches in diameter essentially quadruples the available surface area of the wafer. A doubling of the surface area occurs when moving from a 4-inch to a 6-inch wafer, and with every subsequent jump in size comes further substantial increases in surface area.

Unfortunately, theoretical efficiencies gained through the use of larger wafers are drastically undercut if existing manufacturing equipment is unable to cheaply or easily scale up to accommodate the larger form factors.

Efficiencies gained through the use of larger wafers are drastically undercut if existing manufacturing equipment is unable to cheaply or easily scale up to accommodate the larger form factors

Patterned sapphire substrates (PSS) serve a dual-purpose role in the LED industry. On the wafer supplier side, they are money-makers, since PSS wafers represent higher gross margins than traditionally polished sapphire wafers. On the product development side, PSS-based LEDs are more efficient, more effective light sources.

"The PSS reduces the dislocation density in the GaN (gallium nitride) layer and enhances the light extraction efficiency (LEE) from the LED chip by scattering the light confined in the GaN layer attributed to the critical angle between GaN ($n=2.4$) and the sapphire substrate ($n=1.7$) (or air ($n=1.0$)),” according to researchers at Yamaguchi University in Japan (Kazuyuki Tadatomo and Narihito Okada, 'Development of patterned sapphire substrate and the application to the growth of non-polar and semi-polar GaN for light-emitting diodes', Proc. SPIE 7954, 795416 (2011); <http://dx.doi.org/10.1117/12.874179>).

Dry etching is currently the most common method for producing PSS wafers. At this point, the techniques and technology for dry etching — including the inductively coupled plasma (ICP) variant of dry etching are commonplace: lithography exposes a pattern onto the sapphire substrate's photoresist, which is subsequently anisotropically etched into the crystalline structure via exposure to fluoride-base plasma gas and microwave energy. The resulting highly uniform and densely packed dome-shaped pattern encourages lateral film growth, resulting in fewer defects and increased light refraction. The LEDs formed using dry-etched PSS wafers produce highly efficient, very bright light.

Dry etching is a very slow process with a low throughput rate. Depending on the type of film used and the depth of the pattern being etched, a standard 2-inch wafer can take between 30 and 60 minutes to etch. Although it is nearly impossible to talk about average rates, given all the possible variables in the process, it is estimated that dry etching rates range between 50nm to 200nm per minute, or 20 minutes per micron. ▶

▶ The dry etch process also does not scale effectively. As wafer size increases, throughput of a dry etcher falls as fewer wafers fit inside the vacuum chamber. This means more expensive plasma etching tools are required to obtain the same throughput as was achieved on smaller wafers. More tools also come with increased operational costs, such as facilities, maintenance, utilities and consumables.

In comparison, the high-temperature wet etching process provides the dual advantages of being extremely fast and much cheaper than dry etching.

During high-temperature wet etching, gallium nitride (GaN) or indium gallium nitride (InGaN) coated wafers are placed in a tank containing a mixture of etching and buffering agents — normally sulphuric and phosphoric acids typically in a 1:1 or 3:1 ratio. Prior to submersion, a silicon dioxide mask is spun onto the sapphire substrate via a plasma-enhanced chemical vapour (PECVD) process and lithography is used to expose the desired pattern. Temperatures ranging from 260°C and 300°C are applied to the mixture. These temperatures greatly surpass those used in traditional semiconductor fabrication (which typically range from 150°C to 180°C).

Rather than etching rates increasing along a linear scale as the temperature rises, they increase exponentially. Hence a 300°C temperature may have an etch rate that is twice as fast as the etch rate experienced at 260°C. Conversely, Taiwanese researchers have demonstrated that “the etching rate increased linearly when the H₂SO volume ratio increased from 0 to 75%” (Wuu et al, ‘Fabrication of the Pyramidal Base Sapphire Substrates for High-Efficiency Based InGaN-Based Light Emitting Diodes’, *Journal of Electrochemical Society* 153 (8)G765–770 (2006)).

According to Rajiv K. Singh, founder & CTO of Sinmat, a provider of chemical mechanical planarization (CMP) technologies, high-temperature wet etching rates can be measured in microns per minute, with over 1µm per minute certainly achievable under the correct conditions. He says it is reasonable to expect a standard 2-inch wafer to be fully etched in five minutes.

Natsuko Aota, an engineer at Namiki Precision Jewel Co Ltd, is a proponent of the wet etching process and believes in its role as a key cost reducer in LED mass production.

The high-temperature wet etching process holds the advantage over dry etching in terms of speed, cost and scalability. A process tank for a batch of 6-inch wafers, for example, costs only slightly more than a tank designed for a batch of 2-inch wafers and can hold the same number of wafers.

Of course, the use of extremely hot chemicals can pose a challenge for manufactures. Chemicals hot enough and powerful enough to rapidly etch sapphire surfaces must be contained and handled safely. At the core of any system is the tank. It must be designed not to



react with any of the chemicals, so tanks (such as the Imtec Acculine XE-Series — pictured) are constructed of high-purity, virgin annealed quartz. They contain no plastics that come in contact with the mixture. Built-in temperature sensors feed precise readings back to the systems management equipment. As added safety features, the XE-Series includes a cool-down module to house the hot chemistry while it cools and an overflow tank that can hold 120% of the volume of the main tank, in case an accident should occur.

The PSS that results from the high-temperature wet etching process is a significant improvement on a non-patterned wafer in terms of light extraction and efficiency. The process results in the creation of truncated cone shapes — conical structures with flat tops (see Figure 1). ▶

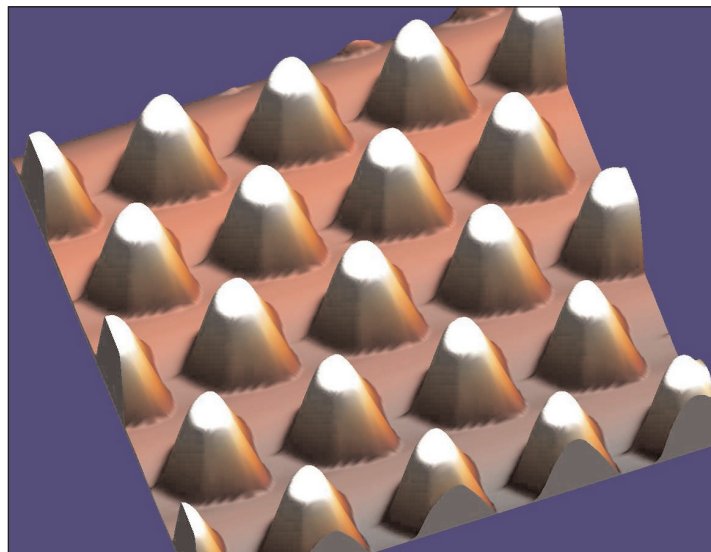


Figure 1. Flat top surfaces of cones from wet etching.

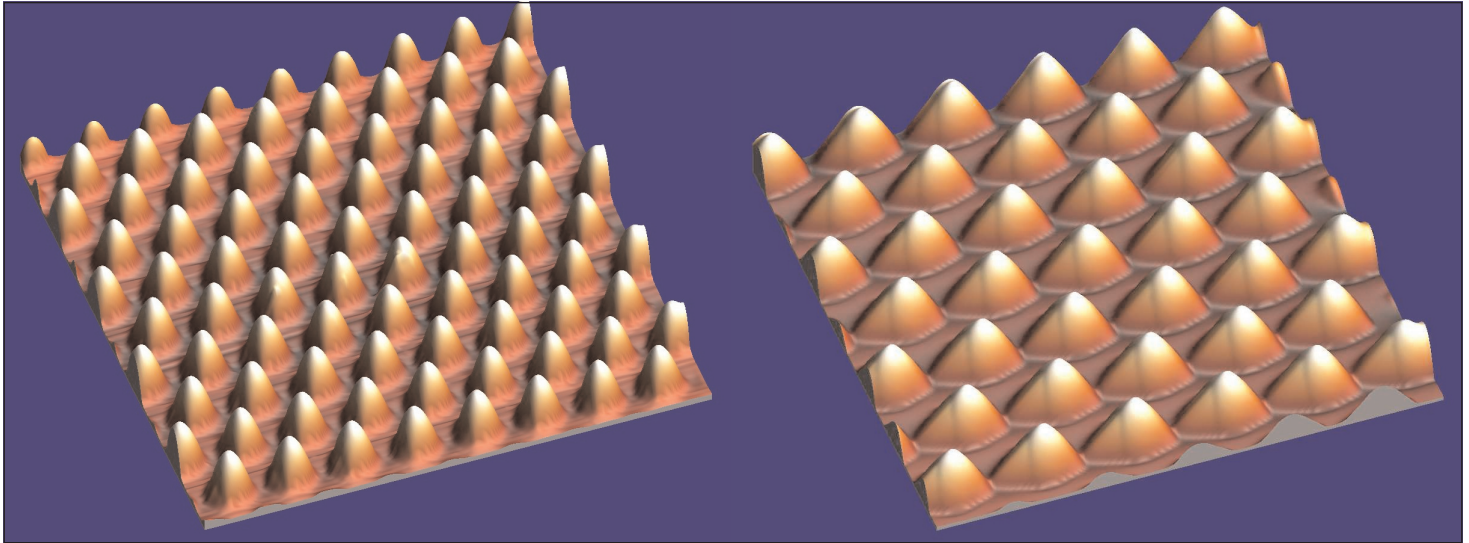


Figure 2. Formerly flat, truncated shapes are now polished and rounded (left), more closely resembling dry-etched PSS patterns (right).

Unfortunately, the flat top surface of the cone poses two significant challenges to those used to working with the dry etching process. The flat topped surfaces act to discourage the lateral growth of film and encourage vertical film growth, resulting in an increased number of defects. Additionally, the shape of the structures inhibits efficient light refraction.

Since this is still a relatively new process, research is being conducted into improving the quality of wet-etched sapphire wafers. One company undertaking such research is Sinmat, which has developed a method to polish the flat structures, thereby producing rounder, more efficient domes, which more closely resemble the shape of those produced by the dry etching process (see Figure 2).

Others are investigating the creation of patterns other than cone shapes. At National Chung Hsing University in Taiwan, researchers created truncated-triangle-striped patterned-sapphire substrate and a rhombus-like air-void structure at the GaN/sapphire interface to increase the light extraction efficiency. The truncated-triangle-striped patterned-sapphire substrate was fabricated through a wet etching process in hot sulfuric and phosphoric acid solutions. A rhombus-like air-void structure at the GaN/sapphire interface was formed through a wet etching process along a V-shaped air-void structure on the patterned sapphire substrate. After testing, the researchers concluded that "the [rhombus-like air-void structure LED] RA-LED has a 65% light-output power enhancement, a smaller divergent angle, and a periodic higher light intensity profile compared to a [flat sapphire substrate standard LED] STLED that provides a high external quantum efficiency in nitride-based LED applications," (Dai et al, 'Enhanced the Light Extraction Efficiency of a InGaN Light Emitting Diodes with an Embedded Rhombus-Like Air-Void Structure', Applied Physics Express 3 (2010) 071002).

Currently, LED manufacturers have the choice of two very different manufacturing processes. Dry etching creates bright, efficient LEDs but does so slowly and with limited throughput. Wet etching is fast and very scalable, but produces LEDs that are not quite as effective or efficient. Wet etching, however, presents a considerable cost saving over dry etching, even if polishing touch-up work is performed on the wafers to increase light extraction efficiencies. It also scales much more efficiently, making cost savings multiply dramatically as throughput and wafer size increase.

Dry etching creates bright, efficient LEDs but does so slowly and with limited throughput. Wet etching is fast and very scalable, but produces LEDs that are not quite as effective or efficient. Wet etching, however, presents a considerable cost saving over dry etching, even if polishing touch-up work is performed on the wafers to increase light extraction efficiencies

Looking at the financial side, Sinmat's Rajiv K. Singh breaks the numbers down like this: "Say you look at a flat substrate, and then you make a patterned substrate, the cost of making a pattern substrate increases the cost by 20% or maybe 25%. The wet etch would decrease that added cost by half."

Given the combination of per-unit cost saving with significantly higher etch-rates, LED manufacturers and sapphire wafer suppliers need to give high-temperature wet etching serious consideration. ■

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www.thefoxgroupinc.com

Freiberger Compound Materials

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 Fax: +49 3731 280 106

www.fcm-germany.com

Kyma Technologies Inc

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Fax: +1 919 789 8881
www.kymatech.com

Nikko Materials

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USA
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Fax: +1 480 899 0779
www.nikkomaterials.com

SiCrystal AG

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Fax: +49 (0) 9131 / 73 22 37
www.sicrystal.de

sp3 Diamond Technologies

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Fax: +1 503 693 8275
www.sesmi.com

TECDIA Inc

(see section 16 for full contact details)

III/V-Reclaim

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Fax: +49 8728 911 156
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5 Deposition materials

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6 Deposition equipment

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7 Wafer processing materials

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Fax: +1 617 965 5818

www.microchem.com

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(see section 10 for full contact details)

Praxair Electronics

(see section 5 for full contact details)

8 Wafer processing equipment

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www.spp-pts.com

TECDIA Inc

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Veeco Instruments Inc

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9 Materials & metals

Goodfellow Cambridge Ltd

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www.powerandenergy.com

SAES Pure Gas Inc

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11 Process monitoring and control

k-Space Associates

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Fax: +1 734 668 4663



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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12 Inspection equipment

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www.jawoollam.com

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14 Chip test equipment

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SUSS MicroTec Test Systems

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www.suss.com

15 Assembly/packaging materials

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www.epak.com

Gel-Pak

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www.gelpak.com

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16 Assembly/packaging equipment

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Switzerland
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Fax: +41 329257115
www.ismeca.com

Kulicke & Soffa Industries

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Fort Washington,
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USA
Tel: +1 215 784 6000
Fax: +1 215 784 6001
www.kns.com

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Tel: +1 760 931 3600
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18 Chip foundry

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Tel: +44 141 579 3000
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www.compoundsemi.co.uk

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Fax: +33 169 33 02 92
www.ums-gaas.com

19 Facility equipment

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Fax: +1 541 917 3623
www.marlerenterprises.net

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www.semitech.us

22 Used equipment

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24 Consulting

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25 Resources

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E-mail: ictf15@intergroup.co.jp

www.ictf15.jp

14–15 November 2011

3rd Concentrated Photovoltaic Summit USA

San Jose, CA, USA

E-mail: matt@pv-insider.com

www.pv-insider.com/cpv

15–16 November 2011

Netherlands MicroNanoConference '11

Conference Centre De ReeHorst, Ede, The Netherlands

E-mail: m.reinhold@fhi.nl

www.micronanoconference.nl

17–18 November 2011

2nd Utility Scale PV Plant Optimization

San Jose, CA, USA

E-mail: jack@pv-insider.com

www.pv-insider.com/optimizationusa

28 November – 2 December 2011

2011 MRS Fall Meeting

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E-mail: info@mrs.org

www.mrs.org/fall2011

30 November – 2 December 2011

Ecosystems for Solid State Lighting 2011: Linking Light to Sensors, Smart Grids and Information Infrastructure

Washington DC, USA

E-mail: info@pira-international.com

www.intertechpira.com/

eco-systems-for-solid-state-lighting-2011.aspx

5–7 December 2011

57th annual IEEE International Electron Devices Meeting (IEDM 2011)

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www.ieee-iedm.org

21–26 January 2012

SPIE Photonics West 2012

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http://spie.org/photonics-west.xml

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E-mail: LubaH@pennwell.com**www.strategiesinlight.com****12–16 February 2012****SPIE Advanced Lithography 2012**

San Jose, CA, USA

E-mail: customerservice@spie.org**http://spie.org/advanced-lithography.xml****4–8 March 2012****OFC/NFOEC 2012****(Optical Fiber Communication Conference and Exhibition/National Fiber Optic Engineers Conference)**

Los Angeles Convention Center, CA, USA

E-mail: info@ofconference.org**www.ofcnfoec.org****18–19 March 2012****China Semiconductor Technology International Conference (CSTIC 2012)**

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Abstract deadline: 30 October 2011

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Shanghai New International Expo Centre (SNIEC), China

E-mail: laser@mami-shanghai.com**www.world-of-photonics.net/en/laser-china/start****21–23 March 2012****7th Asia Solar Photovoltaic Industry Exhibition**

Shanghai Expo Theme Pavilion, China

E-mail: info@aiexpo.com.cn**www.asiasolar.cc/en****25–30 March 2012****8th conference on Porous Semiconductors - Science and Technology (PSST-2012)**

Hotel Monte Malaga, Spain

Abstract deadline: 25 December 2011

E-mail: info@the-psst.com**www.the-psst.com****9–13 April 2012****2012 MRS Spring Meeting**

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E-mail: info@mrs.org**www.mrs.org/spring2012****15–20 April 2012****Light+Building 2012**

Frankfurt am Main, Germany

http://light-building.messefrankfurt.com**16–18 April 2012****CPV-8 International Conference on Concentrating Photovoltaic Systems**

Toledo, Spain

E-mail: iinfo@cpv-8.org**www.cpv-8.org/cms****16–20 April 2012****SPIE Photonics Europe 2012**

The Square Conference Center, Brussels, Belgium

E-mail: customerservice@spie.org**http://spie.org/photonics-europe.xml****19–20 April 2012****4th Photovoltaics Thin-Film Week**

Berlin, Germany

E-mail: info@solarpraxis.de**www.solarpraxis.de/en/conferences****23–26 April 2012****2012 CS MANTECH (International Conference on Compound Semiconductor Manufacturing Technology)**

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E-mail: csmantech@csmantech.org**www.csmantech.org****23–27 April 2012****SPIE Defense, Security, and Sensing 2012**

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