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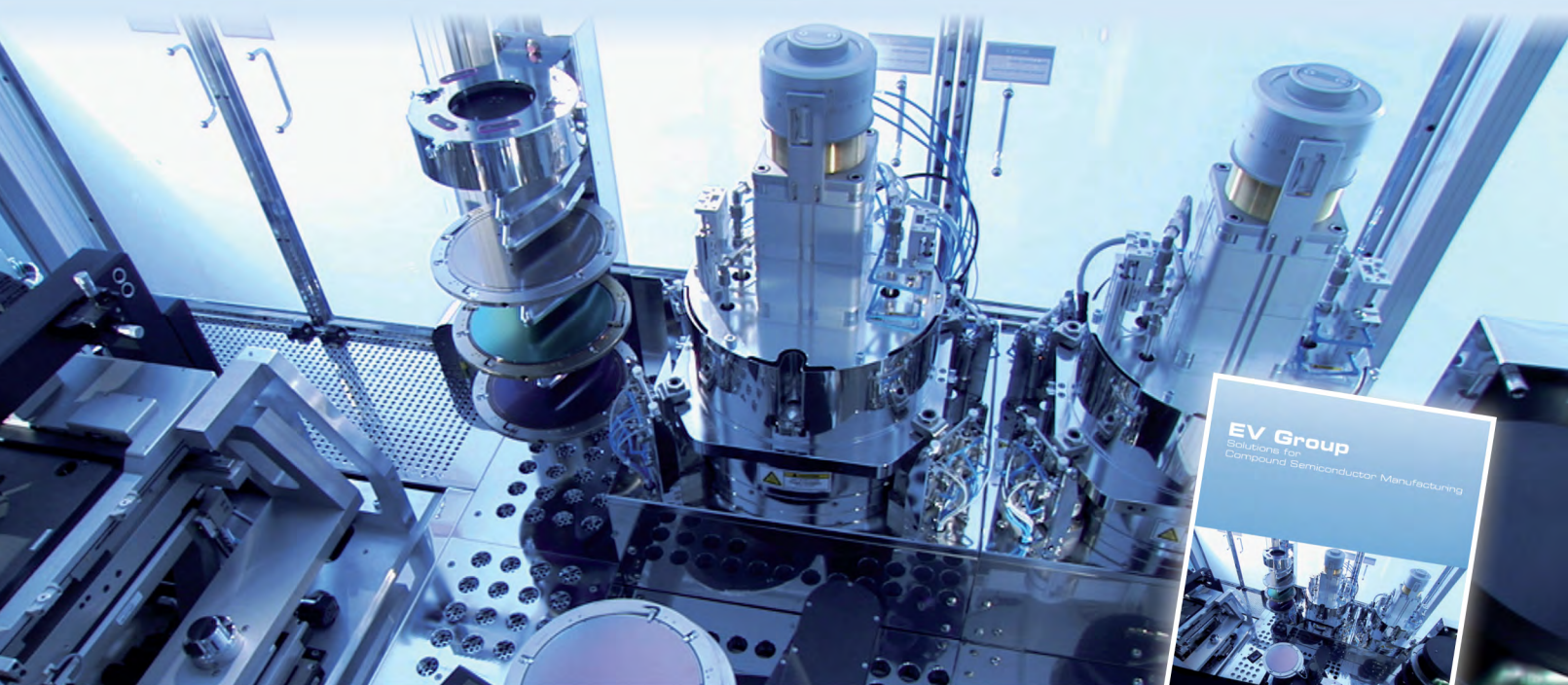
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Osram opens China LED assembly plant

Pseudo-direct gaps for efficient light emission and absorption

Analog Devices buying Hittite • News from IMS & PCIM Europe
Microsemi enters MMIC market • QinetiQ acquires Redfern

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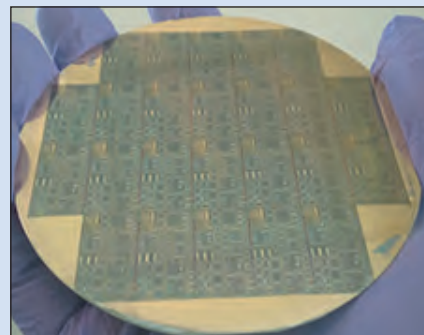


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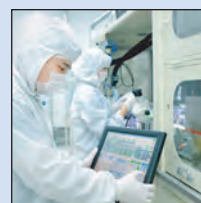
p27 University of Arkansas has designed SiC-based ICs that can survive at temperatures over 350°C.



p42 A packaged device from GaN Systems, which has launched a family of normally-off 100V GaN transistors spanning 20–80A with low on-resistance.



p58 At May's CS ManTech event, Brewer Science unveiled the Apogee bonder for temporary wafer bonding applications.



Cover: Product testing at Osram's new LED assembly plant in Wuxi, China, which has been formally opened. The factory has a floor area of about 100,000m² and will employ as many as 2100 staff by 2017. Osram is investing a low three-digit-million euro amount to set up the plant. **p74**

China driving LEDs and wireless

On pages 48–51 of this issue we catch up with the first-quarter financial results of MOCVD system makers Veeco and Aixtron, which have reported their highest order levels in more than two years. Capacity utilization rates in LED fabs are continuing to improve, driven by faster-than-expected adoption of LEDs for lighting applications. With nearly 80% of Aixtron's revenue already coming from Asia (and its new MOCVD tool — due for launch in Q2/2014 — currently being sampled in Greater China), China is assuming even greater importance with increasing adoption of both LED lighting and smartphones in emerging markets.

Indeed, IHS reckons that, for the first time, a Chinese LED maker (MLS) has entered the top 10 ranking of the world's largest LED makers (see page 6). Meanwhile, number 2 LED maker Osram of Germany has opened a second LED assembly plant in Asia, in Wuxi, China (adding to its plant in Malaysia), citing that China accounts for over 20% of the lighting market and is expected to rise from €15bn in 2013 to €23bn by 2019.

Regarding wireless communications, power amplifier maker Anadigics has also reported smartphone design wins with multiple Chinese OEMs, and cites a forecast by Digitimes Research of more than 30% growth in smartphone shipments from Chinese OEMs in 2014 (see page 10). Likewise, RF front-end component maker TriQuint has appointed a new distributor in China, driven by accelerating build-outs of LTE networks. It also says that its multi-band multi-mode power amplifiers and filtering solutions have captured 18 reference design wins spanning all six major chipset providers in Greater China (see page 14).

TriQuint's bulk acoustic wave (BAW) filter technology is also cited by Research In China as a key motive for the merger with RF Micro Devices, announced in February (which has just passed the deadline for any action by the US Federal Trade Commission or Department of Justice — page 15). The mobile RF industry's focus has been shifting from power amplifiers to filters, the market research firm notes (see page 9). The most valuable part of a mobile RF system is now not the PA but the filter (especially BAW filters, which are an essential part for 4G).

Another merger, announced in early June, is the acquisition of Hittite Microwave by Analog Devices, aiming to complement its silicon-based RF and signal-conversion technology with Hittite's RF, microwave and millimeter-wave technology, targeting industrial, communications infrastructure and automotive markets (page 19). Meanwhile, GigOptix is acquiring silicon-based Tahoe RF Semiconductor, in order to further expand its wireless portfolio from E-band to V-band frequencies for point-to-point wireless backhaul and other adjacent markets such as consumer GPS devices (page 20).

In addition, other large semiconductor firms are increasing their interests in compound semiconductors, including Japan's Furukawa swapping a license to its GaN patent portfolio for a stake in US-based GaN HEMT power conversion device maker Transphorm (page 43) and silicon-based analog/mixed-signal foundry X-FAB partnering with SiC diode and MOSFET supplier Monolith on high-volume production on 150mm SiC wafers (page 26). Meanwhile, Toyota has unveiled SiC-based power semiconductors that can shrink hybrid electric vehicle power control units by 80% versus silicon (page 28).

For further news on SiC and GaN device developments from the IMS and PCIM Europe events, see pages 30–42.

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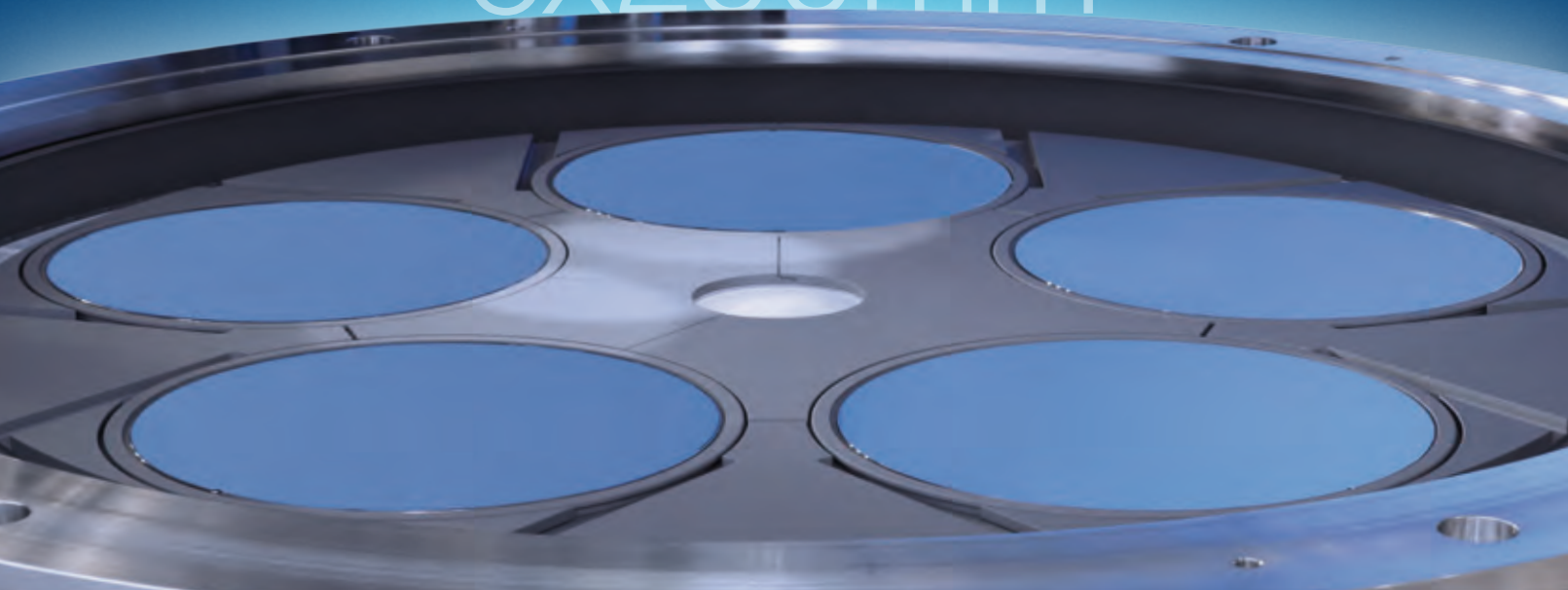
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First Chinese supplier enters top 10 ranking of packaged LED makers

China's massive investments in LED manufacturing capacity are paying off, with a Chinese company entering the top 10 global ranking (by revenue) of packaged LED makers for the first time, according to the IHS LED Intelligence Service of market research firm IHS Technology.

China's MLS Electronics Co Ltd rose from 14th place in 2012 to 10th in 2013. The other top 10 players are based in Japan (Nichia 1st and Toyoda Gosei 9th), Germany (Osram Opto 2nd), South Korea (Samsung Electronics 3rd, Seoul Semiconductor 4th and LG Innotek 7th), the USA (Lumileds 5th and Cree 6th), and Taiwan (Everlight 8th).

"Since 2011, most of the new LED production capacity that has been added worldwide has occurred in China," says Jamie Fox, principal LED analyst for IHS. "Because of this, it was inevitable that Chinese companies eventually would penetrate the ranks of the top 10 LED suppliers," he adds. "MLS was first to join the global elite, having established itself as the clear leader in the Chinese market by capitalizing on strong domestic demand. For the major suppliers, MLS' ascent into the market's upper ranks represents a clear signal that Chinese firms soon will become major competitors in the global LED business."

China's LED market lights up

MLS is one of many Chinese LED suppliers that have sprung up amid the surge in production. However, the other firms do not even rank among the top 20 global suppliers, notes IHS. China's LED supply base is massive and highly fragmented, with thousands of small manufacturers located across the country.

"Despite leading the domestic

Rank	Company Name	Company Headquarters
1	Nichia	Japan
2	Osram Opto	Germany
3	Samsung Electronics	South Korea
4	Seoul Semiconductor	South Korea
5	Lumileds	United States
6	Cree	United States
7	LG Innotek	South Korea
8	Everlight	Taiwan
9	Toyoda Gosei	Japan
10	MLS	China

market, MLS accounted for less than 10% of Chinese LED revenue in 2013," says Alice Tao, China LED analyst at IHS. "The next five largest LED suppliers in China represented only about 20% of the market."

With the rise of LED manufacturing capacity in China, concerns have risen relating to overcapacity. Some of the equipment purchased for metal-organic chemical vapor deposition (MOCVD) manufacturing is now sitting idle in China.

Observers have fretted that the overcapacity could result in the shutdown of some Chinese suppliers, notes IHS. However, so far only a few of the smaller Chinese vendors have closed their LED operations. Most of the top companies remain active in the market, with some posting strong profit margins.

Insular market goes global

MLS and the smaller Chinese suppliers mostly compete among themselves for a share of the large domestic LED market. The international portion of sales for these companies is hence very small.

At the same, the extremely low prices in the Chinese market make

the country inaccessible to overseas suppliers. Because of this, foreign LED makers do not encounter Chinese competitors very often.

But that situation will change rapidly, it is forecast. IHS expects the LED revenues of Chinese vendors to grow steadily over time, as

the country's economy continues to grow strongly. Because of this, Chinese LED suppliers will begin to sell more internationally and come into competition with foreign rivals.

Barriers to entry

Both intellectual property and quality are concerns for international customers considering Chinese suppliers. However, several factors suggest that these concerns could be alleviated over time. These include patent expirations, China's established history in other industries, the sheer volume of manufacturing capacity in the country, and the fact that many LED lamps are assembled in China.

So far, top-tier LED suppliers such as Nichia, Osram, Lumileds and Cree have seen only a small impact from Chinese vendors on their sales, especially in the general lighting market in regions such as Europe and the Americas. However, this will not necessarily be the case by the end of the decade, says IHS.

For instance, MLS has started 2014 on a strong note, and may have even ranked among the IHS top 10 LED suppliers in the first quarter.

www.ihs.com

LED market growing 9% in 2014 to \$16.6bn

After the recession in 2011 and 2012, the LED industry saw a turning point in 2013 when the die and package LED markets rose 8.3% from 2012 to about \$15.188bn, according to the 'Global and China LED Industry Report, 2013–2014' from Research In China. In 2014, the LED market is continuing to recover, growing 9% from 2013 to \$16.562bn. However, the market is expected to slow down in 2015 due to oversupply and a new round of price wars that may arise.

The global LED industry can be divided into four clusters. First, Europe and America underline general lighting, with an emphasis on high reliability and high brightness. Second, Japan embodies the most comprehensive technology, performing outstandingly in both general lighting and backlight displays. Besides, it also targets general lighting, automobiles, mobile phones and TVs. Third, South Korea and Taiwan target laptop display backlighting, LED-TV backlighting and mobile phone backlighting with large shipments, low unit price and low margin. Last, mainland China focuses on AlInGaP, outdoor displays, advertising screens and signal lights, which require low technology and reliability, and in these fields customers are scattered and the unit price is low.

Since 2011, a large number of mainland Chinese enterprises have entered the LED industry, causing panic, says the report. In reality, none (including the giant Sanan Optoelectronics) are capable of producing white LED chips or grasping the related patents, it adds. Mainland China therefore has to import or purchase all the white LED chips it needs from foreign firms.

Mainland Chinese LED enterprises rely on local government subsidies, which were huge in 2010–2013. For example, Elec-Tech International was subsidized with RMB270m in 2010, RMB311m in 2011, RMB224m in 2012 and RMB315m in 2013; but the firm's net income was only

Top 30 LED Vendors in the World by Revenue, 2012–2014

USD mln		2012	2013	2014E
Nichia		2,395	2,510	2,608
Samsung		1,218	1,390	1,398
OSRAM		1,106	1,198	1,258
LG INNOTEK		849	933	908
Seoul Semiconductor		731	921	1,058
Cree		757	895	928
Everlight	Pure Package	644	832	993
Epistar		674	749	1,017
Liteon	Pure Package	543	674	792
Lumileds		568	610	608
Lumens		414	577	708
Toyota Gosei		660	538	470
Sharp		409	486	508
LEXTAR	Pure Package	489	463	499
Sanan		258	360	398
Citizen	Pure Package	380	338	350
Kingbright Electronics	Pure Package	240	270	290
Unity Opto	Pure Package	255	233	293
Optotech		223	215	217
Harvatek	Pure Package	127	157	211
Genesis	Pure Package	123	132	171
Formosa Epitaxy		164	148	165
TYNTEK		113	140	225
Nationstar	Pure Package	106	115	118
Bright LED	Pure Package	113	94	83
Edison Opto		77	92	119
HuaLei Optoelectronic		50	85	108
Tekcore		55	62	67
ELEC-TECH		60	62	88
HC SemiTek		52	51	116

RMB4.6m in 2013. Without these subsidies, the company would be in a serious deficit. In 2014, Sanan Optoelectronics has obtained RMB4bn from Xiamen's government, which is keen to attract the firm back from Wuhu to Xiamen.

Many mainland Chinese LED downstream enterprises are characterized by small scale, severe homogenization and intense price war. They are unable to get government subsidies or conduct financing in the stock market. Consequently, in 2014 many of them may go bankrupt, reckons the report.

Since 2013, LED industry development has been mainly in packaging. In future, LED cost reduction will depend on packaging not epi. Packaging comprises over 50% of the LED chip cost. Currently, chip-on-board (COB) and flip-chip packaging are not only the most promising

types but also represent the future direction.

COB performs strikingly in street lighting and high-power general lighting. However, it is inferior to flip-chip in fields where volume is important, such as TV back-light units (BLUs). In addition, flip-chip's cost advantage is more obvious. From the perspective

of cost and application, COB will become the future mainstream in lighting design, the report reckons.

Flip-chip made its debut in 2008, and became mature in early 2012. Its biggest advantage is that it can enter surface-mount technology (SMT) production lines directly under high current without wirebonding and manual welding. Also, it is small. The market is forecasted to leap from \$1.5bn in 2013 to \$5.5bn in 2017. In the BLU field, flip-chip will become the mainstream package type.

Prior to 2014, LED cost cutting concentrated on epitaxy, so epi vendors saw a sharp decline in profits. Many of them even exited the industry due to losses. After 2014, packaging factories will suffer the cost-cutting pressures, so some of them with poor technical capabilities may see falling profits, forecasts the report.

www.researchinchina.com

Gallium market to grow 40% by 2020 as general lighting rises from 18% to 33% of demand

Electronic power management to fall from 50% to 43% of total

Demand for gallium will rise rapidly between 2014 and 2020 as general lighting moves away from incandescent and fluorescent lamps to light-emitting diodes, but this strong growth is unlikely to result in any tightness in supply as the market is oversupplied and likely to remain so, forecasts market research firm Roskill Information Services Ltd in the latest edition of its report 'Gallium: Global Industry Markets & Outlook'.

Production dominated by China

Chinese capacity for primary gallium production (as a by-product of alumina) is estimated to have risen from a third to 80% of the global total between 2009 and 2013. Despite the increase in capacity, world production of primary gallium is estimated by the United States Geological Survey (USGS) to have fallen by about 100 tons in 2013 to 280 tons. Some 220 tons of this was produced in China, where stocks are accumulating. Recycling, particularly in Japan, is an important element of supply.

Consumption mainly in Japan, but China is catching up

By far the largest market is in Japan, but its share of the global market is estimated to have fallen from as high as 80% in the mid-2000s to about 50% in 2013. While Japan is likely to remain the world's dominant gallium market for some years, the growth of the optoelectronics and electronics industries in China, together with the abundant domestic supply of gallium, indicates that the Chinese market will eventually become the largest. The global gallium market is forecast to rise by 40% to about 422 tons per year (tpy) by 2020, with use in general lighting rising from 18% to 33% of total demand. Gallium's use for electronic power management will remain the largest market, but will decline from 50% to 43% of the total, forecasts the report.

Use of GaN expanding rapidly

The use of gallium nitride (GaN)-based integrated circuits and LEDs is widening and increasing, with a number of companies researching and developing its potential, notes the report. The use of gallium compound LEDs (particularly GaN-based) in all types of solid-state lighting (SSL) applications has become a major use for gallium. The SSL market comprises architectural, commercial, consumer portable (e.g. torches), industrial, outdoor and residential, signals (e.g. traffic lights) and motor vehicles. Architectural lighting has been the largest market, but may be overtaken by outdoor and residential lighting.

GaN power semiconductors can operate at higher temperatures, power levels, voltages and frequencies than gallium arsenide (GaAs) and silicon. There are power applications for GaN in power distribution, industrial and heavy electrical systems, and turbines, heavy machinery, advanced industrial control systems and electro-mechanical computing systems. GaN can also work across a very broad range of other high-frequency, high-power and microwave electronic devices used in cable TV, aerospace applications, utility grids, electric vehicles and wireless applications such as base-stations. GaN semiconductors are also used in LEDs for backlighting of LCD flat panel displays in computers, TVs and mobile telephones, and in signage, adds the report.

GaAs semiconductors and semi-insulators remain an important market

GaAs has historically been the most widely used gallium compound semiconductor. Its main modern uses are in power amplifiers — principally for mobile phone ICs — and in LEDs for backlighting of televisions, computers and phones.

Speed is the main advantage of GaAs. It is a faster, more efficient substrate material than silicon for ICs as electrons travel about five times faster in GaAs than they do in silicon. In addition, GaAs can operate over a wider range of temperatures than silicon, and has much higher radiation hardness. It is hence particularly useful for space applications and military hardware.

Thin-film PV cells potentially a growing market for gallium

A small amount of gallium is used in thin-film copper indium gallium (di)selenide (CIGS) photovoltaic (PV) cells. Thin-film technology is being researched intensively, because it is much lighter and more flexible than silicon crystal, and its use is growing. The semiconducting materials used to absorb the sun's rays are deployed as thin films only a few microns deep. Amorphous silicon, cadmium telluride (CdTe) and copper indium (di)selenide (CIS) compete with CIGS in the thin-film market, notes the report.

Impact of changes in gallium market on prices?

Despite growing demand for use in LED lighting, and a widely held expectation that GaN-based LED lighting will become the norm in the next ten years, gallium prices in 2013 and the early part of 2014 fell to their lowest ever levels in real terms. This is because gallium supplies from a combination of both primary and secondary sources are deemed more than sufficient to meet any likely demand. With only 11 producers of primary gallium in the world (seven of which are in China), it is possible that a producer price, based on costs and a profit margin, could come into force. This may lead to a gradual increase in prices from the very low levels seen in first-half 2014, reckons the report.

www.roskill.com/gallium

<http://minerals.usgs.gov/minerals/pubs/commodity/gallium>

Focus of mobile RF industry shifting from PAs to filters

In the 'Global and China RF Industry Report, 2013–2014', market analyst firm Research In China notes that the biggest event in the RF industry in 2014 is RF Micro Devices' 'takeover' of Triquint Semiconductor.

Triquint suffered consecutive losses in 2012 and 2013. In first-quarter 2014, its revenue fell by 3.6% year-on-year, and its operating margin was negative 11.3% (following negative 3.2% the prior quarter and negative 18.8% a year previously). Losses were mainly attributed to the aggressive capacity expansion (as much as seven manufacturing centers) before 2011 and excessive expectations. Additionally, Triquint showed a serious dependence on large customers (in particular, 57% of its revenue came from Apple).

In contrast, RFMD is just exiting its predicament. In its early years, RFMD placed undue reliance on its client Nokia, but it witnessed poor performance in 2011–2012 due to the impact of Nokia. However, RFMD

recovered in 2013 and its operating revenue rose substantially. RFMD was attracted by Triquint's bulk acoustic wave (BAW) filter technology, summarizes the report.

The mobile RF industry's focus has been shifting from power amplifiers (PAs) to filters, the report notes. In the 4G era, the most valuable part of a mobile RF system is the filter (especially BAW) rather than the PA. The biggest difference between 4G and 3G lies in BAW, which is an essential part for 4G. A regional LTE phone needs a BAW filter valued at \$1.25, a SAW filter worth \$2.25, and a PA that only costs \$1.75. As for a global roaming LTE phone, a SAW worth \$3, a BAW worth \$3.50 and a PA worth \$2 are required.

The report also reckons that Qualcomm's RF360 CMOS PA design (announced in early 2013) is changing the entire mobile RF industry in a revolutionary way, as the gallium arsenide (GaAs) PA is facing a fierce attack from CMOS PA. The RF360 design subverts the

opinion that CMOS PAs can only be used on low-end phones. Specifically for CMOS PAs, Qualcomm has designed the QFE1100, which is a front-end module involved with envelope tracking technology. QFE1100 can help CMOS PAs to improve thermal efficiency, reduce heat by 30% and cut power consumption by 20%, it is said.

ZTE's flagship cell phone Grand S II LTE uses Qualcomm's CMOS PAs — QFE2320 and QFE2340 — for the first time. The combination of QFE2320 and QFE2340 can cover all major cellular modes, including LTE TDD/FDD, WCDMA/HSPA +, CDMA 1x, TD-SCDMA and GSM/EDGE, with the RF band 700–2700MHz. Qualcomm has basically monopolized the smartphone modem and CPU markets, and may dominate the PA field, reckons the report. However, mobile phone vendors will still cooperate with GaAs PA suppliers in order to ensure their equal status, it concludes.

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Wireless infrastructure drives RF power market over \$1bn GaN bridging gap between high-frequency performance of GaAs and power handling of silicon LDMOS

Spending on RF power semiconductors for the wireless infrastructure markets leapt up again in 2013 to more than \$1bn, according to the study 'RF Power Semiconductors' from ABI Research's High-Power Active Devices research service, which examines devices that have power outputs of more than 4W and operate at frequencies up to 3.8GHz (representing the bulk of applications in use currently).

While other markets are seeing some moderation in growth as the global economic picture and political factors come into play, some sub-markets are showing a nice upside, the firm says. Also, gallium nitride — long seen as the likely promising new 'material of choice' for RF power semiconductors — is contin-

uing its march to capture share, especially in wireless infrastructure.

"GaN is delivering increasing market share in 2014 and is forecast to be a significant force by 2019," notes ABI director Lance Wilson. "It bridges the gap between two older technologies, exhibiting the high-frequency performance of gallium arsenide combined with the power handling capabilities of silicon LDMOS," he adds. "It is now a mainstream technology which has achieved meaningful market share and in future will capture a significant part of the market."

The vertical markets showing the strongest performance outside of wireless infrastructure in the RF power semiconductor business are the defense-oriented segments,

which Wilson describes as now being "a significant market" in total. Despite the poor press for defense-oriented electronic hardware, the actual performance in 2013 was better than originally thought for some sub-segments, he adds.

The last study that ABI published on this topic appeared late in 2013. With the current release, analysis of the six main vertical segments — wireless infrastructure; military; industrial, scientific, and medical (ISM); broadcast; commercial avionics and air traffic control; and non-cellular communications — is expanded from 24 sub-segments to 29 sub-segments.

<https://www.abiresearch.com/market-research/product/1014673-rf-power-semiconductors>

Anadigics expands WiFi infrastructure portfolio and secures design wins at key OEM

Anadigics Inc of Warren, NJ, USA has launched the AWL5910 power amplifier (PA), optimized for WiFi infrastructure and multimedia applications including access points, routers, media gateways, set-top boxes, and smart TVs.

The new 5GHz power amplifier supports the 802.11a/n/ac standards and delivers a combination of linearity, efficiency and gain, while minimizing external component requirements. This level of performance and integration enables manufacturers to reduce both time-to-market and bill of materials, says Anadigics, while developing WiFi-enabled products that provide higher throughput with greater range, as well as consume less power. The AWL5910 has been adopted for use in multiple high-performance connectivity solutions which are expected to ramp in the upcoming quarter.

"The new AWL5910 provides world-class linearity, efficiency and gain to ensure high-speed WiFi

connectivity, all while reducing BOM costs and minimizing PCB space requirements," claims Jonathan Griffith, VP of WiFi products. "Leading OEMs recognize the strategic value our AWL5910 provides, and this is generating excellent design-win traction in a critical growth segment for Anadigics."

The firm's 802.11ac WiFi power amplifiers for infrastructure applications leverage its patented InGaP-Plus technology and unique design architectures to offer performance and integration. The AWL5910 PA provides 31dB of linear power gain and ultra-low 1.8% of EVM (error vector magnitude) at 22dBm output power to ensure stable, reliable high-throughput WiFi connectivity in the toughest 802.11ac modulation formats. The AWL5910 integrates additional functionality by removing unnecessary surface-mount passives and integrating a digital PA enable interface that eliminates the need

for an external buffer amplifier. This solution also features a high-accuracy integrated detector that facilitates accurate power control over varying load conditions (3:1 VSWR) and extends the usable detector dynamic range from 5dBm to 26dBm, enabling extremely high transmission data rates.

The compact 4mm x 4mm x 0.8mm QFN package also incorporates RF ports internally matched to 50 Ohms and DC blocked to reduce PCB space requirements. In addition, a CMOS-compatible control interface improves ease of use.

These performance and integration advantages, coupled with the power efficiency and thermal characteristics, enable multiple input multiple output (MIMO) designs that consume less power and are more thermally efficient, says Anadigics.

Samples of the AWL5910 are available now for qualified programs.

www.anadigics.com

Anadigics gains multiple design wins at Chinese smartphone OEMs

Anadigics says that its ProEfficient and ProVantage power amplifiers (PAs) have been selected by multiple Chinese OEMs to enable wireless connectivity in new smartphone designs.

"According to a recent report by DigiTimes Research, the sequential annual growth rate in smartphone shipments from Chinese OEMs is expected to exceed 30% in 2014," notes president Dave Cresci. "Anadigics is well positioned to capitalize on this expected growth with design wins at several key OEMs, including Huawei, ZTE, Coolpad and Innos," he adds. "We anticipate that these new design wins for our ProEfficient and ProVantage power amplifiers should enable a significant increase in our mobile products revenue at Chinese OEMs."

ProEfficient and ProVantage solutions utilize Anadigics' patented InGaP-Plus technology to deliver high performance and integration. ProEfficient power amplifiers also leverage the firm's unique design architectures to offer high efficiency across all power levels as well as low quiescent current to maximize battery life, enabling greater talk time and longer data application use. ProVantage power amplifiers are designed to combine high performance with space-saving integration and lower overall sys-

The sequential annual growth rate in smartphone shipments from Chinese OEMs is expected to exceed 30% in 2014

tem cost. Both ProEfficient and ProVantage also have compact packages with internal voltage regulation and integrated DC blocks on the RF ports to reduce PCB space requirements. RF matching is optimized for output power, efficiency, and linearity in a 50Ω system.

Both ProEfficient and ProVantage are designed for use with an external switch mode power supply (SMPS) to support average power tracking (APT), which further increases efficiency and reduces current consumption at low and medium operating powers. Anadigics says that its complete portfolio of power amplifier solutions provides high linearity to ensure stable cellular connectivity and high-data-throughput 3G and 4G connections.

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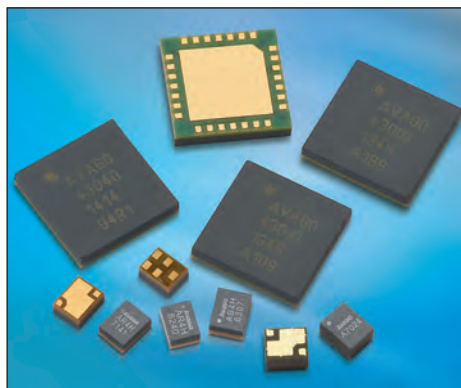
Avago debuts small-cell PAs & LTE/WiFi coexistence filters

Avago Technologies Ltd (a supplier of III-V-based analog interface components for communications, industrial and consumer applications) has announced four new RF power amplifiers (PAs) for small-cell base transceiver station (BTS) applications and a full spectrum of LTE/WiFi coexistence FBAR (film bulk acoustic resonator) filters for mobile and wireless infrastructure applications.

Expanding on Avago's proven MGA-43xxx PA family, Avago has introduced the MGA-43003, MGA-43013, MGA-43024 and MGA-43040 featuring high linearity, gain and power-added efficiency (PAE) with integrated power detector function.

Product highlights are as follows:

- MGA-43003 (LTE band 3 PA): linear P_{out} of +27dBm at 48dBc ACLR (adjacent channel level rejection); gain of 41.7dB; PAE of 14%.
- MGA-43013 (LTE band 12, 13 and 17 PA): linear P_{out} of +27dBm at 48dBc ACLR; gain of 33.5dB; PAE of 16.5%.
- MGA-43024 (2.4GHz WiFi PA): P_{out} of +27.8dBm at 2.5% EVM (error vector magnitude); gain of 40.5dB; PAE of 14.8%.



Avago's MGA-43xxx PA family

- MGA-43040 (LTE band 40 PA): linear P_{out} of +27dBm at 48dBc ACLR; gain of 42dB; PAE of 13%.
- ACPF-7x24 (2.4GHz WiFi filters): insertion loss of <1.7dB (Ch 1–13); 50dB attenuation in band 40; 55dB attenuation in band 7.
- ACPF-7x41 (LTE band 41 filters): insertion loss of <2.1dB; WiFi attenuation (Ch 1–11) of >40dB.
- ACPF-8x40 (LTE band 40 filters): insertion loss of <1.5dB; WiFi attenuation (Ch 5–13) of >40dB.
- ACMD-6x07 (LTE band 7 duplexers): Tx insertion loss of <2.5dB; Rx insertion loss of <2.0dB; WiFi attenuation of >45dB.

"Avago is a leading provider of RF front-end solutions for small-cell

applications with the industry's most comprehensive product offering of LTE PAs and LTE/WiFi coexistence filters," claims Ron Ruebusch, senior VP & general manager of Avago's Wireless Semiconductor Division. "The introduction of our four new MGA-43xxx PAs and full showcase of our LTE/WiFi coexistence filters further demonstrate Avago's commitment to addressing the growing small-cell market segment," he adds.

"With mobile data demand overwhelming the mobile network, small cells are becoming an important part of building capacity for LTE," asserts Joe Madden, principal analyst at Mobile Experts. "The early days of femtocells are now changing to multi-band, multi-mode small cells where 3G, LTE and Wi-Fi must operate simultaneously without interference," he adds. "The industry needs high-performance RF filters and power amplifiers to make these multi-mode radio nodes successful."

Samples and production quantities are available now through Avago's direct sales channel and worldwide distribution partners.

www.avagotech.com/smallcell

MACOM accredited as DoD Trusted Foundry

M/A-COM Technology Solutions Inc of Lowell, MA, USA (which makes analog semiconductors, components and subassemblies for analog, RF, microwave and millimeter-wave applications) says that its wafer fabrication facility in Lowell has been accredited by the US Department of Defense (DoD) as a Category 1A Trusted Foundry.

Such accreditation distinguishes MACOM as a trusted manufacturer of integrated circuits for classified and unclassified US military and aerospace applications. The Category 1A designation is conferred to microelectronics vendors exhibiting the highest levels of process integrity and protection.

Administered by the Defense Microelectronics Activity (DMEA) organization, the Trusted Foundry program aims to ensure the trustworthiness of electronic components used for critical national security systems. It provides a way for the DoD to assess the integrity and confidentiality of IC design and manufacturing processes, establishing stringent requirements spanning chain of custody assurance, supply continuity, and anti-tampering and anti-reverse engineering measures.

The Trusted Foundry program ensures that the US government has guaranteed access to specialized, high-performance components. MACOM says its wafer fab is suited

to meet this requirement, supporting high-diversity fabrication and niche process variants offering the high-performance characteristics that many DoD applications demand.

"Customers demand supply options as the RF and microwave industry faces increased consolidation," says senior VP & general manager Suja Ramnath. "Accreditation reinforces MACOM's experience, commitment and expertise in servicing the aerospace and defense market. It acknowledges the work we have been doing for the last six decades and ensures that our customers enjoy the same level of trusted quality and supply for years to come."

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TriQuint captures 18 reference design wins with all six major chipset providers in Greater China

RF front-end component maker and foundry services provider TriQuint Semiconductor Inc of Hillsboro, OR, USA says that its filtering solutions and multi-band, multi-mode PA modules (MMPAs) for LTE smartphones have captured 18 reference design wins with all six major chipset providers in Greater China.

"Our high-performance filters and MMPAs have earned a spot on 18 new reference designs in Greater China," says Todd DeBonis, VP of global sales & strategic development. "TriQuint is proud to collaborate with chipset suppliers and OEMs in this key market to accelerate the next generation of RF and solve wireless 4G coexistence challenges," he adds.

Engineers developing consumer devices in China and Taiwan rely heavily on reference designs from chipset providers such as MediaTek. These technical blueprints give OEMs a proven solution, reducing risk significantly, shortening design cycles and speeding time to market, says TriQuint. This is a crucial advantage for Chinese smartphone makers who are expanding beyond their own borders into the hyper-

competitive global market, the firm adds.

"As Chinese consumers move to data-enabled smartphones and LTE band counts increase, TriQuint's premium filters are playing a crucial role in solving the most challenging interference issues in today's crowded RF spectrum," comments MT Hsieh, technical director of MediaTek's Smartphone business unit. "We selected TriQuint's advanced bulk acoustic wave (BAW) filters not only for their superior performance, but also knowing we could count on TriQuint's high-volume manufacturing capacity to assure supply as we pursue a bigger

Engineers developing consumer devices in China and Taiwan rely heavily on reference designs from chipset providers... Chinese smartphone makers are expanding beyond their own borders

share of the global market."

MediaTek, which provides systems-on-a-chip products for wireless communications and home entertainment, overtook Intel in 2013 to capture the number-two spot in the 3G UMTS baseband market, according to market research firm Strategy Analytics. Its recent LTE chip announcements signal its intention to drive 4G baseband market share and revenues around the globe.

In addition to reference design wins, TriQuint's filters and MMPAs have scored multiple design wins for high-volume 4G smartphones in China (the world's largest single smartphone market). Sales there soared more than 85% last year, according to market research firm Gartner. TriQuint is also benefiting from the build-out of 4G network infrastructure in China with increased sales of its base stations and other communications products. Analysts forecast that more than 400,000 Chinese 4G LTE base-stations will be deployed in 2014 alone.

www.triquint.com/applications/mobile-devices/advanced-filters

TriQuint appoints new distributor in China for mobile RF solutions

RF front-end component maker and foundry services provider TriQuint Semiconductor Inc of Hillsboro, OR, USA has appointed Shenzhen-based Upstar Technology — one of the fastest-growing providers of electronic components and solutions in China, with offices in Shanghai and Beijing — as its new distributor of mobile products in the country.

Upstar provides OEMs (original equipment manufacturers), ODMs (original design manufacturers) and EMS (electronics manufacturing services) in China with a wide range of electronic components. With this new partnership, TriQuint's customers in China now

have an expanded channel to access the firm's RF solutions for mobile products.

"Upstar's LTE focus and mobile-centric product line mesh well with TriQuint's overall business strategy for China," says Todd DeBonis, TriQuint's VP of global sales and strategic development. "Upstar will provide our customers better access to TriQuint's innovative RF technology, and will help fuel our growth initiatives. "Thanks to its strong sales and design support teams, Upstar has earned an excellent reputation for working closely with global partners and customers to address their unique requirements," he adds.

"We look forward to partnering closely with TriQuint to deliver the benefits of its RF innovations to customers throughout our fast-growing region," says Upstar's acting general manager Richard Lo.

China is the world's largest wireless communications market, with growth driven by rapid consumer adoption of mobile devices and accelerating build-outs of LTE networks. TriQuint says that it has captured numerous design wins in China for leading smartphones and has also been selected for reference designs by multiple global and regional chipset partners.

www.upstartech.com/en
www.triquint.com/how-to-buy

TriQuint wins chipset reference design to deliver Gigabit Wi-Fi for whole-home HD video streaming & demanding multimedia applications

RF front-end component maker and foundry services provider TriQuint Semiconductor Inc of Hillsboro, OR, USA says that a leading chipset provider has selected its two new high-performance 5GHz WLAN front-end modules (FEMs) for the industry's fastest commercially available 4x4 MU-MIMO 802.11ac chipset. With almost 2Gbps total throughput, the chipset streams carrier-grade IPTV to multiple devices in full 1080p or 4K Ultra HD resolution. TriQuint says that its modules provide the improved linearity, power consumption and thermal performance critical for delivering high-quality HD video in Wi-Fi set-top boxes and media gateways.

TriQuint has also launched a family of three filters to solve challenging Wi-Fi/LTE interference issues. Using TriQuint's bulk acoustic wave (BAW) technology, they enable users to extend Wi-Fi ranges while meeting stringent spectrum regulations worldwide. The firm has already secured multiple design

wins for the filters in Wi-Fi access points, home media gateways and automotive infotainment markets.

"As demand for high-bandwidth Wi-Fi connectivity grows, our customers and chipset partners count on TriQuint to solve the

Shipments of consumer and enterprise WLAN access points will reach 170 million and 25 million, respectively, at the end of 2014. As new devices are rolled out with the faster 802.11ac Wi-Fi standard, sales are accelerating rapidly: 802.11ac devices are expected to represent 45% of consumer Wi-Fi equipment shipments at the end of 2014

toughest system challenges so they can deliver best-in-class wireless broadband capabilities," says James Klein, VP for Infrastructure and Defense Products. "TriQuint continues to drive WLAN innovation and capture design wins for its high-performance BAW filters in several applications," he adds. "We're leveraging our broad in-house RF technology portfolio and integration expertise to deliver products for the fast-growing WLAN infrastructure connectivity market."

According to a recent market report, shipments of consumer and enterprise WLAN access points will reach 170 million and 25 million, respectively, at the end of 2014. As new devices are rolled out with the faster 802.11ac Wi-Fi standard, sales are accelerating rapidly: 802.11ac devices are expected to represent 45% of consumer Wi-Fi equipment shipments at the end of 2014, according to ABI Research. www.triquint.com/applications/networks/wlan-bluetooth

HSR waiting period expires for RFMD-TriQuint merger with no action by FTC or Department of Justice Merger still awaiting approval by both shareholders

The waiting period under the US Hart-Scott-Rodino (HSR) Antitrust Improvements Act of 1976 in relation to the merger between RF Micro Devices Inc of Greensboro, NC, USA and RF front-end component maker and foundry services provider TriQuint Semiconductor Inc of Hillsboro, OR, USA (announced on 24 February) expired on 13 June, with no action by the US Federal Trade Commission or the Department of Justice.

RFMD and TriQuint agreed to combine under a new holding company in an all-stock, merger-of-equals transaction. Upon completion of the

transaction, RFMD shareholders will receive 0.25 of a share of the new holding company for each share of RFMD common stock, and TriQuint shareholders will receive 0.4187 of a share for each share of TriQuint common stock. RFMD and TriQuint shareholders are each expected to hold about 50% of the new holding company's shares issued and outstanding immediately after completion of the transaction.

Completion of the HSR Act waiting period satisfies one of the conditions required to finalize the transaction. The merger is subject to approval by both TriQuint and RFMD share-

holders, other required regulatory approvals, and customary closing conditions.

In connection with the proposed merger, Rocky Holding Inc, a newly formed holding company under RFMD, has filed with the US Securities and Exchange Commission (SEC) a Form S-4 which includes a registration statement and a preliminary prospectus (with respect to Rocky Holding shares to be issued in the merger) and a preliminary joint proxy statement of TriQuint and RFMD in connection with the merger.

www.triquint.com
www.rfmd.com

Skyworks raises June-quarter revenue guidance from \$535m to \$570m

Diluted EPS guidance raised from \$0.73 to \$0.80

Skyworks Solutions Inc of Woburn, MA, USA (which makes analog and mixed-signal semiconductors) has raised its revenue guidance for fiscal third-quarter 2014 (to end-June) — given on 22 April — from \$535m (up 11% on the March quarter's \$481m and 23% on \$436.1m a year previously) to \$570m (up 19% and 31%, respectively).

The firm has also raised its guidance for non-GAAP diluted earnings per share from \$0.73 (up 18% on the March quarter's \$0.62 and 35% on \$0.54 a year previously) to \$0.80 (up 29% and 48%, respectively).

"Skyworks is capitalizing on the growing opportunity within the

Internet of Things as well as increasing analog complexity associated with higher-data-rate connectivity standards, both of which are enabling us to substantially outpace the growth of the broader semiconductor market," says chairman & CEO David J. Aldrich. "These macro trends continue to validate our investments in highly differentiated, custom solutions that are facilitating an expanding set of end-markets. Based on our design-win traction and order visibility, we anticipate continued strength beyond the June quarter as our products continue to gain

momentum," he adds.

"We also expect our recently announced joint venture with Panasonic to further enrich our systems capabilities, broaden our technology portfolio and enhance our financial returns," says executive VP & chief financial officer Donald W. Palette.

"We anticipate the Panasonic transaction will provide at least 100 basis points of gross margin accretion in fiscal 2015, paving the way for continued top- and bottom-line outperformance for the foreseeable future," Palette concludes.

www.skyworksinc.com

Skyworks introduces suite of low-noise amplifiers targeting 4G LTE wireless infrastructure

At the IEEE MTT-S International Microwave Symposium (IMS 2014) in Tampa, FL (3–5 June), analog semiconductor maker Skyworks Solutions Inc of Woburn, MA, USA unveiled a suite of ultra-low-noise amplifiers (LNAs) — now available for both sampling and production — for cellular infrastructure, wireless connectivity and broadcast communication applications.

The new LNAs provide what is claimed to be best-in-class noise figure (NF) as well as high gain and linearity, improving receiver sensitivity and dynamic range. Receiver sensitivity is a key specification of any radio used in wireless communications, given its important role in detecting and separating signals, as well ensuring effective operation.

Housed in compact 2mm x 2mm, 8-pin, dual flat no-lead packages, the SKY67150-396LF and SKY67153-396LF are optimized for 300–2200MHz and 700–3800MHz, respectively, with active bias, high linearity, superior gain and what is

claimed to be industry-leading NF performance. Internal active bias circuitry provides stable performance over temperature and process variation. The LNA family uses a common layout with band-specific tuning and offers the ability to externally adjust supply current for system-level optimization.

"By leveraging our systems-level expertise, specialty processes and differentiated packaging technologies, we are offering customers highly optimized solutions for a wide range of communications applications," says John O'Neill, VP of broad markets marketing.

The new devices also help to reduce performance variation over process and temperature changes, and provide highly flexible direct current biasing, in addition to fast on/off functionality with minimal switching — improving overall system power efficiency, the firm adds.

With accelerating 4G LTE network deployment, mobile operators are investing to keep pace with the growth in mobile data traffic, says

Skyworks. In fact, mobile broadband demand is at an all-time high, with some operators reporting a doubling of data traffic in each of the last five years. This is creating pressure to deploy more efficient network technologies that can deliver increased mobile data capacity at a lower cost. As a result, operators are investing heavily in advanced LNA-intensive infrastructure platforms.

According to the report 'LTE Base Station Market Forecast 2014–2024: Top Companies Creating the Next Generation Infrastructure for 4G Mobile Telecommunications' issued in February by Visiongain, 2014 will be a pivotal year and one of significant growth for LTE base-stations as mobile operators will need to increase network capacity to handle the explosive growth in data traffic. In addition, TechNavio's analysts forecast that the global LTE base-station market will rise at a compound annual growth rate (CAGR) of 49.5% by 2016.

www.skyworksinc.com

Skyworks' CEO elected chairman; general manager made president

The board of directors of Skyworks Solutions has elected CEO David J. Aldrich to the additional post of chairman of the board. David J. McLachlan (chairman since 2008 and a director since 2000) remains a board member and has been designated lead independent director.

Also, executive VP & general manager Liam K. Griffin has been promoted to the role of president. "This structure will enable us to hone our focus on long-term strategic growth opportunities during this transformative time for Skyworks," says Aldrich. "Liam has a proven

track record of results and I am confident that, in his new role, he will continue to provide strong leadership and direction as we accelerate our evolution into a larger and more diversified analog semiconductor company."

www.skyworksin.com

Microsemi enters MMIC market

Microsemi Corp of Aliso Viejo, CA, USA (which designs and makes analog and RF devices, mixed-signal integrated circuits and subsystems) has announced its entry into the monolithic microwave integrated circuit (MMIC) market.

Building on its history in RF, microwave and millimeter-wave solutions, the new portfolio initially consists of 16 products spanning DC–40GHz and includes wideband amplifier, low-noise amplifier and switch products designed for the defense, communications, instrumentation and aerospace industries.

Microsemi has active MMIC product developments using both established gallium arsenide (GaAs) and emerging gallium nitride (GaN) technologies. According to the firm Strategy Analytics, the addressable market for GaAs MMICs in Microsemi's tar-

geted markets such as defense and communications will be about \$500m by 2015. ABI Research also estimates the market for GaN MMICs to be about \$100m by 2018.

Microsemi says that the attributes of its highly differentiated MMIC products lead to faster design cycle times and smaller overall solution sizes in electronic warfare (EW), signal intelligence (SIGINT), military communication and other applications such as instrumentation equipment.

"Leveraging Microsemi's extensive experience and capabilities in these markets has allowed us to work closely with industry-leading customers to define and develop products that solve engineers' problems in new and creative ways," says MMIC product line director Ray Crampton. "Response to our initial

MMICs has been exceptional and we are aggressively working to expand our offering with numerous active developments in both GaAs and GaN-on-SiC technologies."

Microsemi says that its new MMIC products include several differentiating factors, including:

- the MMA001AA DC–20GHz wide-band amplifier, which has positive gain slope with over 17dB gain at 20GHz;
- the MMS002AA single-pole, double-throw switch, which features about 45dB of isolation from DC–20GHz; and
- the MMA016AA DC–15GHz amplifier, which has a power-selectable feature that allows users to adjust power consumption based on the requirements of a particular application.

www.microsemi.com/mmics

GCS offers P3 InGaP HBT and 0.25μm E-mode pHEMT foundry processes

Pure-play III-V compound semiconductor wafer foundry Global Communication Semiconductors LLC (GCS) of Torrance, CA, USA says that its proprietary indium gallium phosphide (InGaP) heterojunction bipolar transistor (HBT) process is now being offered to address 802.11ac requirements in which high gain, high linearity and high efficiency are key requirements for 5GHz operation. The firm is also now offering the 0.25μm enhancement-mode (E-mode) low-noise pseudomorphic high-electron mobility

(pHEMT) process for high-performance receiver applications, with useful frequencies of up to 26GHz.

"Most available HBT processes have a maximum stable gain (MSG) of 23dB, while our P3 InGaP HBT process can achieve a MSG of 26dB at 5GHz, which meets the 802.11ac and the key LTE 4G PA requirements for high gain, high efficiency, high linearity and robustness," says CEO Brian Ann. "A BV_{ceo} of 18V allows the amplifiers to operate beyond a typical 5V_{dc} bias for most HBT amplifiers," he adds.

"In addition, we introduced a new 0.25μm E-mode pHEMT super low-noise process to further enhance our broad portfolio of pHEMT process family," Ann continues. The new pHEMT process achieves an F_{min} of 0.38dB with an associated gain of 13.5dB @ 12GHz. "The process also has an F_{max} of 170GHz, which is capable of meeting most high-frequency commercial receivers and military phased-array radar systems with demanding performance requirements," notes Ann.

www.gcsincorp.com

Northrop Grumman samples E- and W-band InP HEMT LNAs for commercial as well as military applications

Northrop Grumman Corp of Redondo Beach, CA, USA has developed two high-performance monolithic microwave integrated circuit (MMIC) broadband ultra-low-noise amplifiers (LNAs) that are now in production (at its wafer fab in Manhattan Beach) for immediate delivery.

The indium phosphide (InP) high-electron-mobility transistor (HEMT) LNAs are for use in E- and W-band commercial, civil and military applications such as communication links, sensors, millimeter-wave imaging, radars and digital microwave radios.

The ALP283 is a 1.7mm² InP HEMT LNA that operates at 80–100GHz

for W-band millimeter-wave imaging applications, sensors and communication links. The power amplifier provides 29dB of linear gain, 2.5dB typical noise figure, 1dB gain compression power (P1dB) of 3dBm (2mW), and a 2dB typical average noise figure from 80–100GHz.

The ALP275 is 2.125mm² InP HEMT LNA that operates at 71–96GHz for E- and W-Band communications links. The power amplifier provides more than 26dB of linear gain, 3dB typical noise figure, and P1dB of 4dBm (2.5mW).

The compact die design of each LNA greatly reduces footprint size and exhibits ultra-low-noise performance and high gain, says the firm.

The LNAs are the initial release of products designed with the firm's InP process, which has already been used in Northrop Grumman's military communication systems. "For the first time, Northrop is offering products for similarly demanding commercial applications," says Frank Kropschot, general manager, Microelectronics Products and Services.

To ensure rugged, reliable operation, both LNAs are fully passivated. Both bond pad and backside metalization are Ti/Au, which is compatible with conventional die attach, thermocompression and thermosonic wire bonding assembly techniques.

www.northropgrumman.com/mps

Production ramps up on AEHF satellite payloads containing 36,000 MMICs from Northrop Grumman

More than 36,000 integrated circuits fabricated by Northrop Grumman for the US Air Force's fifth and sixth Advanced Extremely High Frequency (AEHF) satellites are allowing production to ramp up on a broad scale for both payloads.

Each payload contains about 18,000 high-frequency MMICs for frequency conversion, amplification and switching. They are integrated throughout major subsystems that enable real-time mobile, global access. Those include secure crosslinks, anti-jam uplinks and downlinks, and super-high-gain earth coverage antennas.

The company provides AEHF payloads for Lockheed Martin Space Systems of Sunnyvale, CA, which is the prime contractor for the next generation of protected military communications satellites. Three AEHF satellites are on-orbit currently and three more are in production by the Lockheed Martin–Northrop Grumman industry team.

"The Air Force procured these advanced, high-frequency MMICs through block buys early in the

payload development cycle," says Stuart Linsky, VP, communication programs, at Northrop Grumman Aerospace Systems. "Along with cost and schedule savings, the parts were more efficient to produce."

Northrop made the devices at its fab in Manhattan Beach, CA. As a Department of Defense Trusted Foundry, the facility is dual-use, producing commercial ICs in large volumes for more than 20 years. "By implementing commercial best practices in making military integrated circuits, we're able to generate further cost savings for the Air Force," Linsky says.

The MMIC-based components operate at microwave frequencies between 300MHz and 300GHz and beyond, and have many benefits compared with those used in other communication satellite payloads, such as discrete transistors and passive components, says Northrop Grumman.

A single MMIC-based component the size of a quarter, for example, handles as many functions as a traditional, brick-size electronic

'black box', representing one reason why AEHF payloads are half the size and weight of previous-generation MILSTAR satellite payloads while providing 10 times the capacity.

One Advanced EHF satellite will provide greater total capacity than the entire Milstar constellation currently on orbit, says Northrop Grumman. Individual user data rates will be five times improved. The higher data rates will permit two-way, jam-resistant transmission of tactical military communication such as real-time video, battlefield maps, and targeting data.

Advanced EHF satellite payloads uniquely contain a full range of features that provide effective protection against the wide range of threats from capable adversaries. These features include anti-jamming for the strongest jammers; low probability of detection and intercept; rapid recovery during a nuclear event; the ability to operate through scintillation; greatly reduced risk from physical attack to ground systems; and significant protection from cyber attack.

Analog Devices to buy Hittite

Analog Devices Inc (ADI) of Norwood, MA, USA (which provides semiconductors for signal processing applications) has agreed to acquire Hittite Microwave Corp of Chelmsford, MA, USA (which designs and manufactures analog, digital and mixed-signal RF, microwave and millimeter-wave ICs, modules and subsystems as well as instrumentation) for \$78 per share in cash. This represents a 29% premium on the closing price of Hittite's common stock on 6 June of \$60.56 per share.

The agreement reflects a total enterprise value for Hittite of about \$2bn. ADI expects to fund the acquisition through a combination of cash on hand and short-term

debt financing. The transaction is expected to be accretive to ADI's non-GAAP earnings per share.

The boards of directors of each company have approved the transaction, which is expected to close near the end of ADI's fiscal third-quarter 2014 (to end-July), subject to regulatory approvals and other customary closing conditions.

"Hittite's strength in RF, microwave and millimeter-wave technology complements ADI's RF and signal-conversion expertise," says ADI's president & CEO Vincent Roche. "Our combined capabilities will enable us to bring more complete solutions to our customers and address more of the industrial,

communications infrastructure, and automotive markets," he believes.

"We welcome the very talented Hittite team, as we together leverage our strong product portfolios and customer relationships," Roche adds.

"Our combined efforts will accelerate the course of innovation throughout cellular and microwave communications infrastructure, automotive, industrial instrumentation, aerospace and defense," believes Hittite's president & CEO Rick D. Hess.

ADI also reaffirmed financial guidance for its fiscal Q3/2014, for revenue to rise by 1–5% and for diluted earnings per share to be \$0.60–0.64.

www.analog.com

Hittite and Xilinx demonstrate complete radio solutions

At the IEEE MTT-S International Microwave Symposium (IMS 2014) in Tampa, FL, USA (3–5 June), Hittite and Xilinx Inc of San Jose, CA, which provides all-programmable field-programmable gate arrays (FPGAs), systems-on-chip (SoCs) and 3D ICs, gave demonstrations of complete radio solutions for 60GHz millimeter-wave small-cell backhaul and 1024QAM microwave radio cellular backhaul.

Complete 60GHz small-cell backhaul demonstration

Hittite's 60GHz silicon germanium (SiGe) transceiver chip-set interfaces directly to the Xilinx 256 QAM millimeter-wave ModemSmartCORE IP to support up to 750Mbps data throughput capacity and configurable channel bandwidths from 50 to 250MHz with FDD and TDD modes to formulate a lower-power-consumption small-cell backhaul radio solution.

Hittite's 60GHz transceiver chip-set is a complete millimeter-wave to baseband solution. The transceiver incorporates universal IQ interfaces for direct modulation and demodulation and the chip-set implements the entire transmitter and receiver chains with on-chip frequency syn-

thesizers, frequency converters and the transmit power amplifier and receive low-noise amplifier (LNA). Hittite will release its next-generation 60GHz transmitter and receiver chipset later this year with increased output power (>15dBm), a new frequency synthesizer with support for 64-QAM modulation and covering 57–66GHz in 250MHz step size, an integrated power detector, and analog or digital gain control, all in 4mm x 6mm surface-mount packages.

Xilinx's 256-QAM millimeter-wave modem (part of its SmartCORE IP portfolio) is a highly configurable point-to-point and point-to-multi-point capable modem. It consumes less than 5W of power at >1Gbps data rates and incorporates all the key features and capabilities that users require to accelerate the development of next-generation backhaul solutions. It supports RS and LDPC forward error correction (FEC), CPRI for fronthaul or 10GbE for backhaul, as well as the JESD204B interface for emerging data converter devices. The core can be extended to also support wider-band supports such as 500MHz with up to 3.5Gbps throughput.

1024QAM microwave radio split-mount outdoor unit (ODU) backhaul demonstration

Hittite's transceiver chip-sets interfaces directly to the Xilinx QPSK to 1024QAM SmartCORE IP modem to construct a fully functional split-mount outdoor unit (ODU) microwave radio. The 6–42GHz transceiver chip-set is a simplified, cost-effective solution consisting of highly integrated IF transceiver ICs, high-linearity microwave IQ transmitter and receiver ICs, low-phase-noise microwave synthesizers ICs and the transmit power amplifier, all with what is claimed to be industry-leading performance and surface-mount packaging.

The Xilinx modem implements all the features of modern microwave radio backhaul, including QPSK to 1024QAM modulation with software-configurable bandwidths of 3.5–112MHz. The modem supports Gigabit Ethernet with software-configurable features including closed-loop digital pre-distortion, automatic correction of TX and RX IQ impairments, equalization, and XPIC and ATCP configuration support.

www.xilinx.com

www.hittite.com

GigOptix to acquire Tahoe RF Semiconductor

Wireless portfolio expanded from E-band to adjacent RF markets

GigOptix Inc of San Jose, CA, USA (a fabless supplier of analog semiconductor and optical communications components for fiber-optic and wireless networks) has agreed to acquire Tahoe RF Semiconductor Inc of Auburn, CA, USA, a full-service turnkey provider of RF/analog RFICs, IP and fully integrated systems and subsystems on a chip. The deal was due to close on 30 June (the first day of GigOptix's fiscal Q3/2014) when Tahoe RF's team of engineers will become GigOptix staff.

The acquisition of Tahoe RF "brings to GigOptix a solid team of very experienced RF engineers and a rich portfolio of proven silicon IP into our RF and Wireless product line," comments chairman & CEO Dr Avi Katz. "The acquisition of Tahoe RF is one more step in our continuous quest to strengthen our industry-leading RF engineering team, and enable GigOptix to address increasing aggregate data bandwidth demand through our optimized monolithic microwave integrated circuit (MMIC) products targeted at point-to-point wireless backhaul applications," he adds. "The acquisition also puts us in an excellent position to expand into adjacent RF and wireless market opportunities, including consumer and high-volume enterprise applications, such as GPS devices."

Expanding wireless product line

Tahoe RF has an extensive library of silicon-proven customizable IP cores and solutions — including RF front-ends, low-power transmitters,

direct conversion receivers, low-noise amplifiers, and fractional-N frequency synthesizers, as well as automatic gain control and RF receiver patents — which can be leveraged to create optimized integrated subsystems and systems.

"To support the strong RF and wireless chipset demand that we have seen so far this year, we have acquired Tahoe RF to further expand our Wireless Product Line engineering team," says Dr Raluca Dinu, VP & general manager of GigOptix's High-Speed Communications division. "GigOptix is trailblazing a path to providing a rich RF and wireless roadmap for the industry, striving for leading performance, increased integration, while delivering lower costs," he adds. "Crafted together with Tahoe RF team, our updated RF and wireless products roadmap is available to our partners now. We are looking forward to providing our customers with the newest chipsets in the point-to-point wireless backhaul and adjacent markets as early as this year."

GigOptix's E-band radio shipments are expected to hit 6000 per month, with total shipments in 2014 exceeding 50,000, driven by the deployment of LTE cellular infrastructure in support of the ever-growing demand for mobile data for smartphones. The deployment of small cells, addressed by V-band (60GHz) devices, is expected to be one order of magnitude greater than regular cells in urban areas, and demand for V-band radios is

expected to accelerate in the next two years with volumes at much higher than E-band.

According to ETL Wireless Research's 10th Edition (April 2014) of the 'Global Digital PTP Radio Market Analysis and Forecast', global point-to-point 1Gbps high-capacity radio volumes will grow in the 60GHz and 70/80GHz bands during 2014–2018. Ethernet 1Gbps high-capacity radio shipments should grow from over 1000 in 2014 to over 89,000 in 2018 at 60GHz, and from over 42,000 in 2014 to over 136,000 in 2018 at 70/80GHz.

RF and wireless expertise

Tahoe RF's CEO & president Irshad Rasheed joins GigOptix as director of marketing for the RF and Wireless Product Line within the High Speed Communications business unit. "The knowledge and IP that accompany Irshad and the Tahoe RF team will be applied to extend GigOptix' wireless product portfolio from E-band to adjacent operating radio frequencies such as V-band and others," says Dinu. "As such, GigOptix is also uniquely positioned to become a dominant supplier in the V-band chipsets based on our specialized core skills, leading RF performance, and disruptive roadmap," he reckons. "With the RF and wireless expertise we are acquiring from Tahoe RF, the RF and Wireless product line is in an excellent position to expand into new emerging markets," he believes.

www.tahoerf.com
www.gigoptix.com

GigOptix showcases RF MMICs and E-band products at IMS

At the IEEE MTT-S International Microwave Symposium (IMS 2014) in Tampa Bay, FL, USA (3–5 June), GigOptix showcased RF MMICs and E-band products, including:

- the EWH2001 DC–20GHz power amplifier (PA) MMIC;
- the EXP8602 and EXP8603 81–86GHz high E-band PAs;

- the EXP7602 and EXP7603 71–76GHz low E-band PAs;
- the EXE8602 71–86GHz broadband power detector; and
- the iT2008 DC–26.5GHz PA and iT2009 2–26.5GHz power amplifier.

GigOptix has also developed highly integrated SiGe transmitter and receiver chipsets — the low

E-band transmitter (EXU7610) and receiver (EXD7610) and the high E-band transmitter (EXU8610) and receiver (EXD8610) — available for sampling in late 2014.

The EXP7602/3 and EXU7610 form a two-chip low E-band transmitter. The EXP8602/3 and EXU8610 form a two-chip high E-band transmitter.

DelfMEMS raises €5.4m in round-C funding

DelfMEMS of Villeneuve d'Ascq, France, which develops RF MEMS (micro-electro-mechanical systems) switching solutions in radio-frequency (RF) communications (targeting next-generation multi-standard, multi-mode, mobile telephony) has secured €5.4m (\$7.4m) in round C funding from FSN PME – le Fonds Ambition Numérique (managed by bpifrance Investissement, in the context of the Programme d'Investissements d'Avenir), together with Iris Capital, VIVES, Capitalaria and existing investors (A2D Invest, Finovam, Rhône-Alpes-Création, Eurekap!, Helea Financiere and business angels).

The new funding will enable DelfMEMS to accelerate industrialization of its products, supporting its growth in next-generation, wireless front-end modules for mobile devices such as smart-phones and tablets that need multi-standard, multi-mode mobile telephony.

The move to multiple wireless standards to meet the requirement of always-on data access is creating the need for high-speed RF switching. DelfMEMS says that its technology uses a new, integrated, micro-mechanical building block based on a strong, totally new IP portfolio that includes seven key patents. The switch is an anchorless and push-pull mechanical device that is deflected by electrostatic forces to switch RF signals based on the principle of current electro-mechanical relays/switches. The firm claims that it solves past issues and improves insertion loss, linearity, integration, hot switching behavior, switching time and power consumption to simplify RF architectures.

DelfMEMS says that benefits of its RF MEMS switches include improved receiver sensitivity, leading to fewer dropped calls and better call quality together with optimal carrier aggregation switching for massively improved data rates. Combined with high levels of RF integration, this also results

in a lower bill-of-materials cost for the RF front-end module, and significantly longer battery life by reducing the RF module's power consumption by up to 20%.

"The progress that we have made in turning RF MEMS switches into reality has really impressed our investors," claims CEO Guillaume d'Eyssautier. "The test silicon has shown that we have cracked the problems that have caused many MEMS companies to fall by the

roadside... We will have samples for customers to evaluate in a few weeks," he adds. The latest round of financing will be used to consolidate the organization and be ready for production ramp-up by the end of 2014.

DelfMEMS exhibited at the 2014 IEEE MTT-S International Microwave Symposium (IMS) in Tampa Bay, FL, USA (1–6 June).

www.delfmems.com

www.bpifrance.fr



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Peregrine adds six sales channel partners to drive UltraCMOS HPA design wins in EMEA and Asia Pacific

In connection with its annual worldwide sales conference, Peregrine Semiconductor Corp of San Diego, CA, USA, a fabless provider of radio-frequency integrated circuits (RFICs) based on silicon-on-sapphire (SOS) and silicon-on-insulator (SOI), has announced the appointment of six new sales channel partners in order to drive design wins for UltraCMOS high-performance analog (HPA) products in the important market regions of Europe, Middle East and Africa (Interlligent, Link Microtek and Vostock) and Asia Pacific (Asiacom, Tecnomix and Acromax).

"EMEA and the Asia Pacific are regions where Peregrine sees a tremendous growth opportunity for our UltraCMOS HPA products," says VP of sales & marketing Carl Burrow. "These sales partners have advanced RF knowledge and expertise, especially as it relates to applications for our HPA products," he adds.

Peregrine's HPA products include RF switches, tuners, digital step attenuators, power limiters and mixers. Built on UltraCMOS technology, these products offer advanced performance, flexibility, reliability and ease of use, says the firm. UltraCMOS HPA products are

used in a wide range of applications including automotive, military and defense, test & measurement equipment, and wireless infrastructure.

Peregrine's worldwide sales conference gathers international sales representatives and distributors for educational sessions on the firm's UltraCMOS technology and integrated RF solutions. This year's 2-day conference in Tampa, Florida, drew 120 attendees and took place before the 2014 IEEE MTT-S International Microwave Symposium (IMS) exhibition (3–5 June).

www.psemi.com

Agilent's ADS software chosen by GIT Japan for front-to-back MMIC and silicon RFIC implementation

Agilent Technologies Inc of Santa Clara, CA, USA says that GIT Japan Inc — a provider of interface technologies between people and information, and a competence center for ultrawideband (UWB) chipset and module development — has selected Agilent EEsof EDA's Advanced Design System (ADS) electronic design automation platform for complete gallium arsenide / gallium nitride- and silicon-based RFIC/MMIC implementations.

"We successfully used the ADS front-to-back design flow for UWB power amplifier MMIC design in a WIN pHEMT process," says GIT's president & CEO Shogo Ida. "We also used it when expanding our portfolio to include silicon-based designs using IBM's high-performance SiGe BiCMOS technology. We chose ADS because it delivers proven RF circuit simulation, integrated EM solvers and RF-relevant backend support. It was key to our first-time-right tape-outs and enabled us to introduce unique products on time."

ADS is claimed to be the most widely used platform for III-V MMIC

design but also provides a complete RFIC design flow — including layout, enhanced foundry-certified PDKs (process design kits), LVS (layout-versus-schematic) and DRC (design rule checker) — which is crucial for implementing wireless front-ends. The scalable front-to-back solution not only facilitates the job of the MMIC and RFIC designer from the beginning, but also directly integrates with other domains, such as RF modules and RF system-in-package (SiP) design.

Key ADS features like ADS Layout and Desktop DRC and LVS help to simplify and speed the design flow. For example, ADS Layout features an RFIC toolbar for easier, more efficient physical design and trace routing. Desktop DRC and LVS help to verify and correct layouts against foundry DRC rules prior to tape-out and to catch errors early in the design cycle, all from the users' desktop. In addition, ADS' integrated 3D planar EM simulator Momentum combines full-wave and quasi-static EM solvers for simplified passive, interconnect and parasitic modeling.

"As a leader in the GaAs MMIC world, we have seen the popularity of the ADS platform for silicon-based RFIC design grow tremendously over the years," says Juergen Hartung, RFIC marketing manager for Agilent EEsof EDA. "Customers can now use these kits for a variety of RF CMOS, RF SOI and SiGe BiCMOS technologies to enjoy full back-end support that includes schematic-driven layout creation, layout-versus-schematic check, and integrated 3D planar electromagnetic and 3D-FEM simulators."

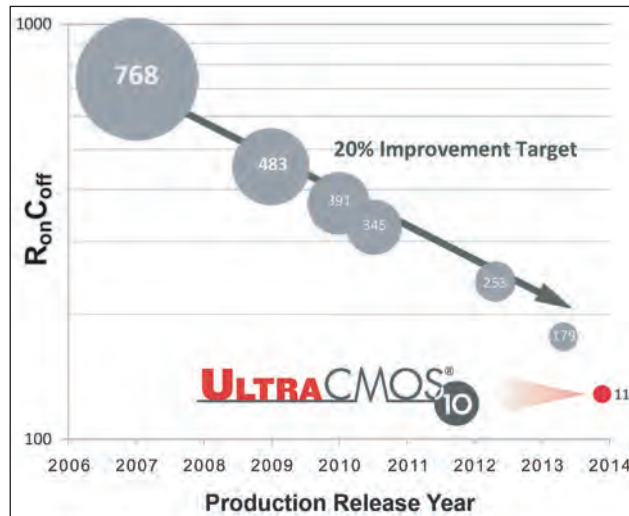
As electronic design automation software for RF, microwave and signal integrity applications, ADS applies technologies such as X-parameters and 3D electromagnetic simulators. Agilent says that ADS 2014 addresses the challenging design complexity and integration needs of commercial wireless and aerospace/defense companies by enabling them to design multi-technology RF system-in-package modules and to perform complex electromagnetic simulations, all with greater ease and speed.

www.agilent.com/find/eesof-ADS

Peregrine ships first UltraCMOS 10 production units

Peregrine Semiconductor Corp of San Diego, CA, USA, a fabless provider of radio-frequency integrated circuits (RFICs) based on silicon-on-sapphire (SOS) and silicon-on-insulator (SOI), has shipped the first RF switches built on its UltraCMOS 10 technology platform. With partner GLOBALFOUNDRIES, it has also completed product and process qualification for the RF SOI technology.

Introduced in October 2013, UltraCMOS 10 technology provides smartphone makers with what is claimed to be unparalleled performance and flexibility. The 130nm technology combines the performance of UltraCMOS technology with the economies of SOI, and delivers a more than 50% performance improvement over comparable solutions, it is reckoned. The technology addresses the unique growth requirements for mobile applications and is the foundation of Peregrine's next-generation RF



switches, tuners and power amplifiers, including UltraCMOS Global 1 (claimed to be the industry's first reconfigurable RF front end).

"UltraCMOS 10 technology builds on Peregrine's 25 year legacy of providing high-performance integrated RF solutions," says Mark Miscione, VP of RF technology solutions. "Our technology platform was created to advance the future of RF design

with a comprehensive SOI solution."

To develop UltraCMOS 10, Peregrine collaborated with GLOBALFOUNDRIES, a tier-one foundry and provider of semiconductor manufacturing technology. Together, they co-developed a unique fabrication flow for the versatile RF SOI platform. With the qualification process complete, UltraCMOS 10 technology is now a

fully qualified technology platform.

"Peregrine has a strong history of innovation and performance leadership, and we believe this trend will continue with the co-developed UltraCMOS 10 technology, the highest-performance RF SOI technology," comments KC Ang, senior VP & general manager of Singapore operations at GLOBALFOUNDRIES.

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Soitec and Simgui partner to produce 200mm SOI wafers in China for RF and power semiconductor markets

Soitec of Bernin, France, which makes engineered substrates including silicon-on-insulator (SOI) wafers and III-V epiwafers, and Si-based materials firm Shanghai Simgui Technology Co Ltd, which provides both SOI wafers and epi foundry services, have formed an international partnership to address both China's growing demand and limited global production capacity for 200mm SOI wafers used in fabricating semiconductors for RF and power applications. Simgui was spun off from the Shanghai Institute of Microsystem and Information Technology (SIMIT) within the Chinese Academy of Sciences (CAS) and is now a joint venture with a group of investors from Silicon Valley.

As well as giving Soitec its first wafer production capability in China, the agreement boosts the industrial manufacturing capacity of SOI wafers to meet increasing worldwide usage and represents the first step in establishing an SOI ecosystem in China.

The deal includes a licensing and technology transfer agreement under which Simgui will manufacture 200mm SOI wafers using Soitec's proprietary Smart Cut technology. Simgui will establish a high-volume SOI manufacturing line to directly supply the Chinese market. It will

also manufacture Soitec's 200mm SOI wafers for the global market outside China, expanding Soitec's supply to customers worldwide. Beyond this initial cooperation, the two firms plan to expand their collaborative efforts in the future to take advantage of their synergies.

The partnership "amplifies the ecosystem using Soitec's technology and reinforces our competitive offer," says Soitec's chief operating officer Paul Boudre. "While paving the way for future cooperation between our two companies, it also reinforces Soitec's global leadership position in SOI and immediately bolsters our presence in the Chinese market," he adds.

"In addition to Soitec's SOI product volume for the RF market doubling in the last two years, the products themselves are becoming the preferred solutions for RF switches embedded in smart-phones and tablets," notes Dr Bernard Aspar, general manager of Soitec's Communication and Power business unit. "This collaboration with Simgui will allow us to respond to the fast-growing demand we are seeing from our customers," he adds.

"Considering that China takes over a 60% market share of the worldwide semiconductor market, to have a strategic collaboration with

Soitec is very important to us," says Simgui's chairman Dr Xi Wang. "This will enable us to grow our current SOI market share and address new opportunities as we help to develop China's SOI ecosystem," he says.

"The access to Soitec technology is an accelerator for Simgui to become a key player in thin SOI manufacturing," reckons Simgui's general manager Dr Feng Zhang. "On the other hand, this partnership will complete Simgui's capabilities such as Simbond, which will further strengthen both parties' SOI competitiveness."

The strategic partnership enables Soitec and Simgui to strengthen their positions in the high-growth markets for RF and power semiconductors. While applications for power ICs include automotive electronics, lighting and power supplies, RF semiconductors are key drivers of 4G smart-phones. China is the world's largest smart-phone market. Soitec claims that its RF-SOI products are already used in manufacturing by most of the leading RF foundries and have been adopted as the preferred substrates for 4G and LTE mobile computing and communication applications.

www.simgui.com.cn/en
www.soitec.com

Soitec appoints head of microelectronics business in North America

Soitec has named Thom Degnan as VP of sales & business development for its Electronics Division in North America. This comes as the Electronics Division is focusing its SOI technology on fast-growing mainstream and emerging mobile communication markets — from smart phones to Internet of Things — with products including FD-SOI wafers for digital electronics and RF-SOI wafers for RF applications.

Degnan will be based in San Diego and report to Thomas Piliszcuk, corporate senior VP of global sales,

business development & marketing for the Electronics Division.

"With his valuable insight from the chip-making side of the business, Thom is a great asset to provide leadership in driving adoption of Soitec products in our target market segments," says Piliszcuk. "He brings a wealth of knowledge in business development and customer service."

Before joining Soitec, Degnan was VP & general manager of the Americas Region of Intel Mobile Communications, then VP of business development for Intel's

Services Division. Previously he was VP & general manager of the Americas Region of Infineon Technologies, responsible for all sales, business development & marketing for its Communications Division (acquired by Intel in 2011).

Earlier, Degnan held executive management positions within Qualcomm and Scientific Atlanta (now part of Cisco). He also has experience in starting and participating in three early-stage technology firms in the satellite and mobile communications markets.

TowerJazz releases enhanced RF SOI CMOS & SiGe PDKs

Specialty foundry TowerJazz has announced availability of enhanced RF silicon-on-insulator (SOI) CMOS and high-speed silicon-germanium (SiGe) process design kits (PDKs) for its 0.18 μ m process technology.

The kits were developed for use with Agilent Technologies' Advanced Design System (ADS) software and target a wide range of analog markets including front-end modules (FEMs) for mobile phones, tablets and WiFi terminals, fiber-optic connections for data centers and network infrastructure, radar for automotive collision avoidance, and other high-frequency applications.

The enhanced PDKs enable reductions in die size and bill of materials via new advanced inductor-based passive components (e.g. significant area savings are possible when using solenoids which provide 250% more inductance per area compared with regular inductors). The new PDKs also improve simulation accuracy for die packaged in thin form factors and allow the simulation of thermal effects across chips that are critical in many of the targeted applications.

In addition to inductors, the PDKs now support scalable solenoids

(series inductors), balun/transformer devices and improved model capabilities to account for substrate thinning and flip-chip packaging effects. Ultra-thin substrates of 100 μ m or less are common in the assembly of FEM chips, while flip-chip stand-off distances between the chip surface and the circuit laminate can be on the order of 80 μ m.

The Electro-Thermal Simulator in ADS from electronic design automation software supplier Agilent EES of EDA has been enabled for high-speed SiGe BiCMOS technology, allowing designers to simulate the impact of thermal coupling across the chip. Thermal effects in SiGe designs can cause degradation in both performance and reliability. This new capability allows designers using the ADS PDK for TowerJazz's SBC18HA process to 'design around' the thermal effects by optimizing design parameters in conjunction with layout modifications.

TowerJazz and Agilent demonstrated the PDKs at the IEEE MTT-S International Microwave Symposium (IMS) in Tampa (3–5 June) and the Design Automation Conference (DAC) in San Francisco (2–4 June).

Complementing TowerJazz's RF SOI and SiGe BiCMOS technologies with Agilent's design enablement will speed customers' time to market, says Ori Galzur, VP of the TowerJazz VLSI Design Center. "We constantly strive to provide our customers a clear advantage in bringing analog products to market by offering the best process technology together with a sophisticated design infrastructure," he adds.

"Our mutual customers can now leverage RF critical functionalities like cutting-edge inductor design capability and electro-thermal analysis in TowerJazz's leading RF process technologies," says Juergen Hartung, RFIC marketing and foundry program manager of Agilent's EEs of EDA. "Based on a full 3D thermal solver tightly integrated with ADS circuit simulation and IC layout environment, this solution provides accurate 'thermally aware' simulation results, including steady-state, transient and envelope analyses, that account for thermal coupling between devices as well as heat transfer through the die and packaging."

www.towerjazz.com

www.agilent.com/find/eesof-ads2014

Power noise & reliability sign-off design kit from ANSYS, TowerJazz

TowerJazz and engineering simulation software provider ANSYS Inc of Canonsburg, PA, USA are collaborating to deliver comprehensive power noise and reliability sign-off flow for mutual customers. With increased use of analog and RF ICs in electronic systems including consumer, automotive, medical and industrial applications, the ability to accurately predict the performance of these ICs prior to production has become a critical design challenge, they say.

ANSYS and TowerJazz have created a foundry-certified power noise analysis PDK that includes reference flow guidelines, collateral, example test cases and flow setup guidance to enable analog and RF designers to produce optimized ICs more

quickly and with confidence, minimizing cost and maximizing manufacturing yield, reckon the firms. The reference flow allows mutual customers to efficiently use ANSYS Totem and ANSYS PathFinder and enable manufacturing of their ICs in accord with TowerJazz's process requirements. These tools are said to be essential, since voltage drop and specialized reliability checks such as electromigration (EM) and ESD simulations cannot be performed using Layout Versus Schematic (LVS), Design Rule Check (DRC) and extracted simulation tools.

"As the mixed-signal and analog content increase in various markets, a robust and foundry-certified power noise and reliability sign-off

flow becomes critical," says Aveek Sarkar, VP of product engineering and support at ANSYS' subsidiary Apache Design. "We are able to provide optimized tools and methodologies for joint customers to enable a clean design flow, higher yield and reduced field failures," he adds.

"Close collaboration between TowerJazz and Apache on custom analog design kit development enables our customers to efficiently deliver more robust and reliable designs for next-generation electronic products," says Ori Galzur, VP of TowerJazz's VLSI design center. "This design kit will enable our customers to use the industry's standard power, noise and reliability sign-off."

www.ansys.com

Monolith and X-FAB partner on SiC power diode and MOSFET production

1200V devices already demonstrated on 150mm SiC wafers

Silicon carbide (SiC) diode and MOSFET supplier Monolith Semiconductor Inc of Ithaca, NY, USA has formed a strategic partnership with silicon-based analog/mixed-signal foundry X-FAB Texas Inc of Lubbock, TX, USA to manufacture 150mm SiC wafers in a high-volume production line.

Currently, the high cost of SiC devices has limited the widespread adoption of SiC power diodes and MOSFETs, says Monolith. The partnership aims to dramatically lower the cost, improve reliability and expand availability of SiC diodes and MOSFETs, enabling their widespread adoption in high-performance and high-efficiency power electronics systems.

"Monolith's revolutionary SiC MOSFET design and silicon-compatible processes enable manufacturing of high-performance and highly reliable SiC MOSFETs in a cost-effective CMOS fab," says the firm's CEO Sujit Banerjee. "X-FAB Texas has a long history of delivering high-quality semiconductor products to automotive and industrial customers," he comments. "We have already transitioned Monolith's SiC technology into X-FAB's CMOS fab and have demonstrated 1200V SiC devices

manufactured on 150mm SiC wafers."

Monolith's development of SiC devices is partially supported by the US Department of Energy's (DOE) Advanced Research Projects Agency-Energy (ARPA-E) SWITCHES program ('Strategies for Wide-Bandgap, Inexpensive Transistors for Controlling High-Efficiency Systems'). "By using existing silicon manufacturing infrastructure, we dramatically reduce the overhead costs to manufacture Monolith's SiC devices, and we reap the advantage of the high-yield manufacturing systems at X-FAB," notes Monolith's president Kevin Matocha. "The aggressive cost goal of the ARPA-E SWITCHES program has driven us to find new ways to dramatically reduce the production cost of SiC power MOSFETs," he adds.

"The SWITCHES program is designed to develop new wide-bandgap semiconductor devices promising increased switching frequency, enhanced high-temperature operation, and reduced power losses at substantially lower cost relative to today's solutions," comments SWITCHES program director Tim Heidel. "With SWITCHES just over six months under way, we are excited to see our project teams

already beginning to show positive signs toward reaching their technical and market goals."

In addition to the SiC device developments under the ARPA-E SWITCHES program, Monolith and X-FAB are anchor partners of the newly formed PowerAmerica manufacturing institute centred at North Carolina State University (NCSU) and funded by US Department of Energy's Advanced Manufacturing Office.

"We are excited to be part of the institute which will further improve the manufacturability and cost of SiC power devices," comments Andy Wilson, X-FAB's director of strategic marketing.

"With X-FAB's high-quality TS-16949 manufacturing capability, we are poised to support SiC power device manufacturing for Monolith Semiconductor," he adds. "We are fabricating SiC power devices using our existing 150mm silicon production facility, and this will break the primary cost barriers and allow proliferation of SiC power devices."

Monolith aims to offer 900–1700V SiC diodes and MOSFETs and is preparing for SiC power device sampling in early 2015.

www.xfab.com

www.monolithsemi.com

Mitsubishi Electric to supply 3.3kV, 1500A railcar traction inverter with all-SiC power module to Odakyu

Tokyo-based Mitsubishi Electric Corp has received an order for its railcar traction inverter with all-silicon carbide (SiC) power modules (made with SiC transistors and SiC diodes), placed by Odakyu Electric Railway Co Ltd. This is the first order for 3.3kV, 1500A traction inverters designed for 1500V_{DC} catenaries, says Mitsubishi Electric.

The inverters will be installed in a 1000 Series urban train comprising

four cars in December, following the completion of running tests.

Compared with an existing 1000 Series train, energy savings in the new traction inverter-installed 1000 Series train's main circuit (which also comprises high-efficiency main motors and filter reactor) are expected to reach about 36% when the train is very crowded or 20% at normal occupancy. More detailed figures will be compiled when

Odakyu and Mitsubishi Electric conduct the running tests.

Also, the main circuit of the new traction inverter-installed 1000 Series train should achieve 80% reductions in both size and weight due to the all-SiC power modules having fewer components, leading to big reductions in car-re-modeling costs.

www.MitsubishiElectric.com/products/transportation

Arkansas researchers design SiC-based ICs operable at over 350°C

Research to improve processors, drivers and controllers in power electronics, automobiles and aerospace

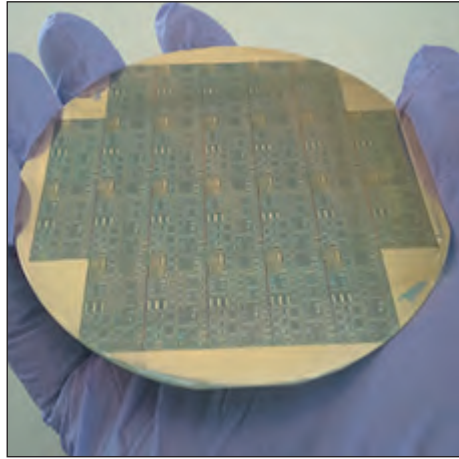
Researchers at the University of Arkansas have designed integrated circuits that can survive at temperatures greater than 350°C (about 660°F). Funded by the US National Science Foundation (NSF), their work could improve the functioning of processors, drivers, controllers and other analog and digital circuits used in power electronics, automobiles and aerospace equipment — all of which must perform at high and often extreme temperatures.

"This ruggedness allows these circuits to be placed in locations where standard silicon-based parts cannot survive," says Alan Mantooth, distinguished professor of electrical engineering (holder of the Twenty-First Century Chair in Mixed-Signal Integrated Circuit Design and Computer-Aided Design in the College of Engineering). "The circuit blocks we designed contributed to superior performance of signal processing, controllers and driver circuitry," he adds.

One-third of all power produced in the USA passes through some kind of power electronic converter or motor drive before it reaches the end-user. Circuits developed by the team could enable tight integration of control in the tough environmental conditions these applications demand as well as improving electrical efficiency while simultaneously reducing the overall size and complexity of these systems.

The researchers worked with silicon carbide (SiC), which can withstand extremely high voltage and is a good thermal conductor, so it can operate at high temperatures without requiring extra equipment to remove heat.

Led by Mantooth and Jia Di, professor of computer engineering, the team achieved the higher performance by combining SiC



The SiC wafer contains more than 1000 individual circuits.

with wide temperature design techniques. In power electronics and integrated circuits, the work is reckoned to represent the first implementation of a number of fundamental analog, digital and mixed-signal blocks, such as a phase-locked loop (PLL) using a complementary-style SiC technology. A PLL is a control system that generates an output signal whose phase is related to the phase of an input signal. Such a function is critical in circuit applications such as signal synchronization, frequency synthesis, and modulation and demodulation schemes.

The research was part of the NSF's Building Innovation Capacity program, which is designed to

partner university and industry research to build intellectual collaborations so that innovations flow from ideas to solid research results, company prototypes and products. The basis of this innovation ecosystem is the University of Arkansas and two Fayetteville technology firms, Ozark Integrated Circuits (which develops ICs for remote sensing and actuation under extreme environmental conditions) and Arkansas Power Electronics International Inc (APEI) of Fayetteville, AK (which specializes in high-performance electronics for applications including defense, aerospace and hybrid/electric vehicles). Raytheon is also a key partner.

Ozark Integrated Circuits is commercializing the circuit technology. Arkansas Power Electronics International focuses on using the circuits in power applications.

The research funding was awarded to Arkansas Circuit Design Center (which consists of two laboratories, one directed by Mantooth and one by Di). It supports the mission of the University of Arkansas' National Center for Reliable Electric Power Transmission, which is funded as part of the federal government's focus on R&D on smart-grid and renewable technologies. The center is one of just a few university-based research centers

investigating electronic systems to make the USA's power grid more reliable and efficient. The US Department of Energy has funded the center since 2005 because of the university's research expertise in advanced power electronics and long-term investigation of SiC. Mantooth is executive director of the center.



Last fall the U of A circuit design team celebrated completing more than 40 SiC circuit functions.

www.engr.uark.edu

Toyota develops SiC power semiconductor for automotive power control units

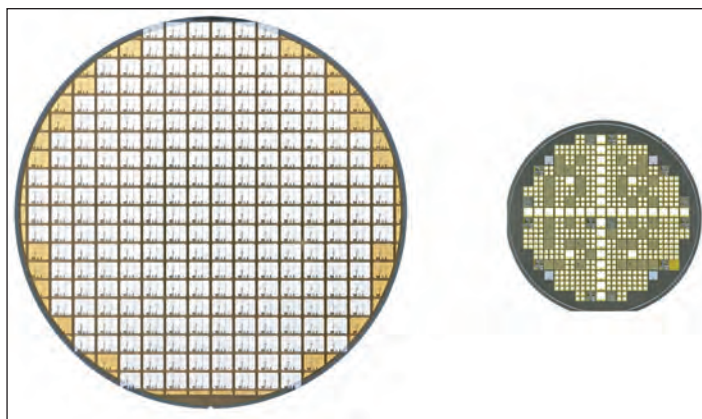
Fuel efficiency boosted by 5%; targets 10%, plus 80% size reduction

Toyota Motor Corporation, in collaboration with Denso Corp and Toyota Central R&D Labs Inc (CRDL), has developed a silicon carbide (SiC) power semiconductor for use in automotive power control units (PCUs). Toyota will begin test driving vehicles fitted with the new PCUs on public roads in Japan within a year.

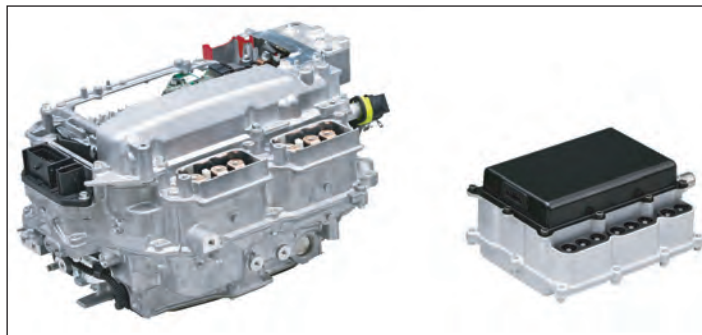
Through use of SiC power semiconductors, Toyota aims to improve hybrid vehicle (HV) fuel efficiency by 10% under the JC08 test cycle of the Japanese Ministry of Land, Infrastructure, Transport and Tourism (MLIT) and to reduce PCU size by 80% compared to existing PCUs with silicon-only power semiconductors. SiC power semiconductors have low power loss when switching on and off, allowing efficient current flow even at higher frequencies. This enables the coil and capacitor, which account for about 40% of the size of the PCU, to be reduced in size.

PCUs play an important role in hybrids and other vehicles with an electrified powertrain: they supply electrical power from the battery to the motor to control vehicle speed, and also send electricity generated during deceleration to the battery for storage. However, PCUs account for about 25% of the total electrical power loss in HVs, with an estimated 20% of the total loss associated with the power semiconductors alone. Therefore, a key way to improve fuel efficiency is to improve power semiconductor efficiency, specifically by reducing resistance experienced by the passing current. Since launching the Prius gasoline-electric HV in 1997, Toyota has been working on in-house development of power semiconductors and on improving HV fuel efficiency.

As SiC enables higher efficiency than silicon alone, Toyota CRDL and Denso began basic research in the



Left: Silicon power semiconductor wafer (transistor). **Right:** SiC power semiconductor wafer (transistor).



Left: PCU with silicon power semiconductors (production model). **Right:** PCU with SiC power semiconductors (future target).



TMC's Hirose Plant.

1980s, with Toyota participating from 2007 to jointly develop SiC semiconductors for practical use. Toyota has installed the jointly developed SiC power semiconductors in PCUs for prototype HVs, and

test driving on test courses has confirmed a fuel efficiency increase exceeding 5% under the JC08 test cycle.

In December 2013, Toyota established a cleanroom for dedicated development of SiC semiconductors at its Hirose Plant, which is a facility for research, development and production of devices such as electronic controllers and semiconductors.

In addition to improved engine and aerodynamic performance, Toyota is positioning high-efficiency power semiconductors as a key technology for improving fuel efficiency for HVs and other vehicles with electrified powertrains. Going forward, Toyota aims to continue to boost development activities targeted at early implementation of SiC power semiconductors.

Toyota exhibited the technology at the 2014 Automotive Engineering Exposition at the Pacifico Yokohama convention center (21–23 May).

www.toyota-global.com

<http://expo.jsae.or.jp/english>

Progress on EU project SPEED presented

Project targets improved efficiency and reliability of high-voltage power transmission and distribution within four years

This year's CWIEME Berlin event (24–26 June) — the world's largest coil winding, insulation and electrical manufacturing exhibition — featured a seminar from Dr Daniel Fernandez, chief technical officer of Spain's INAEL Electrical Systems S.A. and coordinator of the 4-year €20m European Union's Seventh Framework Program (EU FP7) project SPEED ('Silicon Carbide Power Electronics Technology for Energy Efficient Devices'), which began in January.

The project involves 17 companies and research institutions from nine different EU countries — including Spain's INAEL, Centro Nacional de Microelectrónica, Universidad de Oviedo and Ingeteam Power Technology SA, Italy's Enel Distribuzione SpA, France's AnnealSys SAS, Switzerland's ABB Schweiz, Sweden's Ascatron AB and Norstel AB, Germany's Technische Universität München, Gottfried Wilhelm Leibniz Universität Hannover (LUH), Universität Bremen and Fraunhofer Institute of Integrated Systems and Device Technology (IISB), Infineon Technologies of Germany and Austria, the Czech Technical University in Prague, and the UK's University of Nottingham. SPEED aims to make a step change in the efficiency of power generation, distribution and transmission through the use of silicon carbide (SiC) — as a higher-performing alternative to silicon — in high-power semiconductor devices.

"Silicon carbide is a much better insulator than silicon and can withstand far higher voltages — which makes it attractive for high-voltage and high-power electrical circuits," says Fernandez. "The snag is the price."

A key contribution of the project is therefore to establish the technology required to produce lower-cost silicon carbide in sufficiently large amounts to compete with silicon.

SPEED project partners

Spain:

INAEL
Universidad de Oviedo
Centro Nacional de Microelectrónica (CNM)
Ingeteam Power Technology SA

Italy:

Enel Distribuzione SpA

France:

AnnealSys SAS

Switzerland:

ABB Schweiz

Sweden:

Ascatron AB
Norstel AB

Germany:

Technische Universität München
Gottfried Wilhelm Leibniz Universität Hannover (LUH)
Universität Bremen IALB
Fraunhofer IISB
Infineon Technologies

Austria:

Infineon Technologies Austria

Czech Republic:

Czech Technical University in Prague (CVUT)

UK:

University of Nottingham

The SPEED project team has already made progress in growing wafers of consistently high quality, using techniques that Fernandez hopes will be industrialized in the future at very low cost. The next challenge is to use the wafers to fabricate circuits and devices.

"This project is all about developing real-world solutions that will become available in no more than four years," says Fernandez, who will be presenting the research at CWIEME Berlin to an industrial audience comprising energy and utility companies as well as transformer, insulation and switch manufacturers.

The project comprises eight work programs: 'WP1: Advanced SiC Materials: Substrates and Epi', 'WP2: Medium-Voltage SiC Device & Packaging Technologies for Wind Power Applications', 'WP3: High-Voltage SiC Device & Packaging Technologies for Power Transmission Applications', 'WP4: Advanced Characterization & Reliability', 'WP5: SiC-based Power Cells', 'WP6: Demonstrators: Wind Converters and Solid State Transformers', 'WP7: Dissemination and Exploitation', and 'WP8: Project Management, Roadmap Alignment'.

One problem that SPEED aims to solve is the relatively low penetration of renewable energy in the power grid. "When you change wind or solar power into a form that is acceptable to the grid, you lose a lot of energy," says Fernandez. "Our current technology is somehow 'pre-electronic' from this point of view," he adds. "But with silicon carbide devices you could feed much more power into the system, allowing us to increase the total contribution of renewable energy on the grid."

This increased efficiency also has the potential to reduce energy costs, but another more certain benefit is increased reliability, says Fernandez. More robust transmission and distribution devices would limit disruptions to supply and lay the foundations for the spread of electric vehicles as well as other new electricity-based systems, he adds.

Fernandez is presenting 'SPEED EU Project — Power electronics and the next generation of efficiency: The EU consortium seeking to make breakthroughs with SiC technology across the supply chain' at CWIEME Central on 26 June.

www.speed-fp7.org

www.inael.com

Mitsubishi shipping sample 1200V hybrid SiC power semiconductor modules for high-frequency switching

Tokyo-based Mitsubishi Electric Corp has started shipping samples of new 1200V hybrid silicon carbide (SiC) power semiconductor modules for high-frequency switching applications. Featuring SiC diodes, the modules achieve high efficiency, downsizing and weight reduction in inverters for power conditioners and other power equipment, uninterrupted power supplies (UPS) and medical device power supplies.

The new hybrid SiC power modules include the following: 48mm x 94mm CMH100DY-24NFH (100A) and CMH150DY-24NFH (150A); the 62mm x 108mm CMH200DU-24NFH (200A) and CMH300DU-24NFH (300A); and the 80mm x 110mm CMH400DU-24NFH (400A) and CMH600DU-24NFH (600A), all with 2in1 connection.

Exhibited at Power Conversion Intelligent Motion (PCIM) Europe in Nuremberg, Germany (20–22 May), the modules are the latest addition to Mitsubishi Electric's NFH Series of next-generation hybrid SiC power semiconductor modules which, due to their SiC diodes, reduce electric power loss in high-frequency switching applications.

Features of the modules include: (1) 40% reduction in power loss contributes to efficiency, downsizing and weight reduction of total system

- Incorporates a SiC Schottky barrier diode (SBD) and silicon IGBT for transistors in high-frequency switching applications.

- Contributes to system efficiency because the SiC-SBD does not have recovery current, so power loss is reduced by about 40% through significantly lower switching loss.

- Contributes to downsizing and weight reduction of system components (such as reactor and heat sink) due to high-frequency switching and a significant reduction in power loss.

- (2) Suppresses surge voltage through internal inductance reduction

- A low-inductance package has been adopted for high-frequency switching applications.

- The 100A and 150A modules reduce internal inductance by about 30% compared to conventional IGBT module using silicon.

The package is also compatible with conventional power modules for easy replacement.

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

www.MitsubishiElectric.com

ABB funds Zurich power semiconductor professorship

ABB of Zurich, Switzerland, which focuses on electric power engineering and industrial automation, has granted 5m Swiss Francs to the ETH Zurich Foundation to support the development of high-performance power semiconductors, with the aim of improving the efficiency of power conversion systems and energy transmission over long distances as well as industrial solutions. The ETH Zurich Foundation acts as a bridge between companies, private individuals, foundations and ETH Zurich (the Swiss Federal Institute of Technology) to help the university reach its strategic goals.

The funding from ABB Switzerland, which will be distributed over 10 years, creates a fourth professorship within the electrical energy initiative at ETH Zurich. It is aimed at not only boosting research and teaching but also supporting industrial partners with their work.

Power semiconductor research is becoming increasingly important,

says ABB. Power electronics are used to shape electric current according to specific requirements, making it possible to control the speed of electric motors, enable trains to accelerate and decelerate gently, allow renewable energies to be integrated into the power grid, and electric vehicle batteries to be charged in just 15 minutes.

"This undertaking will pay dividends in the development of the electricity network of the future," believes ABB's CEO Ulrich Spiesshofer. "We need to decouple economic growth from energy consumption," he adds. "This contribution underscores ABB's commitment to power and productivity."

ABB (which invests \$1.5bn annually in R&D) partners with universities worldwide as part of its mission of helping customers to reduce energy consumption and boost efficiency. With a history that spans nearly 160 years and 21 Nobel Prize winners, ETH Zurich is an ideal partner,

states ABB.

ABB says that, with this donation, it strengthens the university's initiative aimed at intensifying its electrical energy technology activities and bolstering its position in electrical energy research.

"This newly created post will expand educational opportunities for our students as well as aid research and development of new technologies and materials in an area which is crucial for Swiss energy policy," says ETH's president Ralph Eichler. "An important research focus for the new professorship will be the deployment of new semiconductors in the high-voltage electrical network of the future."

ABB is already constructing a power electronics research lab near Baden in Switzerland, where staff are working on power semiconductor technologies. Further developments are also being pursued at ABB Semiconductors in nearby Lenzburg.

www.abb.com

Microsemi launches 1200V SiC MOSFETs for high-voltage industrial applications

Microsemi Corp of Aliso Viejo, CA, USA (which designs and makes analog and RF devices, mixed-signal integrated circuits and subsystems) has introduced its new silicon carbide (SiC) MOSFET product family with new 1200V solutions. The new SiC MOSFETs are designed for high-power industrial applications where efficiency is critical, including solutions for solar inverters, electric vehicles, welding and medical devices.

Microsemi reckons that it is well positioned to capitalize on SiC semiconductor market growth. Yole Développement estimates that the SiC power semiconductor market will grow 39% year-on-year from 2015 to 2020, and market research estimates the SiC semiconductor market will grow 38% year-on-year to \$5.3bn by 2022.

New SiC MOSFETs

Designed to help users to develop solutions that operate at higher frequency and improve system efficiency, the new SiC MOSFETs provide patented technology features including:

- what is claimed to be best-in-class $R_{DS(on)}$ versus temperature;

- ultra-low gate resistance for minimizing switching energy loss;
- superior maximum switching frequency; and
- ruggedness with superior short-circuit withstand.

"Microsemi continues to expand its SiC product portfolio by capitalizing on our in-house SiC fabrication capabilities and delivering innovative high-power solutions," says Marc Vandenberg, general manager of the firm's Power Products Group.

The 1200V SiC MOSFETs are rated at 80mΩ and 50mΩ and provide more development flexibility by offering both industry-standard TO-247 and SOT-227 packages:

- APT40SM120B — 80mΩ, 40A, TO-247 package;
- APT40SM120J — 80mΩ, 40A, SOT-227 package;
- APT50SM120B — 50mΩ, 50A, TO-247 package; and
- APT50SM120J — 50mΩ, 50A, SOT-227 package.

New SiC MOSFET power modules

SiC MOSFETs are also integrated into the firm's expanded MOSFET power modules, which are used in battery charging, aerospace, solar,

welding and other high-power industrial applications. The new power modules provide higher-frequency operation and improve system efficiency.

New 1700V Schottky diodes

The SiC MOSFETs are also complemented by Microsemi's complete product line of SiC Schottky diodes. The new 1700V SiC Schottky diode expands the line beyond the existing 1200V and 650V options. These products are designed with what is claimed to be superior passivation technology for ruggedness in outdoor and humid applications.

The new 1200V SiC MOSFETs are available now in TO-247 packages and in July in SOT-227 packages. SiC MOSFET power modules and the 1700V Schottky diode are available now.

Microsemi's SiC solutions, power products, sensor devices, ultra-low power radios and system-on-chip (SoC) FPGA-based motor control solutions were displayed at the PCIM (Power Conversion Intelligent Motion) Europe 2014 event in Nuremberg, Germany (20–22 May).

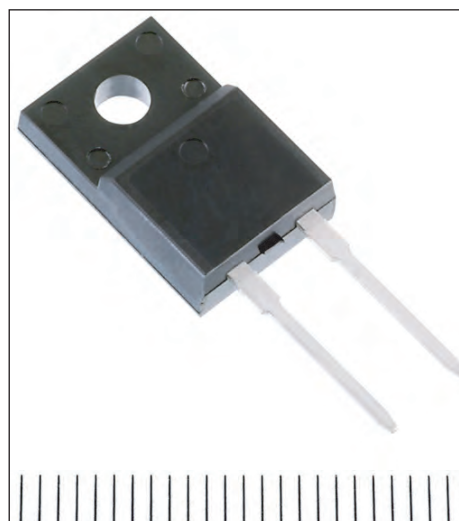
www.microsemi.com/sicmosfets

Toshiba expands 650V SiC Schottky barrier diode range

Toshiba Corp's Semiconductor & Storage Products Company has expanded its family of 650V silicon carbide (SiC) Schottky barrier diodes (SBDs) with the addition of insulated TO-220F-2L packaged products. Mass production shipment has begun.

The four new TO-220F-2L packaged products (TRS6A65C, TRS8A65C, TRS10A65C and TRS12A65C) expand the 6A-, 8A-, 10A- and 12A-rated line-up, correspondingly, of the existing TO-220-2L packaged products (TRS6E65C, TRS8E65C, TRS10E65C and TRS12E65C).

SBDs are suited to applications including server power supplies and power conditioners for photovoltaic



Toshiba's 650V SiC Schottky barrier diode in an insulated TO-220F-2L package.

power generation systems, says the firm. They can also act as replacements for silicon diodes in switching power supplies, where they are 50% more efficient (according to a Toshiba survey).

The firm adds that SiC power devices offer more stable operation than existing silicon devices - even at high voltages and currents - as they significantly reduce heat dissipation during operation. They meet diverse industry needs for smaller, more effective communications devices and suit industrial applications ranging from servers to inverters.

www.semicon.toshiba.co.jp/eng/product/diode/sic/index.html

All-SiC 300A, 1.2kV 62mm half-bridge module doubles power density for converters up to megawatt level

Cree Inc of Durham, NC, USA says that its silicon carbide (SiC) technology continues to enable smaller, lighter, more efficient and lower-cost power systems with a new all-SiC 300A, 1.2kV half-bridge module. Packaged in an industry-standard 62mm housing, the new module is said to reduce energy loss due to switching by more than five times compared to the equivalent silicon solution. This efficiency enables for the first time, it is said, all-SiC high-power converters rated up to the megawatt level, extending Cree's SiC chip technology into high-current power modules.

"The drop-in feature of Cree's new all-SiC power module allows us to achieve 99% efficiency while reducing the power module count by a factor of 2.5 in our existing HF induction heating systems," comments John K. Langelid, R&D manager at EFD Induction. "These benefits are greatly valued as a reduced cost of ownership by our end customers."



62mm C2M module and direct mount gate driver.

The new all-SiC 62mm half-bridge module's switching efficiency and performance allow designers to reduce the amount of magnetic and cooling elements, delivering double the power density and a lower system cost while also reducing end-user cost of ownership, claims Cree. Offering a simplified two-level topology that is feasible at higher frequencies, the new module can also eliminate the need to invest in multi-level silicon-based solutions.

The new SiC power module is available with multiple gate driver options and is pin compatible to

standard 62mm half-bridge modules, including IGBT modules rated at 450A or more, allowing designers to quickly and easily evaluate the module's capabilities.

"Utilizing our success in large-area SiC power devices, we have extended the benefits of SiC power modules to the 100kW to 1MW power range for applications such as induction heating, central solar inverters and active front-end (AFE) motor drives," says Cengiz Balkas, general manager & VP, Cree Power and RF. "These new power modules are introduced at a breakthrough price-performance point that unlocks immediate cost savings in these applications," he reckons.

The new CAS300M12BM2 all-SiC 300A, 1.2kV half-bridge module will be available at preferred distributors such as Mouser, Digi-Key and Arrow's RF & Power Business, priced at \$451 each for 1000-unit quantities. Companion gate drivers are available from Cree and Prodrive.

www.cree.com/power/CAS300M12BM2

Cree launches discrete 20A and 50A 650V silicon carbide Schottky diode rectifiers for power supplies

Cree has added two new discrete 650V silicon carbide rectifiers to its Z-Rec Schottky diode portfolio. Made using Cree's SiC technology, the C5D50065D and CVFD20065A are said to deliver ultrafast switching frequencies, higher efficiencies, improved thermal characteristics, enhanced reliability, simplified circuit design, and reduced costs for power electronic systems.

Rated at a blocking voltage of 650V and a continuous forward current of 50A, the C5D50065D Schottky diode is the first member of Cree's high-power CPW5 diode family to be released in packaged form. Available in a TO-247-3 package, it provides up to 2000A of non-repetitive surge capability at 25°C, combined with the

high continuous current-carrying capability of the CPW5 family. The 50A rectifier is suited to demanding applications such as automotive on-board chargers, server power supplies, power conditioning, and high-reliability aerospace and military power systems.

Developed to provide increased switching efficiency through a reduced forward voltage, the CVFD20065A Schottky diode provides 20A of forward current capability with a nominal voltage drop of only 1.35V at 25°C and is the first product to be released as part of Cree's new family of Low V_F Z-Rec Schottky diodes. Cree has also taken additional steps to bolster the surge capability of the CVFD20065A, resulting in a

forward surge rating of 1400A at 25°C (10µs pulse) – the highest of all commercially available 20A, 650V SiC Schottky diodes, it is claimed. The 20A rectifier is available in a TO-220-2 package and is rated for a blocking voltage of 650V. With its increased switching efficiency and high surge capability, the new 20A diode was designed with HVAC (heating, ventilation and air conditioning) power supplies and switched-mode power supplies (SMPS) in mind, but is also suitable for motor drives and power inverters operating in the 5–10kW range.

www.cree.com/Power/Products/Diodes/TO247/C5D50065D

www.cree.com/Power/Products/Diodes/TO220/CVFD20065A

First 1200V/25mΩ MOSFET in TO-247 package

Cree claims to have shattered the on-resistance barrier of traditional 1200V MOSFET technology by introducing the first commercially available silicon carbide (SiC) 1200V MOSFET with an $R_{DS(ON)}$ of 25mΩ in an industry-standard TO-247-3 package. The C2M0025120D SiC MOSFET is expected to be adopted in photovoltaic (PV) inverters, high-voltage DC/DC converters, induction heating systems, electric vehicle (EV) charging systems and medical CT applications.

Based on Cree's proven C2M SiC MOSFET technology, the new device has a pulsed current rating (I_{DS} pulse) of 250A and a positive temperature coefficient, providing greater design flexibility to explore new design concepts. The high I_{DS} pulse rating makes the device suitable for pulsed power applications, says Cree, and the positive temperature coefficient allows the devices to be paralleled to achieve even higher power levels.

The higher switching frequency of the new C2M0025120D enables power electronics design engineers to reduce the size, weight, cost and complexity of power systems, says Cree. For medical applications,



Cree's new C2M0025120D 1200V MOSFET.

such as CT systems, Cree's C2M MOSFETs provide a five-fold reduction in switching losses and enable much higher power density, it is claimed. Combined with the lower switching losses, the added benefit of low $R_{DS(ON)}$ greatly improves the thermal characteristics and can potentially even eliminate system fans, resulting in quieter and more cost-effective medical imaging systems, says the firm.

Cree has also demonstrated that, by implementing the C2M0025120D in a PV string-inverter, it is possible to develop a highly efficient and

compact 50kW grid-tied solar inverter with a power-to-weight ratio of 1kW/kg. This results in a string inverter that is significantly more efficient and half the weight and size of the state-of-the-art commercial 50kW systems available currently, Cree reckons. Additionally, for rooftop PV inverters, the smaller size and lighter weight greatly reduce the installation costs.

Cree offers several tools to help engineers get started with their next designs, including full reference designs of recommended SiC MOSFET gate driver circuits.

Customers can also purchase Cree CRD-001 gate driver boards, which provide a convenient way to quickly evaluate the C2M0025120D using industry-standard components. Further, the MOSFETs are also compatible with a host of industry-standard gate drivers from leading IC companies such as TI, Avago and IXYS.

Cree exhibited the C2M0025120D SiC MOSFET at PCIM (Power Conversion Intelligent Motion) Europe 2014 in Nuremberg, Germany (20–22 May).

www.cree.com/Power/Products/MOSFETs/TO247/C2M0025120D

Raytheon chosen to demo next-gen modular radar system

Raytheon Company of Waltham, MA, USA has been awarded a \$6m study and demonstration contract by the US Office of Naval Research (ONR) to further develop an enterprise air surveillance radar (EASR) powered by gallium nitride (GaN) technology.

Raytheon's EASR concept leverages proven Radar Modular Assembly (RMA) architecture matured on Air and Missile Defense Radar (AMDR). EASR's flexible approach meets the performance needs of different candidate ship classes for ship self-defense, situational awareness, air traffic control, and weather monitoring.

The Radar Modular Assembly

affords EASR the scalability to be used on a variety of ship sizes across a diverse set of mission requirements, ultimately offering reduced total ownership cost across all the EASR-equipped platforms. The RMA has been designed and tested to prove that it operates successfully in the stressing EASR naval marine environments.

"The Navy is committed to leveraging the latest in technology and innovation to stay ahead of evolving threats," says Paul Ferraro, VP of Advanced Technology Programs for Raytheon's Integrated Defense Systems (IDS) business in Tewksbury, MA. "The next-generation EASR radar program is the latest

example of Raytheon's partnership with ONR to drive advancement and provide affordable best in class solutions," he adds.

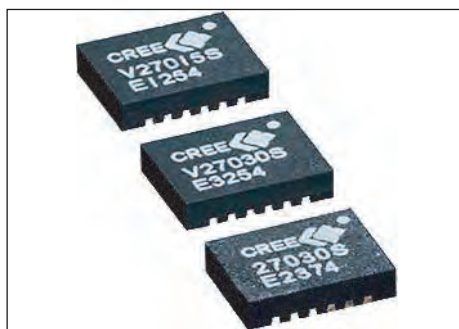
Raytheon claims that it is the world's largest producer of active phased arrays and has a long history of providing naval radar systems. Its experience as the provider of Dual Band Radar (DBR) and SPS-49 is directly applicable to EASR. Raytheon says that its EASR approach directly benefits the US Government by applying proven technologies and leveraging investment by both the Navy and Raytheon in the ONR Digital Array Radar (DAR) and AMDR programs.

www.raytheon.com

Cree launches low-cost extended-bandwidth GaN HEMTs to support data-hungry small-cell networks

As high-data-rate applications put more strain on LTE wireless networks, solutions such as small-cell base-stations (BTS) and carrier aggregation will be needed to bridge the bandwidth gap in high traffic areas. In response to broader bandwidth demand, Cree Inc of Durham, NC, USA has introduced a family of RF gallium nitride (GaN) HEMTs that delivers bandwidth and efficiency performance to support busy LTE networks. Fabricated in plastic dual-flat no-leads (DFN) surface-mount packages, the new GaN HEMT RF transistors also provide the affordability needed to replace less efficient silicon or gallium arsenide (GaAs) transistors in these applications, says Cree.

"The trend of ever-increasing amounts of data-rich applications will drive the need for small-cell deployment to improve wireless network performance," says Tom Dekker, director of sales & marketing of Cree's RF business unit. "Our



industry-leading GaN technology will provide the desired bandwidth, flexibility, efficiency and affordability our small-cell customers demand," he adds.

The new GaN HEMT DFN product family includes 28V and 50V, 15W and 30W unmatched transistors. The frequency-agile transistors are capable of operating at 700MHz–3.8GHz instantaneous, and may be optimized for band splits. Multi-band capability creates design flexibility that helps small cell OEMs speed their time to market and allows operators to reconfigure the same small-cell unit for different market requirements.

In high-efficiency applications, Cree's GaN HEMT RF transistors help to reduce the size and weight of LTE cellular network transmitters and simplify thermal management. These efficiency gains generate significant energy savings in operational costs. Cree developed Doherty reference design CDPA27045 utilizing 15W and 30W HEMT DFN transistors to demonstrate the technology's efficiency. The design delivers about 50% drain efficiency at 10W average power under a LTE 7.5dB peak-to-average ratio signal, and covers 2.5–2.7GHz instantaneous RF bandwidth while offering 16dB of linear gain.

The new family of GaN HEMT DFN RF transistors is based on Cree's qualified 50V, 0.4μm-gate-length process. Samples and reference designs are available for the CGH27030S (30W, 28V, 0.4μm), CGHV27015S (15W, 50V, 0.4μm) and CGHV27030S (30W, 50V, 0.4μm) GaN HEMT transistors.

www.cree.com/smallcell

Northrop Grumman launches high-power GaN amplifiers for Ka-band SatCom terminals

Northrop Grumman Corp of Redondo Beach, CA, USA has launched two high-power gallium nitride (GaN) MMIC power amplifiers for Ka-band satellite communication terminals and point-to-point digital communication links.

Manufactured at the firm's wafer fab in Manhattan Beach, the APN228 and APN229 power amplifiers were developed using Northrop Grumman's proprietary GaN HEMT power process and provide saturated output power of 13W and 8W, respectively. The second-generation power amplifiers offer what is claimed to be the highest power density of any existing Ka-band GaN product on the market.

The broadband two-stage ampli-

fiers both operate at 27–31GHz and, when integrated in high-efficiency solid-state power amplifiers (SSPAs), allow for higher data rates in communication systems.

The APN228 is a 16.0mm² MMIC PA providing 19.5dB of linear gain, 41.2dBm (13W) of saturated output power and power-added efficiency (PAE) greater than 27%, offering an option for next-generation high-power and high-efficiency SSPAs for commercial and military satellite applications.

The APN229 is a 7.41mm² MMIC PA providing 20dB of linear gain, 39dBm (8W) of saturated output power and PAE greater than 30%, and can act as a complementary driver amplifier to the APN228.

"GaN-based SSPAs are a far more desirable solution to costly traveling-wave tubes, which require more complex, higher-voltage power supplies and a lengthier production time," says Frank Kropschot, general manager, Microelectronics Products and Services, Northrop Grumman Aerospace Systems. "APN228 and APN229 will allow our customers to reduce the cost and complexity of power-combining, and offer a significant cost advantage compared to the current generation of Ka-band products," he believes.

Samples of the MMIC PAs will be available by mid-July, and packaged versions will be available for sampling later this year.

www.northropgrumman.com/mps

Cree launches low-cost, high-power GaN RF transistors to enable higher-data-rate telecom systems

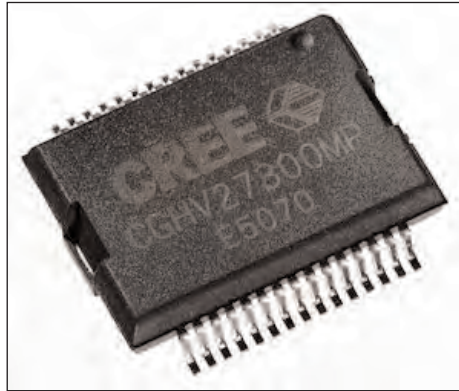
Initial products include first 300W, 2.7GHz plastic-packaged gallium nitride telecom transistor

At the IEEE MTT International Microwave Symposium (IMS 2014) in Tampa (1–6 June), Cree Inc of Durham, NC, USA introduced a new family of high-power GaN RF transistors based on a plastic package design, leveraging the RF performance of GaN in a low-cost platform.

Initial products include what is claimed to be the industry's first 300W plastic-packaged transistor operating at 2.7GHz, delivering saturated output power (P_{sat}) efficiency of 65% and broadband capability at nearly half the price of the same GaN transistor housed in an industry-standard ceramic package. Scalable to high power levels and capable of operating in all cellular telecom bands up to 3.8GHz, the new GaN transistors are expected to enable the deployment of smaller, lower-cost macrocell radio units capable of supporting the growing data demands of cellular LTE networks.

"The RF transistor market for wireless telecom infrastructure is approaching \$1bn annually," comments Lance Wilson, research director at analyst firm ABI Research. "Silicon LDMOS has been the dominant technology for the past 20 years but recently GaN RF power devices have captured meaningful market share based on performance; however, acceptance has been limited thus far due to its higher cost," he adds. "Cree's newest family of high-power plastic products will drive down the cost of GaN transistors to a point that is nearing Si LDMOS levels and will accelerate broader adoption in telecom applications. This will make GaN transistors a principal choice for next-generation wireless networks," he believes.

Cree says that its new broadband GaN transistors have the flexibility to operate across multiple cellular



Cree's CGHV27300MP 2.7GHz 300W GaN HEMT.

bands, helping network operators deploy carrier aggregation solutions that join different bands of spectrum and create larger data pipes to support faster download speeds and enable additional network capacity. Cellular base-station OEMs can also leverage this flexibility to speed their time to market by addressing market requirements with fewer band-specific amplifiers.

Cree also says that its proven GaN technology provides efficiency that improves a system's thermal design and reduces

cost. More efficient solutions allow for smaller and lighter radio units, alleviating loading on already overcrowded cellular towers. Increased efficiency also creates significant savings on utility costs necessary to run the networks.

"Our new low-cost line of high-performance plastic-packaged transistors will transform the way telecom OEMs approach base-station platform design, providing greater flexibility and networking options for cellular operators to serve their customer base," believes Cree's RF business director Jim Milligan. "Our new packaging platform allows us to break a significant cost barrier that has prevented telecom infrastructure providers from fully exploiting the full performance capability of GaN technology," he adds. "By delivering broadband and high-efficiency performance in a cost-effective solution, we believe GaN is poised for rapid adoption by setting a new standard for performance and price."

Available at power levels of 60, 100, 150, 200 and 300W, the new plastic GaN HEMT RF transistors can operate at frequencies up to 3.8GHz. In addition, the family offers transistors pre-matched to cellular bands at either 690–960MHz, 1800–2300MHz or 2300–2700MHz. Cree's GaN plastic-packaged transistors used in Doherty amplifiers have demonstrated 80W average power at 2.6GHz with 50% drain efficiency under 7.5dB PAR (peak-to-average ratio) LTE signals at 50V, with 17dB of gain at rated output power. The entire family of 50V plastic GaN transistors is verified to meet moisture sensitivity level (MSL-3) and JEDEC environmental standards.

www.cree.com/telecom

The RF transistor market for wireless telecom infrastructure is approaching \$1bn annually. Silicon LDMOS has been the dominant technology for the past 20 years but recently GaN RF power devices have captured meaningful market share based on performance; however, acceptance has been limited thus far due to its higher cost

IN BRIEF

MACOM showcases GaN portfolio at IMS 2014

At the IEEE MTT International Microwave Symposium (IMS 2014) in Tampa, FL, USA (4–6 June), M/A-COM Technology Solutions Inc of Lowell, MA, USA (which makes analog semiconductors, components and subassemblies for analog, RF, microwave and millimeter-wave applications) showcased its gallium nitride (GaN) product portfolio as well as featuring a suite of new products targeted at applications spanning industrial, scientific, medical, point-to-point wireless and X-band radar.

At IMS, MACOM presented:

- GaN portfolio — featuring what is claimed to be the industry's broadest portfolio of GaN power products, ranging from 100W GaN in plastic to 1000W ceramic GaN devices.
- Demonstration of MACOM's GaN-on-silicon integrated amplifier family. The live demo will feature matched, broadband, integrated amplifiers operating over a 30–2500MHz frequency band, showcasing the ease of use of the products for a variety of applications.
- E-band amplifier — what is claimed to be the industry's highest-power broadband MMIC power amplifier with an integrated power detector, delivering saturated output power (Psat) of 25dBm and gain of 20dB over the 71–86GHz frequency band.
- A new family of high-performance, ultra-compact broadband mixers, suitable for multi-market customers.
- X-band multi-function module — a fully integrated MMIC packaged in a 7x7 QFN, enabling dual-path transmit/receive operation over the X-band.

www.macomtech.com
www.ims2014.org

Sumitomo expanding GaN-on-SiC device production with Aixtron CRIUS MOCVD system for RF data transfer market growth from 2015

Deposition equipment maker Aixtron SE of Aachen, Germany says that Japan's Sumitomo Electric Device Innovations Inc (SEDI) has ordered a CRIUS metal-organic chemical vapor deposition (MOCVD) system, to be delivered in 4-inch wafer configuration, in order to boost production of gallium nitride on silicon carbide (GaN-on-SiC) devices for RF data transfer applications. The purchase was made in first-quarter 2014 for delivery at SEDI's Electron Devices Division in Yokohama in third-quarter 2014.

SEDI is preparing for an expected ramp-up in demand starting in 2015 and chose the Aixtron system due to its reputation for 4" wafer uniformity and precise process control, which is especially important for device production on cost-intensive SiC wafers.

The new reactor will be equipped with optional features such as dynamic gap adjustment, ARGUS in-situ temperature control, and an EpiCurve TT metrology system from LayTec.

The ARGUS monitoring device provides full wafer mapping in real time for optimum control of the growth process. Extended flexibility is enabled by allowing the adjustment of the process gap between the showerhead and the substrate.

SEDI already has a range of GaN high-electron-mobility transistor (HEMT) devices on offer for radar, mobile phone base-stations, and general applications. The HEMT devices exhibit high power amplification up to 14GHz RF, enabled by GaN-on-SiC.

www.aixtron.com
www.sedi.co.jp/e

Sumitomo Electric launches GaN HEMTs for space applications

At the IEEE MTT-S International Microwave Symposium (IMS2014) in Tampa, FL (3–5 June), RF, wireless and optical communications component and module provider Sumitomo Electric Device Innovations USA Inc of San Jose, CA (SEDI, a subsidiary of Japan's Sumitomo Electric Industries Ltd, or SEI) showcased next-generation gallium nitride (GaN) high-electron-mobility transistor (HEMT) devices for space applications.

Sumitomo Electric Device Innovations USA says GaN provides the benefits that space applications require such as operation at much higher temperatures, higher power-added efficiency (PAE) and wider bandwidth than gallium arsenide (GaAs), all while reducing overall operational cost.

"Sumitomo Electric is dedicated to offering a broad range of space qualified RF products over 30 years," says SEDU's president John Wyatt. "The combination of high power, high gain and excellent efficiency performance makes our next-generation GaN HEMTs for space very attractive design solution," he reckons. "For example, ES/SGN15H150IV provides 150W output power at 1.575GHz with power-added efficiency of 71.2%."

Operating at 50V, the new devices offer high output power in a single-ended package, with PAE of more than 70% and gain of 18dB at 1.5GHz.

Samples for evaluation up to 150W will be available in August.

www.sei-device.com

Cree launches highest-power and -frequency plastic-packaged GaN transistors for low-cost radar & datalinks

Cree Inc of Durham, NC, USA has introduced what it claims are the industry's highest-power continuous wave (CW) RF gallium nitride (GaN) high-electron-mobility transistors (HEMTs) packaged in a dual-flat no-leads (DFN) format.

Targeted at the cost-sensitive sub-100W commercial radar and data-link amplifier market segments, the new 6- and 25-watt DFN transistors effectively obsolete the use of inefficient gallium arsenide (GaAs) transistors in C- and X-band frequencies, claims Cree, and also enable the practical replacement of short-life tube-based technology for commercial radar applications such as weather, marine and surveillance.

Based on Cree's proven 40V, 0.25µm-gate-length high-frequency process, Cree reckons that its GaN DFN transistors deliver twice the saturated output power (PSAT) efficiency and transistor gain of GaAs IMFETs (internally matched field-effect transistors) in a package size that is nearly 20 times smaller at comparable power levels and

The 6W CGHV1F006S DFN-packaged GaN HEMT



frequencies. In high-capacity microwave data links used in enterprise, point-to-point and airborne communication networks, the new transistors extend the communication range while delivering twice the linear efficiency of GaAs-based amplifiers. This higher efficiency gives RF designers the flexibility needed to reduce amplifier size and weight, creating savings in operating and total lifecycle costs, says Cree.

"For years, commercial microwave radar transmitters have been plagued with the compromised field life of tube-based amplifiers that carry significant maintenance costs," says Tom Dekker, Cree's director of RF sales & marketing.

"Historically, high-capacity data links were limited to the use of inefficient GaAs IMFETs," he adds. "By delivering superior efficiency and power capabilities at an affordable price, our new GaN DFN transistors enable for the first time the replacement of these legacy technologies in lower-power, cost-sensitive commercial systems."

The new DFN devices can also make act as drivers for Cree's CGHV96100 and CGHV96050F2 fully matched FETs for X-band frequencies, enabling the output- and drive-stage transistors to operate from the same voltage rail. This allows convenient, regulated power distribution to economize board space compared with a mixed-voltage transistor line up.

Samples and reference designs for C- and X-band are available now utilizing the CGHV1F006S (6W) and CGHV1F025S (25W) GaN DFN transistors. Large-signal models are also available for Agilent's ADS and AWR Microwave Office simulators.

www.cree.com/affordableGaN

Artesyn launches 48V-output DC–DC converter module supporting GaN power amplifier systems

Artesyn Embedded Technologies of Tempe, AZ, USA (formerly Emerson Network Power's Embedded Computing & Power business), which designs and manufactures power conversion and embedded computing solutions for communications, computing, medical, military, aerospace and industrial applications, has announced its highest-power-output dc–dc converter module.

Housed in a full-brick format, the AGF800 series offers typical efficiency of more than 94.5% and a wide input range of 36–75V. A 48V model (AGF800-48S48) is designed to support the rapidly growing number of high-power wireless base-station

(BTS) deployments using GaN technology for increased power density and higher efficiency. The 48V model can deliver up to 16.7A output current, while the 28V model can deliver up to 28.6A output current.

An aluminium baseplate structure gives AGF800 series modules excellent thermal performance. Both models can operate between –40°C and +85°C ambient temperature, and can continue to operate at full power up to 100°C base-plate temperature — all without air cooling.

The AGF800 series dc–dc converter modules also offer a wide trim range of 24–53V for the nomi-

nal 48V output version and 14–33V for the nominal 24V output version.

Other features include remote enable, remote output sense, trim, auxiliary output, power-good signal; and protection features such as input under-voltage lockout, output over-current protection, output over-voltage protection, and over-temperature protection. No minimum load requirement helps to increase reliability and contributes to a mean time before failure (MTBF) of 1 million hours (calculated according to Telcordia SR-332-2006).

www.artesyn.com/power/power-supplies/websheet/505/AGF800

API launches 500–1000W, 18GHz GaN-based pulsed power amplifiers for TWT replacement

API Technologies Corp of Orlando, FL, USA, a designer and manufacturer of systems, subsystems, modules and components for RF, microwave, millimeter-wave, electromagnetic, power and security solutions in critical and high-reliability applications, has expanded its line of gallium nitride (GaN)-based power amplifiers to include designs that operate with pulsed output power levels of 500–1000W and frequencies to 18GHz. The new pulsed solid-state power amplifiers were debuted at the IEEE MTT-S International Microwave Symposium (IMS 2014) in Tampa, FL (3–5 June).

The new power amplifiers can serve as a cost-effective replacement for traveling wave tubes (TWT), as the amplifiers' long life and reduced size and weight offer better efficiencies

than their TWT counterparts.

API's GaN-based pulsed power amplifiers can be used in numerous military and high-end commercial applications including radar, communication transmitters, and jamming systems.

The unique power amplifiers are designed and manufactured in the USA and use in-house thin- and thick-film technologies as well as surface-mount technology (SMT). They are offered in hermetically sealed packages using mixed SMT and chip-and-wire (hybrid) manufacturing processes.

For high-frequency applications, waveguide components can be integrated into the floor of the package to reduce combining losses and further increase functionality such as embedded harmonic filtering.

Other options of the GaN-based power amplifiers include sleep mode, blanking, forward/reverse power detection, discrete power supply designs for wide DC input voltage ranges, as well as microprocessor-based customer-defined control features for bias optimization, temperature compensation, fault monitoring, and customer interferences.

"API's feature-rich architecture, combined with complementary design tools provide engineers a suite of customizable solutions to meet challenging requirements in performance, packaging, and lead times," says Dennis Barrick, API's technical marketing manager, RF/Microwave & Microelectronics (RF2M-US).

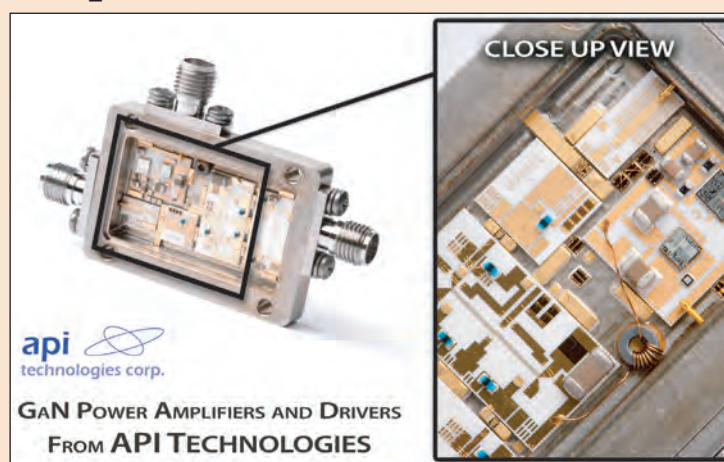
<http://micro.apitech.com/1000-watt-pulsed-power-amplifier>

API debuts broadband GaN power amplifier drivers providing complete front-to-back amplifier solution

At the IEEE MTT-S International Microwave Symposium (IMS 2014), API debuted a line of GaN drivers to provide a complete, front-to-back amplifier solution for applications requiring high levels of gain and output power.

The hybrid-based power amplifier drivers are an extension of the firm's broad RF and microwave amplifier product range, which includes small-signal, low-noise, and high-power-output products, for commercial, military, medical and industrial applications.

Operating at frequencies up to 26GHz and with a broad range of output levels from 500mW to 500W, API's GaN power amplifier drivers are suitable for applications including radar, communication transmitters, jamming systems, optical drivers, and medical imaging electronics. Their broadband capabilities and rugged architecture suit use in harsh environmental or weather conditions, such as



"With the ability to operate without damage over a wide range of input and output VSWR conditions, these power amp drivers are ideal for a variety of high-powered amplifier applications, includ-

communications systems in developing countries or field-deployed military equipment.

The drivers are manufactured using in-house thin- and thick-film technologies, as well as surface-mount technology (SMT) using a void-free die attach processes. Leveraging a mixed SMT and chip & wire (hybrid) process ensures high reliability and stability in a highly compact, hermetically sealed package, says the firm.

ing both API-designed and customer-designed power amplifier products," says Dennis Barrick, API's technical marketing manager, RF/Microwave & Microelectronics (RF2M-US). Drivers and power amplifiers are offered in class A, AB linear and C designs.

Full environmental screening and 100% electrical testing over temperature is available to ensure compliance with customer specification requirements`.

Element Six's GaN-on-diamond wafers shown by Raytheon to provide three-fold boost in power density versus GaN-on-SiC for RF devices

Luxembourg-registered synthetic diamond materials firm Element Six (a member of the De Beers Family of Companies) says that its gallium nitride (GaN)-on-diamond wafers have been proven by Raytheon Company to significantly outperform industry-standard gallium nitride-on-silicon carbide (GaN-on-SiC) in RF devices — reducing thermal resistance, increasing RF power density, and preserving RF functionality.

In high-electron-mobility transistor (HEMT) devices, Raytheon achieved a three times improvement in GaN-on-diamond's RF areal power density compared with GaN-on-SiC devices, says Element Six. The GaN-on-diamond devices also demonstrated a nearly three times reduction in thermal resistance, it adds. Raytheon used several industry-standard thermal measurement techniques, including time-domain thermal reflectance (TDTR), laser flash and resistance thermometry, as well as finite-element modeling, to establish the consistency of the results.

Upon reaching these milestones, Raytheon has met the aggressive

objectives of the US Defense Advanced Research Project Agency's (DARPA) Near Junction Thermal Transport (NJTT) program, which aimed to develop GaN RF devices that exhibit three times or greater improvement in power density through improved thermal management.

Element Six claims that its GaN-on-diamond substrates exhibit an advantage over other substrate materials because synthetic diamond dissipates heat up to five times more effectively than silicon or silicon carbide. This, coupled with the close proximity of the diamond to the GaN, results in a dramatic reduction in the thermal resistance of GaN-on-diamond wafers. Lower thermal resistance enables simpler and less expensive thermal management systems and reliable operation in higher ambient temperatures, as well as more cost-effective RF devices.

"Heat issues account for more than 50% of all electronic failures, and limit GaN's inherent power-density performance potential," says Adrian Wilson, director of Element Six Technologies Group.

"RF and high-voltage power device manufacturers that leverage GaN-on-diamond will have access to unmatched wafer thermal conductivity, and be able to deliver rapid, efficient and cost-effective heat extraction," he adds. "As the first company to make GaN-on-diamond wafers commercially available, we look forward to collaborating with manufacturers to tap into the unique properties of synthetic diamond."

Having been designed for manufacturers of transistor-based circuits with high-power, high-voltage and high-frequency characteristics, Element Six reckons that its GaN-on-diamond wafers can lead to the creation of smaller, faster, more energy-efficient and higher-power electronic devices that have longer lifespans and improved reliability. GaN-on-diamond technology offers advantages over all other available RF semiconductor materials, delivering superior system performance and cost, the firm claims, making it suitable for next-generation device technology in both defense and commercial applications.

www.e6.com/GaN

Diamond Microwave launches 2–6GHz GaN SSPA

Diamond Microwave Devices Ltd of Leeds, UK, which was spun out in 2006 from the diamond electronics team of Element Six and specializes in gallium nitride (GaN)-based microwave solid-state power amplifiers (SSPAs), is extending its range of SSPAs to include a 2–6GHz model that can be operated in either pulsed or CW mode.

Announced at the IEEE MTT-S International Microwave Symposium (IMS 2014) in Tampa, FL, USA (3–5 June), the DMSC5001 is an ultra-compact broadband amplifier that complements the firm's existing

SSPAs in the X-band and Ku-band. All of Diamond Microwave's amplifiers are suitable for use in demanding defence, aerospace and communications applications.

"We are releasing provisional data at IMS 2014 for a new 2–6GHz ultra-compact design, which is demonstrating 100W peak power in pulsed mode at 2GHz and an average power capability of 50W across the full band," says managing director Richard Lang. "This amplifier measures only 120mm x 100mm x 20mm, excluding the heat sink," he adds.

"Once again we are pushing the boundaries of solid-state power amplifier technology with an extremely compact solution," Lang says.

The amplifier designs are flexible in layout and architecture, and are fully customizable to meet individual specifications for electrical, mechanical and environmental parameters.

Amplifiers with pulsed power outputs in excess of 1kW and with multi-octave performance are also under development.

www.diamondmw.com

EPC appoints Applications Engineering director to create benchmark power converter designs and assist customers in using eGaN FETs

Efficient Power Conversion Corp (EPC) of El Segundo, CA, USA, which makes enhancement-mode gallium nitride on silicon (eGaN) power field-effect transistors (FETs) for power management applications, says that Dr John Glaser has joined its engineering team as director, Applications Engineering.

Glaser's focus will be on designing lower-loss and higher-power-density benchmark architectures and converters — initially in high-voltage applications — that demonstrate the benefits of using GaN transistors. Glaser's research and practical experience in these applications will be shared with customers to accelerate customer designs using eGaN FETs. His designs will aim to demonstrate GaN transistors' superior performance over MOSFETs.

Glaser has a doctorate in electrical engineering as well as a master's degree from the University of Arizona, and an undergraduate



Dr John Glaser.

Glaser will focus on designing lower-loss and higher-power-density benchmark architectures and converters — initially in high-voltage

degree from the University of Illinois, Urbana-Champaign (UIUC). Prior to joining EPC he was a senior engineer at the General Electric Global Research Center for over 16 years, where he served in technical and project leadership roles for

power processing projects, including energy-efficient lighting, RF power sources, silicon carbide (SiC) semiconductor applications, advanced magnetic component modeling and design, appliance controls, radar power supplies, aircraft power, failure analysis and correction. Glaser has also served as an adjunct professor teaching power electronics at Rensselaer Polytechnic Institute (RPI) in Troy, NY.

EPC says that Glaser joins a team of application engineers that has demonstrated not only direct support of customers' adoption of eGaN power transistors but has also contributed to the rapidly expanding bibliography of technical literature on GaN technology, as evidenced by technical articles and presentations including the upcoming publication by Wiley of the team's second edition of the textbook 'Gallium Nitride for Efficient Power Conversion'.

EPC presents GaN technology for envelope tracking power supplies, high-efficiency wireless power transfer and high-frequency buck converters

At the PCIM (Power Conversion Intelligent Motion) Europe 2014 conference in Nuremberg, Germany (20–22 May), Efficient Power Conversion Corp (EPC) of El Segundo, CA, USA, which makes enhancement-mode gallium nitride on silicon (eGaN) power field-effect transistors (FETs) for power management applications, gave three application-focused technical presentations on the enabling capability of eGaN FETs in 10MHz buck converters for envelope tracking; how a novel new topology featuring eGaN FETs increases efficiency in wireless power transfer by 20%; and how an optimized parallel layout of eGaN power tran-

sistors achieves efficiencies above 96.5% in a 480W converter:

- Poster Dialogue Session: 'Multi Megahertz Buck Converters Using eGaN FETs for Envelope Tracking', presented by Johan Strydom;
- 'Improving Performance of High Speed GaN Transistors Operating in Parallel for High Current Applications', presented by David Reush; and
- 'eGaN FET Based Wireless Energy Transfer Topology Performance', presented by Michael de Rooij.

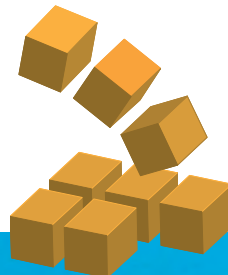
Also, during the conference, co-founder & CEO Alex Lidow will participate in two industry expert

panel discussions on the accelerated adoption of wide-bandgap semiconductors such as GaN in a vast array of applications:

- Podium Discussion: 'Mature Wide Band Gap Semiconductors'; and
- Power Electronics Europe Magazine Session: 'Si vs. SiC/GaN – Competition or Coexistence'. "Selection [by the technical review committee of PCIM Europe] supports our belief that the superior performance of GaN technology has gained the interest and acceptance of power system design engineers around the world," comments Lidow.

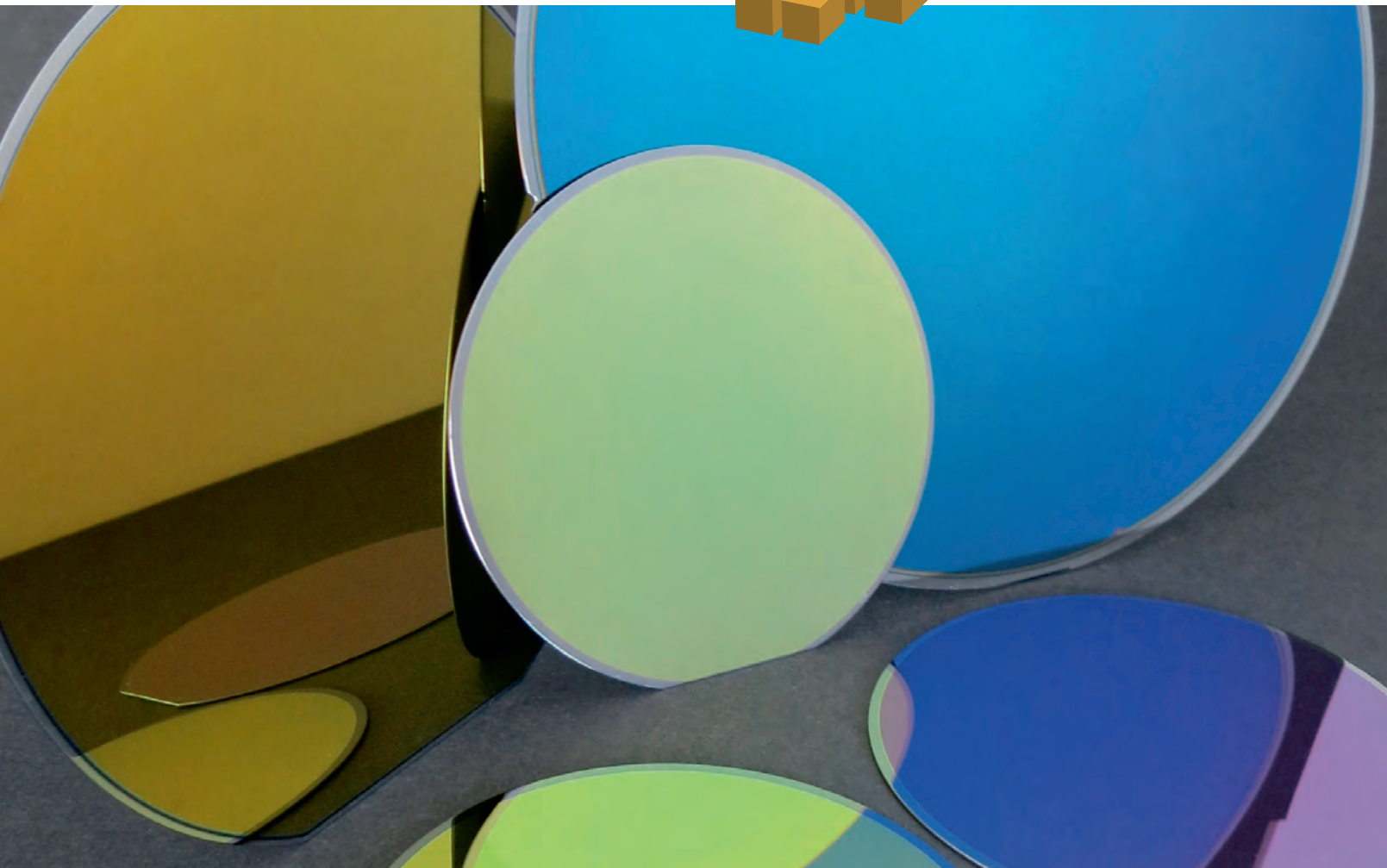
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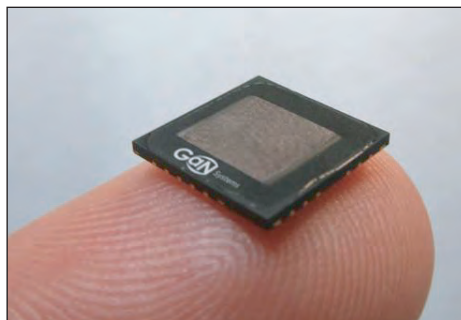
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GaN Systems launches normally-off 100V gallium nitride transistors in optimized low-inductance and thermally efficient packaging

GaN Systems Inc of Ottawa, Ontario, Canada, a fabless developer of gallium nitride (GaN)-based power switching semiconductors for power conversion and control applications, has launched a family of normally-off 100V GaN transistors that spans 20–80A with very low on-resistance. GS61002P, GS61004P, GS61006P and GS61008P are, respectively, 20A/21mΩ, 40A/11mΩ, 60A/8mΩ and 80A/5mΩ parts, while GS71008P is an 80A/5mΩ half-bridge device.

The new enhancement-mode



A packaged device from GaN Systems.

parts feature a reverse current capability, source-sense for optimal high-speed design and low total gate charge (QG) and reverse

recovery charge (QRR). RoHS compliant, the devices are delivered in GaN Systems' near-chipscale, embedded GaNPX package, which minimizes inductance and optimizes thermal performance.

"We believe we are the first company to have such a wide range of parts available for are sampling now," says president Girvan Patterson. Applications include high-speed DC–DC converters, low-voltage AC motor drives, inverters and switched mode power supplies.

www.gansystems.com

GaN Systems presents lateral transistors for hybrid electric vehicles; launching high-current devices

GaN Systems exhibited at PCIM (Power Conversion Intelligent Motion) Europe 2014 in Nuremberg, Germany (20–22 May).

PCIM focuses on power electronics and its applications in intelligent motion, renewable energy and energy management, and GaN Systems has selected the event to reveal its latest developments and make two announcements on its gallium nitride power semiconductors.

At the PCIM 2014 conference,

Larry Spaziani presented the paper 'Lateral GaN Transistors — A Replacement for IGBT devices in Automotive Applications' (written by chief technical officer John Roberts) explaining the performance improvements that GaN devices achieve in drive train power requirements for hybrid and electric vehicles (HEVs). Worldwide, several groups of researchers are undertaking work on replacing silicon insulated-gate bipolar transistors (IGBTs) in these

applications. Spaziani is presenting results achieved by GaN Systems' devices, which are based on the firm's unique Island Technology intellectual property (IP). The presentation will include a comparison between the company's products and competing offerings.

Also at PCIM, GaN Systems made two major announcements: the forthcoming commercial availability of its GaN high-current devices and 100V process qualification.

www.mesago.de/en/PCIM/main.htm

GaN Systems introduces 650V normally-off gallium nitride transistor family

GaN Systems has announced five new normally-off 650V GaN transistors optimized for high-speed system design.

The GS66502P, GS66504P, GS66506P and GS66508P are, respectively, 8.5A/165mΩ, 17A/82mΩ, 25A/55mΩ and 34A/41mΩ parts, while the GS43106L is a 30A/60mΩ cascode.

The new 650V enhancement-mode GaN devices feature a

reverse current capability, zero reverse recovery charge and source-sense for optimal high-speed design. RoHS compliant, the devices are delivered in GaN Systems' near-chipscale embedded GaNPX package, which eliminates wire bonds, thereby minimizing inductance. This package also optimizes thermal performance and is extremely compact, says GaN Systems.

"With these new 650V parts as well as our recently announced 100V family, GaN Systems offers a very wide range of parts which are available for are sampling now," says president Girvan Patterson. Applications include high-speed DC–DC converters, resonant converters, AC motor drives, inverters, battery chargers, and switched mode power supplies."

www.gansystems.com

Transphorm obtains exclusive licensing rights to Furukawa's GaN patent portfolio

Furukawa takes minority equity stake in Transphorm to secure supply of GaN products; targets technical collaboration

Transphorm Inc of Goleta, near Santa Barbara, CA, USA (which designs and delivers power conversion devices and modules) has obtained a sole worldwide license to Furukawa Electric Co Ltd's extensive gallium nitride (GaN) power device portfolio, which includes about 40 US issued patents and 110 Japanese issued patents. Transphorm also has certain rights to sublicense these patents.

The licensed family of patents encompasses various aspects of GaN power device manufacturing, materials and circuits, including key patents for GaN-on-silicon epitaxial growth technology. As part of the agreement, Furukawa Electric also made an equity investment in Transphorm. The deal brings Transphorm's total GaN IP portfolio to over 300 US patents/applications and over 650 worldwide patents/applications, including a combination of internally developed, acquired and licensed patents.

Transphorm says that, over the last several years, GaN semiconductors have emerged as a technology enabler for the next wave of compact and energy-efficient power conversion systems, ranging from ultra-small adapters, high-power-density PCs, server & telecom power supplies, to highly efficient PV inverters and motion control systems.

Transphorm has established a power conversion platform, involving introducing what was claimed to be the first 600V GaN HEMT products after successfully passing JEDEC qualification. Most recently it has demonstrated 100 million hours lifetime using high-voltage accelerated testing (again, a first for a GaN power device, the firm says). "As GaN power devices are now poised for rapid market penetration, a strong intellectual property position is essential to growing the GaN business," notes Roger Borovoy, Transphorm's IP counsel from Fish & Richardson. "The Furukawa license, combined with a very

significant internal GaN portfolio, unquestionably makes Transphorm the key player," he adds.

"Furukawa Electric has conducted original GaN research starting from the 1990s and amassed a strong patent portfolio in GaN power devices and materials," says Takahide Kimura, corporate senior VP, New Business Development, at Furukawa Electric. "As we sought to unlock the value of this portfolio, as well as to secure a supply of GaN products for our own applications, Transphorm was an ideal choice. Additionally, Furukawa Electric is also willing to have further technical collaboration with Transphorm, as a strategic partner, beyond this license and investment," he adds.

"Furukawa Electric has made a significant equity investment and obtained a minority equity stake in Transphorm," says Transphorm's CEO Fumihide Esaka. "We are pleased to announce this strong partnership with a global leader like Furukawa Electric."

www.transphormusa.com

Transphorm appoints HY-LINE as Central Europe distributor

Transphorm has completed a distribution agreement with HY-LINE Power Components GmbH of Munich, Germany to stock and distribute its family of 600V GaN high-electron-mobility transistors (HEMTs) in Central Europe.

HY-LINE's technical expertise will support the growing demand for JEDEC-qualified 600V GaN products that have now grown to the level requiring an expanding sales channel to respond to opportunities, specifically in Germany, Switzerland and Austria.

"HY-LINE is specialized in offering cutting-edge, energy-saving technology. Transphorm's technical

leadership in the emerging GaN technology including, to-date, being able to offer production volume of 600V GaN-on-silicon HEMTs, has moved GaN from potential to practical use in high-efficiency power conversion systems," comments HY-Lines' CEO Jochen Krause. "This distribution agreement with Transphorm will allow us to offer these unique products to customers in Central Europe who require the power savings that only GaN can achieve," he adds.

"We selected HY-LINE Power Components based upon their technical expertise and ability to

both create and support demand in the rapidly growing segment of the power conversion market," says Transphorm's VP of sales Bret Daniels. "With the completion of qualification last year, Transphorm's GaN devices have moved from advanced engineering research into product design and production, which makes this the right time to expand into distribution."

Transphorm says that, based on its proprietary EZ-GaN platform, its power conversion solutions reduce power system size, increase energy density and deliver high efficiencies across the grid.

www.hy-line.de/power

AWR and ANSYS partner on HFSS for Microwave Office

AWR Corp of El Segundo, CA, USA (a National Instruments Company), which supplies electronic design automation (EDA) software for RF and high-frequency components and systems, and engineering simulation software provider ANSYS Inc of Canonsburg, south of Pittsburgh, PA, USA have integrated ANSYS HFSS into AWR's Microwave Office high-frequency circuit design software. This integration unites the industry standard for full-wave electromagnetic (EM) field simulation and NI AWR Design Environment/ Microwave Office to quickly and accurately simulate microwave circuits.

With this design flow, Microwave Office users can access HFSS for the analysis of EM fields and coupling of 3D structures such as passive components, bumps, bond wires, and

pins, which are essential for designing and realizing microwave circuits like monolithic microwave integrated circuits (MMICs), densely populated RF circuit boards and multi-function modules.

The link between the two software tools is leveraged from AWR's EM Socket open-standard interface, which enables AWR users to access a range of electromagnetic (EM) tools from within the Microwave Office design environment. The EM Socket architecture also allows AWR Microwave Office users to essentially simulate EM structures with a single mouse click using either AWR's AXIEM 3D planar method of moments solver or Analyst 3D finite-element method EM software.

In addition to enabling ANSYS HFSS 3D EM simulation capabilities

from within the NI/AWR Design Environment, the connection allows the resulting 3D layered format exported from the EM Socket interface to connect to the ANSYS multi-physics portfolio, which includes SIwave for signal/power integrity analysis and Icepak for thermal characterization.

"Collaborating with third-party firms to expand both the breadth and depth of technology available within the NI AWR Design Environment has been a mainstay of our product offering," says AWR's VP of marketing Sherry Hess.

A joint talk 'A Streamlined Design Flow Featuring AWR Microwave Office and ANSYS HFSS' was presented on 3 June at the IEEE International Microwave Symposium in Tampa, www.awrcorp.com

Agilent acquires electrothermal analysis technology

Agilent Technologies Inc of Santa Clara, CA, USA has acquired electrothermal analysis technology from Gradient Design Automation Inc of Palo Alto, CA, which provides HeatWave electrothermal analysis software (used to identify hazards and improve performance in integrated circuits subject to temperature variations during operation).

Agilent EEsof EDA (which supplies electronic design automation software for microwave, RF, high-frequency, high-speed digital, RF system, electronic system level, circuit, 3D electromagnetic, physical design and device-modeling applications) now has sole ownership of Gradient's core technology and will serve customers of both Agilent's integrated Advanced Design System software solution and Gradient's HeatWave solution.

The electrothermal analysis technology allows designers to identify and correct thermal problems during integrated circuit development.

"Thermal management is one of the toughest challenges facing modern IC designers," says Agilent

EEsof EDA's general manager Todd Cutler. "That's why our integrated ADS electrothermal solution was so well received by customers following its introduction and has already been adopted by several major RFIC/MMIC vendors." The latest announcement "further reinforces our commitment to continue working to solve this difficult challenge."

The acquisition stems from a cooperative agreement between Agilent and Gradient that began in 2012, when a version of Gradient's technology was integrated into the ADS software as part of a comprehensive multi-technology solution for RFIC and MMIC development. In 2013, Agilent announced an expanded business relationship with Gradient that included increased financial commitment on Agilent's part in exchange for increased access to Gradient's electrothermal analysis technology.

"The growth of Gradient's business is proof that the unique software technology we created is highly effective at solving an important industry problem," says Gradient's

president Ed Cheng. "Agilent, an established market leader in the EDA industry, will now carry the technology forward and work to further expand its market reach."

Agilent's newly acquired electrothermal analysis technology was demonstrated, along with 20 of the firm's newest design and measurement solutions, at the IEEE MTT-S International Microwave Symposium (IMS) in Tampa, FL, USA (1–6 June). Agilent partners, co-located around the Agilent booth, demonstrated solutions for modeling and device characterization; semiconductor foundries; IC, wafer, and PCB design, test, and prototyping; antenna measurement systems and test chambers; and custom systems. Also, Dr Robert Shimon, an R&D manager in Agilent's High Frequency Technology Center, provided his insights on 'How Digital Markets are Driving Microwave Technology' at the MicroApps Theater.

For a video demonstration of the ADS Electrothermal Simulator, see: <http://youtu.be/ixfzlz05fZek>.

www.agilent.com/find/eesof-ads2014

Agilent and Cascade ally to streamline wafer-level RF measurements

Agilent Technologies Inc of Santa Clara, CA, USA and Cascade Microtech Inc of Beaverton, OR, USA have announced a strategic alliance to provide fully configured and validated RF measurement solutions that streamline wafer-level semiconductor measurements while delivering guaranteed configuration, installation and support.

"Agilent and Cascade Microtech are the worldwide leaders in test & measurement and on-wafer probing, offering both the expertise and products to provide all the building blocks for wafer-level device testing," claims Gregg Peters, VP & general manager of Agilent's Component Test Division. "By aligning our efforts and respective solutions, we are pioneering a new model for the delivery of uniquely differentiated wafer-level measurement solutions to our mutual semiconductor customers."

Specifying and configuring a wafer-level RF measurement system can be challenging and time-consuming, often requiring equipment to be sourced from multiple suppliers and then configured and verified on-site by the customer, says Agilent. The time to first measurement can hence be long. Wafer-level measurement solutions (WMS) from Agilent and Cascade now provide the equipment needed to perform accurate and repeatable DC and RF measurements, device characterization and modeling, while realizing significant time savings to first measurement, it is claimed.

"Semiconductor process development, modeling and characterization tasks are evolving, time-to-market cycles are shrinking, and the need for greater accuracy is increasing," says Cascade's president & CEO Michael Burger. "By working with Agilent to provide guaranteed wafer-level measurement solutions, we can now provide semiconductor engineers the tools they need to perform accurate and



Agilent and Cascade Microtech 200mm device characterization solution

fast advanced DC and RF measurements on both components and devices to get their products to market on time," he adds.

The new wafer-level measurement solutions combine Cascade's wafer probe stations, probes and calibration tools with Agilent's test instrumentation and measurement and analysis software. Each solution configuration is pre-validated to ensure it meets customers' specific application needs, then validated again — based on previously agreed-upon acceptance criteria — after installation by Cascade. Guaranteed configuration means that any parts missing from the configured solution will be

The wafer-level measurement solutions combine Cascade's wafer probe stations, probes and calibration tools with Agilent's test instrumentation and measurement and analysis software

provided by either Agilent or Cascade Microtech, free of charge.

The firms have also collaborated to deliver unique workflow solutions software based on Agilent's WaferPro-XP measurement software. Together with Cascade's Velox probe station software, users can now develop complete wafer test suites for a variety of

measurement needs (e.g. S-parameters, DC-IV/CV, noise figure, Flicker noise, and gain compression). This combination of software provides a coherent environment for test development, say the firms.

Each wafer-level measurement solution is backed by the offer of a full support package, with access to regional solution experts skilled in on-wafer test and measurement. Cascade acts as the single point of contact to ensure quick problem resolution.

Agilent and Cascade wafer-level RF measurement solutions are now available in a range of configurations, from a fully integrated new solution with either a semi-automated or manual prober, to application-specific hardware upgrades to existing probe stations. Agilent's new WaferPro-XP measurement software platform for R&D device characterization can also be added to an existing wafer-level measurement solution. Pricing depends on solution configuration.

www.agilent.com/find/wms

www.cascademicrotech.com/measureone

India's NALCO sourcing technology for 10 tonne per annum gallium extraction plant

Indian aluminium producer aiming to exploit bauxite resources

National Aluminium Company Ltd (NALCO, India's largest domestic aluminium producer) has invited expressions of interest (EOI) for sourcing an environmentally friendly technology for a 10 tonne per annum (TPA) gallium extraction plant that it plans to establish at its Alumina Refinery in Damanjodi, Odisha State, India either through a joint venture or standalone. The firm targets gallium metal with a purity of $\geq 99.99\%$ (4N+).

NALCO was incorporated in 1981 following investment by the Indian government in order to exploit part of the bauxite deposit discovered on the East Coast of India. The company was subsequently listed on the LME (London metal exchange).

NALCO operates a multi-location Bauxite Mines-Alumina-Aluminium complex (along with a captive power plant) in Odisha. A major expansion program (Phase 1) was completed in 2001, and a Phase 2 expansion was completed in July

2012, leading to an upgrade of the firm's refinery activities and ongoing upgrade of its mines. The firm has bauxite mines in the Panchpatmali hills of Koraput district in Odisha, with a capacity of 4.8 million tonne per annum (MTPA) that is being expanded to 6.3 MTPA.

"NALCO invites EOI from the interested and competent manufacturers/technology suppliers interested in providing technology for extraction of gallium from Nalco Bayer liquor (intermediate process liquor generated from digestion of bauxite by the Bayer process) and having expertise in production and marketing of metallic gallium or gallium compound," the firm says.

The process of extracting alumina from its mineral bauxite in caustic liquor solution is known as the 'Bayer' process. Bauxite received from the mines is either stacked in stockpile or fed directly to a secondary crusher for size reduction. Secondary crushed bauxite from

the silo is fed to the ball mill, along with caustic liquor for grinding. Ground bauxite slurry after pre-desilication is digested at atmospheric pressure (at a temperature of 105–106°C) for the extraction of alumina. Undigested bauxite is separated as red mud. Aluminate liquor is cooled to precipitate ATH (alumina trihydrate), which is calcined to produce alumina. Gallium dissolves in the liquid phase and becomes enriched over time as NALCO has not been extracting gallium metal or any compound until now. However, some gallium escapes from the plant liquor during the discharge of red mud as well as with product alumina.

On receiving proposals from interested parties, a fresh tender will be floated to the shortlisted parties for selection of the suitable technology provider for gallium extraction from bauxite resources.

www.nalcoindia.com

[/download/EOI-Gallium.pdf](http://download/EOI-Gallium.pdf)

Lake Shore adds 7-inch magnet version of AC/DC Hall measurement system

Lake Shore Cryotronics Inc of Westerville OH, USA, which makes scientific sensors, instruments and systems for measurement and control, says that its new Model 8407 Hall-effect measurement system features a 7-inch magnet for measuring mobilities at the low end of the DC-field measurement range, from 1 to $10^6 \text{ cm}^2/\text{V.s}$.

Like the existing Model 8404 (which has a 4-inch magnet), the Model 8407 can be also ordered with AC-field measurement capabilities. With AC-field measurement added, the system is capable of measuring materials with extremely low mobilities (down to $10^{-3}/\text{V.s}$). These can include photo-



voltaic (solar cell), thermoelectric and organic electronic materials,

which have electronic properties that can be difficult to measure with DC-field Hall methods.

Software included with the system enables both van der Pauw and Hall-bar measurements, measuring samples with gated Hall bars to account for gate bias, setting up loops with varying temperatures and gate voltages, performing time loops of measurements for longer unattended

operation, and more.

www.lakeshore.com

Veeco launches Apex Gas Mixing System to improve process control and cut costs at 20nm and below

Epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA has introduced the Apex Gas Mixing System for point-of-use gas mixing. The system generates precise binary gas mixtures on a single platform for use in semiconductor applications at 20nm and below.

Compared with existing methods, the system improves concentration control, providing tighter process management, increased tool uptime and reduced manufacturing costs. It is optimized for advanced silicon epi applications and other processes requiring low-concentration, high-precision and cost-sensitive gas mixtures.

"The Apex system provides precise control of germane and diborane flux for doped silicon germanium films that have a critical impact on device performance with tight

process control limits," says Christopher Morath, senior director, Veeco Flow Technologies Group. "Consequently, the Apex system allows manufacturers to improve real-time process control by up to a factor of ten as compared to mixed gas cylinders. This will enable users to increase both yield and throughput."

Powered by Veeco's production-proven Piezocon Gas Concentration Sensor, the system reduces production costs by allowing manufacturers to purchase lower-cost, higher-concentration gases, then dilute them at the point of use to immediately cut gas purchase costs by as much as 60%, it is reckoned. The total installed base of Piezocon Gas Concentration Sensors is over 3000 sensors worldwide, in both silicon semiconductor and metal-organic chemical vapor deposition (MOCVD) applications.

By using the Piezocon Gas Concentration Sensor to measure and control the mixture in real time, manufacturers eliminate the problems associated with constant flow mixers requiring wasted materials and constant scrubbing, says Veeco, adding to the already substantial cost savings. Using the Apex Gas Mixing System provides stable output and precise control of gas concentration, resulting in higher process tool up-time and eliminating the need to re-qualify after every gas cylinder change. These improvements reduce — and in some cases eliminate — system down-time due to routine cylinder changes. These features allow the system to drive real-time control, high precision and reproducibility, and lower cost of ownership, the firm adds.

www.veeco.com/Apex



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Veeco's revenue rises 24% in Q1/2014, driven by MOCVD recovery

MOCVD orders rise 59% as leading customers expand capacity

For first-quarter 2014, epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA has reported revenue of \$90.8m, up 24% on \$73.2m last quarter and 47% on \$61.8m a year ago.

Growth was driven mainly by LED & Solar revenue rising to \$70.8m, up 26% on \$56.5m last quarter and 67% on \$42.3m a year ago. Of this, metal-organic chemical vapor deposition (MOCVD) revenue was \$64m, up 28% on \$50m last quarter. Molecular beam epitaxy (MBE) revenue was \$6.8m, up on \$6m last quarter. Data Storage revenue was \$20m, up 18% on \$17m in Q4 but just 2.5% on \$19.5m a year ago.

"After a long downturn in our MOCVD business, LED fab utiliza-

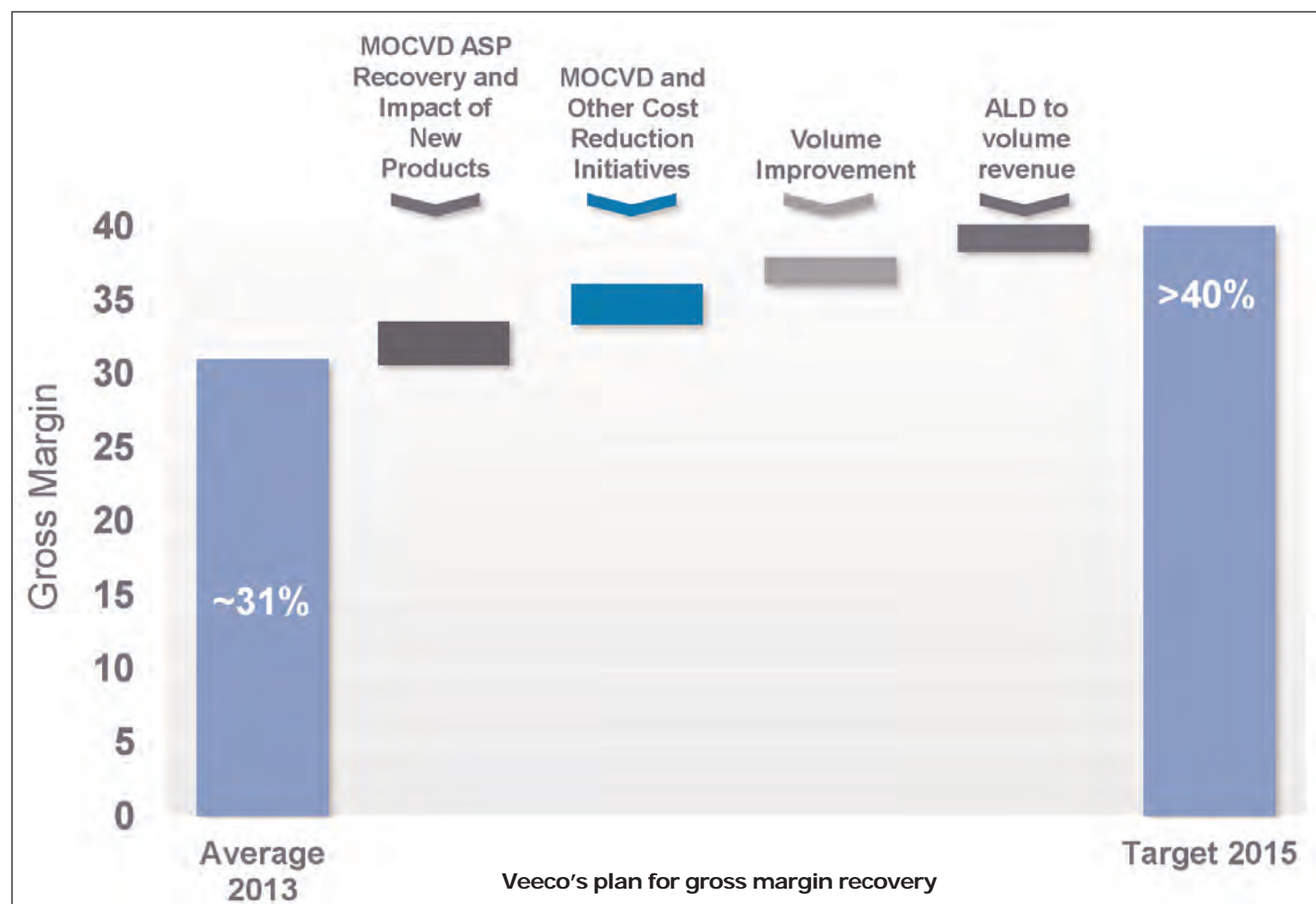
tion rates have improved to high levels at most key accounts and LED adoption is happening faster than many had expected," comments chairman & CEO John Peeler. "Our customers are also reporting better market demand for LED backlighting products," he adds.

"Q1 was a significant improvement over the last quarter with higher revenue, better margins and lower OapEx [operating expenditure]," says chief financial officer & executive VP David Glass.

After plunging from 31% in Q3/2013 to just 21% in Q4, gross margin spiked to 37% in Q1 (above the expected 33–35%), due the higher sales volumes being supplemented by a very favorable mix of higher-priced product. After spiking up from

\$39m in Q3/2013 to \$48m in Q4 (due to a few non-recurring items), OpEx has been cut back to \$41m (below the expected \$42–43m).

Benefiting from the higher sales volume, improvement in gross margin, and lower OpEx, non-GAAP adjusted EBITA (earnings before interest, taxes and amortization) has been cut from a loss of –\$15.7m a year ago and a peak of –\$26.6m last quarter to just –\$2.7m in Q1. This was mainly due to a loss of –\$0.65m from Data Storage (cut from –\$3.1m last quarter, but compared with a profit of +\$0.38m a year ago) plus unallocated corporate loss of –\$4.2m, outweighing an adjusted EBITA profit from LED & Solar of +\$2.1m (compared with losses of –\$16.5m last quarter and



–\$11.2m a year ago). This is despite the LED & Solar segment now including Veeco's atomic layer deposition (ALD) business (Synos Technology, acquired last October) and hence carrying all of the pre-revenue ALD costs being incurred.

Net loss has been cut from \$7.5m (\$0.19 per share) a year ago and a peak of \$16.4m (\$0.42 per share) in Q4 to \$2.4m (\$0.06 per share).

As forecasted, investments in next-generation products and in growth businesses caused cash and investments to decline modestly during the quarter, from \$495m to a still strong \$483m. In particular, cash in short-term investments fell (from \$281.5m to \$267.4m) as Veeco builds working capital.

For the second consecutive quarter, Veeco's book-to-bill ratio was over 1. Specifically, orders were \$102.6m, up 21% on \$85m last quarter and 46% on \$70.4m a year ago (and the highest in nearly two years). Data Storage orders fell from \$27.7m a year ago and \$21.6m last quarter to \$15.4m. LED & Solar orders have risen to \$87.1m, up 37% on \$63.3m last quarter and more than doubling from \$42.7m a year ago. Since MBE orders more than halved sequentially from \$11m to \$5m, the increase was driven by a 59% rise in MOCVD

orders from \$52m to \$83m (up from just \$37m a year ago, and the highest since third-quarter 2011). Orders were received from top LED customers throughout Asia and elsewhere. "Our leading customers are beginning to place orders for capacity expansions," notes Peeler. During the quarter, overall order backlog rose from \$143m to \$155m.

For second-quarter 2014, Veeco expects revenue of \$87–97m. Net loss is expected to rise to \$9.2–5.6m (\$0.23–0.14 per share). Due mainly to a weaker product mix, gross margin should fall back to 30–32%. OpEx will rise again temporarily (to \$42–43m) due to annual salary increases and equity compensation, as well as some duplicate costs as Veeco moves forward on a cost-saving geographic footprint consolidation of one its businesses. "In second-half 2014, we have planned to scale back OpEx by a couple of million dollars quarterly, as the impact of cost-reduction measures take hold," notes Glass.

"On our earnings call last quarter, we discussed our plans to bring margin back over 40% through the introduction of new products, cost reductions and increase volumes," continues Glass. "Although it is not likely we will get there this year, we

do expect to see some improvements in our margins during the second half of 2014, hopefully moving us more solidly into the mid-30s range," he adds.

Q2 orders should be similar to or better than Q1, with continued strength in MOCVD. "Yet, the timing and magnitude of key customer expansions could cause MOCVD orders to be lumpy and somewhat unpredictable on a quarterly basis, and we lack the visibility to see into the second half of the year," comments Peeler. "We continue to invest in MOCVD product and technology development to further improve our customers' cost of ownership and manufacturing capability," he adds.

"We are pleased to have made progress improving Veeco's profitability and remain focused on our strategy to turn around our performance by: (1) developing and launching game-changing new products that enable cost-effective LED lighting, flexible OLED encapsulation and other emerging technologies; (2) improving customer cost of ownership as well as our gross margins; (3) driving process improvement initiatives to make us more efficient; and (4) lowering expenses," Peeler concludes.

www.veeco.com

Veeco appoints new chief financial officer

Veeco has appointed Shubham Maheshwari as its new executive VP, finance & chief financial officer (CFO). He replaces David D. Glass, who announced his retirement from Veeco last December.

Maheshwari has more than 20 years of experience in engineering and finance. Most recently, he was CFO of OnCore, a global manufacturer of electronic products in the medical, aerospace, defense and industrial markets. Previously, he held various finance roles including senior VP finance, treasury, tax & investor relations at Spansion, a provider of Flash-memory-based embedded system solutions.



Maheshwari helped to lead Spansion's emergence from bankruptcy to become a successful public company. Prior to Spansion, he spent over ten years at semiconductor equipment manufacturer KLA–Tencor in various senior-level corporate development and finance roles, including VP of corporate development and corporate controller. While at KLA–Tencor, he worked on over \$1bn in acquisition transactions. Maheshwari holds a B.S. in

Chemical Engineering from Delhi's Indian Institute of Technology, an M.S. in Chemical Engineering from Kansas State University, and an MBA from the Wharton Business School, University of Pennsylvania.

"Shubham brings an ideal mix of highly relevant financial leadership experience to Veeco," comments chairman & CEO John Peeler.

"Veeco has done an impressive job managing through an extended downturn, but I think the best is still in front of the company," says Maheshwari. "I look forward to helping to strengthen the business and capitalizing on the significant growth opportunities ahead."

Aixtron's quarterly orders the highest in over two years

Slight pick-up in demand seen from LED makers

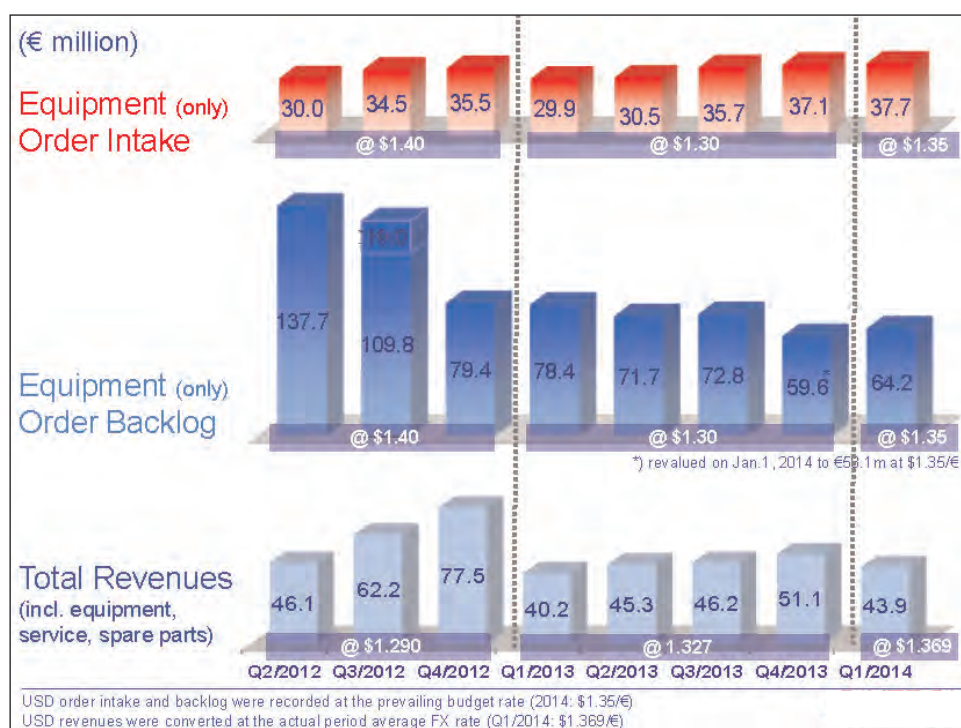
For first-quarter 2014, deposition equipment maker Aixtron SE of Aachen, Germany has reported revenue of €43.9m, down 14% on €51.1m last quarter but up 9% on €40.2m a year ago.

Of total revenue, 73% (€32.1m) came from equipment sales and the remaining 27% from spares & service sales (similar to a year ago). The largest equipment market sector is LEDs (73% of revenue). Next largest is silicon equipment for the production of DRAM memory chip. On a regional basis, 79% of revenue came from Asia, 17% from Europe, and 4% from the USA.

Capacity utilization rates at leading LED makers remain at relatively high levels and demand for LEDs continues to rise. But, despite this, there was still no noticeable increase in investments in LED manufacturing capacity expansions in Q1/2014, says the firm.

Impacted by a less favorable product mix, gross margin has fallen from 34% last quarter to 25%. However, this is still a big improvement on -119% a year ago (negative, due to inventory write-down and other restructuring costs).

Operating expenses have fallen significantly, compared with €28.6m a year ago and €30m last quarter, to €21.7m, due partly to restructuring charges included in the previous year's figure plus the firm's ongoing cost optimization program (part of the firm's 5-Point-Program plan launched a year ago) that has significantly lowered the firm's fixed-cost base. In particular, while general & administrative expenses fell year-on-year by just 6% to €5.1m, selling expenses fell by 43% to €3.9m. R&D expenses have fallen further, from €16.6m a year ago and €15.8m last quarter to €13.7m, although this is still a relatively high level (31% of revenue), underlining the strategic importance of Aixtron's internal R&D capabilities, says the firm.



Consequently, EBIT (operating loss) has improved from -€76.3m a year ago and -€12.6m last quarter to -€10.9m (an EBIT margin of 25% of revenue — level with last quarter but a big improvement on -190% a year ago). This was due mainly to inventory write-downs and restructuring charges included in the previous year's figures, but it also reflects the reduction in operating costs mitigating the losses related to the low sales volumes (particularly in the core market for LED manufacturing equipment).

The operating loss plus tax- and restructuring-related payments meant that free cash flow has fallen further, from €9.3m a year ago and -€0.2m last quarter to -€13.8m. During the quarter, cash and cash equivalents hence fell from €306.3m to €292m (with no debt).

Equipment order intake was €37.7m, up 26% on €29.9m a year ago and remaining relatively steady (up 2%) compared with €37.1m last quarter — still at low levels but the fourth quarter of sequential growth and the highest in more than two years. Order backlog of €64.2m at the end of Q1 was down 18% on €78.4m a

year ago but up 10% on last quarter's €58.1m (revalued as of 1 January at the exchange rate of 1.35 US\$/€ valid at that time).

"Sentiment among customers is improving as the growth in the LED market drives the customers' profitability," comments president & CEO Martin Goetzeler. "According to leading market research firms, the LED market demand will continue to grow. This positive outlook, in combination with our new MOCVD tool to be launched in the second half of this year [currently being sampled in Greater China], underlines our confidence in our future development." Goetzeler reiterates the importance of consistent R&D investments: "Independent of current market developments, we continue to maintain a strong focus on R&D, providing for a competitive technology portfolio and supporting future business development. We will continue to monitor these investments very closely — in line with our ongoing focus on cost management and the improvement of processes which are amongst others central elements of our 5-Point-Program," he adds.

► “We are seeing a slight pick-up in demand for equipment from LED manufacturers, but that pick-up is not strong enough for us to change our guidance for 2014,” says Goetzeler. Aixtron has hence reiterated its guidance (given at the end of February) for full-year 2014 revenue to be in line with last year’s (which was €182.9m). The firm does not expect to be profitable on an EBIT basis. Nevertheless, management expects a year-on-year improvement in earnings due to progress made in cost savings and restructuring.

“Aixtron’s most immediate growth opportunity is in LEDs, and it is starting to feel as if another tipping point for LED adoption within general lighting is imminent,” says Goetzeler. “Prices of LEDs have halved over the last 24 months, and 60W-replacement bulbs are now available at reasonable prices in most major markets. In Germany, some 60W-equivalents are selling for as low as €9.99, and in the USA,

Aixtron’s CFO leaves firm as executive board is reduced to two members

Aixtron’s chief financial officer Wolfgang Breme left the group on 31 May by mutual agreement to pursue new career opportunities outside the company.

A new CFO will not be appointed. Executive Board chairman Martin

Goetzeler will take over the tasks previously performed by Breme. The service agreement of the current chief operating officer Dr Bernd Schulte will be renewed for a term of three years until end-March 2018.

Home Depot is currently selling a 60W Cree replacement LED below \$10,” he adds. “Market research firms are assuming enormous growth in the LED market in the coming years.” According to the market research firm IHS from December 2013, the market for general lighting LEDs is expected to grow from €495m shipped units in 2013 to €3.6bn shipped units in 2020. The consultancy firm McKinsey estimates that by 2016 nearly half of the world’s spending on lighting will be on LED luminaire.

“We not only believe that Aixtron is well positioned in LEDs but also, thanks to our continuing investment in R&D, that we have a sustainable opportunities in the silicon and organic semiconductor technologies, as well as in compound semiconductors, for example for power electronics,” says Goetzeler.

Aixtron’s business model should allow it to become profitable as equipment and spares demand volumes reach €250m annually, with gross margin of 40% and operating expenses (OpEx) of €100m.

www.aixtron.com

www.laytec.de

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 **LAYTEC**
Knowledge is key

SPTS gifts £600,000 of BluGlass shares to Swansea Uni

Plasma etch, deposition and thermal wafer processing equipment maker SPTS Technologies Ltd of Newport, Wales, UK has gifted Swansea University more than £600,000 worth of shares in BluGlass Ltd of Silverwater, Australia.

Spun off from the III-nitride department of Macquarie University in Sydney in 2005, BluGlass developed a low-temperature process using remote-plasma chemical vapor deposition (RPCVD) to grow materials including gallium nitride (GaN) and indium gallium nitride (InGaN) on glass substrates, potentially offering cost, throughput and efficiency advantages for the production of LEDs and concentrated solar cells.

"SPTS has strong ties with Swansea University, and has benefited from the knowledge exchange projects through the University's Department of Research and Innovation (DRI)," says SPTS' CEO William Johnson. "The DRI, which acts as the bridge

between industry and academia, has enabled us to extend the scope of our research beyond our existing markets and gain access to funding, which has proven invaluable to our R&D teams," he adds. "This gift of shares in BluGlass is our way to pay back by 'paying it forward' to the University in not just the current value of the shares but the potential future value of BluGlass and the opportunities for potential collaboration between Swansea University, BluGlass and Sydney's Macquarie University."

Current collaboration with Swansea includes a project funded by the UK's Technology Strategy Board (TSB) for the development of micro-needles for bio-medical applications. The project, which includes SPTS process equipment for Swansea's cleanroom, was instrumental in developing a design for manufacturing quality packaged micro-needles, which are achieving a 100% success rate in initial testing.

"Swansea University are absolutely delighted by this gift and indeed with the highly successful and ongoing collaboration with SPTS and the University's College of Engineering, particularly the work being done with Dr Owen Guy," says Dr Gerry Ronan, Swansea's head of IP. "We pride ourselves on our ability to collaborate with industry and this is an enlightened and most welcome way of strengthening such relationships," he adds.

"SPTS is at the forefront of micro-device process and manufacturing technology, and we remain committed to investing in R&D to ensure market competitiveness and industry sustainability," says Johnson. "Our gift to Swansea University underpins our ongoing commitment to supporting the success of the Department of Research and Innovation."

www.bluglass.com.au

www.spts.com

www.swansea.ac.uk/research_inno

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SAMCO relocates US East Coast regional office

SAMCO Inc of Kyoto, Japan, a supplier of plasma etch, chemical vapour deposition (CVD) and surface treatment systems to compound semiconductor device makers, has relocated its US East Coast regional office. Due to a rise in customers in the Northeast, the existing office in North Carolina has been moved to New York (85 Broadway, Suite F Amityville, NY 11701 USA; Tel: +1-631-464-0664; E-mail: info@samcointl.com), where the new office opened on 15 May. The relocation is aimed at enhancing SAMCO's sales presence and service capability in the region.

Founded in 1979, SAMCO has been primarily engaged in manufacturing thin-film deposition (PECVD), etching (ICP, RIE, DRIE) and surface treatment (plasma and UV-ozone cleaning) process equipment for compound semiconductor

production, especially applications such as LEDs and power devices.

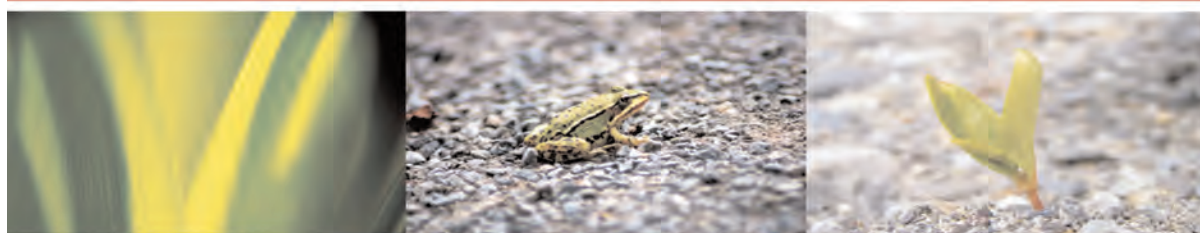
In 1987, SAMCO's US West Coast office was established in Silicon Valley and became the platform for its R&D, sales, and service operations in the USA. Due to rising business interest from the East Coast in recent years, the first East Coast office was set up in 2010 near North Carolina's Research Triangle Park (the largest research park in the USA), aiming to speed sales and service in the region. However, the North Carolina office was distant from key East Coast customers such as Princeton, University of Delaware and several growing corporations, all of which are in the Northeast. In anticipation of further sales expansion in the Northeast, the East Coast office has been relocated to New York to allow for easy access to universities, R&D centers,

and corporations around major cities in the Northeast.

SAMCO says that it promotes academic-industrial alliance in research, and is already engaging in joint research and technical exchange with institutions such as Princeton University. The new office will allow the dispatch of technical personnel from SAMCO's headquarters in Japan to the New York office and the strengthening of the firm's collaborative research ability with universities on the East Coast.

In April 2013, SAMCO's West Coast office (OPTO Films Research Laboratory) was moved to a larger facility, enabling a boost in R&D capabilities. With the addition of technical personnel to the new East Coast office in New York, SAMCO hopes to increase its North American annual sales revenue to more than \$10m.

www.samcointl.com



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IN BRIEF

OEM Group and SEMSYSCO settle lawsuit

Semiconductor capital equipment providers OEM Group of Phoenix, AZ, USA and Semiconductor Systems Corporation (SEMSYSCO GmbH) of Salzburg, Austria have entered into an agreement that settles all litigation between the parties.

OEM Group provides new and re-manufactured systems, specialized upgrades, genuine parts, certified service, software licensing, and process application development. Its LEGENDS technology portfolio is based on exclusive intellectual property acquired from semiconductor brands, including: P5000, Tegal Etch, Sputtered Films Endeavor, Equinox, MRC Eclipse, AGHeatpulse, Varian Sunset, Lam AutoEtch and Applied Materials—Semitool surface preparation equipment. OEM Group also provides foundry services designed for piezoelectric AlN films, yield-optimization and process development.

Semsysco designs and manufactures standard and custom manual, semi-automated and fully automated process equipment — both wet chemical and vapor — for single-wafer, batch and large format substrates. Applications include etch and clean (including gallium arsenide and silicon), photoresist strip, metal lift-off, wafer thinning and reclaim.

As part of the settlement, SEMSYSCO has agreed to refrain from selling 200mm and below manual batch products in the USA for five years. However, there is no restriction on SEMSYSCO selling any other products in the USA or selling any products outside the USA. All other terms of the settlement are confidential.

www.oemgroupinc.com

www.semsysco.com

Plasma-Therm wins Customer Satisfaction Awards

For the 16th consecutive year, plasma process equipment maker Plasma-Therm LLC of St Petersburg, FL, USA has received awards in the Customer Satisfaction Survey conducted by market research firm VLSIresearch.

"It reflects on the performance of our systems for a wide variety of specialty semiconductor applications, and the emphasis we place on supporting customers over the long term," says Plasma-Therm's CEO Abdul Lateef. In the 2014 Customer Satisfaction Survey, the firm received the following awards:

- 10 BEST — Focused Suppliers of Chip Making Equipment;
- THE BEST — Suppliers of Fab Equipment.

The '10 BEST' awards recognize the top-rated suppliers of fab, test, and assembly equipment together, in categories based on a three-year average of revenues: 'Large' suppliers and 'Focused' suppliers.

'THE BEST' awards recognize performance by equipment suppliers based on equipment type, including Fab (chip fabrication), Test, Assembly, Materials, Display, and others.

VLSIresearch says that survey participants worldwide were asked to rate equipment suppliers among 15 categories based on three key factors: supplier performance, customer service, and product performance. A total of 3516 surveys were returned, resulting in 55,918 total responses.

Plasma-Therm plasma processing workshop at Shanghai Jiao Tong University

Researchers recently attended Plasma-Therm's plasma processing workshop, sponsored by the Center for Advanced Electronic Material and Devices (AEMD) at Shanghai Jiao Tong University. Attendees from disciplines as diverse as MEMS, solid-state lighting, power, photonics and nanotechnology participated in the full-day event to learn about fundamental and advanced technologies used in semiconductor device fabrication, materials research and nanotechnology. Plasma-Therm has conducted more than 15 one- and two-day workshops at universities and institutions in

Singapore, the USA, Sweden, China, South Korea, and Israel.

"Our technical workshops continue to attract enthusiastic attendees to learn about plasma processing," notes Dr David Lishan, principal scientist and workshop lecturer.

"The lectures covered a wide range of dry etching knowledge," comments AEMD's executive deputy director professor Xiulan Cheng. "It began with a step-by-step introduction of basic etching principles, guiding the attendees on to advanced applications of the etching technologies," he adds.

www.plasmatherm.com



Dr David Lishan, Plasma-Therm principal scientist and workshop lecturer.

MPI acquires fellow Taiwanese firm Allstron

Technology to reduce time to market for latest RF product line and speed development of RF probes

Taiwan's MPI Corp, which provides production semiconductor test solutions, has acquired Taipei-based Allstron Corp, which was established in 2008 and has developed RF wafer probes and calibration substrates up to 110GHz for applications such as production test, RF device characterization, modeling and circuit-board test.

MPI reckons the acquisition and infusion of technology significantly reduces the time to market for its latest RF product line and speeds its design and development of RF probes for process development of advanced semiconductor integrated circuits.

"There are significant opportunities for improvement within the global test markets," says MPI's marketing VP Rob Carter. "Having incorporated Allstron's products and technology within MPI's latest test solutions and by utilizing our MEMS-based manufacturing expertise; we are able to accelerate the completion of our RF portfolio for the Advanced Semiconductor Test product line," he adds. Along with the MPI suite of calibration products such as QAlibria software and calibration substrate line, the enhanced Allstron product brand will have a significant impact on RF

testing by providing shortened lead-times while improving quality and electrical performance, Carter reckons.

"Infusing Allstron's products into MPI Corporation's offerings is a powerful solution for global RF test market," says Allstron's president Tennyson Lee. "With MPI's RF applications expertise, QAlibria calibration software, engineering probe systems, and global support structure, the customer experience is on the verge of a significant and positive change."

www.allstron.com

www.mpi-corporation.com

Ichor tripling capacity in Scotland after regional funding

Ichor Systems Ltd, an OEM licensed supplier of re-manufactured equipment & services based in the Scottish Enterprise Technology Park, East Kilbride, UK, is to create new jobs and triple its capacity with a move to new 36,600ft² premises at Hamilton International Park near Blantyre, Scotland.

Formerly known as Semi Scenic, the firm was founded in 2003 and was acquired by Ichor Systems Inc of Tualatin, OR, USA in April 2012.

"We have been working with Ichor Systems for a number of years and are pleased to have been able to support them with a Regional Selective Assistance (RSA) grant of £175,000 to help with this expansion into new facilities," says Scottish Enterprise's business support director Eleanor Taylor. "Ichor is a successful player in the global market and the move to these new premises will enhance its delivery of real value-added products and services to its customers throughout the world and exploit further growth opportunities," she adds.

"We have recently secured a global product licence from industry giant Lam Research which means



Ichor's new facility in Hamilton International Park.

that in future we will sell specific licensed legacy products directly to end-users throughout the world to develop our Scotland-based operation in the face of tough competition from other locations," says Ichor Systems Ltd's managing director Don Nicolson. "As a result, and with steadily increasing worldwide demand across the industry for our services, we are forecasting an 80% growth in turnover this year," he adds.

"We have outgrown our existing 12,000ft² plant in East Kilbride's Scottish Enterprise Technology Park where we have been since 2005. We are obliged to move if we are to fulfil our ambition and, with the support of both our parent company and SDI [Scottish Development International], we have been enabled to do just that,"

Nicolson continues.

The new facility, which will require an extensive fit-out program due to the semiconductor industry's clean-room requirements, will deliver up to ten new jobs as well as securing the future of Ichor Ltd's existing staff. Nicolson expects the new site to be ready for production before the end of 2014.

www.ichorsystems.com/legacyservices.html

www.scottish-enterprise.com/rsa

MKS completes acquisition of Granville-Phillips

MKS Instruments Inc of Andover, MA, USA (which provides instruments, subsystems and process control solutions that measure, control, power, monitor and analyze critical parameters of manufacturing processes) has completed its acquisition of Granville-Phillips' assets (a former division of Brooks Automation Inc of Chelmsford, MA) for \$87m.

Granville-Phillips is a provider of vacuum measurement and control instruments to the semiconductor, thin-film and general industrial markets, with sales of about \$30m

in 2013. Founded in 1954, it operated as an independent company until its acquisition by Helix Technology in 1998. It became part of Brooks Automation through the merger of Helix and Brooks in 2005.

MKS says that the acquisition further strengthens its position in the vacuum gauge market. MKS claims to be the market leader in direct pressure measurement, and Granville-Phillips is a leader in indirect vacuum gauges, with a reputation for quality, reliability and performance, the firm adds.

The Granville-Phillips business will be operated as the Granville-Phillips division of MKS and will be integrated into MKS' Pressure Measurement business. The acquisition is not expected to have a material impact on second-quarter revenue or non-GAAP earnings. MKS' management expects the acquisition to be accretive to non-GAAP earnings in fiscal 2014, and also expects future cash flow benefits due to the availability of tax amortization on most of the purchase price.

www.mksinst.com

SEMI-GAS adds MGE-XS with two independent automatic switchover systems to mini gas enclosure line

SEMI-GAS Systems, a division of Applied Energy Systems Inc of Malvern, PA, USA that makes high-purity gas source and distribution systems, has added the model MGE-XS to its mini gas enclosure product line. Created to store and deliver ultra-high-purity process gases from small gas cylinders, the addition to the range of Xturion custom gas systems also incorporates automatic cylinder switchover capabilities to help minimize manufacturing down-time and operator interaction.

The MGE line now comes in two process models, each with two separate compartments housing two individual manifolds with separate purge inlets and vent outlets. The original MGE-X houses two process cylinders and two dedicated purge cylinders. The new MGE-XS houses four process cylinders (providing two independent automatic switchover systems) in one compact package that is 69" high by 32" wide by 27" deep (suited for low-flow applications or limited space).

The new mini gas enclosure line features an ergonomically bottom-mounted SEMI-GAS GigaGuard GSM Controller with 4.3" color touch-screen, making cylinder changes and system status monitoring easy, says the firm.

The GSM oversees all operations, including the monitor and control of all process and purge gas electrical components and pneumatically actuated valves. The controller can function independently or with an optional kit that can communicate via an Ethernet network, enabling centralized, facility-wide equipment monitoring and data collection.

In the event of excess gas flow, fire detection or facility shut-down input, pneumatically actuated emergency shut-off (ESO) valves interrupt process gas supply to the manifold lines, initiating automatic shutdown. A pneumatic ESO button is mounted on the front of the enclosure to manually trigger a system shutdown. In either event, an audible horn and blinking LED status lights notify operators that a risk has been detected.

The exhaustible MGE-XS enclosure accommodates hazardous and non-hazardous gases and is constructed of welded 11-gauge cold-rolled steel. It also has reinforced rear-mounting holes for wall installations or an optional welded steel rack for free-standing use. To customize on-site fit-up of the MGE-XS, each unit has adjustable steel shelves, adjustable cylinder straps and adjustable back- or top-mounted exhaust ducts.

All MGE-X systems meet SEMI S2 and Uniform Fire Code requirements and are equipped with UL-approved fire sprinklers and 1/4" safety glass windows. Self-closing and lockable doors and windows, as well as a steel cylinder divider plate and gas identification safety labels, come standard, further meeting the specifications for the safe handling of hazardous production materials.

Internal panel components are orbitally welded, helium leak tested and certified to the highest purity standards. All valves, regulators, transducers, tubing and fitting bodies are 316L stainless steel to prevent corrosion from hazardous gas.

"SEMI-GAS created a defining way to deliver low-volume gases with the compact MGE-X, and the XS model is another advance," says division manager Jim Murphy. "Even with low-volume applications, customers want to minimize human-system interaction and maximize process tool up-time," he adds. "MGE-XS accomplishes both these industry demands with automatic switch-over capabilities, while also meeting the same expectations for safety, reliability, quality and minimal footprint found in the original ground-breaking model."

<http://semi-gas.com>

MicroSense ships LED sapphire wafer measurement tools

MicroSense LLC of Lowell, MA, USA, which supplies dimensional non-contact wafer metrology equipment for manufacturing silicon, compound semiconductor and power devices as well as magnetic metrology systems for MRAM (magneto-resistive random-access memory) manufacturing, has announced multiple shipments of its new, next-generation UltraMap C200 automated sapphire wafer metrology tool.

Designed specifically for high-throughput dimensional measurement of sapphire wafers for LED manufacturing, the UltraMap C200 provides throughput of 90 x 6"-diameter sapphire wafers per hour with what is reckoned to be low cost of ownership (CoO). The system uses MicroSense's proprietary two-sided capacitive sensing technology to measure sapphire wafer geometry, including thickness, TTV (total thickness variation), bow, warp, and LTV (local site thickness variation).

"LED manufacturers typically don't make their own sapphire wafers, so incoming quality control has become a requirement for LED



The UltraMap C200A system.

chip makers as the industry continues to migrate from primarily 2" wafers to 4", 6" and 8" wafers," says David Kallus, director of Dimensional Wafer Metrology at MicroSense. "LED manufacturers have found high sapphire wafer bow strongly correlates to LED yield loss. The UltraMap C200 utilizes our proprietary capacitive sensing technology and advanced high-density wafer mapping algorithms to provide world-leading measurement repeatability and throughput," he claims.

"Sapphire factories are scaling to capacities unheard of before, driven by the LED and smartphone component markets," says Kallus.

"In order to improve sapphire wafer yields and drive down wafer cost, wafer manufacturers need to measure at more steps in the wafering process," he adds. "Unlike metrology tools based on optical methods, the MicroSense UltraMap C200 measures sapphire wafers and substrates with any surface finish — as-cut, lapped, ground, polished, textured and patterned sapphire substrates (PSS) — without sacrificing wafer throughput or measurement repeatability," Kallus claims. "Wafer surface condition has no effect on measurement performance."

Capable of handling wafers of 2–8" in diameter, the UltraMap C200 is available in three versions, including tools with robotic loading, robotic loading with cassette sorting, and a bench-top tool.

MicroSense's latest developments in sapphire wafer metrology, MRAM wafer metrology and high-resolution capacitive sensors are on display in booth 2143 South Hall in the Moscone Center at the SEMICON West 2014 show in San Francisco (8–10 July).

www.microsense.net

MEI displays enhanced metal lift-off and etch systems

MEI Wet Processing Systems and Services (a subsidiary of MEI LLC) of Albany, OR, USA introduced its metal lift-off and advanced etch systems at the 2014 International Conference on Compound Semiconductor Manufacturing Technology (CS ManTech) in Denver (19–22 May). MEI exhibited its advanced process technologies for its semiconductor wet benches, with specific applications for compound semiconductor wet processing, including metal-lift off, silicon etch, metal etch (including gold etch), indium gallium phosphide (InGaP) and gallium arsenide (GaAs) etch.

MEI says that it has made a process breakthrough to enable higher-yielding and more cost-

effective metal lift-off processing, suiting the manufacturing of compound semiconductors and MEMS (micro-electromechanical system) devices. The firm's FluidJet batch wet processing system for metal lift-off now achieves zero metal re-deposition on either the front side or back side of the wafer, reducing device damage, while using up to 80% less chemical than current single-wafer

The FluidJet batch wet processing system for metal lift-off now achieves zero metal re-deposition on either the front side or back side of the wafer

processing solutions, it is reckoned. FluidJet also enables highly efficient, easily obtained gold and metal reclaim, reducing waste and downtime, it is claimed. In addition, FluidJet saves manufacturing floor space by reducing the wet process footprint requirement by at least 60% over single-wafer spray tools, the firm adds.

MEI also introduced its proprietary Advanced Etch Process Solutions for GaAs, InGaP, metal etch and silicon etch, which provide improvements in etch stability, etch uniformity, decreased contamination, and improved concentration controls, as well as lower cost of ownership, MEI says.

www.meillc.com

Brewer Science unveils Apogee temporary wafer bonder

Brewer Science Inc of Rolla, MO, USA, which provides thin-wafer-handling materials, processes and equipment, has unveiled the Apogee bonder for temporary wafer bonding applications. The firm says that this marks a milestone in leveraging its ability to combine processing equipment, high-temperature temporary adhesives, and process integration into a thin-wafer handling solution.

Apogee supports multiple temporary bonding/debonding technologies including thermal slide, mechanical peel, and laser release debonding. The new system completes Brewer Science's thin wafer handling tool suite for low-volume compound semiconductor production of RF filters, analog power devices, LEDs, and solar devices. The firm says that this collection of tools provides reduced time to market for ultrathin wafer technologies using Brewer Science's integrated material and process solutions.

Delivering high accuracy, interface capabilities, and process flexibility,



Brewer Science's Apogee bonder.

the Apogee bonder's features include the following:

- a substrate size range of 50–300mm;
- dual rigid platens that heat the wafer stack from both sides, minimizing thermal defects;
- ultraflat self-leveling platens that minimize total thickness variation (TTV);
- Evacuated bond chamber eliminates voids;
- separation of carrier and device during pre-bond evacuation;
- a total thickness variation of <10%; and
- real-time access and control to process data and push notifica-

tions.

Brewer Science says that its processing equipment allows users to cost-effectively enter new areas of product development and low-volume manufacturing. The equipment product suite can be used to develop process technologies for compound semiconductor, ultrathin CMOS, and MEMS manufacturing as well as thin films, sensors, and advanced packaging. The compact footprint, intuitive design, durability, and experience add up to years of high-performance processing that makes the tool suite suitable for low-volume production or R&D lab environments.

Technology strategist Justin Furse presented 'Thin Wafer Bonding/Debonding in Low-Volume Compound Semiconductor Production' on 20 May at the Exhibitor Forum of the 2014 International Conference on Compound Semiconductor Manufacturing Technology (CS ManTech) in Denver (19–22 May).

www.brewerscience.com/apogee
www.csmantech.org

Brewer Science commercializes megasonic developer for MEMS and compound semiconductor applications

Brewer Science has announced the first commercial placement of a Cee 300MXD megasonic developer. The developer was commissioned by MicroChem Corp (MCC) of Newton, MA, USA, which makes specialty chemicals including photoresists, optical dyes and ancillary materials for micro-electro-mechanical systems (MEMS), microelectronics, lithography, specialty displays, packaging, and optoelectronics applications.

The Cee 300MXD applies uniform acoustic energy to spinning substrates to gently dissolve and remove films and residues without damaging fragile device structures. This precision handling results in stable dimensional control of vertical profiles uniformly across the wafer surface, enabling fabrication of

high-aspect-ratio structures for the MEMS, display, compound semiconductor, and advanced packaging markets. Applications include RF power, MEMS, sensors, and acoustic wave devices used for wireless communication.

"As the MEMS industry and integrated packaging technology continue to demand higher-aspect-ratio structures for TSV and RDL layers, enhanced development techniques will likely become mainstream," says MicroChem's applications engineering manager Michael Stan. "The cost-effective approach being pioneered by Brewer Science gives a supplier such as MicroChem Corp the advantage of being able to rapidly prototype formulations and processes to meet these demands."

"The Cee 300MXD developer features state-of-the-art technology that creates a viable pathway for our customers to decrease process cycle times, reduce cost of ownership, and accelerate time to market," reckons Brewer Science's equipment technology strategist Justin Furse.

"The Cee 300MXD megasonic developer gives customers a bridge from the lab to production by allowing them to avoid significant capital investment," he adds. "Our semi-automated equipment delivers quality and precision comparable to automatic multi-million-dollar tools and is suitable for low-volume prototyping with a seamless transition to high-volume manufacturing."

www.microchem.com
www.brewerscience.com/developers

Ferrotec's Temescal launches mid-sized Auratus enhanced electron-beam metallization system

Materials, component and precision system supplier Ferrotec Corp, whose Temescal division of Livermore, CA, USA manufactures electron-beam-based evaporative coating systems, has launched the Temescal UEFC-4900, a mid-sized ultra-high-efficiency electron-beam metallization system for lift-off compound semiconductor applications.

A smaller system that is optimized for 100 and 150mm production wafer processes, the UEFC-4900 offers all the benefits of the Auratus deposition process enhancement methodology, producing near-perfect uniformity while delivering a reduction of up to 40% in material consumption, resulting in significant cost savings on process materials like gold and platinum compared to traditional box coaters.

The UEFC-4900 is designed for active compound semiconductor production environments that use electron-beam evaporation and lift-off coating processes. It features a conical-shaped vacuum chamber that doubles the wafer capacity of the system compared to the similarly sized Temescal FC-2800. The system also features a patent-

pending High-Uniformity Lift-off Assembly (HULA) design that uses a dual-axis motion to optimize collection efficiency.

"With the UEFC-4900, we are bringing our most advanced Auratus process enhancements to customers operating 100 and 150mm production lines traditionally served by our FC-2800 system," says Temescal's managing director Gregg Wallace. "From its unique chamber design to the HULA for wafer handling, the UEFC-4900 pumps down faster, coats more wafers, and runs more batches per day than the comparably sized FC-2800," he adds. "But the real power of this system is its precision, producing near-perfect uniformity while reducing process material consumption by up to 40%. For IDMs [integrated device manufacturers] and foundries, this equates to better quality devices that cost less."

The UEFC-4900 features significantly increased wafer production capacity, since it can process up to 25 150mm wafers in a batch (more than double the capacity of the FC-2800, with a similar footprint and power consumption).

With its unique conical-shaped chamber and multiple cryopumps, the UEFC-4900 pumps down to process pressure significantly faster than conventional box coaters, the firm says. With pumping capacity of 39,000 liters per second, the system can reach 5×10^{-7} Torr faster than the FC-2800, reducing production time lost waiting for the system to get to process pressure and increasing the number of batches that can be run per day.

The system incorporates Temescal's Auratus deposition process enhancement methodology, a proprietary optimization methodology for lift-off electron-beam evaporative coating that incorporates patent-pending technology to achieve what is claimed to be unprecedented levels of uniformity, precision, and collection efficiency. Auratus enables Temescal system users to coat wafers with near-perfect uniformity, resulting in more consistent, better-quality products and fewer defects, adds the firm. The Auratus methodology also has the capability to increase the effective deposition rate, enabling increased throughput.

www.temescal.net

Temescal's first UEFC-4900 e-beam metalization system ordered by Plessey for MaGIC LED production

Ferrotec says that the first of its new Temescal UEFC-4900 systems will be delivered to Plessey Semiconductors Ltd of Plymouth, UK.

Plessey's proprietary MaGIC (Manufactured on GaN-on-Si I/C) process produces a unique, thin layer of GaN-on-silicon, and the UEFC-4900 offers the benefits of the Auratus Deposition Process Enhancement Methodology, including near-perfect uniformity and reduction in material consumption.

"At only 2.5µm for both buffer and epitaxial layer, our MaGIC process uses a much thinner GaN layer compared to the 8µm thick-

ness typical on most other LED processes," says Plessey's operations director Mike Snaith. "When you're working with this level of precision, the uniformity and efficiency that you can achieve with a Temescal system is essential. The UEFC-4900 will be an excellent upgrade from our FC-2800 platform with its Auratus enhancements such as increased capacity, faster throughput, and reduced cost of operations," he adds.

"Plessey is making tremendous inroads into reducing the cost of high-brightness LEDs with its unique GaN-on-silicon process,"

comments Temescal's managing director Gregg Wallace. "By producing high-performance GaN LED structures on standard silicon substrates, Plessey is able to deliver industry-standard performance at a dramatically reduced cost of manufacture," he adds. "With the UEFC-4900, our most advanced Auratus process enhancements and our excellent local support, this tool will help Plessey achieve larger batch sizes and improved efficiencies, all while maintaining the critically precise process parameters."

www.plesseysemiconductors.com/

GT to make larger-capacity 165kg-boule sapphire furnace available from Q3/2014

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 power electronics markets) says that it will be making its next-generation ASF165 sapphire growth furnace (for the production of high-volume and high-quality sapphire material) commercially available in third-quarter 2014.

Expected to be the only commercially available sapphire production furnace capable of producing high-quality 165kg boules in high volume, the new system will deliver a 40% increase in boule size compared with the existing ASF115.

The ASF165 is currently in the beta testing stage and is expected to be ready for volume shipments from Q3/2014. Customers with installed ASF units, or those who



opt to take delivery of new ASFs out of backlog prior to the general availability of the ASF165, will be able to upgrade to the larger-capacity system when they become available.

ASF165 units will also be available to new customers targeting the LED and industrial markets.

"The ASF165 gives customers a competitive advantage and lower cost of ownership by providing a sapphire furnace that significantly increases capacity and reduces cost," says president & CEO Tom Gutierrez. "Several industry analysts are forecasting an increase in demand for sapphire material, and we believe that ASF customers who take advantage of the larger-capacity ASF165 will be well positioned to serve this anticipated demand."

GT also indicates that it has developed more advanced ASF technology capable of producing boules significantly greater than 165kg, but it intends to keep this more advanced ASF system captive for an extended period of time.

www.gtat.com

GT and EVG co-develop processes and equipment for bonding sapphire and SiC lamina to glass, silicon & plastics GT to sell resultant bonding and coating equipment

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 power electronics markets) has announced several new initiatives aimed at expanding its portfolio of sapphire and silicon carbide (SiC) solutions for next-generation consumer and industrial products.

The firm has entered into a memorandum of understanding (MOU) with EV Group (EVG) of St Florian, Austria (a supplier of wafer bonding and lithography equipment for MEMS, nanotechnology and semiconductor applications) to work together in various collaborative arrangements including jointly developing high-volume production processes and equipment neces-

sary to bond the ultra-thin sapphire and SiC lamina, produced by GT's Hyperion technology, to engineered substrates such as glass, silicon, and plastics.

GT also says that it will begin working with a leading glass substrate producer to develop specially engineered substrate materials that can be bonded to ultra-thin sapphire lamina to create unique composite solutions that expand the reach of sapphire into a broader set of applications.

In addition, GT has acquired patent-pending technology for producing low-cost, scratch-resistant aluminium oxide coatings for various substrates including glass and plastics. These are expected to provide some of the durability and scratch-resistant properties of crystalline sapphire at a lower price

point to address market opportunities where cost is paramount and not all of the properties of sapphire are required.

GT's business model will be focused on selling the bonding and coating equipment developed through these initiatives.

"Our sapphire composite material development program is focused on leveraging the combined expertise of GT and our technology partners in order to build a new market for low-cost and highly durable substrate solutions for next-generation consumer and industrial products," says GT's president & CEO Tom Gutierrez. "These programs enhance our technology portfolio and leverage our significant investment in our Hyperion technology."

www.EVGroup.com

www.gtat.com

EVG wafer bonding and bond alignment systems installed at Penn State University

EV Group (EVG) of St Florian, Austria (a supplier of wafer bonding and lithography equipment for MEMS, nanotechnology and semiconductor applications) has shipped an EVG510 semi-automated wafer bonding system and an EVG620 automated bond alignment system to the University of Pennsylvania (Penn). The systems are installed in the Quattrone Nanofabrication Facility in the Singh Center for Nanotechnology at Penn in Philadelphia, where they are being used for anodic and thermocompression bonding processes in the fabrication of advanced micro- and nano-systems.

"Academic institutions like the University of Pennsylvania provide critical contributions to advanced research and development across a multitude of high-technology industries," comments EVG's chief scientist Dr Viorel Dragoi.

"Penn's Quattrone Nanofabrication Facility is using our wafer bonder and bonding alignment systems to help their students, faculty and corporate partners to move their cutting-edge research forward into new and exciting nanotechnology applications."

The Quattrone Nanofabrication Facility is a multi-user facility serving the nanofabrication needs of the Penn community as well as those of external users. It houses a suite of tools for micro- and nanofabrication, including optical and electron-beam lithography, vapor deposition, etching, packaging and electrical testing. Adding bonding capabilities via the EVG510 and

Adding bonding capabilities via the EVG510 and EVG620 systems enables the facility to implement new processes

EVG620 systems enables the facility to implement new processes that can support applications such as microfluidics, MEMS, and heterogeneous integration.

The EVG510 wafer bonding system provides fully automated processing with manual loading and unloading. It features EV Group's field-proven uniform heating and pressure application systems. With a modular bond chamber design that accommodates wafer sizes up to 200mm, the EVG510 is claimed to provide the lowest cost-of-ownership for both R&D and pilot-line production. The EVG620 system supports bond alignment of double- or triple-wafer stacks up to 150mm wafer sizes, and offers what is claimed to be the highest precision, flexibility, ease of use and modular upgrade capability.

www.evgroup.com/en/products/bonding/waferbonding/evg510semi

Shanghai University orders Aixtron BM R&D reactor for graphene and nanotube research

Deposition equipment maker Aixtron SE of Aachen, Germany says that Shanghai University has ordered a BM R&D reactor to be used by its Sino-Sweden Microsystem Integration Technology Center (SMIT).

"We will be launching extensive new research into the application of nanotubes and grapheme using the BM capabilities in thermal- and plasma-based chemical vapor deposition," says professor Johan Liu, who leads the graphene/nanotube research at SMIT. "We chose the Aixtron system as we achieved excellent results in our long-standing work with the BM reactor at Chalmers University in Sweden," he adds. "The system has been a workhorse for similar research for the last five years, giving us consistently good results, high uptime, ease of use and process flexibility."



Aixtron's BM R&D reactor.

Liu will be developing next-generation thermal interface/dissipating materials, heat spreaders, multi-chip interconnects and through-silicon vias (TSV) for semiconductor chip packaging using the BM reactor.

Established in 2003, SMIT combines expertise from Shanghai University and Chalmers University of Technology in Gothenburg, Sweden. Founded as a cross-border institution, the center conducts research on microsystem and microelectronics integration by focusing on new technology for future microsystems for industrial applications.

With extensive experience in graphene research, Chalmers is leading the EU's Future Emerging Technology (FET) flagship project 'Graphene', in which Aixtron plays a key role in the 'Graphene Flagship' research initiative by contributing its expertise to enable large-scale graphene growth through the development of next-generation deposition equipment.

www.aixtron.com

Crystal IS adds VP of operations and expands plant

Crystal IS Inc of Green Island, NY, USA, which makes ultraviolet light-emitting diodes (UVC LEDs) grown pseudomorphically (strained) on aluminum nitride (AlN) substrates, has appointed John Gartner as its first vice president of operations.

Gartner has more than 30 years of experience in manufacturing and engineering, including establishing and growing manufacturing operations for clean and reliable energy solutions. His expertise will help transition Crystal IS from R&D to a manufacturing company of UVC LEDs for life sciences, environmental monitoring and disinfection applications. "Crystal IS has committed to mov-



John Gartner.

ing from R&D to commercial product development," comments Gartner. As well as adding Gartner, Crystal IS continues to expand its Green Island facility, preparing it for full-scale production and shipping of soon-to-be-announced Optan product with the addition of:

- a raw material furnace as well as three additional furnaces and a chiller to double manufacturing capacity;
- a new lab and production equipment for fine wafer polishing;

- moving fabrication in-house to the AK Fuji facility; and
- 23% staff growth across the organization in areas including application engineering, quality, customer support and product marketing.

"As the industry leader in developing UVC LEDs, our move from R&D to commercial production was inevitable," says CEO Larry Felton.

"Appointing John Gartner as our first vice president of operations and expanding our manufacturing capacity demonstrates our commitment to commercializing our superior technology and getting our breakthrough products to customers."

www.crystal-is.com

Crystal IS makes available AlN-based Optan UVC LEDs

Crystal IS has made available its Optan UVC LED. Reckoned to be the first commercial semiconductor product based on native AlN substrates, Optan provides a technology platform for increased detection sensitivity, essential for analytical and life sciences instrumentation — from monitoring of chemicals in pharmaceutical manufacturing to drinking water analysis.

Optan is targeted at design engineers looking to overcome limitations associated with traditional UV lamps, including deuterium and xenon flash lamps. Crystal IS says that Optan allows developers to fully exploit the power of UV-based technology to improve productivity, increase accuracy and create greater flexibility in product designs.

"Optan will help instrument manufacturers build smaller, more powerful tools and products with a lower overall system cost," says CEO Larry Felton.

Light output and spectral quality of the Optan UVC LED — enabled by the low-defect AlN substrate — yields what is said to be best-in-class reliability and longer lifetimes, a 'game changer' for life sciences and analytical instrumentation, including environmental monitoring.

Immediate applications include:

- HPLC (high-performance liquid chromatography), a powerful tool in analysis for detecting chemicals and compounds in life sciences;
- spectrometers, used in multiple applications in testing and analysis across biotech, life sciences and environmental monitoring; and
- water quality monitoring sensors, which are becoming increasingly important for detecting chemicals in water (from fracking, water security and the use of treated wastewater).

Optan LEDs are currently available in peak wavelengths from 250nm to 280nm and power bins from 0.5mW to 2mW (compared with just 1mW for UVC LEDs grown on sapphire). The new LEDs are suitable for spectroscopic applications because of their high spectral quality (with wavelength bins of 5nm — comparable with sapphire-based UVC LEDs) and reliability (with a lifetime of 3000 hours at the maximum drive current of 100mA — versus just 300-800 hours for sapphire-based UVC LEDs — and 7000 hours at 20mA). Full availability for all bins under 3mW is anticipated for third-quarter 2014, with higher-power bins (3-4mW) available this Fall. The LEDs are sup-

plied in a TO-39 ball lens package with a viewing angle of 15°. However, future higher-power versions for applications requiring higher light output (e.g. disinfection and sterilization) will be provided in different packages (e.g. SMT). Such products in development are currently undergoing quality testing.

As Crystal IS geared up for full-scale production, it tripled furnace capacity for optoelectronic-grade AlN substrates and, between January 2013 and March 2014, increased staffing by 23% (to 42) in Green Island (where the firm conducts substrate growth and MOCVD epitaxy, as well as product development). Additional senior-level recruitment is expected over the next 6-8 months. Already, last November, Crystal IS' parent firm, Japan-based integrated chemical manufacturer Asahi Kasei, announced that during 2014 it would build a trial production line at its 'Fuji branch' subsidiary (where it has an R&D lab) to manufacture germicidal UV LEDs (from where it will ship the fabricated chips to packagers in Asia). Asahi Kasei is said to be investing ¥10bn (\$100m) in its UV LED unit.

www.cisuv.com/products/optan

Plessey further expands GaN-on-Si LED production with another Aixtron CRIUS II-XL MOCVD system

Deposition equipment maker Aixtron SE of Aachen, Germany says that Plessey Semiconductors Ltd of Plymouth, UK has purchased another CRIUS II-XL metal-organic chemical vapor deposition (MOCVD) system for manufacturing gallium nitride LEDs on silicon wafers (GaN-on-Si) as it further expands its production capacity. The Close Coupled Showerhead (CCS) system, delivered recently with a 7x6" configuration, will supplement an existing production system from Aixtron (delivered in July 2012).

"Our MaGIC (Manufactured on GaN-on-Si I/C) LED product in particular has been successfully launched this past year," says Plessey's chief technology officer Dr Keith Strickland. "As a result, we now plan to step up our production. To this end, and given our positive experience with Aixtron's CRIUS II-XL system, we have purchased a fur-



Aixtron's CRIUS II-XL MOCVD system.

ther system of this type and are thus maintaining our successful cooperation with Aixtron," he adds.

"CRIUS II-XL convinced us with its high throughput rates and low operating costs for GaN layer growth on 6-inch silicon substrates," says Plessey's operations director Mike Snaith. "Moreover, Aixtron is actively supporting us in further optimizing our production processes," he adds.

The latest order "offers further confirmation that GaN-on-silicon, a high-performance, efficient epitaxy process, is becoming increasingly established as an alternative to growth on

sapphire," comments Dr Frank Schulte, vice president of Aixtron Europe. "The associated potential production cost savings will further promote the establishment of LED as a light source," he adds. "Aixtron is well prepared for this market development and will also be supporting Plessey in further optimizing its GaN-on-silicon technology."

www.plesseysemiconductors.com/led-plessey-semiconductors.php

Comprel to distribute Plessey's GaN-on-Si LEDs in Italy

Plessey Semiconductors has entered into a distribution agreement with electronics distributor Comprel Srl of Nova Milanese, Italy to expand its European network with coverage in the Italian market for its gallium nitride on silicon (GaN-on-Si) LED products.

"We entered the SSL (solid-state lighting) market three years ago with the aim to introduce new



Michele Busnelli.

technology in a booming sector," notes Comprel's commercial managing director Michele Busnelli. "We are very pleased to work with a distributor that entered the lighting market some years ago

and therefore has considerable knowledge of the local customer base and what is required to be successful," comments Plessey's regional sales director David Owen. "Comprel has a dedicated team working in the Italian lighting market place, which will accelerate the time to market for Plessey GaN-on-Si LEDs in this high-growth region."

www.comprel.it

Alcom to distribute Plessey's GaN-on-Si LEDs in Benelux

Plessey Semiconductors Ltd has entered into a distribution agreement with Netherlands-based electronics distributor Alcom Electronics B.V. to expand its European network with coverage in the Benelux market for its gallium nitride on silicon (GaN-on-Si) LED products.

"The innovative Plessey LED solution fits very well within Alcom's market approach," says Alcom's

managing director Marcel den Bak. "We are offering the newest technology in the respective markets we are active in, making sure that our customers can be more competitive in their end applications. Plessey, being an early adaptor of GaN-on-Si LED technology, will bring Alcom and its customers an extremely competitive, high-quality light source," he believes.

"Plessey is very pleased to work with a distributor that has been focusing on the solid-state lighting market for a considerable number of years," says Plessey's regional sales director David Owen. "Alcom has a dedicated team working in the lighting segment and therefore considerable knowledge of the growing Benelux lighting industry."

www.alcom.nl

Seoul Semiconductor launches Acrich3 LED, interfacing with smart-lighting control technologies

South Korean LED maker Seoul Semiconductor has launched Acrich3, its next generation of smart-lighting LED technology.

Acrich3 not only provides lighting designers with an easy-to-use solution but, coupled with smart lighting control technologies, it can further enhance energy savings, performance and aesthetics of LED lighting systems, says the firm. With Acrich3, Seoul Semiconductor is positioned to penetrate the smart lighting market, which is expected to reach KRW10 trillion (US\$9.76bn, or €7.12bn) by 2020.

One of the barriers in replacing conventional lighting technologies with solid-state lighting products is the compatibility of existing triac or phase-cut dimmers with LED retrofit lamps. Acrich3 is designed to work with most existing TRIAC dimmers without sacrificing power quality or efficiency, ensuring con-

sumers can take advantage of both energy savings and ambiance lighting controls, says the firm.

Furthermore, the new Acrich3 solution enables users to make the transition from wall-dimmer-controlled LED lights to smart lighting control systems. Acrich3 technology can interface through a wide variety of wireless networks such as Zigbee, WiFi, Bluetooth in order to control dimming, CCT (correlated color temperature), zoning and scheduling — all from a tablet or a smartphone — to optimize both energy savings and the aesthetic benefits of LED lighting.

While existing smart lighting LED systems require complex AC/DC converters, the 6mm x 6mm Acrich3 IC can be operated directly from AC, reducing component count and improving reliability, says Seoul Semiconductor. It also has an in-built auxiliary power

source to power sensors to interface with smart lighting controls.

“LED lighting, optimized in combination with advanced intelligent lighting control systems, is becoming more important in both residential and commercial lighting applications,” says Jay Kim, executive VP of Seoul Semiconductor’s Lighting sales division. “Seoul Semiconductor has invested over four years to make the perfect smart lighting system”, he adds. “Seoul Semiconductor plans to launch several new modules with Acrich 3 technology for the use in residential, commercial, and industrial lighting systems.”

Acrich3 technology was showcased at the Light Fair International (LFI 2014) exhibition in Las Vegas (3–5 June) and at the Guangzhou International Lighting Exhibition in China (9–12 June).

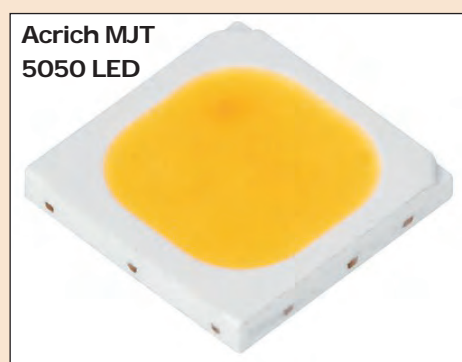
www.seoulsemicon.com

High-power Acrich MJT 5050 LEDs launched for outdoor lighting

Seoul Semiconductor has released a new generation of Acrich MJT 5050 LEDs, with high lumen output, reliability and cost performance optimized for outdoor lighting.

At a drive current of 20mA and a forward voltage of 64V, the cool-white SAW0LH0A LED, with a correlated color temperature (CCT) of 4700–7000K (5600K typical) and minimum color rendering index (CRI) of 70, delivers typical luminous flux of 180lm (at 25°C, 5000K) and can be driven to a maximum current of 60mA (delivering up to 440lm). The 2600–3700K CCT (3000K typical), 80-CRI warm-white SAW8LH0A LED delivers typical luminous flux of 155lm (at 25°C).

The new Acrich series delivers a combination of high lumen output, efficacy, reliability and lumens per dollar, says the firm. This results in designs where fewer LEDs are used, which leads to smaller and



lighter fixtures, enabling cost savings on a system level. This latest Acrich series delivers high performance without sacrificing reliability or cost, adds the firm, making it suitable for the outdoor lighting market, where high efficacy and lifetime are critical.

Utilizing proven and reliable Acrich MJT (Multi-Junction chip Technology) high-voltage architecture and with package dimensions of 5mm x 5mm x 0.65mm, the new Acrich LED eliminates the tradeoff between

size and efficacy, says the firm. Designers can take advantage of the high efficiency of high-voltage DC drivers or eliminate the driver by driving the LEDs directly from AC using the Acrich IC.

“In addition to high efficacy and reliability, the total cost of ownership (CoO) is an important metric for the street and area lighting market,” states Jay Kim, executive VP of the Lighting sales division. “This product will enable the market to come up with the next generation of high-quality, efficient and competitively priced LED lamps,” he believes. “The payback period, especially for streetlights, can be significantly reduced with the new Acrich LED without compromising on reliability or efficiency,” Kim adds. “In the future, Seoul Semiconductor will introduce more products to penetrate the outdoor area lighting market.”

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Bridgelux expanding China operations

R&D center opened in Xiamen; applications lab to open in Shanghai

Bridgelux Inc of Livermore, CA, USA (a vertically integrated manufacturer of solid-state light sources for lighting applications) has announced an expansion of its China operations, significantly increasing its investment and capabilities in China.

To better serve its rapidly growing customer base in China, Bridgelux has opened an R&D center in Xiamen dedicated to supporting the development and manufacture of new solid state lighting products, including extensions to its V Series chip-on-board (COB) product line. In addition, the firm will be opening an applications lab in Shanghai's Hongqiao district to assist its China customers with the design and enhancement of lamps and fixtures that integrate Bridgelux's LED light source products.

Over the last decade, the Chinese LED market has expanded rapidly, to an estimated RMB32bn for LED lamps and luminaire and over RMB8bn at the LED package level in 2013. Bridgelux says that, with

its dedication to low-cost LED solutions, it has grown its business steadily over its 10-year history in the country. "Our customers in China are playing an increasingly important role in the global lighting market," says Tim Lester, VP of operations & chief financial officer. "We are committed to supporting them in their rapid growth and worldwide expansion by dramatically increasing our local in-country capabilities."

Opened earlier this year, Bridgelux's Xiamen R&D facility is co-located with Kaistar Lighting, a strategic supply chain partner and investor in the firm. In only a few months, Bridgelux has hired several engineers and installed a pilot line and test equipment. It plans to continue to build critical engineering and product development capabilities at the Xiamen facility through 2014 and beyond. Bridgelux also plans in future to utilize the Xiamen facility in support of the development and manufacture of products geared to

meet the requirements of the Chinese market, working closely with Kaistar and taking full advantage of the company's manufacturing assets in the region.

The new Shanghai applications lab will be located in Bridgelux's existing office location in the Hongqiao area. It will be modeled after the Bridgelux Application Test (BAT) lab in Livermore, providing critical application design support, including optical, mechanical, thermal, and certification testing services. The firm reckons that, with these capabilities on the ground in China, it will be well positioned to support its customers' need for faster cycle times.

"With the help of local Bridgelux resources, our customers will be better positioned to participate in the rapid replacement of legacy technologies with high-quality, cost-effective LED lamps and fixtures in China and throughout the world," says Lester.

www.bridgelux.com

Bridgelux expands V Series line of LED chip-on-board light sources

At the Light Fair International (LFI) show in Las Vegas, Bridgelux launched its V10 and V15 LED array products, further expanding its V Series line of LED chip-on-board (COB) light sources (which has shipped millions of units in more than 20 countries since launch last September, representing a quarterly growth rate of 52%).

Extending the technology and performance of the Vero line of LED arrays by featuring high flux density in small-size light source packages, the V10 and V15 are particularly suited to commercial and residential lighting markets requiring high quality and tight beam control, says the firm.

Bridgelux says that, in addition to providing high-quality light with high flux density, the V10 and V15 offer a total cost of ownership

advantage over incandescent, halogen and fluorescent technologies, with greater energy efficiencies — producing up to 118 nominal lumens per watt (lm/W) — and a projected lifetime of over 20 years.

Typical applications include downlights, track and spot lighting, and landscape lighting, with V15 being a suitable replacement for 35W ceramic metal halide luminaires. Nominal lumen outputs range from 1000 to 3000 lumens for the V10 and V15, respectively.

The V10 and V15 are available in a variety of correlated color temperature (CCT) and color rendering index (CRI) options and are compatible with optics, drivers and holders readily available from third-party suppliers. With more than 9000 hours of LM80 test data

and R9 values that exceed California Energy Commission requirements for luminaires and lamps, the new V Series arrays support Energy Star and other rebate programs while also including ANSI-compliant 3-step binning, reducing stock-keeping units (SKUs) while bringing consistent high-quality white-point light to this new segment, says the firm.

Also at LFI, Bridgelux showcased several new additions to the Vero Series (claimed to be the industry's first COB with a 10-year warranty) including multiple ultra-high-CRI and cool-white light combinations, specific CCT/CRI combinations for healthcare, entertainment, bakery, grocery, deli and textile applications, along with new Zhaga options.

www.bridgelux.com/products/v-series

LatticePower commercializes GaN-on-Si LED, launching high-performance light fixtures

At the LightFair International 2014 exhibition in Las Vegas (3–5 June), LatticePower of Nanchang, Jiangxi Province, China — which claims to be the first firm to commercialize gallium nitride on silicon (GaN-on-Si) LEDs — displayed its next generation of light fixtures, including new proprietary GaN-on-Si LED track, high-bay and flood fixtures.

LatticePower says that growing GaN material on a silicon substrate has been a vexing problem for the industry as a result of the material lattice mismatch and thermal expansion mismatch between GaN thin film and silicon substrate. These mismatches contribute to defects in the material, cracking on the wafer, and poor quantum efficiency of the epi-layer.

By developing a series of proprietary technologies to overcome the mismatch problems, LatticePower says that it is able to manufacture

consistent-quality and reliable LEDs. The firm's GaN-on-Si LEDs offer high light density and better thermal dissipation, it is claimed.

LatticePower's GaN-on-Si technology uses a larger-diameter (6-inch) silicon wafer fabrication process that lowers unit cost and increases throughput for significant cost reduction, resulting in a cost at least 30% lower than the equivalent top-tier sapphire process, it is reckoned.

The firm also has developed

The firm also has developed a unique system-in-package approach that differs from others by combining integrated GaN-on-Si LEDs with a silicon-substrate-based heat-sink

a unique system-in-package (SiP) approach that differs from others by combining integrated GaN-on-Si LEDs with a silicon-substrate-based heat-sink. This new platform permits easy scalability, low-cost production and automated manufacturing for lighting fixtures.

As a vertically integrated company, LatticePower designs, engineers and manufactures all the components in its lighting products, optimizing performance for commercial applications and reducing time-to-market at scale. The firm is hence displaying three new fixtures that use its GaN-on-Si LED technology — a track light, high-bay and flood. All of LatticePower's products are certified to international standards for the general lighting market, including indoor and outdoor applications.

www.lpglighting.com

www.latticepower.com

Luminus launches XNOVA Sensus LED series color-targeted COB LED arrays

Luminus Devices Inc of Billerica, MA, USA, which makes PhlatLight (photonic lattice) LEDs for solid-state lighting (SSL) applications, has launched the XNOVA Sensus LED series chip-on-board (COB) LED arrays featuring warm-white light with chromaticity coordinates targeted below the black-body locus (BBL). The XNOVA Sensus LED series features illumination products with targeted color points designed to enhance perception in specific environments such as retail, grocery and hospitality.

Recent studies have demonstrated that people have a preference for warm-white color temperatures slightly below the BBL which they perceive as a pure, crisp, whiter light, while the majority of warm-white LED products are targeted to generate light precisely on the BBL.

In addition to providing the appearance of pure white, customers have reported that XNOVA Sensus LED array provide more appealing color renditions of skin tones and greater color saturation. They are also attracted to the similarity between the white point of XNOVA Sensus LED light and traditional metal halide bulbs.

"Our XNOVA Sensus COB LED arrays provide our customers with the highly desirable, below-BBL white light that meets emerging market demands, while still providing color control within the American National Standards Institute 3000K color space," says Jim Miller, executive VP of sales & marketing. "Sensus goes beyond the traditional definitions of white light used by most LED manufacturers and targets color points that have greater appeal

to human emotion and perception of light quality," he adds.

The XNOVA Sensus LED arrays are available in 2- or 3-step McAdam ellipse color accuracy, which is fully inscribed below the BBL and within the ANSI 3000K color space. In addition, they are tested at 85°C, where they deliver 120lm/W typical and 80 CRI (color rendering index) minimum. Light-emitting diameters are available in seven sizes from 6.3mm to 22mm, enabling users to achieve a typical flux output from 470 lumens to over 7500 lumens.

Luminus showed the XNOVA Sensus COB LED array at the Lightfair International (LFI 2014) show in Las Vegas (3–5 June) and at China's Guangzhou International Lighting Exhibition (9–12 June).

www.luminus.com/products

Lumileds' CoB LED arrays reach 10,000lm at 100lm/W for downlights and outdoor/industrial fixtures, targeting CDM 70–100W luminaire equivalents

Philips Lumileds of San Jose, CA, USA is now delivering what it claims is the highest flux and most efficient LED arrays in higher lumen packages. Its new LUXEON CoB 1211 is suitable for industrial and outdoor applications and is a replacement for 70W- and 100W-equivalent ceramic discharge metal halide (CDM) lamps. As the latest addition to Lumileds LUXEON chip-on-board (CoB) arrays portfolio, the CoB 1211 delivers efficacy of 100-130lm/W, depending on the color temperature and color rendering index (CRI) of the luminaire. Specifically, the CoB 1211 achieves cool-white output exceed-



Lumileds' new LUXEON CoB 1211 LED array.

ing 10,000lm and 100lm/W at 70CRI, while achieving a light emitting surface (LES) of only 19mm.

"The LUXEON CoB 1211 has the best combination of a small light emitting surface and high efficacy at its specific lumen package," reckons product line director Eric Senders.

Lumileds says that its LUXEON CoB products enable low-cost luminaire design that results in what is claimed to be the highest-flux LEDs with low thermal resistance substrates. They also reduce heat-sink needs and — with an existing ecosystem of compatible holders, drivers and optics — enable faster time to market, adds the firm.

www.philipslumileds.com/LUXEONCoB

Mouser receives Top Catalog Distributor award from Lumileds

Mouser Electronics Inc, an engineering resource and global authorized distributor of semiconductors and electronic components, has been named Top Catalog Distributor for 2013 by LED maker Philips Lumileds of San Jose, CA, USA (which has a comprehensive portfolio of high-power, mid-power, array, and color LEDs).

Mouser was cited specifically for Point of Sales Top Performance. The global design-fulfillment distributor says it holds the largest market share industry-wide, has the greatest number of new customers, and is the fastest with new product introductions of any of Lumileds' catalog distributors.

"With Mouser's help, we have the opportunity to bring our comprehensive portfolio of application-optimized LEDs to an even broader group of new and innovative companies," says Kris Keuser, Lumileds' senior director of worldwide distribution. "Our business union provides the perfect avenue for our extensive product line to quickly meet the demands of our



Left to right: Lumileds' Jeffrey Raggio and Adam Osmancevic, along with Mouser Electronics' Eric Flodstrom and Jeff Newell.

rapidly growing customer base," he adds.

"In addition to demonstrating a highly collaborative effort in marketing, Lumileds continues to launch leading-edge, high-quality lighting components," comments Russell Rasor, Mouser's VP of supplier management. "That fits perfectly with the Mouser model to deliver the newest products and advanced technologies to lighting designers."

Lumileds claims to have pioneered the use of solid-state lighting in products such as the first LED backlit TV, the first LED flash in camera phones, and the first LED daytime running lights (DRLs) for cars. Lumileds claims that it now offers one of the most comprehensive portfolios of LEDs.

Mouser stocks all of the latest innovations from the firm.

Lumileds brings the LED's qualities of energy efficiency, digital control and long life to spotlights, downlights, high-bay and low-bay lighting, indoor area lighting, architectural and specialty lighting as well as retrofit lamps. Also, offering LEDs in chip, packaged and module form delivers supply chain flexibility for next-generation illumination.

www.mouser.com/philips-lumileds



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www.evatecnet.com

Soraa launches full-visible-spectrum large LED lamps

At the LightFair International 2014 event in Las Vegas (3–5 June), Soraa Inc of Fremont, CA, USA, which develops solid-state lighting technology built on 'GaN on GaN' (gallium nitride on gallium nitride) substrates, launched a series of full-visible-spectrum large LED lamps. The new line of AR111, PAR30L (Long Neck), PAR30S (Short Neck), and PAR38 lamps complements the firm's MR16 lamp, creating a full line of products to light restaurant, retail, hospitality, and residential applications.

All of Soraa's lamps feature the firm's unique full-visible-spectrum Violet-emission 3-Phosphor (VP3) LED technology powered by GaN-on-GaN, enhancing rendering of colors and whiteness. VP3 Vivid Color utilizes every color in the rainbow, especially deep red emission, to render warm tones, and achieves a color rendering index (CRI) of 95 and deep red (R9) rendering



Soraa's new AR111 and PAR30 full-visible-spectrum large LED lamps.

of 95 at correlated color temperatures (CCTs) from 2700K to 5000K. VP3 Natural White is achieved by engineering the violet emission to properly excite fluorescing agents in natural objects such as human eyes and teeth as well as manufactured white materials such as clothing, paper and cosmetics; resulting in whiteness rendering the same as observed under daylight or incandescent illumination, but without using ultra-violet light.

"No other LED technology is able to

efficiently combine all aspects of the full-visible-spectrum to provide a full-color, natural lighting experience without an elaborate lamp design," claims chief technology officer Mike Krames. "Gone are the days when energy efficiency meant inferior light quality, as instigated by fluorescent lighting and perpetuated by standard blue-based white LEDs."

Soraa's 8° AR111 is claimed to be the only LED product that matches halogen levels, with a CBCP (center-beam candle power) that is 50% higher than the nearest 80-CRI competitor. The PAR30L and PAR30S lamps offer the only 8° narrow spot option on the market without active cooling, achieving a CBCP more than twice that of the nearest 80-CRI competitor, it is claimed. All of Soraa's full-visible-spectrum lamps are available in 25°, 36° and 60° beam angles and come in a wide range of color temperatures.

www.soraa.com

SNAP accessory available on PAR30, PAR38 and AR111 LED lamps

At LightFair, Soraa launched large-lamp versions of its SNAP System, along with new accessories.

Launched in April last year, Soraa's MR16 SNAP System allows users to customize light directly on the lamp rather than on the fixture. With the addition of PAR30, PAR38 and AR111 LED lamps to the SNAP System line, users now have a choice of lamps as well as accessories to tailor light in restaurant, retail, hospitality, museum, and

residential applications.

Soraa says that, due to its bright point-source GaN-on-GaN LED and prismatic optic, its LED lamps can accept a magnet in the center of the lens, enabling a simple accessory attachment mechanism without a major impact on light output or efficiency. The easy-to-use magnetic accessories allow users to adjust the color, shape and soon the direction of the light beam, adds the firm.

"The SNAP System provides endless possibilities for beam shaping and color tuning," says George Stringer, senior VP of North American sales.

All SNAP System LED lamps have Soraa's signature elements of full-visible-spectrum light; point-source optics for uniform beams of high intensity; and Violet-emission 3-Phosphor (VP3) Vivid Color and VP3 Natural White (revealing whiteness and colors in every environment).

Soraa's SNAP System wins Red Dot Design Award

Soraa's SNAP System has received the Red Dot Award: Product Design 2014. The 40-person jury featured specialists tasked with selecting products that excel in design innovation, functionality and ecological compatibility.

"Accessories are an important tool in lighting designers' palettes as they allow designers to configure

and fine-tune lighting scenes with dedicated light distributions, colors, and directions," says George Stringer, senior VP of North American sales. The SNAP System provides the flexibility to change beam characteristics without having to change the light source, he adds.

The annual Red Dot Award: Product Design is said to be one of the

world's largest design competitions. In 2014, the jury received 4815 entries from 53 countries, but only the best 1120 received an award (including just 17 LED lamp products).

This is the second year in a row that Soraa has won a Red Dot Award. Last year, the firm received the award for its VIVID MR16 LED lamp.

www.red-dot.org

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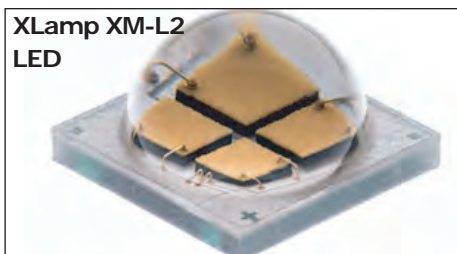
FerroTec

Cree's XM-L2 EasyWhite LED gives 38% boost over XM-L

Cree has launched the XLamp XM-L2 EasyWhite LED, delivering more than 1100 lumens of color-consistent light from a 5mm x 5mm package and enabling a 38% gain in light output and efficacy as a drop-in upgrade to the first-generation XM-L EasyWhite LED.

Based on Cree's EasyWhite technology, which combines the what is claimed to be industry's tightest color binning and intense light output from a single LED, the XM-L2 EasyWhite LED is optimized to replace halogen technology.

"The new XLamp XM-L2 EasyWhite LED offers greater optical control and an immediate performance boost to our existing designs using the XM-L EasyWhite LED," comments Tom Tang, chairman of lighting manufacturer Tons Lightology Inc. "Having a drop-in replacement eliminates the need to re-design existing products, which lowers costs and helps speed our time to market."



Developed to be used as a single component in small-form-factor lighting designs, the XM-L2 EasyWhite is designed to emulate the appearance and match the color consistency of halogen lamps. It offers 2-step and 4-step MacAdam ellipse bins to deliver what is claimed to be the industry's best color consistency, as required for retail, residential, museum and hospitality applications.

"We were the first to introduce an LED optimized for 50-watt halogen performance with the XLamp MT-G EasyWhite LED," notes Paul Thieken, Cree's director of marketing, LED Components. "Now, with the XM-L2 EasyWhite LED, Cree delivers the

same amount of light with the best color consistency in a package that is 70% smaller, reducing the system cost for LEDs in halogen-replacement."

Characterized at 85°C, the XM-L2 EasyWhite LED is available with 80 and 90 minimum color rendering index (CRI) options, correlated color temperatures (CCTs) ranging from 5000K to 2700K, and forward voltage configurations of 6V or 12V. Lighting manufacturers seeking ENERGY STAR qualification can take advantage of the XM-L2 EasyWhite LED's 'successor' status to the XM-L EasyWhite LED and use just 3000 hours of LM-80 data — half of what is normally required — for ENERGY STAR qualification.

Product samples are available now and production quantities are available with standard lead times.

www.cree.com

[/LED-Components-and-Modules/Products/XLamp/Arrays-Directional/XLamp-XM-L2-EasyWhite](http://www.cree.com/LED-Components-and-Modules/Products/XLamp/Arrays-Directional/XLamp-XM-L2-EasyWhite)

Cree increases stock repurchase program to \$300m

Cree's board has approved an increase in its stock repurchase program. The firm is now authorized to repurchase up to \$300m of shares, from 20 June 2013 through to the program's new expiration date on 28 June 2015.

Cree recently bought 2.1 million shares of its common stock under the program at an average price of \$47.11 per share (an aggregate

value of \$99.6m). There is hence \$200.4m in aggregate purchase price value remaining in the stock repurchase program.

The repurchase program can be implemented through open market or privately negotiated transactions at the discretion of management. The firm will continue to determine the time and extent of any repurchases based on its eval-

uation of market conditions and other factors.

The board has also authorized Cree to secure a working capital line of credit facility of up to \$150m, which will provide the firm with short-term flexibility to optimize its net investment return on its cash and investments while funding its general business needs.

www.cree.com

Cree introduces three-way LED bulb

Cree has expanded what it claims is America's best-selling LED bulb portfolio with the 3-Way Cree LED Bulb.

Unlike incandescent and prior LED alternatives with light levels that were only useful as two-way bulbs, the 3-Way Cree LED Bulb provides three light levels distinctly visible to the naked eye, delivering illumination for any application from task lighting to ambient lighting, says the firm. The three-way bulb emits warm,

incandescent-like light while consuming up to 90% less energy, it is reckoned. Available at The Home Depot for \$24.97, it is about half the cost of comparable LED bulbs.

"The 3-Way Cree LED Bulb is another example of Cree's commitment to providing consumers with choice and flexibility to encourage more rapid LED adoption," says Norbert Hiller, Cree's executive VP, lighting.

Giving consumers complete control over their lighting with a simple flip of a switch, the 3-Way Cree LED Bulb provides 320, 820 or 1620lm (equivalent to 30W, 60W and 100W incandescents) in one bulb in a soft-white (2700K) color temperature while consuming as little as 3W. The bulb lasts 25,000 hours, works in any orientation, and is backed by Cree's 10-year consumer warranty.

www.homedepot.com/cree

Cree launches 200 lumen per Watt XP-L LED, boosting performance by 50% as drop-in upgrade for XP-G

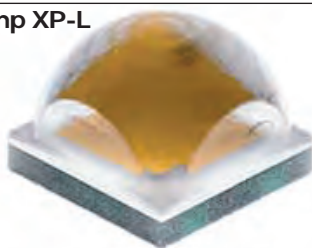
LED chip, lamp and lighting fixture maker Cree Inc of Durham, NC, USA has introduced the XLamp XP-L, which is claimed to be the first commercially available single-die LED to achieve efficacy of up to 200 lumens per watt (LPW) at 350mA. Delivering up to 1226 lumens in a 3.45mm x 3.45mm package, the XP-L enables an immediate performance increase of 50% or more as a drop-in upgrade for lighting designs based on XLamp XP-G LEDs.

"Its next-level performance enables us to create the next generation of light output and efficacy for our directional lighting products," comments Mike Joye, president of landscape lighting fixture maker Auroralight Inc of Carlsbad, CA, USA. "Since XP-L uses the existing XP footprint, we can expand our product lineup quickly and without the burden of increased development time and cost that would be expected for such a significant performance enhancement."

Cree claims that, as the brightest member of the industry's only family of high-density-class discrete LEDs, the new XP-L also touts the industry's highest optical control factor (OCF), a measurement of the impact that LED size and performance have on directional lighting applications. With its high OCF, the XP-L can enable lighting manufacturers to improve the performance of existing lighting designs in the XP footprint, reduce the size and cost of new designs, and create innovative new solutions to address applications ranging from lamps to stadium lighting, adds the firm.

Characterized and binned at 1050mA (85°C), the XP-L LED is available with a color rendering index (CRI) up to 90 and color temperatures ranging from 2700K to 8300K. As a 'successor' product to the XLamp XM-L2, lighting manufacturers seeking ENERGY STAR qualification can use just 3000 hours of LM-80 data, potentially saving up to

XLamp XP-L
LED



4 months in the approval process.

Product samples are available now and production quantities are available with standard lead times.

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Osram opens LED assembly plant in China

Second back-end plant supplements Penang, targeting Chinese lighting

In a further move to strengthen its position in the LED market, Germany's Osram has officially opened its LED assembly plant in Wuxi, China. The factory has a floor area of about 100,000m² and will employ as many as 2100 staff by 2017. Osram is investing a low three-digit-million euro amount to set up the plant. "With this step, we are not only expanding our fully loaded backend LED capacities but also boosting our presence in the world's largest single lighting market," says Osram Licht AG's CEO Wolfgang Dehen. "Asia, and particularly China, are key growth drivers for the global lighting and therefore the LED industry," he adds.

China accounts for more than 20% of the world's lighting market and has recorded fast growth over the past few years, particularly in the uptake of LED lighting technologies. The country's total general illumination market is expected to rise from about €15bn in 2013 to €23bn by 2019, while the market share of semiconductor-based



Product testing at Osram's new LED assembly plant in Wuxi.

products such as LEDs is forecast to surge from only 29% to more than 60%.

With the new LED assembly in Wuxi, Osram says that it will be in a better position to address that growth. The contracts for the plant's location were signed in May 2012, followed by groundbreaking that August. "Osram's new LED assembly plant will play a key role in forging Wuxi's LED industry value chain, and we believe operation of the plant will help Wuxi to become one of the foremost optoelectronic semiconductor bases in China, and

even Asia," stated Wang Quan, deputy secretary of Wuxi Party Committee and mayor of Wuxi.

Planned and run by the Osram Opto Semiconductors business unit, the factory is the firm's second back-end site where LED chips are assembled them into packages, adding to the existing site in Penang, Malaysia. Osram Opto Semiconductors also operates front-end chip production sites at its headquarters in Regensburg, Germany, as well as in Penang. The Wuxi plant will be capable of an annual output of up to several billion LEDs.

"Our business has always been a global business and, taking into account the size and growth prospects of the Chinese market, Wuxi is a perfect fit for our manufacturing footprint," reckons Osram Opto Semiconductors' CEO Aldo Kamper. "The plant will help us to further develop our professional know-how and understanding of our customers' products."

www.osram-os.com

Online LED Information Base for downloading technical specs

Osram Opto Semiconductors says that its new LED Information Base is an online tool for selecting LEDs for applications in the automotive, industry, consumer and general illumination sectors. Users can quickly and easily find suitable components and then obtain the specifications in digital form that they need for their design projects, says the firm.

The new online tool eliminates checking and copying down values from LED data sheets, since users can now download technical characteristics directly. The LED Information Base (LIB) online portal includes the complete portfolio of LEDs in the visible wavelength range. "Our database currently contains hundreds of product ver-

sions. It is being constantly updated and expanded," says Martin Moritz, who is in charge of the project.

Until now, technical product information for LEDs has been compiled in data sheets and delivered primarily mostly in pdf format. Product developers have had to make a note of the values and enter them in their own design tools. Characteristics such as changes in parameters as a function of temperature are presented in the data sheets as analog graphs. Product developers have then had to manually note the values in order to enter them into their own design tools.

However, in the LED Information Base, users simply select the

appropriate LED, click on the data they need, and receive the raw data as an Excel file for downloading. The data available includes current-dependent and temperature-dependent characteristics, emission characteristics and typical emission spectrums.

Osram Opto Semiconductors says that the LED Information Base provides product developers with access to all the information they need for their design calculations. It is located on the web with data that is easy to download and is regularly updated. All that is needed for password-protected access is online registration with name, company and email address.

<https://apps.osram-os.com>

Osram's low-profile, compact, rectangular mid-power LEDs increases design freedom via light guides

Osram Opto Semiconductors GmbH of Regensburg, Germany says that the low-profile rectangular shape of its new Synios E4014 LED enables emitted light to be injected into light guides so that a wide range of design ideas can be turned into reality. The mid-power LEDs also have a robust plastic package, a particularly uniform distribution of light, and what is claimed to be an excellent price-performance ratio. The LEDs are intended primarily for visually enhancing 'white goods' and for lighting systems in vehicles and displays.

The Synios' low height of only 0.57mm and its footprint of 4mm x 1.4mm provide a suitable basis for low-profile elongated luminaire and lighting designs, such as those for backlighting displays. The LEDs are not equipped with a lens, so they can easily be used for injecting light into light guides. The new E4014 opens up a range of design-oriented lighting solutions, such as integration in the glass shelving in



Osram Opto's new Synios E4014.

refrigerators and other white goods, car interior lighting, and strip lighting on the floors of buses and trains.

"Refrigerators and washing machines are not exactly renowned for their exciting designs," says Volker Mertens, marketing LED at Osram Opto Semiconductors.

"The new Synios is ideal for enhancing their looks and even meeting high requirements in terms of lighting design," he adds.

"For similar lighting tasks, but at a lower performance level, we already have the [3.0mm x 1.4mm x 0.8mm] Topled E3014 in our portfolio."

Where each of the two LEDs is used depends on the requirements of the particular application. If brightness and color fidelity are needed, then Synios at a brightness of 41lm (at a drive current of 100mA) and a color rendering index (CRI) of 80 is the right choice. If brightness is not as important, then the 70-CRI Topled E3014 (with 7.3lm at 20mA) is suitable. Power ratings are 0.5W for the Synios E4014 and 0.1W for the Topled E3014.

The beam angle for both LEDs is 120°. The color temperatures of Synios are between 4000K and 5000K and can therefore be tailored to the particular application.

The robust plastic package is one of the benefits of the new Synios, in addition to the uniform distribution of light, high efficiency, flexibility and long life of around 50,000 hours. In view of the intended applications, the ESD (electrostatic discharge) stability is 5kV (versus 2kV for the Topled E3014).

www.osram-os.com

Osram adds 90-CRI models to Duris S 5-LED range

Osram Opto Semiconductors GmbH of Regensburg, Germany has added to its Duris S 5 family of LEDs with two further models with color rendering index of more than 90, suitable for the home (e.g. installed in downlights or LED retrofit lamps).

The one-chip version of the new Duris S 5 (GW PSLMS1.CC) has luminous flux of 20.5lm at 65mA (typically at 3000K). Typical forward voltage is 2.9V. The two-chip version (GW PSLPS1.CC) has high luminous flux of 83lm at 150mA (typically at 3000K). Typical forward voltage is 6.35V. The package size for both is 3.2mm x 3mm.

"This product family now offers customers even greater flexibility in terms of performance, areas of application and technology," says Janick Ihringer, product manager



Osram Opto's new Duris S 5 LED.

for General Illumination. The previous Duris S 5 versions already had a high color rendering index of more than 80. The new 90-CRI LEDs are suitable particularly for applications where the colors have to appear as natural as possible. Their main use will therefore be in

the home. For example, light from the new Duris S 5 models make the colors of wooden dining tables and flooring look rich and natural, says Osram. Natural color rendering also plays an important role in shop lighting, whether for clothing or food.

The new LEDs are part of the Duris product family. The E, P and S series contain LED versions in different qualities of light and for all output ranges (high-power, mid-power and low-power) suitable for numerous lighting applications. A robust plastic package, a compact design and a particularly homogeneous distribution of light are other properties common to all members of the family, says Osram.

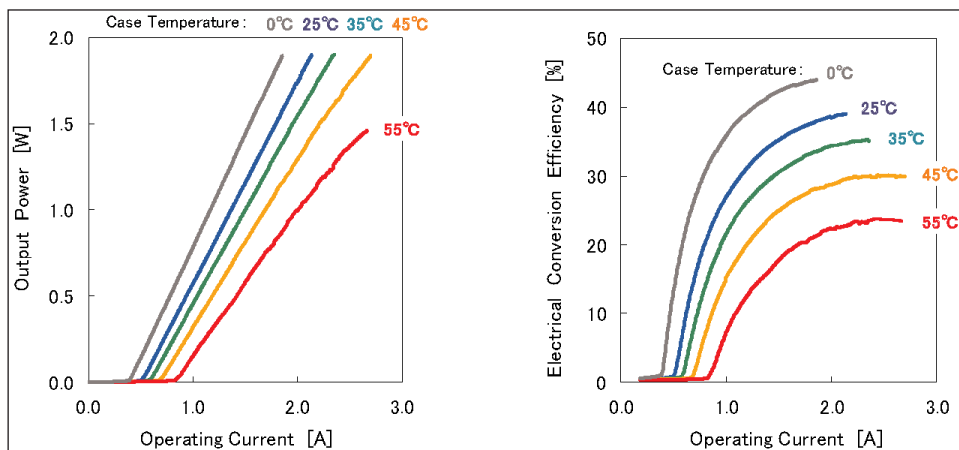
www.osram-os.com/duris

Mitsubishi Electric develops record 1.8W 9.0mm TO-packaged 638nm red laser for projectors

At the Laser Display Conference (LDC 2014) at National Chung Hsing University in Taichung, Taiwan (19–20 June), Tokyo-based Mitsubishi Electric Corp presented a 638nm-wavelength red laser diode (LD) with what is claimed to be record output power of 1.8W (under continuous-wave operation) in this package size (9.0mm TO-can) for projector light source applications.

Light sources for color projectors are conventionally lamps, but these are being replaced with solid-state light sources offering higher energy efficiency, better color reproduction and longer life. In particular, laser diodes deliver high output power while consuming low power because of their high power-conversion efficiency, says Mitsubishi Electric.

Previously, the output power of red laser diodes with wavelengths shorter than 640nm was insufficient for high-brightness projector applications at high temperatures. As a first step to overcome this limitation, Mitsubishi Electric applied specialized window-mirror structures and epitaxial growth technology to develop a laser diode, packaged in a 5.6mm-diameter transistor-outline can (TO-can), achieving 0.5W power output under continuous-



Output power (left) and conversion efficiency characteristics versus current.

wave (cw) operation. The firm then applied an improved laser diode structure (with optimized layer structure and emitting-region size) in a 9.0mm TO-can package to achieve what is claimed to be industry-leading output power of 1.8W at a 638nm lasing wavelength. Due to lasing at a short wavelength, luminosity as a red light source exceeds 220lm, meeting the demands for bright projector systems, says the firm.

Mitsubishi Electric also claims that the new 638nm red laser achieves industry-leading electrical conversion efficiency of 38% at 1.8W (at 25°C), helping to reduce

power consumption. In addition, due to using a large TO-can package with a diameter of 9.0mm, good heat dissipation allows a wide operational temperature range, e.g. emitting 1.8W (cw) over 0°C to +45°C and 1.3W (cw) above 55°C.

Mitsubishi Electric plans in future to enhance its new laser diode's high-power, low-consumption characteristics further, targeting commercial launch in the fiscal year ending March 2016, when demand for laser light sources for projector applications is expected to take off.

www.mitsubishielectric.com/semiconductors/products/opt/laserdevice

Emcore settles Nichia's patent infringement lawsuit

Emcore Corp of Albuquerque, NM, USA, which makes compound semiconductor-based components and subsystems for the fiber-optic and solar power markets, has settled the patent infringement case brought by Japanese LED maker Nichia Corp before the US District Court for the Eastern District of Texas.

In November 2011, Emcore exclusively licensed several of its non-core LED patents to Taiwanese LED maker Everlight Electronics Co Ltd. In April 2012, Everlight filed suit against Nichia, alleging infringement of Emcore's US Patent No. 6,653,215

that it had licensed. Since Emcore still owned the '215 patent, the complaint named Emcore as a mandatory co-plaintiff. The suit, however, is principally a dispute between Everlight and Nichia. Following a petition initiated by Nichia, on 11 February the US Patent and Trademark Office issued a Final Written Decision in which it found all claims of the '215 Patent to be unpatentable. In March, Nichia and Everlight agreed to dismiss the claims pertaining to Emcore's '215 patent from the lawsuit without prejudice.

In June 2013, Nichia filed a complaint against Emcore in the US District Court for the Eastern District of Texas alleging infringement of Nichia's US Patent No. 7,295,587 ('Semiconductor Laser Having Optical Guide Layer Doped for Decreasing Resistance'). The settlement now resolves the '587 lawsuit. Emcore acknowledges validity of that patent and pays Nichia damages. Nichia agrees to grant Emcore a non-exclusive, royalty-bearing license to the patent.

www.nichia.com
www.emcore.com

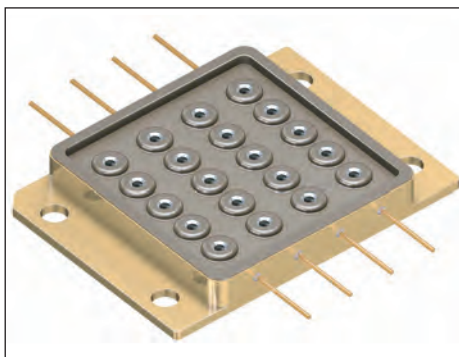
Osram introduces 50W compact multi-chip laser module for projector applications

Osram Opto Semiconductors GmbH of Regensburg, Germany has introduced what it claims is the first compact laser multi-chip package. The new PLPM4 450 module can pack up to 20 blue laser chips into a single butterfly package for projection applications.

Blue laser diodes in combination with a converter wheel (which converts part of the blue light into the two primary colors of red and green) are used as the light source for laser projectors. Up to now, to achieve sufficient brightness for professional applications, more than 20 individual laser diodes had to be combined.

Osram Opto says that, instead of taking the laborious approach and constructing a light source from individual laser diodes, in order to achieve high optical output in the PLPM4 450 it has optimized the chip parameters to double the single-chip output from 1.6W to 3.2W and also improved the thermal resistance of the module.

The PLPM4 450's 25.5mm x 35mm package accommodates four copper bars with up to five blue laser chips emitting at wavelengths of 440–460nm (with an emission surface of 16mm x 16.5mm) connected in series and operated at a current of 2.3A each. The multi-chip module can hence offer overall light output of 50W (at a



Osram's PLPM4 450 multi-chip laser.

package temperature of 50°C) from a typical electrical input of 165W, achieving efficiency of 30%.

Professional laser projectors can hence achieve brightness of more than 2000 lumen with only one packaged component. If several modules are installed in a projector, brightness levels far in excess of 5000 lumen are then possible (e.g. for devices in large conference rooms). Also, lifetime (until a 50% reduction in light) is up to 20,000 hours (depending on ambient conditions).



Osram Opto also says that, due to the special design and the improved optical output power of the individual chip, the price per optical watt can be reduced significantly. Another price benefit comes from the greatly reduced production costs — installation and alignment of a multi-chip package involve less time and lower costs than for a large number of individual metal can packages. The light from all the laser chips can therefore be colimated with a single lens array. "The innovative package simplifies the integration of laser technology in projectors considerably, enabling a breakthrough in the projection market," reckons marketing manager Stephan Haneder.

Volume production of the PLPM4 450 will start at the end of 2014. Samples will be available in the summer. The Osram Specialty Lighting business unit will also be integrating the multi-chip package in a new generation of phaser light modules for projection applications (where 'phaser' is a hybrid of 'phosphor' and 'laser'). Phaser light modules based on the multi-chip package will feature a particularly compact design and be capable of being used in combination, making them easy to integrate into existing projector architectures, says the firm.

www.osram-os.com

Ultra-thin 940nm infrared LED in small MIDLED package

Everlight Electronics Co Ltd (Taiwan's largest LED assembly manufacturer) has launched the IR92-01C/L491/2R ultra-thin 940nm-wavelength top-view infrared LED in a miniature MIDLED package. The small SMD surface-mount device has been developed for applications where high power output, narrow beam angle or available space is of concern.

The 940nm IR toped comes in a 2mm x 1.4mm MIDLED package

with an ultra-low thickness of 0.7mm, making it suitable for space-constrained end-products such as tablets, smart-phones etc. Along with a low forward voltage of 1.3V at a drive current of 20mA, a high output power of 25mW/sr at 70mA, and a narrow viewing angle of 45° for higher output intensity without lens, Everlight's IR92-01C Series is suited to IR data transmission applications such as remote

controls, proximity and optical touch sensors, night-vision cameras or high-tech touch panels. Other applications include light curtains or barriers, turbidity sensors and coin counters.

The IR92-01C Series in a MIDLED package is Pb-free, halogen-free and RoHS-compliant.

Samples are available now, upon request.

www.everlight.com

Daylight delivers first commercially available laser-based infrared microscopy platform

Daylight Solutions Inc of San Diego, CA, USA, which makes molecular detection and imaging systems based on mid-infrared quantum cascade lasers (QCLs) for scientific research, life science, industrial process control and defense applications, has delivered what it claims is the first commercially available laser-based infrared microscopy platform.

The microscope was delivered to Dr Rebekah Drezek's Optical Molecular Imaging and Nanobiotechnology Laboratory at Rice University in Houston, Texas. The system will initially be used to conduct -

*research into laser-based infrared microscopy for the optical diagnosis of breast cancer. "The combination of spectral tunability and rapid imaging in these wavelength ranges is unprecedented," comments Drezek.

Marketed under the brand name Spero, the microscope opens up research possibilities with chemical imaging and analysis on a real-time basis, says the firm. Powered by Daylight's broadly tunable QCL technology, Spero offers what is claimed to be a unique combination of visibility, instantaneous results in 'live mode', and a small resource footprint to easily fit into any lab or



Daylight 's new Spero laser-based infrared microscopy platform.

clinical setting.

The system's capabilities are further augmented by automated computational algorithms that enable identification and segmentation of complex chemical signatures. Applications range from label-free tissue and cell diagnostics in life sciences to materials analysis in industrial markets.

Drezek's initial phase of research,

funded by the National Science Foundation's Small Business Engineering Research Center Collaborative Opportunity (SECO) program, will seek to demonstrate the unique advantages of a tunable, mid-infrared laser-based system over that of a conventional Fourier transform infrared (FTIR) microscope. The program will also include an evaluation of the Spero's full and sparse data collection modes. In full data collection mode, a complete spectral scan can be collected in five minutes. This will be compared to the sparse data collection mode, in which only a small subset of key wavelengths are rapidly collected in seconds.

During the second phase of the research, the MCF10A and SKBR3 breast cell lines will be analyzed with the system to assess the predictive value of the infrared spectral data for normal, cancer, and cancer sub-types.

"We have always appreciated our close collaboration with Dr Drezek and Rice University," says president Paul Larson. "Her talented team will leverage the advanced capabilities of the instrument to make a very significant impact on the continuing fight against breast cancer."

www.daylightsolutions.com/spero

Daylight wins CLEO 2014 Innovation Award Grand Prize

Daylight Solutions has received the CLEO/Laser Focus World 2014 Innovation Award Grand Prize for Spero, the first laser-based infrared microscopy platform.

CLEO (the Conference on Lasers and Electro-Optics) in San Jose, CA (8-13 June) brings together researchers and industrial experts worldwide. The annual Innovation Awards recognize companies "that have made major contributions to advancing the field of optics and photonics through recently launched products and services".

Combining the latest high-power, broadband QCL sources and a new family of high-NA, wide-field objectives, it is claimed that Spero significantly outperforms existing infrared microscopes, such as Fourier transform infrared (FTIR), in traditional metrics, including spatial resolution, speed, signal-to-noise ratio, and field-of-view, while also enabling new functionality such as live video absorbance contrast imaging and rapid sparse wavelength data collection.

The award follows two other

awards for Spero at the Pittcon 2014 conference, where the microscope was named 'Top Pittcon Product' by Strategic Directions International Inc and was also nominated for the Pittcon Editors Awards.

Daylight's president & chief operating officer Paul Larson is accepting the award at the CLEO Plenary Session on 10 June in the San Jose Civic Auditorium. A live demonstration of the Spero microscope was given in Daylight's booth on the CLEO exhibit floor.

www.cleoconference.org

Tyndall and Cork Institute of Technology renew photonics and process analysis based MoU

Ireland's Tyndall National Institute (based at University College Cork) and the Cork Institute of Technology (CIT) have signed a new memorandum of understanding (MoU) to renew and expand their existing partnership.

The partnership forms part of a broader collaboration between the two institutions that is valued at over €50m to date. The new agreement will focus on delivering world-class research, providing highly skilled industry-relevant graduates to the workforce, and generating new businesses from innovative technologies. Tyndall, University College Cork (UCC) and CIT achieved success in the last series of European Union (EU) funding, reaching €75m collectively in more than 260 research projects (with an average success rate of 20%), and are actively pursuing the Irish government's target of winning €1.2bn via EU Horizon 2020 (the EU's new framework program for research and innovation for 2014-2020).

Photonics is a key focus of collaboration and research of CIT at Tyndall. The CIT research group CAPP (Centre for Advanced Photonics and Process Analysis), based at Tyndall, undertakes work on a diverse range of applications across telecoms, lighting, medicine, agriculture and robotics. As an integral part of the (Science Foundation Ireland (SFI)-funded Irish Photonic Integration Centre (IPIC) at Tyndall, CAPP joins the 100 researchers from four institutes developing new light-enabled technologies.

CAPP recently announced its participation in the EU Framework Programme 7 research project NISTAS (Non-Invasive Screening Of The Status Of The Vascular System). Working with Cork-based industry partners Epi-Light Ltd (which makes LED-based modules and systems) and Open Innovation Partners (a research commercialization firm) plus six other Euro-



Pictured Left - Right, UCC president Dr Michael Murphy, Tyndall National Institute CEO Dr Kieran Drain, Minister for Research and Innovation Sean Sherlock TD, and CIT president Dr Brendan Murphy

pean partners, the project aims to develop a new light-based medical instrument for the non-invasive and rapid diagnosis of cardiovascular illnesses that is inexpensive and portable. By 2050, the population aged over 80 is expected to have increased by 170%, and cardiovascular diseases are by far the greatest cause of death (over 50%) in this age group.

Tyndall and CIT's NIMBUS Centre for Embedded Systems Research have worked on several national and international projects that have looked to improve energy efficiency and demand using technologies such as wireless sensor networks and embedded systems, energy harvesting, auto-commissioning and simulation models. These have taken advantage of the extensive test beds established in the city, including CIT's national test bed for micro-generation.

"The Government has targeted €1.25bn in EU funding under the European Horizon 2020 program and it will be programs such as CIT@Tyndall that will play an important role in securing this funding to drive research and innovation both nationally and internationally," comments Seán Sherlock

TD, Ireland's Minister for Research & Innovation.

"After 15 years of collaboration which has enabled us to utilize the existing infrastructure of both institutions, we are delighted to have renewed and expanded our partnership with CIT," comments Tyndall's CEO Dr Kieran Drain. "The pro-

gram has proved very successful, and collaborations with centres such as CAPP and NIMBUS have a proven track record of delivery since their inception. We are focused on delivering programs that will drive maximum economic impact and accelerate the growth of new business. With 10 currently active projects worth over €5m, we are looking forward to building for the future," he adds.

"The CIT@Tyndall program has enjoyed great success and has gone from strength to strength since it was signed in 2008," notes UCC president Michael Murphy. "We are the only two Irish academic institutions that offer a joint degree program, and the existing memorandum of understanding has enabled CIT and UCC to collaborate closely on EU projects," he adds.

"The CIT-Tyndall collaboration and broader spirit of cooperation has been extremely important in furthering the research capabilities and industry partnerships of both CIT and UCC," states CIT's president Brendan Murphy.

www.tyndall.ie

www.cit.ie

www.epi-light.com

www.openinnovationpartners.com

POET provides update on 100nm initiative, process equipment upgrade, and technology design kits

100nm targeted by end-Q2/2014; upgraded MBE system growing longer-wavelength devices; TDKs available by end-Q3/2014

POET Technologies Inc of Toronto, Canada — which, through subsidiary OPEL Defense Integrated Systems (ODIS Inc) of Storrs, CT, USA, has developed the proprietary planar optoelectronic technology (POET) platform for monolithic fabrication of integrated III-V-based electronic and optical devices on a single semiconductor wafer — has issued a progress update on its 100nm initiative, on the upgrade of its molecular beam epitaxy (MBE) system, and on its technology design kit for the Planar Electronic Technology (PET) subset of the POET process.

100nm initiative

This milestone (M-8) is associated with reducing the feature size of key POET devices to the 100nm range in scale. POET had previously achieved sub-200nm scaling, as announced in first-quarter 2014. "While work progresses to drive down feature size further, our technical team now believes that it will achieve this milestone in the near-term," says the firm.

Among the technical challenges addressed by the team are short-channel effects and the development and implementation of a novel technique based on using a non-gold-based contact, without liftoff, to achieve selfalignment. This results in a general digital device format for III-V technologies. Many of these processes have been captured as new intellectual property for the firm by the submission of patent applications.

"The team has worked relentlessly through multiple hurdles on its way to completion of the 100nm milestone," notes executive chairman & interim CEO Peter Copetti. "The scale-down to sub100nm scale will demonstrate our ability to fabricate competitive digital devices with III-V materials to a point that has never been demonstrated before,"

he believes.

The technical team has targeted the end of second-quarter 2014 for completion of this milestone.

Upgraded MBE

The MBE system is a key piece of process equipment on the POET pilot line. Earlier this year, the firm announced that there was a requirement for the MBE system to be taken off-line for maintenance, as well as for source material replenishment and a major upgrade. In anticipation of this, the firm used it to produce all material required for the 100nm initiative, ahead of the scheduled outage.

As anticipated, the upgrade work required a total of two months of off-line work. This scheduled work is now completed, and the MBE system is back in service, growing wafers for use in further POET device work.

"With the old MBE system, we had demonstrated the short-wavelength optical capabilities of our process, mainly for data-center applications," notes chief scientist Dr Geoff Taylor. "With our newly upgraded MBE system, our capabilities have expanded to fabricating optical devices with long wavelengths. This is critical for our POET offerings in the long-haul, networking and optical equipment market."

With our newly upgraded molecular beam epitaxy system, our capabilities have expanded to fabricating optical devices with long wavelengths. This is critical for our POET offerings in the long-haul, networking and optical equipment market

PET technology design kit (TDK)

This PET/TDK milestone (MS-12) focuses on devices requiring only the electronic subset of the POET process; PET offers lower-cost and simpler process fab options for applications that do not require the full POET optical feature set. The PET/TDK allows the firm to deliver its technology to fab partners and customers, and enable further innovation to integrate both analog and digital functions together — an application that is not possible currently using silicon CMOS.

The PET/TDK milestone is progressing well, and as planned, says the firm. As noted previously, the addition of Daniel DeSimone to the team has allowed this activity to remain on track, while other activities progress in parallel.

Moving PET/TDK forward requires optimizing the process technologies and devices using computer-aided design (TCAD) simulation. Specific TCAD efforts focus on complementary heterostructure field-effect transistors (HFETs) and bipolar transistors (HBTs). This design basis will support complementary HFET (CHFET), bi-CHFET, bipolar and thyristor device fabrication.

For CMOS technologies (both existing and on the roadmap), PET/TDK models will be available to third parties around the end of Q3/2014.

"While timelines have had to accommodate challenges in our drive to 100nm, I am encouraged by the significant recent progress, especially in parallel with our PET/TDK achievements," says Copetti. "Our potential partners and customers have noted this significant progress, and this has allowed me and my executive team to have very detailed discussions with them under non-disclosure agreements, many of them ongoing at this time."

www.poet-technologies.com

Picometrix announces sample availability of 10G APD ROSA

Picometrix LLC (a subsidiary of Advanced Photonix Inc) has announced sample availability of its avalanche photodiode (APD) receiver optical sub-assembly (ROSA). General product availability is planned for third-quarter 2014.

The AT-10D ROSA is an XMD-compliant form factor for use in high-performance 10Gbps transceivers and transponders for high-speed data and telecoms applications and the emerging 10G fiber-to-the-home (FTTx) markets. The AT-10D utilizes patented APD technology that provides high bandwidth and sensitivity over temperature in a low-cost, industry-standard package. The firm plans to provide a suite of its APD products to support a market that will increase at a compound annual growth rate

(CAGR) of 33% to over \$160m by 2017, according to industry analysts.

"We are leveraging our core APD technology to support our customers' needs as the demand for higher bandwidth moves from the long-haul and metro markets into the enterprise and FTTx markets," says Rob Risser, general manager of Picometrix and chief operating officer of API. "The AT-10D represents our next-generation; low-cost package targeted at high-volume and high-growth 10 Gbps markets," he adds. "Our product family plans include both 2.5 and 10Gbps APDs in front-side and back-side illuminated configurations with standard packaging options, including TO-46, chip-on-carrier and chip-on-tape configurations."

www.picometrix.com

IN BRIEF

Advanced Photonix prices public offering to raise \$2.5m

Advanced Photonix of Ann Arbor, MI, USA (which designs and makes APD, PIN, and FILTRODE photo-detectors, HSOR high-speed optical receivers, and T-Ray terahertz instrumentation) has priced an underwritten public offering of 5,391,304 shares of its Class A common stock at \$0.53 per share.

The firm also granted underwriter B. Riley & Co LLC a 30-day option to purchase up to an additional 808,696 shares on the same terms and conditions.

Advanced Photonix plans to use the net proceeds of about \$2.5m to reduce its indebtedness and pay certain related fees.

www.advancedphotonix.com

QD Laser and NanoQuine develop wearable see-through display laser eyewear based on retina imaging

QD Laser Inc of Kanagawa, Japan and the Institute for Nano Quantum Information Electronics (NanoQuine) at the University of Tokyo have announced the development of wearable see-through display Laser Eyewear (LEW) based on laser retina imaging optics, marking what is claimed to be a significant milestone for daily-use smart glasses. The proof-of-concept model was exhibited at the 2014 Open House of the Institute of Industrial Science, the University of Tokyo (6–7 June).

A variety of wearable smart devices such as head-mounted displays and smart glasses are now being developed worldwide. However, almost all adopt easy-to-attach liquid crystal displays (LCDs), with some having been commercialized.

Proposed early in the 1990s, laser retina imaging exhibits high brightness, high color reproducibility and wide viewing angle to provide an image at any position and with any

size (since the laser scanning system has a very wide horizontal viewing angle of 60° or more). Also, since the image is projected onto the retina after converging the light beam in the entrance pupil of the observer, so-called Maxwell view optics enables focus-free viewing (i.e. picture clarity is independent of the individual visual power, whether short-sighted or far-sighted). Despite such advantages, laser retina imaging displays are yet to be commercialized, due mainly to the design difficulty.

The Laser Eyewear is based on the original laser imaging optical system, where red/blue/RGB (i.e. red, blue, and green) semiconductor laser light is reflected and scanned on a MEMS mirror to project an image through the pupil onto the human retina. This also achieves completely see-through characteristics (indispensable for augmented reality). The principle of the laser retina imaging optics allows smaller size (162mm

wide for the proof-of-concept model, one of the smallest in head-mounted displays and smart glasses), lower power consumption, and lower cost than any other existing devices based on LCDs, it is claimed, opening up the path to consumer devices (i.e. daily-use smart glasses with a natural fit). QD Laser's technology helps to provide eyewear comparable to daily-use glasses in terms of size, weight and fit by miniaturizing individual functional elements such as the lasers, MEMS, and optics.

QD Laser is to continue further development of the Laser Eyewear (LEW) in terms of size and power consumption. It plans to release wired LEW as a support tool in the workplace by the end of 2015, and to release consumer-oriented wireless LEW as daily-use information devices by the end of 2017.

www.qdlaser.com

www.nanoquine.iis.u-tokyo.ac.jp

NeoPhotonics' revenue grows 22% year-on-year to \$68.2m in Q1/2014

100G deployments driving growth as access products ramp down

For first-quarter 2014, NeoPhotonics Corp of San Jose, CA, a vertically integrated designer and manufacturer of both indium phosphide (InP) and silica-on-silicon photonic integrated circuit (PIC)-based modules and subsystems for high-speed communications networks, has reported revenue of \$68.2m, down 8% on \$74.4m last quarter but up 22% on \$56.1m a year ago (and the firm's highest ever Q1 revenue).

There were three 10%-or-greater customers:

- Alcatel-Lucent at 13% (the same as last quarter);
- Ciena 14% (down from 16%); and
- China's Huawei Technologies 35% (up from 30%).

Geographically, revenue mix was:

- 52% from China (up from 47%);
- 20% from the Americas (down from 23% last quarter);
- 7% from Japan (down from 9%);
- 21% from the rest of the world (level with last quarter).

The Speed & Agility product group contributed \$49.8m (73% of total revenue), up \$13.7m year-on-year (from 64% of total revenue).

Of this, High Speed products (i.e. 100G and to a smaller extent 40G) contributed \$28.3m (42% of revenue), up 29% on a year ago (from 39% of revenue). However, this is inclusive of the acquisition (at the end of Q1/2013) of LAPIS Optical Components Unit (OCU), a designer and manufacturer of lasers, laser drivers, photodiodes and amplifiers for high-speed networks (now renamed NeoPhotonics Semiconductor), which has boosted the firm's 100G product portfolio.

The Access product group contributed \$14.3m (21% of total revenue), down \$1.4m year-on-year.

On a non-GAAP basis, gross margin was 22%, down on 23.1% a year ago and (due mainly to the impact of annual price negotiations) down on 27.5% last quarter.

Net loss was \$9.5m (\$0.30 per diluted share), up from \$1.8m (\$0.06 per diluted share) last quarter and \$5.3m (\$0.17 per diluted share) a year ago. Adjusted EBITDA was a loss of \$4.2m, compared to a profit of \$3m last quarter and a loss of \$1.8m a year ago.

Capital expenditure was \$2.1m, down from \$5.2m last quarter due to the completion of CapEx programs initiated in Q4/2013.

During the quarter, cash, cash equivalents and short-term investments hence fell

from \$75m to \$61.3m.

"Despite ASP [average selling price] declines from fourth-quarter pricing negotiations and the unfavorable impacts of product mix and of the timing of the Chinese New Year, during the quarter we witnessed increasing strength in both our Access shipments and in our backlog for 100G products," notes president & CEO Tim Jenks. "While the first quarter was a challenging one as we added 100G capacity and announced several new PIC-based 100G products, we are increasingly confident that NeoPhotonics is well positioned to benefit from the rapid growth in deployment of 100G systems worldwide," he adds.

"NeoPhotonics has made significant progress in scale, product range and focus on new products," believes Jenks. The integration of NeoPhotonics Semiconductor is now largely complete, with products integrating components from both NeoPhotonics and NeoPhotonics Semiconductor already shipping. Both the next-generation small-form-factor

The current 100G market strength will be bolstered by metro 100G growth, and then by data-center 100G growth

Integrated Coherent Receiver and the new CFP2 100G transceiver have increased NeoPhotonics Semiconductor content over its current-generation products. "China 100G deployments are underway, as witnessed by our increasing backlog for the second and third quarters of 2014, with backlog now building for the fourth quarter as well," notes Jenks. "Also in first-half 2013 we opened a new factory in Dongguan, China, with the result that we are currently well able to accommodate the increased volumes we are seeing in our business."

Consequently, during first-quarter 2014 NeoPhotonics' net inventory rose by \$3m to \$67.9m while days of inventory on-hand grew from 106 days to 110 days, as the firm builds inventory ahead of the higher expected 100G shipments over the next several quarters.

For Q2/2014, NeoPhotonics expects revenue to grow by more than 10% to \$73–78m. Gross margin should be 20–25% (an increase of 60 basis points over Q1 at the midpoint of the range due to ongoing operational improvements). Diluted net loss per share should improve to \$0.16–0.26.

CapEx is expected to be \$3–5m per quarter in the next few quarters. On an annual basis, CapEx is expected to be \$12–15m, "suitable to maintain our ongoing growth and production expansion needs".

"While we continue to see strength in Access over the near-term due to growth in China LTE backhaul and FTTX, we remain cautious on the mid- to long-term strength of this business," says Jenks. "There are a number of new entrants in the market which will continue pricing pressure, particularly as volume growth in the industry plateaus... We view this as a mature business at a plateau on volume and therefore with declining revenue over

► the mid-term," he adds.

"In an effort to align internal resources with long-term growth opportunities and improve our profitability, we are working to cull low-margin products and to reduce their support costs," notes Jenks. "In order to satisfy end-of-life terms on many of these products, it will take several quarters to ramp down production and, as a result, we expect this initiative to be an ongoing headwind to sales growth

through the remainder of 2014."

However: "As we complete our initiative to trim low-margin products from the product portfolio, we anticipate seeing an improvement to gross margins overall."

"Looking at the full year of 2014, we continue to believe demand is favorable for NeoPhotonics products, with continued potential in high-speed and coherent products in 100G around the world," reckons chief financial officer Ray Wallin.

"The current 100G market strength will be bolstered by metro 100G growth, and then by data-center 100G growth," adds Jenks. "We view these directions as a mega-trend for our business."

● With the anticipated filing of its Form 10-Q later before the end of June, NeoPhotonics should return to compliance with the filing requirements of the US Securities and Exchange Commission (SEC).

www.neophotonics.com

QinetiQ acquires Redfern Integrated Optics

OptaSense subsidiary's distributed acoustic sensing operation gains low-noise semiconductor laser technology

UK-based aerospace, defence and security technology provider QinetiQ Group plc has acquired Redfern Integrated Optics Inc (RIO) of Santa Clara, CA, USA.

Founded in 2000 in Australia before moving to San Francisco, CA, USA in 2003, RIO is a supplier of low-noise single-frequency (1550nm) narrow-linewidth laser optical transmitters (based on its proprietary PLANEX planar external-cavity-laser technology) for fiber-optic and remote sensing. Specifically, the firm has more than ten years' experience of delivering products to the fiber geophone, LiDAR (light detection and ranging) and distributed acoustic sensing (DAS) markets. Backed by a consortium of venture capital funds led by Southern Cross Ventures and Jolimont Capital, RIO is said to be the first company to develop a commercially viable semiconductor laser with sufficient stability for DAS applications. The firm's products provide what is claimed to be unique performance and reliability, enabling them to serve in harsh environments for both terrestrial and marine oil & gas, wind LiDAR, security, and space applications. Annual revenue in 2013 was \$5m.

QinetiQ says that the acquisition accelerates the development of its subsidiary OptaSense, whose platform technology converts any

standard fiber-optic cable into a distributed acoustic (or seismic) sensor by using laser interrogation to measure minute strains. Applications include oil & gas, defence & security, transport and utilities. Specifically, in infrastructure security, the technology is already in use to monitor 13,000kms of assets, principally providing leak detection and third-party intrusion detection for oil & gas pipelines. The RIO acquisition provides the OptaSense business with secure access to the engineering team developing current and future generations of highly coherent, low-noise semiconductor lasers.

"This acquisition of RIO is an important step in ensuring that OptaSense realizes its full potential as the global leader in distributed acoustic sensing," says QinetiQ's CEO Leo Quinn. "We are committed to supporting the high-growth businesses in our portfolio, accelerating their development as appropriate with acquisitions and partnerships. This acquisition has natural synergies with OptaSense and secures its access to a key supplier in the market," he adds.

"We have been working with RIO for many years and are impressed with the technical capabilities of the team," comments OptaSense's managing director Magnus McEwen-King. "Their products are

ideally suited to the distributed fiber sensing market, especially within the oil & gas sector where high performance and high reliability in harsh environments are essential. We see demand for RIO's laser products continuing to grow across the whole fiber sensing market... Through this acquisition we also gain the ability to shape the future developments of their products to further improve the technical performance of our DAS offerings, especially in the seismic monitoring market," he adds.

"OptaSense has made an excellent strategic acquisition and will greatly enhance RIO's ability to scale their unique technology across a broader range of markets and customers than would normally be accessible to a small start-up," believes Dr Larry Marshall, chairman of RIO and managing director of Southern Cross Ventures. "Our team and investors are pleased that RIO secured such an exceptional partner who will support our customers."

RIO will be integrated with OptaSense but will continue to use the RIO brand name. The transaction is expected to complete within the first half of QinetiQ's financial year and is subject to normal regulatory approvals.

www.rio-inc.com

www.optasense.com

www.qinetiq.com

Oclaro's quarterly revenue falls 7% as drop in 10G and pause in 100G outweighs 40G growth

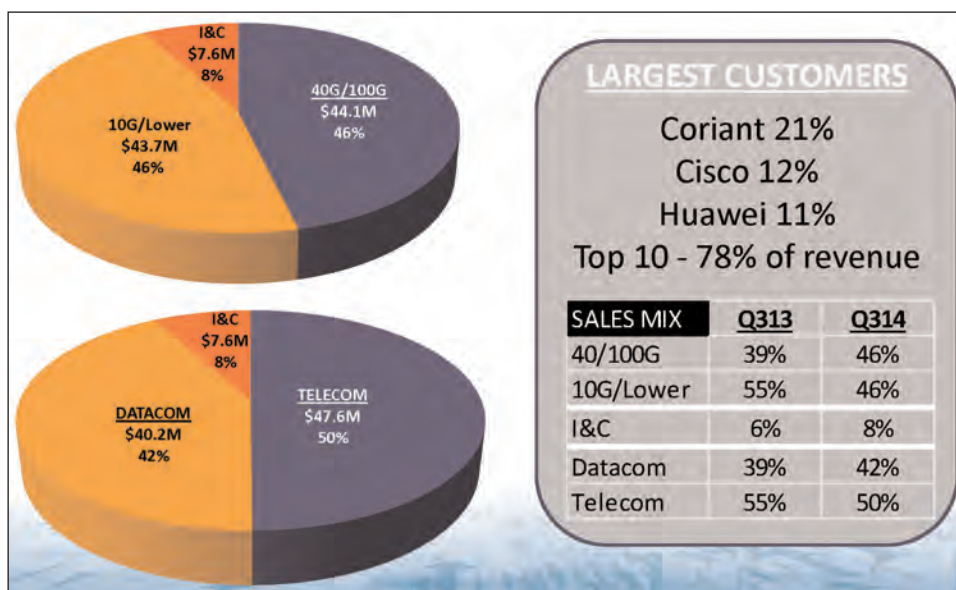
Margins to recover post-restructuring as 100G portfolio takes off

For its fiscal third-quarter 2014 (ended 29 March), Oclaro Inc of San Jose, CA, USA (which provides components, modules and subsystems for optical communications) has reported revenue of \$95.4m, down 7.3% on \$102.9m last quarter and 6% on \$101.5m a year ago (and at the lower end of the expected \$93-103m).

By application, revenue was 50% Telecoms and 42% Datacoms (which together comprised 46% 40G-and-above products and 46% 10G-and-lower products) plus 8% Industrial & Consumer (I&C).

The drop in total revenue was driven by declines of 12% in 10G-and-lower transmission products and 11% in Datacom products, partially offset by growth in 40G-and-above telecom products. "First, we saw lower revenue from vendor-managed inventory (VMI) from two of our largest customers for some of our 10G products," notes CEO Greg Dougherty. "Second, we experienced a bit of a pause for our 100G product on the client side after having strong shipment of our CFP in the December quarter [during which customers pushed Oclaro to deliver a large volume of 100G CFP for China Telecom]. Third, while we had strong customer demand for lithium niobate products, we did not ramp this business as we had planned. We do, however, expect shipments of our 100G coherent lithium niobate modulators to improve dramatically this quarter," he adds. "We had another record quarter for our 40G line-cards as we quickly increased our capacity to meet specific customer orders during the quarter."

The top 10 customers contributed 78% of revenue (up from 75% last quarter), with three greater than 10%. Coriant (formally the Optical Networks business of Nokia Siemens Networks) was again



Breakdown of Oclaro's fiscal Q3/2014 revenue by client, speed and application.

largest with 21% (up from 18% last quarter, including 3% from the merged Tellabs, due to growth in 40G telecom sales). Cisco contributed 12% and Huawei 11% of total revenue (up slightly from 13% and 10%, respectively, last quarter).

Of total revenue, customers in Europe contributed 34% (up from 32% last quarter), China 28% (up from 25%), Southeast Asia 15% (down from 16%), Americas 15% (down from 18%) and Japan 8% (down from 9%), indicating a further shift away from the Americas and Japan to Europe and China.

"While the March quarter results did not meet our expectations, we continued to make good progress on our turnaround plan," says Dougherty.

On a non-GAAP basis, gross margin was 12.3%, up on 6.9% a year ago but down from 17.1% last quarter (and well below the expected 13-17%).

"The March quarter is historically a tough quarter for gross margin due to the annual price negotiations with many of our major customers. This year was no different as we absorbed about 4% decline in pricing," says Dougherty. "In addition

to the expected price impact, gross margin was negatively impacted by certain product rationalization and production ramp decisions made during the quarter and issues related to management of our contract manufacturers," he adds.

"We had some execution issues in our lithium niobate modulator line, resulting in lower-than-expected revenues and much higher manufacturing cost," Dougherty says. "During the third quarter, we did make significant improvements to our lithium niobate processes, which will enable us to increase our shipment by 50% this quarter. The transition to a new process resulted in stranded inventory. Although adversely affecting us in the March quarter, we are now better positioned to address the significant demand for our 100G modulators," he continues.

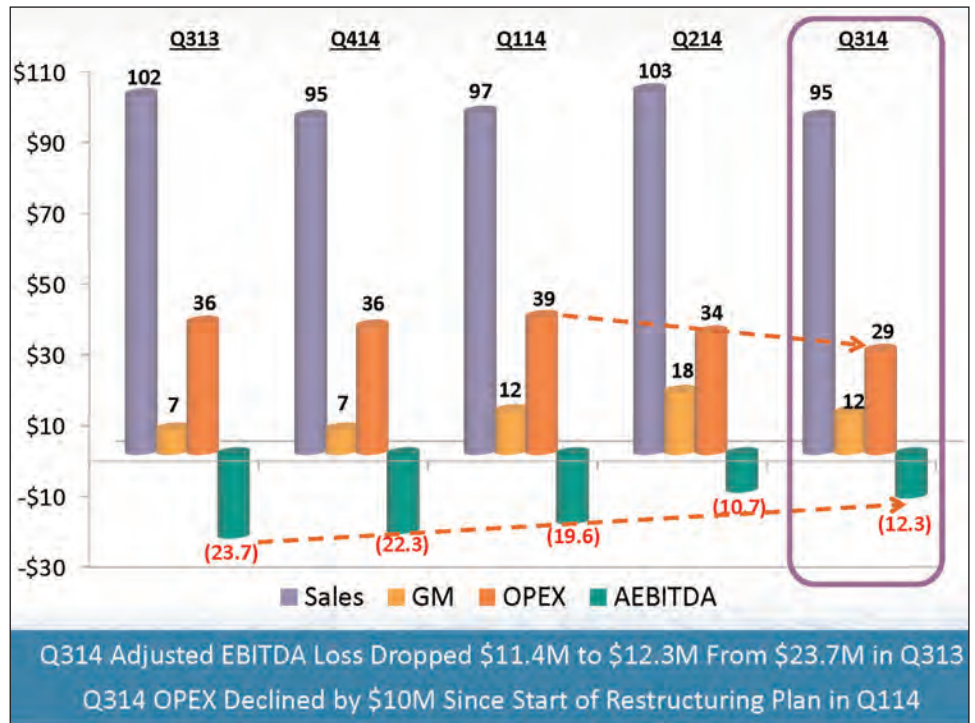
"We also addressed some contract manufacturing management issues relating mostly to start-up cost and variations as we ramped up our transferred line with Venture," says Dougherty. "We have taken steps to improve our management and discipline going forward. We did see

► marked improvement in production coming from Venture as they came up the learning curve. In fact, by the end of the quarter their execution was on par with our manufacturing partners in our internal sites," he adds.

"We also continued to focus on the rationalization of our product portfolio, emphasizing differentiation, market leadership and improved margin. We do not intend to chase markets or product areas and catch up unless we are really confident that we can quickly become a market leader," says Dougherty. "Historically, Oclaro has not done a very good job of integrating its numerous acquisitions or making hard decisions on product line," he comments. "One move that we made this quarter as part of our restructuring was to integrate into Japan all of our client-side pluggable optics products, which were previously designed and supported in San Jose. The move provides stronger management and focus for these products. This restructuring resulted in excess and obsolete inventory."

All this impacted gross margin by about 400 basis points compared with last quarter. Despite this, plus the lower revenue, gross margin has still improved on a year ago. "These actions masked the progress that we made in executing our restructuring plan, in particular our continued reduction of operating and manufacturing overhead costs," Dougherty says. Operating expenses have been cut by \$8m year-on-year, as restructuring actions continue to be ahead of schedule.

"Over the past several months, we have taken and will continue to take aggressive steps to integrate the company and improve our business processes," says Dougherty. Headcount has been cut from about 3000 in June 2013 to 2000 in early January and under 1400 by early April as 500 were transferred during the quarter from the pump product line to II-VI Inc of Saxonburg, PA, USA (which acquired the business last September), as planned. The original plan targeted a headcount of 1500 by July, but the current plan now



Trend in Oclaro's non-GAAP profit and loss.

targets 1350 by then (including planned new hires for 100G product development in the pilot-production line). Regarding ongoing site consolidation, during the quarter Oclaro sold its wavelength-selective switch (WSS) assets in Korea for \$1.4m (eliminating the need for necessary building restoration, equipment disposal and cleanup). Oclaro is now down to 11 sites and will be at 10 by July, as planned. In addition, floor space in the plant in Shenzhen, China was reduced after transferring one and half floors (the pump production line and staff) to II-VI.

"While some of these moves have resulted in negative adjustments impacting gross margin, they are strengthening our foundation for further improvement in our financial performance," says Dougherty.

Loss from continuing operations was \$17.9m, cut from \$27m last quarter (which had an \$8.3m interest charge from the exercise of the firm's convertible note) and \$31.6m a year ago. Adjusted EBITDA (earnings before interest, taxes, depreciation and amortization) was -\$12.3m, up from -\$10.7m last quarter but cut from -\$23.7m a year ago.

Capital expenditure (CapEx) was \$2.4m and the capital lease repay-

ment was \$1.2m (i.e. \$3.6m together). During the quarter, cash, cash equivalents, restricted cash and short-term investments have fallen from \$144m to \$122m.

For fiscal fourth-quarter 2014 (ending 28 June), Oclaro expects revenue of \$90–100m. Gross margin should rise to 12–16%. Adjusted EBITDA should be negative \$13–9m. "Revenue growth will be somewhat muted as our legacy product revenue comes down and our new 100G portfolio takes off," notes Dougherty.

Oclaro continues to see demand for 10G SFP products, supporting the large LTE build-out, primarily in China. "We were sold out last quarter, and likely will be again in the June quarter," notes Dougherty.

"We successfully ramped up our factory in San Jose to support firm customer orders [for 40G line-cards] for June," continues Dougherty.

"However, we were recently informed by our customers that their end-customer — a major North American carrier — has reduced their 40G needs for the second half of this calendar year," he adds. "The new levels being projected are more consistent with the lower run rates of the past year. We continue to expect ►

IN BRIEF

Firecomms shows 530nm long-reach RedLink transmitter and vertical packages

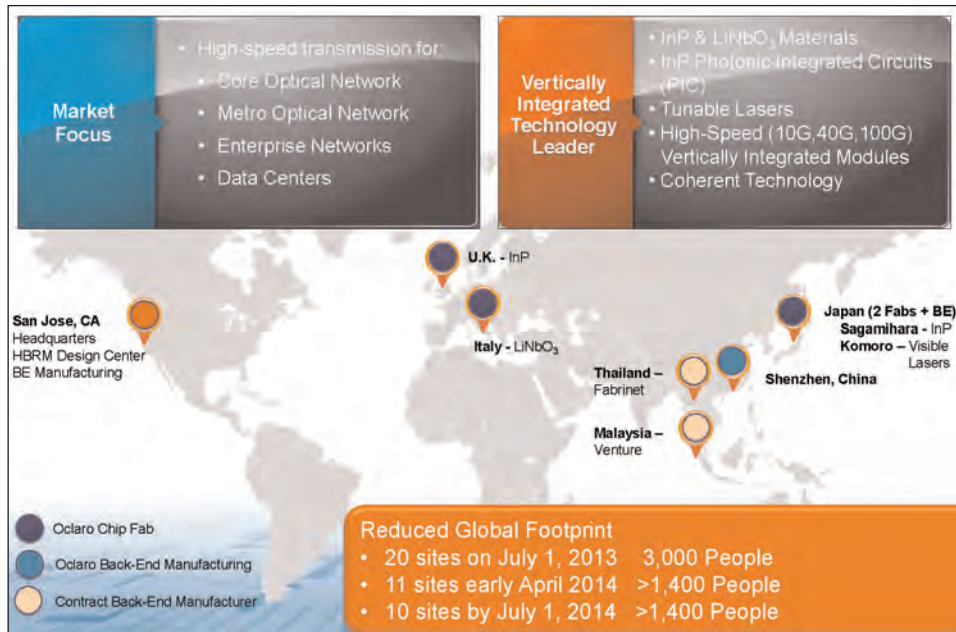
On the MEV booth at PCIM (Power Conversion Intelligent Motion) Europe 2014 in Nuremberg, Germany (20–22 May), Firecomms Ltd of Cork, Ireland and Tongxiang, China (which makes fiber-optic solutions and optical transceivers for communications networks) showcased its full line of RedLink, OptoLock and LC products. The firm highlighted its newest products: the 530nm DC–1Mb RedLink transmitter for applications requiring extended link lengths over plastic optical fiber (POF), and its vertical-style packages in which its full line of RedLink transmitters and receivers are available.

Operating in the green spectrum at 530nm, the FT01MHNG DC–1Mb transmitter is suitable for sensing, CANbus/RS485/RS232 links, gaming, Smart Meter or other industrial command and control applications. The firm says that the transmitter opens up new possibilities for the equipment designer to replace more expensive silica-based solutions with POF, remove repeaters that are no longer needed, and implement new designs requiring galvanic or optical isolation where costs or distances have been previously prohibitive.

Firecomms' vertically aligned RedLink industrial transmitters overcome the challenge of installing devices in large industrial enclosures where final cable assembly can be difficult when the products are horizontally aligned with the internal PCB.

Firecomms also showcased its full line of 125Mb and 250Mb transceivers in OptoLock and new compact LC connectors.

www.firecomms.com



Overview of Oclaro's consolidation of sites and reduction in headcount.

this business to roll down over the course of calendar year 2015."

On the datacom (client-side) of the business, Oclaro has seen a slight uptick in CFP. "We are also seeing the conversion from CFP to CFP2," says Dougherty. "Customers are ramping quickly to convert their interface slots from CFP to CFP2, and we began volume production in Q3 to support that. We expect to see increasing demand for these products to continue throughout this calendar year," he adds. "We are also developing new products such as CFP4 and QSFP28 to continue to maintain our product leadership for a 100G application and support the emerging needs for data-centers." R&D investment is 50% of revenue, focused primarily on 100G solutions for both the client side and line side, as 100G sales have doubled year-on-year.

Oclaro has also established a pilot production line in Caswell, UK (its primary wafer fab on the line-side), allowing it to co-locate early production with chip and package designers. "It allows us to ramp new, highly complex products more quickly, which results in better time to market and increased customer satisfaction," says Dougherty. The line has shown the expected benefits in making the tunable laser assembly for Oclaro's new tunable

SFP+ module. The line will also begin pilot production of the firm's coherent CFP2 product (launched in March) during second-half 2014.

Regarding restructuring costs, in the past two quarters Oclaro has incurred \$10m of its \$20–25m plan and expects the remaining \$10–15m to occur over the calendar year. Regarding normalizing working capital post-divestiture, about half of the \$25–30m adjustment was made in the March quarter, and most of the rest (\$12–17m) should be reflected in the June quarter. CapEx and capital lease needs remain at \$4–5m per quarter. "We will need to continue to fund our adjusted EBITDA losses until we achieve breakeven," says chief financial officer Pete Mangan. In early April, Oclaro established a \$40m working capital line of credit with Silicon Valley Bank, but does not expect to use the facility this year.

Oclaro remains on track to achieve its adjusted EBITDA breakeven target (based on quarterly revenue of \$110m, gross margin of 20%, and operating expenses of 25%) by the December quarter, reckons Mangan.

"Execution of the restructuring plan, combined with a considerable new product momentum, gives us good reason to believe that our turnaround remains on track," says Dougherty.

www.oclaro.com

IQE joins €23m VIDA program to establish Europe-based high-volume supply chain for VCSELs

Aim is to bring manufacturing to level comparable to LEDs and CMOS

Epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK has joined a new consortium to establish a pan-European supply chain capability for the high-volume production of vertical-cavity surface-emitting lasers (VCSELs) for infrared illumination, data communications, gesture recognition and industrial heating applications.

The program's aim is to establish a Europe-based production capability to bring VCSEL manufacturing to a level comparable to LED and CMOS manufacturing. By bringing together existing high-volume production facilities at IQE, along with key end-users, the consortium will deliver an end-to-end production supply chain offering a significant reduction in the cost-per-function for VCSEL devices by reducing gallium arsenide (GaAs) processing costs whilst increasing device performance.

IQE says that VCSELs are key enabling technologies for a wide range of applications where demand is proliferating rapidly as this type of laser becomes the device of choice for many high-volume applications. These include:

- gesture recognition, for gaming and non-contact navigation (e.g. TV, smartphone, tablet);
- depth imaging for 3D vision, using time of flight (ToF) technology, driving the next wave of handset innovation for new phones;

- production-line heating automation, for which significant operating efficiencies can be achieved using VCSEL technology with applications requiring tens of millions of devices;
- low-energy optical storage and fast switching in high-capacity data centers, servers and ultra-high-speed computing;
- high-speed datacoms, including active optical cables (AOC);
- ultra-high-density magnetic storage using heat-assisted magnetic recording (HAMR);
- illumination for IR cameras for security, safety, night vision;
- other industrial heating applications, including paint curing and commercial print shops; and
- cosmetics and healthcare, including hair removal, anti-wrinkle, blemish reduction.

IQE says that it has already demonstrated advances in VCSEL technology including an established 100mm VCSEL process, which has been enhanced by the launch in March of its 150mm VCSEL wafer products for high-volume applications.

The €23m VCSEL Pilot Line for IR Illumination, Datacom and Power Applications (VIDA) program, whose partners include IQE, Philips, STMicroelectronics, Sick and Sidel, will receive funding under the European Commission's ENIAC program, with IQE receiving significant support from the Welsh

Government.

A key impact of the project will be for Europe to secure a leading global position in what is considered to be a vital and rapidly growing segment of photonics.

"By working with key European partners to establish full pilot manufacturing capabilities for high-volume production, we will bring the same principles and economies of scale that apply to LED and CMOS processes, to photonics applications employing VCSELs," says IQE's CEO Dr Drew Nelson.

"IQE has built a powerful technology platform for VCSELs, and recent announcements on our new 150mm process — coupled with achievements such as record low-power consumption and record high-speed data transmission rates — are testament to the strength that IQE will bring to this consortium," he adds.

"IQE offers a strong track record in the manufacture of compound semiconductor wafers and laser devices, and the consortium also includes a number of end customers who have and will expand the design of VCSELs into their existing and new families of products. The consortium represents product commercialization across a diverse range of applications of VCSELs, demonstrating the great versatility of the technology."

www.iqep.com

JDSU announces \$100m stock repurchase program

Optoelectronic chip and module maker JDSU of Milpitas, CA, USA says that its board of directors has authorized a program to repurchase up to \$100m of the firm's common stock through open market or private transactions between now and 27 June 2015 (the end of fiscal 2015).

JDSU generated \$58.3m in free cash flow during the first 9 months

of fiscal 2014. As of 29 March, Emcore had \$926.2m in total cash.

"We have achieved 30 consecutive quarters of positive operating cash flow in varying macroeconomic and industry conditions," says president & CEO Tom Waechter. "Our strong balance sheet and our expectations for future cash flow generation provide JDSU the flexibility to enhance

shareholder value through share repurchases while continuing to invest in future growth and in strategic business development opportunities," he adds.

The timing of repurchases and the number of shares repurchased will depend upon business and financial market conditions.

www.jdsu.com

Finisar reports seventh quarter of revenue growth to record \$306m

Year-on-year growth of 36% in datacoms outweighs drop in telecoms

For its fiscal fourth-quarter (ended 27 April), fiber-optic communications component and subsystem maker Finisar Corp of Sunnyvale, CA, USA has reported its seventh consecutive quarter of sequential revenue growth, to a record \$306m (up 4.1% on \$294m last quarter and 25.7% on \$243.4m a year ago). Full-year fiscal 2014 revenue was a record \$1156.8m (over \$1bn for the first time), up 23.8% on fiscal 2013's \$934.3m due to datacom product revenue rising by 39.1% despite for telecom product revenue falling by 2.5%.

Quarterly revenue for telecom products was \$83m, up 4.4% on \$79.5m a year ago but down 0.7% on \$83.7m last quarter, driven primarily by the impact of the full three months of the annual price reductions for telecom products that typically take effect on 1 January. Revenue for datacom products was \$223m, up 6% on \$210.3m last quarter and 36% on \$163.9m a year ago, due mainly to continued strong demand for 10Gb/s or faster Ethernet transceivers and for transceivers for LTE wireless applications.

"Finisar's revenue is driven primarily by growth in worldwide demand for bandwidth to handle the ever-increasing distribution and use of video, images and digital information," says executive chairman Jerry Rawls. "Another important trend that is benefiting us is the growth in cloud services with larger data centers and an increasing number of longer, higher-speed connections. This increase in the optical content and data centers creates more opportunities for Finisar products," he adds.

On a non-GAAP basis, full-year gross margin has risen from 30.9% for fiscal 2013 to 35.9% for fiscal 2014. However, although up from 32.2% a year ago, quarterly gross margin in fiscal Q4 was 34.2%, but

(\$ Millions)	FY2013	FY2014
DATACOM	590.9	822.0
<i>Y/Y change</i>		39.1%
TELECOM	343.4	334.8
<i>Y/Y change</i>		-2.5%
Total	934.3	1,156.8

down on 37.2% last quarter (and below the expected 35.5%). This was due mainly to the annual price reductions for telecom products as well as the impact of key acquisitions whose products carry a lower gross margin than the corporate average. At the end of January (just one week into fiscal Q4/2014), Finisar acquired u2t Photonics AG of Berlin, Germany (which makes phosphide-based, high-speed receivers and photodetectors) for about \$20m. Due mainly to the acquisition of u2t, operating expenses have risen from \$63.2m last quarter to \$65.9m.

Full-year net income has more than doubled from fiscal 2013's \$63.4m (\$0.64 per diluted share) to a record \$159.2m (\$1.53 per diluted share) for fiscal 2014. However, although almost doubling from \$20.3m (\$0.20 per diluted share) a year ago, quarterly net income of \$37.5m (\$0.36 per diluted share) is down from \$45.5m (\$0.44 per diluted share) last quarter.

During the quarter, cash, cash equivalents and short-term investments fell by \$41.7m from \$554.7m to \$513m, principally due to the acquisition of u2t Photonics, an increase in accounts receivable of \$29.6m, and capital expenditure associated with the build-out of the second building at Finisar's new manufacturing site in Wuxi, China. CapEx rose again, from \$35.4m last quarter to \$36.5m (above the expected \$33m).

"We continue to develop and

release new products, which we expect will enable Finisar to expand our market share and continue to grow revenue," says CEO Eitan Gertel. For fiscal first-quarter 2015, Finisar expects an eighth consecutive quarter of revenue growth to another record of \$320–\$335m.

Gross margin should fall to about 32%, due mainly to the less favorable product mix (including sales of additional transceivers for wireless applications). Operating margin should be 10.3–11.3%. Earnings per diluted share are expected to be \$0.30–\$0.34.

CapEx is expected to rise further to about \$40m in fiscal Q1/2005, driven mainly by continued construction on the shell of the second building of the Wuxi production site. The shell should be completed by fall 2015. "We plan to immediately finish a couple of floors and to fit out additional space one floor at a time, as needed to accommodate growth," says chief financial officer Kurt Adzema. The new building should be occupied by the end of fiscal 2015, he adds.

"During Q4 we closed acquisition of Berlin-based u2t Photonics, and we are happy to announce that we have successfully completed the integration of their team into the Finisar organization," says Gertel. "The first major development program to utilize the former u2t Photonics is our CFP2 coherent module, where we are making excellent progress in our development. By utilizing our vertically integrated advanced indium phosphide laser, modulator and receiver components, we believe we will have the industry-leading product in terms of power consumptions and performance. To date, the market feedbacks have been very positive and more customers are indicating that they are planning to ►

► migrate to a pluggable CFP2 coherent for 100G and 200G coherent architectures," he adds.

"We are continuing to ship qualification samples of our tunable SFP+ to many of our new customers and we expect multiple key qualifications to be completed by the end of the year," Gertel continues. "As a result of our next-generation vertically integrated optics, we continue to believe we will have the lowest-power-consumption module of the industry, of about 1.5W. We expect to be in full production of this product in the second-half calendar year 2014," he adds.

"Our standard and low-profile twin WSS [wavelength selective switch] development is progressing very well and we are being qualified on multiple new line-cards at our customers," Gertel notes. "Due to our long history of developing innovative LCoS [Liquid Crystal on Silicon]-based WSS product, we are offering our customers a higher level of performance than they can obtain from other solutions. Our designs

are using one common platform that can address multiple markets and give our customer the flexibility of buying one product that can be deployed in many different applications and configurations," he claims.

"Our wireless product CPRI [Common Public Radio Interface] business continued to grow in Q4, and we expect this market to continue to grow due to accelerated LTE deployments around the world, but especially in China," Gertel says. "We have a very broad portfolio of short- and long-reach and different data-rate solutions for this market, and we are continuing to cost reduce this product and extend our portfolio while expanding production capacity to meet market demand.

"In datacom we have production released our 100G CFP2 LR4, and we expect this product to ramp throughout the calendar year. Due to our vertical integration of lasers and receivers, our module consumed the lowest power of any

other module in the market," he claims. "We are currently adding capacity in order to shorten our lead times and address opportunities to extend our market share," Gertel adds. "In the 40G market we have increased our market share and we believe we have the broadest portfolio in the market for both transceivers and active optical cables in single-mode and multi-mode configurations.

"In the parallel markets, we are continuing to win new customers for both our 10Gb/s and 25Gb/s per channel board-mounted optical engines, which are proprietary products for Finisar. These high-density solutions are now being used for high-performance computing, routers, interconnects and server applications," Gertel notes. "Currently, our main development focus is on our 25Gb/s per channel product, where we are expecting strong demand from multiple customers in the second half of 2014 calendar year."

www.finisar.com

Emcore expands DOCSIS 3.1 laser family with 1310nm laser module for CATV

Emcore Corp of Albuquerque, NM, USA, which makes compound semiconductor-based components and subsystems for the fiber-optic and solar power markets, has expanded its DOCSIS 3.1 laser line (launched in March) with the release of the Model 1616A DOCSIS 3.1, 1310nm DFB laser module for CATV applications. The 1616A is compliant with the new DOCSIS 3.1 standard, supporting operational bandwidth up to 1.2GHz.

DOCSIS (Data Over Cable Service Interface Specification) is the standard that facilitates the addition of high-speed data transfer over existing CATV systems for internet access through cable TV services. DOCSIS 3.1 is the latest version and is designed to deliver several new benefits to cable companies including greater capacity and speed.

It allows up to 50% more data throughput over the same spectrum to deliver up to 10Gbps downstream and 1–2Gbps upstream. DOCSIS 3.1 also reduces cost-per-bit for data delivery by improving the efficiency of spectrum use.

The 1616A module features Emcore's analog chip design and operates over an industrial temperature range from –40°C to +85°C. Inherent linearity minimizes degradation of broadcast signals, and it is fully Telcordia qualified.

"We are rapidly expanding our DOCSIS 3.1 laser module family to meet growing demand for this fast-emerging standard in the CATV industry," says Jaime Reloj, VP of business development. "The 1616A DOCSIS 3.1, 1310nm laser is a key enabling component for our customers to build DOCSIS 3.1-compliant

1310nm systems," he adds.

Emcore says that all its lasers use the highly linear, directly modulated distributed feedback (DFB) technology synonymous with the highest-quality, high-speed photonics that drove the wide-scale deployment of fiber optics in CATV networks, satellite earth stations and mobile phone antenna sites. The 1616A module extends that heritage of performance and reliability to DOCSIS 3.1 for 1310nm applications.

The 1616A DOCSIS 3.1 1310nm and 1752A DOCSIS 3.1 1550nm DFB laser modules were featured along with Emcore's complete line of CATV components and transmitter systems at the ANGA COM 2014 Exhibition & Congress for Broadband, Cable and Satellite in Cologne, Germany (20–22 May).

www.emcore.com

Semprius demonstrates first four-junction, four-terminal stacked solar cell using micro transfer printing process

Semprius Inc of Durham, NC, USA, which designs and makes high-concentration photovoltaic (HCPV) solar modules, has manufactured the first four-junction, four-terminal stacked solar cell using its proprietary micro transfer printing process (Nature Materials vol13 p593).

Semprius worked in collaboration with professor John Rogers and his team in the Frederick Seitz Materials Research Laboratory at the University of Illinois at Urbana-Champaign as well as researchers at partner Solar Junction Corp of San Jose, CA, USA, which makes III-V multi-junction solar cells for CPV based on dilute-nitride materials.

The new stacked solar cell consists of a three-junction microcell that is stacked on top of a single-junction germanium microcell using Semprius' high-speed micro transfer printing process, which enables the simultaneous formation of thousands of stacked microcells with very high yields. By using four junctions, the stacked cell is able to capture light across a broader portion of the

solar spectrum and therefore achieve efficiencies much higher than conventional silicon and thin-film single-junction solar cells. Initial trials yielded solar cells with measured efficiencies up to 43.9%. The process is capable of achieving solar cell efficiencies greater than 50% in the near future, reckons Semprius.

A key achievement of the project was the development of a new interfacial material that is placed between the top and bottom cell to minimize optical losses within the stack and hence optimize overall conversion efficiency. In addition, the new stacked cell has four terminals, rather than the standard two. This reduces the spectral dependence of the solar cell and increases its energy yield under normal operation in the field.

Semprius is a graduate of the US Department of Energy's SunShot Incubator Program. "This achievement is notable because it establishes a straightforward path to significant future increases in conversion efficiency," comments Dan

Friedman, manager of the National Renewable Energy Laboratory (NREL) III-V Multijunction Photovoltaics Group. "Increasing efficiency is critical to reducing the cost of solar energy because it helps drive down not only module costs, but also many other costs, including the cost of land, labor and wiring."

In 2012, Semprius announced the first mass-produced photovoltaic module exceeding 33% efficiency. In September 2013, it increased this record to 35.5%, as confirmed by Germany's Fraunhofer Institute for Solar Energy Systems ISE.

"Because the process we used is fully compatible with our current production processes, we believe this demonstration can be easily transferred to manufacturing," says VP of technology Scott Burroughs. Over the past two years, Semprius has deployed systems with strategic customers in six US states and eight countries around the world.

www.nature.com/nmat/journal/vaop/ncurrent/full/nmat3946.html
www.semprius.com

Emcore wins new long-term solar cell supply contract

Emcore Corp of Albuquerque, NM, USA has entered into a new long-term supply agreement with Space Systems/ Loral LLC (SSL, a subsidiary of Loral Space & Communications) to manufacture and deliver multi-junction solar cells for SSL's satellite programs. Representing the largest contract in Emcore's history, the new contract follows several other earlier long-term supply agreements between SSL and Emcore.

Emcore has been supplying SSL with solar cells for its satellite programs for 15 years, and in early 2013 delivered its millionth multi-junction solar cell to SSL (which will ultimately represent more than a megawatt of power delivered into space). Emcore says that its long-term business relationship with SSL

has been an important component in the growth of its Photovoltaics division since 1998.

"After so many years of working together, Emcore is not just a trusted supplier, but also a part of the extended SSL team," comments Vivian Mackintosh, VP, Supply Chain Management at SSL. "Emcore makes an important contribution to help SSL meet the demand for the world's highest power spacecraft," he adds.

"SSL has been a cornerstone of our satellite solar power business," says Dr Brad Clevenger, executive VP & general manager of Emcore's Photovoltaics Division.

"We value our long history as a key supplier of solar cells for SSL's space programs and are especially proud that our solar cells have con-

tinued to meet SSL's requirements for performance and reliability for 15 years," says Navid Fatemi, VP of business development of Emcore's Photovoltaics Division.

Emcore manufactures radiation-hard solar cells for space power applications. With a beginning-of-life (BOL) conversion efficiency nearing 30% and the option for a patented, onboard monolithic bypass diode, its multi-junction solar cells provide amongst the highest available power to inter-planetary spacecraft and earth-orbiting satellites, claims the firm. Since 2001 the firm's solar cells or panels have supplied primary power to 130 space missions.

www.sslmda.com
www.emcore.com

High-performance tunnel junctions for ultra-high-concentration multi-junction solar cells

Replacing GaAs with GaInP in cathode adds 1.3% to efficiency

The Group of III-V Semiconductors of the Solar Energy Institute at the Technical University of Madrid (Instituto de Energía Solar at Universidad Politécnica de Madrid, IES-UPM) has developed a highly conductive, high-bandgap p^{++} -AlGaAs/ n^{++} -GaInP tunnel junction (TJ) grown by metal-organic vapour phase epitaxy (MOVPE) with what is reckoned to be outstanding electrical performance, for application in ultra-high-concentration multi-junction solar cells. The TJ is intended to interconnect the top (GaInP) and middle (GaInAs) subcells of triple-junction concentrator photovoltaic (CPV) cells. In as-grown tunnel diodes, an average peak tunneling current density (J_p) of 996 A/cm² and a specific resistance of $7 \times 10^{-5} \Omega \text{ cm}^2$ were obtained, whilst record-performing devices exhibited J_p above 1050 A/cm².

However, it is well documented that, when introduced in multi-junction solar cell structures, tunnel diodes suffer significant degradation as a result of the thermal load associated with the growth of the

rest of the solar cell structure, which typically occurs at much higher temperatures as those used for the growth of the tunnel diode. In order to simulate this effect, researchers at IES-UPM annealed the samples which, after the thermal load, still exhibited high performance, with average J_p reduced to 235 A/cm² and specific resistance raised to $1 \times 10^{-4} \Omega \text{ cm}^2$. Despite this drop, these values are still high enough by far to allow the TJ to operate in the ohmic region up to about 15,000 suns with negligible voltage drop (see Figure).

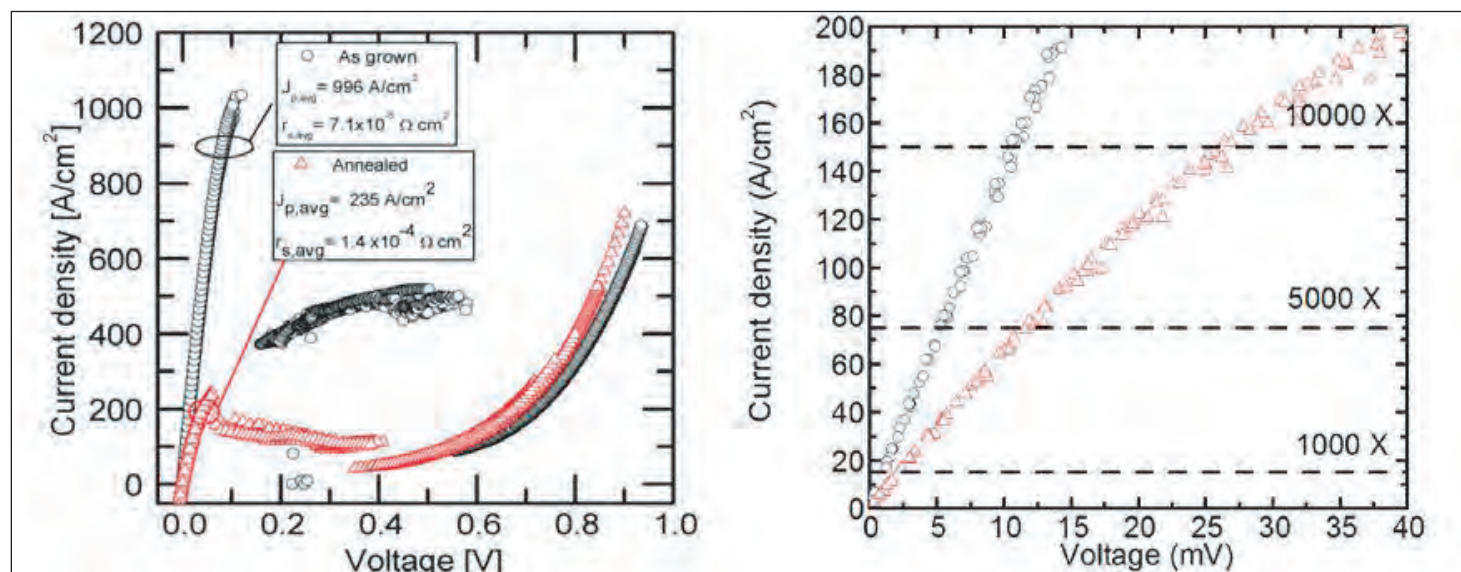
The design and manufacture of multi-junction solar cells — and accordingly tunnel junctions — for operation at ultra-high concentration (i.e. several thousand suns) is one of the research goals of the III-V Semiconductor Group at IES-UPM. In 2008, a GaInP/GaAs dual-junction solar cell with a record efficiency of 32.6% at 1026 suns was achieved [‘A 32.6% efficient lattice-matched dual-junction solar cell working at 1000 suns’, Garcia et al, Appl. Phys. Lett. 94 (2009) 053509]. The tunnel junction employed in that case

(a p^{++} -AlGaAs:C/ n^{++} -GaAs:Te) showed peak current densities of 2000 A/cm² and 300 A/cm² for the as-grown and annealed devices, respectively. (See also ‘Performance analysis of AlGaAs/GaAs tunnel junctions for ultra-high concentration photovoltaics’, I García et al, J. Phys. D: Appl. Phys., 45 (2012) 045101.)

With the aim of improving the transparency of that TJ design, the new TJ has been developed by substituting the GaAs-based cathode by a GaInP alloy. In fact, the optical improvement results in a gain in current of about 0.56 A/cm², which implies an improvement of 1.3% (absolute) in triple-junction cell efficiency — see ‘Highly conductive p^{++} -AlGaAs/ n^{++} -GaInP tunnel junctions for ultra-high concentration solar cells’, Barrigón et al, Progress Photovoltaics 22 (2014), p399.

Researchers at UPM believe that all these characteristics could make this TJ structure a key element in their quest to develop high-efficiency solar cells for operation at ultra-high concentrations.

www.ies.upm.es



Left: Average J–V measurements of p^{++} -AlGaAs:C/ n^{++} -GaInP:Te TJs fabricated with as-grown structures (black circles) and after thermal annealing at 675°C for 30 min (red triangles). Right: Magnification of left figure for low voltages where current densities equivalent to operation at 1000, 5000 and 10000 suns are drawn as references (dotted lines).

First Solar's sales rise 24% in Q1 to \$950m

Full-year guidance raised for gross margin, EPS & operating cash flow

For first-quarter 2014, First Solar Inc of Tempe, AZ, USA — which makes thin-film photovoltaic modules based on cadmium telluride (CdTe) as well as providing engineering, procurement & construction (EPC) services — has reported net sales of \$950m, up 24% on \$768m last quarter and 26% on \$755.2m a year ago (and above the expected \$800–900m). The increase is due mainly to achieving revenue recognition on the 139MW Campo Verde solar project near El Centro in Imperial County, CA, USA, which was constructed last year.

Despite R&D expenses rising from \$29.9m to \$38.8m, total operating expenses have fallen from \$108.1m a year ago to \$97.4m, since selling, general & administrative (SG&A) expenses have fallen from \$74.5m to \$58.7m.

Operating income has risen from \$61.2m a year ago and \$60.3m last quarter to \$139.3m.

GAAP net income has risen from \$59.1m (\$0.66 per fully diluted share) a year ago and \$65.3m (\$0.64 per fully diluted share) last quarter to \$112m (\$1.10 per fully diluted share, above the expected \$0.50–0.60), due primarily to the higher net sales, project cost improvements, and lower restructuring and asset impairment charges.

Compared with operating cash flow of +\$192m last quarter, cash flow used in operations was \$318m, related mainly to ongoing construction of projects that have not yet been sold. During the quarter, cash and marketable securities fell by \$385m, from \$1.765bn to about \$1.379bn. Net cash fell from \$1.5bn to \$1.2bn.

Based on Q1's results, First Solar has raised its full-year 2014 guidance for gross margin from 16–18% to 17–18%; for operating income from \$270–320m to \$290–340m; for earnings per fully diluted share from \$2.20–2.60 to \$2.40–2.80; and for operating cash flow from \$250–450m to \$300–500m.

"In the first quarter we demonstrated significant progress towards achieving the financial and operational targets we outlined at our recent Analyst Day," says CEO Jim Hughes. "We delivered strong earnings in the first quarter and are increasing our financial guidance for the year based on these results. We have also made significant progress in new bookings and continue to execute on our technology roadmap."

www.firstsolar.com

First Solar launches pre-engineered AC Power Block configurable system and Series 4 module at Intersolar Europe

First Solar has launched its modular AC Power Block solar power plant solution and its next-generation First Solar Series 4 cadmium telluride (CdTe) thin-film photovoltaic (PV) module. The firm showcased these and other solutions at the Intersolar Europe 2014 exhibition in Munich, Germany (4–6 June).

Purpose-built for power plant owners and developers seeking to minimize project risk and maximize energy production and revenue, the AC Power Block is a configurable system that can be scaled to address a wide range of project conditions. The pre-engineered system is available in modular units ranging from 800kW to 3.8MW. Based on First Solar's proven PV plant design and energy prediction model, the AC Power Block is backed by a first-year energy performance guarantee and a 25-year capacity warranty.

The new Series 4 module offers up to 8% more energy than conventional crystalline silicon modules with the same power rating, it is reckoned, and is compatible with advanced 1500V plant architectures. The Series 4A variant features a new anti-reflective coated glass, which enhances energy production. The module is backed by First Solar's 25-year Linear Performance Warranty.

"What matters most to our customers is reliable energy output achieved through proven technology. The AC Power Block and the Series 4 module are designed to deliver on those expectations," says Thomas Kuster, senior VP of product management. "As solar energy secures its place in the global energy mix, these offerings demonstrate First Solar's ability to deliver solutions that address our customers' specific needs," he adds.

"The underlying principle behind these new offerings and our existing power systems portfolio is an unwavering focus on a goal that we share with our customers in Europe and around the world: reliable generation of solar energy that is competitive within the framework of the region's energy generation portfolio," says Christopher Burghardt, VP for Europe. "Showcasing our industry-leading range of solutions at the region's premier solar energy exhibition underscores the market's importance to our growth strategy."

Also at Intersolar, First Solar spotlighted its Modules Plus System, which features fixed-tilt and single-axis tracker designs optimized for installation ease, project value, and operational reliability with First Solar's thin-film PV modules.

www.firstsolar.com

IXL opens Adelaide plant to assemble mounting structures for First Solar's Australian projects

The IXL Group has opened its new structure manufacturing plant in Adelaide, South Australia, which will enable it to assemble and deliver the mounting structures for First Solar's 155MW_{AC} utility-scale projects at Nyngan and Broken Hill in New South Wales (Australia's largest utility-scale solar projects).

The plant should create about 40 local jobs. To assist with the capital expenditure required to establish the plant, IXL also received support from the Automotive New Markets Program (ANMP), which is jointly funded by the Commonwealth and Victorian Governments and, in collaboration with the South Australian Government, assists automotive suppliers in diversifying their customer base and product range.

Historically, IXL's metal stamping and roll-forming capability supplied

the local automotive industry. Now, it has a dedicated business unit focused on producing structural components for solar projects. On a site of over 16,000m² with 4000m² building in Salisbury South in Adelaide's northern suburbs, IXL's new facility will produce about 100,000 mounting structures for the Nyngan and Broken Hill projects, using over 6000 tonnes of Australian-made steel. Production is underway.

"As the solar industry continues to grow in Australia, there will be an increasing need and demand for a reliable and efficient local supplier base," says Jack Curtis, First Solar's VP of business development for Asia Pacific. "Continued utilization of local suppliers will not only reduce the cost of delivering solar power to Australia, but it will also create local jobs, develop regional skills and

support more sustainable employment. Local procurement accounts for 56.3% of First Solar's total procurement spending on the Nyngan and Broken Hill projects, with over 450 direct construction jobs to be created and over \$66m spent on local equipment for both projects," he adds.

"As local automotive manufacturing declines, we have sought new business opportunities," says IXL Solar's general manager Claude Dagescy. "Making mounting structures for First Solar has been a natural extension of our business."

IXL previously provided First Solar with a framing capability for the 10MW Greenough River Solar Farm (GRSF) in Western Australia in 2012 (Australia's first utility-scale solar project).

www.ixlsolar.com.au

First Solar and Ingeniero to deliver diesel-PV hybrid solution to Rio Tinto Alcan bauxite mine in Australia

First Solar, international mining group Rio Tinto and Australian solar energy firm Ingeniero have agreed to develop the Weipa Solar Photovoltaic (PV) Project in Queensland, Australia. The project has received official confirmation of funding from the Commonwealth Government, with an initial commitment of \$3.5m from the Australian Renewable Energy Agency (ARENA) to be followed by up to \$7.8m for the second phase.

First Solar will use its expertise in utility-scale grid integration and plant control systems to offer a FuelSmart solution that provides maximum fuel savings while maintaining system reliability. Combined with Ingeniero's design, development and integration experience, the project will generate electricity for Rio Tinto Alcan's (RTA) Weipa bauxite mine, processing facilities and township on the Western Cape York Peninsula.

"Use of solar power will reduce Weipa's annual diesel consumption and its carbon dioxide emissions by around 1600 tons," says RTA general manager Weipa Operations Gareth Manderson, who notes that the hybrid diesel/PV solution will introduce to the site a reliable source of electricity, with low maintenance requirements.

Initial capacity will be 1.7MW, with the potential to expand by an extra 5MW after commissioning of the initial phase. The first phase will generate sufficient electricity to offset up to 20% of the daytime electricity demand, while reducing the diesel consumption for every MW-hr of electricity produced.

"PV complements the existing base-load generation by providing electricity in times of peak demand and reducing the amount of diesel fuel used," says Jack Curtis, First Solar's VP of business development for Asia Pacific. The project shows

how solar PV can be used to power the resources sector, he adds.

"Our collaboration on the Weipa solar PV project is validation of the strength of our ongoing partnership with First Solar," says Ingeniero CEO Steve McRae. "Working together, we can provide the extensive project experience required for off-grid applications and draw on the PV module technology and utility-scale experience provided by First Solar."

With completion scheduled for late 2014, First Solar will supply its thin-film PV modules and other balance of system components, in addition to providing operation and maintenance services for the duration of the project.

RTA will buy the electricity under a 15 year power purchase agreement (PPA). The project is seen as a step towards energy alternatives for remote mining operations.

www.riotintoalcan.com
www.ingeniero.com.au

First Solar to acquire technology provider skytron-energy

Expansion in Europe increases focus on integrated power solutions

First Solar Inc of Tempe, AZ, USA — which makes thin-film photovoltaic modules based on cadmium telluride (CdTe) as well as providing engineering, procurement & construction (EPC) services — has agreed to acquire skytron-energy GmbH of Berlin, Germany, a subsidiary of AEG Power Solutions, which provides utility-scale photovoltaic (PV) power plant management systems, operations and maintenance (O&M) services, data monitoring technology, and equipment to solar power plants throughout Europe. To date, skytron has installed monitoring and control systems in more than 600 plants across Europe with a total peak capacity of 5GWp, more than doubling First Solar's global portfolio of monitored assets. The acquisition is subject to consent by the German merger control authorities (Bundeskartellamt).

The acquisition supports First Solar's initiative to provide full, end-to-end energy solutions that vertically integrate solar services and solutions. It broadens its portfolio of energy assets operated and maintained by the company and

establishes a strategic opportunity to offer additional value-added services to both existing and new customers in Europe.

"skytron has a high-quality, operations-based foundation and a strong portfolio of valued customers," comments Bob Callery, First Solar's VP of operations and maintenance. "They bring considerable strategic value to our global O&M offering, as well as a pathway to expand our services across the entire solar value chain. Our combined expertise enables power plants to operate with the reliability of conventional generation resources, further establishing solar as a given part of the global energy mix," he adds.

"Joining First Solar assures that skytron will continue to provide customers leading-

skytron will operate as a subsidiary of First Solar, and will maintain its own brand identity. Employees will remain with the organization

edge monitoring, supervision and plant control solution systems," says Jeffrey Casper, chief restructuring officer of AEG Power Solutions and member of the board of directors. "skytron benefits from the reach of First Solar's powerful sales and service network, as well as its installed base."

The O&M market in Europe is projected to grow from 25GW in 2013 to 35GW by 2017, says Callery, citing a GTM Research report. skytron grew its monitored fleet by 37% in 2013 while First Solar grew its global monitored fleet by 176%. "There is clearly an opportunity for skytron and First Solar to provide innovative, reliable solutions and expertise to power plant owners," Callery adds.

According to Callery, skytron will operate as a subsidiary of First Solar, and will maintain its own brand identity. "skytron-energy employees will remain with the organization, and operations will continue without disruption," he adds.

www.skytron-energy.com
www.firstsolar.com

First Solar to build 150MW Tenaska Imperial West plant in Southern California

First Solar Inc of Tempe, AZ, USA has been selected by independent energy company Tenaska Solar Ventures (an affiliate of electric generation firm Tenaska of Omaha, NE, USA) to design and build the 150MW_{AC} Tenaska Imperial Solar Energy Center West project near El Centro, CA.

As well as employing its cadmium telluride (CdTe) thin-film photovoltaic modules and single-axis tilt technology, First Solar will provide full engineering, procurement & construction (EPC) on the plant. The project sits on about 1100 acres of previously disturbed land in Imperial County. Tenaska Impe-

rial West is the second solar project in Southern California's Imperial Valley developed, owned and managed by Tenaska. Last November, First Solar completed construction on the 130MW_{AC} Tenaska Imperial Solar Energy Center South power plant for the firm.

"We are pleased to continue our relationship with Tenaska," says Roger Bredder, First Solar's managing director for US Business Development. "This project will provide up to 800 jobs in the Imperial Valley at construction peak, and make a significant economic contribution to the local

community."

Bredder said that the highly qualified local workforce that built Tenaska Imperial South over the past two years will provide a strong pool of experienced workers familiar with First Solar's technology and construction methods.

First Solar has already started engineering and expects to begin construction later in 2014, with full commercial operation anticipated in 2016. San Diego Gas & Electric Company holds a 25-year power purchase agreement (PPA) for all electricity generated by Tenaska Imperial West.

www.tenaska.com

5N Plus renews First Solar CdTe supply & recycling deal until end-March 2019

New supply agreement covers all compound semiconductor needs

Specialty metal and chemical products firm 5N Plus Inc of Montreal, Québec, Canada has entered into new supply agreements with First Solar Inc of Tempe, AZ, USA covering the cadmium telluride (CdTe) thin-film photovoltaic (PV) module maker's compound semiconductor needs until end-March 2019.

5N Plus provides specialty purified metals such as bismuth, gallium, germanium, indium, antimony, cadmium, selenium and tellurium, and also produces related semiconducting compounds such as cadmium telluride (CdTe), cadmium sulphide (CdS) and indium antimonide (InSb) as precursors for the growth of crystals for solar, LED and eco-friendly materials applications. The firm also has fully integrated closed-loop recycling facilities.

5N Plus has renewed its existing CdTe supply agreement and CdTe by-products recycling agreement with First Solar up to end-March 2019. In addition, a new supply agreement broadly covering all of First Solar's other compound semiconductor needs up to end-March 2019, has also been concluded. First Solar has hence agreed to exclusively purchase from 5N Plus all the CdTe required by it on a worldwide basis for the manufacturing of solar photovoltaic modules.

"While we conceded competitive pricing, we believe that this will be largely compensated over the course of the next quarters by the increase of sales volume, providing us with a solid and predictable revenue stream for the next five years," says 5N Plus' president &

CEO Jacques L'Écuyer. "First Solar remains committed to reducing solar module cost and improving efficiency, and we intend to be their preferred solution for doing so through our close technical and commercial relationship... These new supply agreements will allow 5N Plus to benefit from continued growth associated with First Solar's leading position in the solar market," he believes.

"5N Plus has been and continues to be a critical supplier to First Solar," says First Solar's senior VP of global operations Tymen de Jong. "These agreements support our plans to increase the competitiveness of CdTe-based solar modules and are in line with our corresponding roadmap aimed at achieving this."

www.5nplus.com

5N Plus completes \$60m offering of convertible debentures

5N Plus has completed its bought-deal offering of convertible unsecured subordinated debentures worth \$60m (announced on 28 May). The debentures were offered at a price of \$1000 per debenture by way of short-form prospectus in each of the provinces of Canada.

5N Plus opted for convertible unsecured subordinated debentures in order to allow more flexibility in its financing to support its growth, but also as an opportunity to further optimize its capital

structure and average cost of debt over a longer term.

For the short term, 5N Plus will use the net proceeds to reduce indebtedness under its senior revolving credit facility.

The debentures bear interest at a rate of 5.75% per annum, payable semi-annually at the end of June and December each year, from 31 December 2014. They are convertible at the holder's option into 5N Plus common shares at \$6.75 per share (representing a

conversion rate of 148.1481 shares per \$1000 principal amount of debentures). They will mature on 30 June 2019 and may be redeemed by 5N Plus, in certain circumstances, after 30 June 2017.

5N Plus has granted an over-allotment option to the underwriters entitling them to purchase, for a period of 30 days from 18 June, up to \$6m of additional debentures (at \$1000 each) to cover over-allotments, if any.

www.5nplus.com

5N Plus completes acquisition of metallic powder manufacturer AM&M

5N Plus has completed its acquisition of Advanced Machine and Materials Inc (AM&M) of Kanata, Ontario, Canada, which manufactures micron-size metallic powders that can be used in markets including CIGS (copper indium gallium diselenide) powder for thin-film solar panels. The intellectual property and processing capabilities developed by

AM&M allow the cost-effective and high-yield production of spherical, low-oxygen-content powders with uniform particle size.

"We immediately add new products to our existing offering," says 5N Plus' president & CEO Jacques L'Écuyer. "By combining AM&M's technology with our family of high-purity metals and alloys,

we are able to offer our customers a large array of custom-made powders optimized for their specific needs," he adds. "This investment is in line with our growth strategy, which includes developing opportunities further along the value stream for our specialty metals," L'Écuyer concludes.

www.am-m.com

Stion to speed second-half 2014 & 2015 capacity ramp

Preliminary US tariffs to raise prices of Chinese panels pending final decision on 18 August

Stion Corp of San Jose, CA, USA, which makes nanostructure-based CIGSS (copper indium gallium sulphur-diselenide) thin-film photovoltaic panels, says that it will increase manufacturing capacity of its next-generation Elevation Series CIGS solar modules for second-half 2014, and continue to ramp up for increased 2015 demand precipitated by news of the US Department of Commerce's preliminary tariffs on Chinese solar modules shipped to the USA.

Founded in 2006, Stion's high-efficiency Elevation Series CIGS thin-film modules are designed in San Jose and manufactured its first high-volume production facility in Hattiesburg, Mississippi (opened in 2012), with distribution in the USA

and internationally.

The US Commerce Department's announcement last week came after a lengthy countervailing duty investigation (CVD) for solar products imported into the USA from China to address an existing loophole that enabled an unfair pricing advantage to foreign manufacturers, says Stion. The decision will effectively raise prices on solar imports into the USA in the near term, pending a final decision on 18 August. This 'anti-dumping' tariff will significantly increase prices for developers using Chinese-made products for solar installations in all major segments (utility, commercial and residential), adds the firm. Many projects may subsequently be delayed or lose funding if Internal Rates of Return

are adversely affected and the developers are unable to locate a cost-effective, non-Chinese-made technology alternative.

"We understand that this preliminary tariff will put a strain on the US solar market as current major Chinese solar equipment supplier pricing increases from 18% to 35%, with the average Chinese supplier prices increasing by 27%," states Stion's president & CEO Chet Farris. "Stion is committed to serving the US market with the highest-quality US-designed and US-manufactured solar technologies," he adds. "We are ramping up our operations to meet the needs of our domestic customers in the near term and for the growing US solar market over the years to come."

Stion receives ISO 9001 certification for mass-production facility

Stion has received ISO 9001:2008 certification for its manufacturing site in Hattiesburg, MS (the firm's first mass-production facility, opened in 2012) after passing an independent audit of its quality management systems.

Developed by the International Organization for Standardization, ISO 9001 is the world's most widely observed family of standards for developing and maintain quality management systems. NQA (one of the world's largest and most respected ISO regis-

trars) registered Stion after a three-month preparation process. This certification of compliance recognizes that Stion's systems, policies and procedures adhere to the highest quality standards for the products provided to customers.

Stion says that, from its inception in 2006, it has designed a quality management system based on ISO 9001 principles, allowing it to achieve certification in record time. The firm adds that it understands the market's evolving needs, and

continues to adjust its processes to deliver products that meet or exceed customer expectations.

ISO 9001:2008 sets out the criteria for a quality management system and is the only standard in the family that can be certified to (although this is not a requirement). It can be used by any organization, large or small, regardless of its field of activity. ISO 9001:2008 is implemented by over 1 million companies and organizations in over 170 countries.

www.stion.com

Stion adds two executives to support growth

Stion has added two new executives to support its continued growth.

Pete DeGraff has been appointed executive VP of sales & marketing. He has over 18 years of sales and marketing leadership experience in rapid-growth technology organizations, including serving as executive VP of sales & marketing at Satcon Technology Corp. DeGraff received

a Masters in Business Administration from San Francisco State University and a Bachelors Degree from Alma College.

Louis Golato will serve as VP of manufacturing. He has over 30 years of experience leading large and complex semiconductor and lithium battery operations in the USA, China, Korea, Scotland and Taiwan,

including holding similar positions at A123 Systems Inc, Texas Instruments, Digital Equipment and Intel Corp. Golato has a B.S. in Finance from Bryant University.

Founded in 2006, Stion says that it has shipped products to five continents from its mass-production facility in Hattiesburg, Mississippi (opened in 2012).

Avancis acquired by China's CNBM

Continuity of staffing and warranties under existing name targets restart of Fab 2

Avancis GmbH of Torgau, Germany, a subsidiary of Saint-Gobain of Courbevoie, France since 2009 that makes copper indium selenide (CIS) thin-film photovoltaic modules, is selling its solar business to the Chinese building materials and glass manufacturer CNBM (China National Building Materials Group Corporation). The transaction will close following the registration of the new company at the commercial court and the granting of the necessary approvals.

Avancis and its predecessor companies have been developing CIS PV technology since the early 1990s. The firm's current production process relies on its second-generation CIS technology, developed by its R&D lab in Munich and implemented in its production sites in Torgau. In January, Avancis raised its record for externally certified energy conversion efficiency for encapsulated CIS thin-film modules from an aperture efficiency of 15.1% (set in 2011) to 16.6% (for a 30cm x 30cm module), as independently confirmed by the US Department of Energy's National Renewable Energy Laboratory (NREL).

CNBM was founded in 1984 and in 2013 had 180,000 staff and sales of €30.8bn. In 2012 it acquired Germany's CTFSolar GmbH, which provides production equipment and plants for manufacturing cadmium telluride (CdTe) thin-film photovoltaic modules. The Chinese government is currently pursuing a program for the development of solar energy, and CNBM intends to become intensively involved. The acquisition of Avancis will hence play a key role.

With the acquisition of Avancis, CNBM is planning to expand its solar module development and production. Further development of Avancis' technology is an essential prerequisite for implementing CNBM's expansion plans in

Further development of Avancis' technology is an essential prerequisite for implementing CNBM's expansion plans in photovoltaic energy generation in Asia and Europe

photovoltaic energy generation in Asia and Europe, says the firm. The new Chinese owner hence intends to continue to operate the Tech Center in Torgau as well as the laboratory in Munich as R&D facilities and also, if possible, to restart production at Fab 2 in Torgau under the same company name Avancis GmbH.

"With CNBM International Corporation we have found a strong investor who will help us to further advance our CIS technology," says Avancis' chief technology officer Dr Franz Karg. "Together with the recently achieved new efficiency world record for encapsulated thin-film modules [of 16.6%], this is another important milestone for the successful growth of our company."

All 240 staff will be given the opportunity to be employed by the new company under the same terms (with all the rights and obligations existing at the time of the transfer of business to be taken over by the new owner). The Avancis product warranties will remain unchanged and the new company will be the contact for previous and new customers.

Avancis receives general building approval for PowerMax SMART frameless thin-film CIS PV module

Avancis has received general building approval (abZ) from the German Institute for Building Technology (DIBt) for its newest-generation PowerMax SMART frameless thin-film module. The frameless modules can hence now be installed on roofs, facades and building-integrated photovoltaic (BIPV) systems.

"This means a major milestone for Avancis," says managing director & chief technology officer Dr Franz Karg. "It shows that our

quality standards have been proven concerning performance, safety and building-related applicability as well as the consistent further development of our frameless modules," Karg adds.

With approval by DIBt, separate approval of the module for use on roofs and facades is no longer necessary. Also, obtaining individual licenses is no longer necessary. "We give architects, designers and construction companies a building-

regulated thin-film module at hand which meets the highest standards of safety, efficiency, design and aesthetics," says Karg.

In January, Avancis set a new efficiency record of 16.6% for CIS thin-film modules, as confirmed by the US Department of Energy's National Renewable Energy Laboratory (NREL).

Avancis exhibited at the Intersolar Europe 2014 exhibition in Munich, Germany (4–6 June).

www.Avancis.de

Midsummer launches versatile R&D CIGS dep platform

Midsummer AB of Järfälla, Sweden, a supplier of equipment for manufacturing flexible copper indium gallium diselenide (CIGS) thin-film solar cells, has launched the UNO, a low-cost versatile R&D thin-film deposition platform specifically developed for universities and research facilities.

The UNO derives from the CIGS solar cell production but, with its generic design and optional configurations, it is suitable for a range of thin-film research applications. The firm adds that it has a high throughput, flexibility, stability and ability to design complex test series.

"There has been a lot of interest from universities and institutes for a lower-cost version of our commercial DUO production tool for R&D," says CEO Sven Lindström. "We hope that a research tool like this will contribute to accelerate the development of cost-effective and efficient thin-film CIGS and CZTS solar cells on a global scale."

The UNO is a platform for CIGS (copper, indium, gallium, selenium) and CZTS (copper, zinc, tin, sulfide) solar cell research, although it can be used for applications where a sputtered material stack in an unbroken vacuum chain is required (thin-film batteries, fuel cells, small display screens etc.).



The UNO can have up to 13 sputtering cathodes and warm the substrate up to 750°C (1400°F). It can load up to 300 substrates and run automatic test series, where each substrate has different parameter settings. It can also be supplemented with co-evaporation, analytical tools, database and various options.

The UNO has many of the features and design of the DUO, including a small footprint. The biggest difference between the two is that the UNO has only one main vacuum chamber and that sputtering takes place in only one process station at a time (suited R&D).

Another R&D feature is that the UNO can use both glass and stainless-steel substrates and can be equipped with more in-situ measurement stations. As a pure R&D tool and not a low-cost production

tool, the price of the UNO starts at under \$1m, but depends on configuration.

Midsummer's commercial production line is the DUO, a unique and compact CIGS turn-key system with a 5MW annual production capacity. Midsummer's CIGS cells are made on

stainless-steel substrates, making them suitable not only for regular solar panels but also for flexible, lightweight panels that can be used on membrane roofs, landfills or other structures where traditional glass modules cannot be applied.

"Thin-film CIGS solar cells are the solar cells of the future," believes Lindström. "They are increasingly efficient and have many advantages over traditional silicon-based solar cells. They are durable, can withstand vibrations, can be curved and bent, and can be manufactured cost-efficiently in small volumes." Thin-film CIGS solar panels are hence thinner and lighter than traditional silicon solar cells made of glass. They are also non-toxic (cadmium-free) and can be made frameless, suiting buildings and moving vehicles in cities.

Midsummer raises CIGS solar cell efficiency from 15% to 16.2%

Midsummer has raised the energy conversion efficiency of its cells from 15% to 16.2% aperture area for the full 156mm x 156mm cell.

The cell was made in a regular production run and the process is already implemented in the production line. "Considering that the solar cell is made on stainless steel, contains no cadmium and that the production process is an all-dry, all-vacuum process where all layers (including the buffer) are deposited by sputtering, this achievement by our engineers is truly impressive," reckons CEO Sven Lindström.

Lightweight flexible modules

With Midsummer's production system, the cells are manufactured individually and then strung together into modules, as with crystalline solar cells. This way, lightweight flexible modules can easily be made in any size and shape, says the firm.

A dry, all-vacuum process has less stringent requirements for cleanrooms, says Midsummer. Also, avoiding cadmium in the manufacturing process is desirable for the sake of the production staff and also makes it easier to start

low-cost manufacturing of CIGS solar cells.

Market shifting to rooftops

"The global solar cell market is facing a paradigm shift," believes Lindström. "Fewer large solar energy parks are being built in Europe. Instead, focus is moving to installations on large buildings in cities. Lightweight and flexible thin-film solar cells are ideal for this use," he notes. "It is economically and environmentally more beneficial to use solar energy locally, where it is produced."

www.midsummer.se

TSMC Solar engages ex-NREL CIGS expert Rommel Noufi

TSMC Solar Ltd of Taichung, Taiwan, which was founded in May 2009 as a subsidiary of the world's biggest silicon wafer foundry Taiwan Semiconductor Manufacturing Co Inc (TSMC), has announced the engagement of Dr Rommel Noufi in a long-term consulting capacity, to augment its copper indium gallium diselenide (CIGS) R&D program.

Noufi is a 33-year veteran of the US National Renewable Energy Laboratory (NREL), where he was principal scientist and led the team driving CIGS and CdTe (cadmium telluride) cell research. He has

authored over 190 publications and has 8 patents.

TSMC Solar's track record of R&D achievements include producing a TUV-SUD-verified 15.7%-efficient CIGS PV module using production equipment on its production line in mid-2013. The firm is currently expanding its annual capacity from 40MW to reach 120MW in fourth-quarter 2014.

"Noufi played a key role in the development of CIGS as a leading photovoltaic material," comments TSMC Solar's president Ying-Chen Chao. "The addition of his deep

CIGS experience to our R&D effort puts us on solid footing to maintain our rapid improvement of module efficiency over the next several years," he adds.

Noufi sees great potential for CIGS efficiency improvements. "CIGS efficiencies in the lab have reached 20.9%, with a clear path to achieving 23%," he notes. "With its strong R&D, manufacturing and equipment engineering skill set, TSMC Solar is uniquely equipped to develop this potential and bring it into production."

www.tsmc-solar.com

Ascent Solar appoints VP & general manager of EnerPlex

Ascent Solar Technologies Inc of Thornton, CO, USA, which makes lightweight, flexible copper indium gallium diselenide (CIGS) thin-film photovoltaic modules that it integrates into its EnerPlex series of consumer products, has appointed Richard Hashim as VP & general manager of the EnerPlex consumer electronics division.

Hashim brings international C-level experience in the technology and consumer electronics sectors. During 17 years with Corsair Components Inc, he was one of

their pioneering employees, growing and managing a team that built a profitable international company and a global brand from the start-up stage. He has held various executive roles in leadership, general management, sales and marketing, internationally, in Asia and Europe.

"Hashim is perfectly suited to helm the continued rapid expansion of our EnerPlex brand globally," reckons CEO Victor Lee. "His depth of experience in both international and domestic sales, as well as his complex understanding of the

marketing and product development cycles of consumer-oriented businesses, are invaluable assets as we continue to grow the EnerPlex brand worldwide," he adds.

Prior to Corsair, Hashim worked with Shell Petroleum in Malaysia, managing its national branding and advertising campaigns. He holds a Bachelor's degree in International Business from Tufts University and an MBA with a Marketing concentration from Boston University.

www.goenerplex.com

Ascent delivers EnerPlex shipment worth over \$750,000 to Fry's

Ascent Solar Technologies Inc of Thornton, CO, USA, which makes lightweight, flexible copper indium gallium diselenide (CIGS) thin-film photovoltaic modules that it integrates into its EnerPlex series of consumer products, has shipped an order worth more than \$750,000 to Fry's Electronics for their upcoming anniversary sale. Founded in 1985 in Silicon Valley, Fry's Electronics is one of the USA's oldest electronics retailers, and now has 34 retail locations in nine states.

The shipment comprises multiple EnerPlex flagship and accessory product lines, all of which will be

available for sale in Fry's stores beginning 12 May. The completion of this single large order surpasses not only Ascent Solar's entire fourth-quarter 2013 revenue by 30% but also exceeds its EnerPlex first-quarter 2014 product revenue.

The EnerPlex brand represents Ascent's line of consumer products, many of which are integrated with the firm's proprietary CIGS technology.

EnerPlex is extremely pleased to be able to provide support for the demand we have seen for our EnerPlex products through our largest retailer, Fry's Electronics,"

says Richard Hashim, general manager of Ascent Solar's EnerPlex Division. "This order is yet another example of the continuing increase in demand for EnerPlex's ultimate portable power solution, from solar chargers to rechargeable batteries and accessories," he adds.

"Ascent is set to achieve yet another milestone this quarter in terms of product revenue," notes president & CEO Victor Lee. "We are extremely pleased with the momentum and acceleration of our EnerPlex brand building and product acceptance."

www.AscentSolar.com

Improving as-grown indium gallium nitride solar cells

InGaN cells have achieved up to 2% efficiency without coatings or surface treatments, showing potential for multi-junction devices.

Researchers in France have reported on solar cell devices based on indium gallium nitride (InGaN) multiple quantum wells (MQWs) [Sirona Valdueza-Felip et al, Appl. Phys. Express, vol7, p032301, 2014]. Conversion efficiencies of up to 2% were achieved. Although such values are not commercial, there is interest in developing such structures for inclusion in devices that use multiple junctions to optimize power conversion performance with respect to the solar spectrum.

Sirona Valdueza-Felip of CEA-Grenoble, INAC/SP2M/NPSC, comments: "Our work differs from that of others working on InGaN-based solar cells since we give conversion efficiency values of as-grown structures, meaning that neither top or back coating nor surface treatment has been used; just the contribution of the InGaN/GaN MQW structure is taken into account in the efficiency measurements."

"For example, the excellent results obtained by the group of J. S. Speck at University of California Santa Barbara [<http://dx.doi.org/10.1063/1.3591976>] achieved conversion efficiencies of 2.29% for solar cells with 30-period QWs with a rough surface under 1 sun of AM1.5 equivalent illumination. However, without roughening the conversion efficiency dropped to 1.33%."

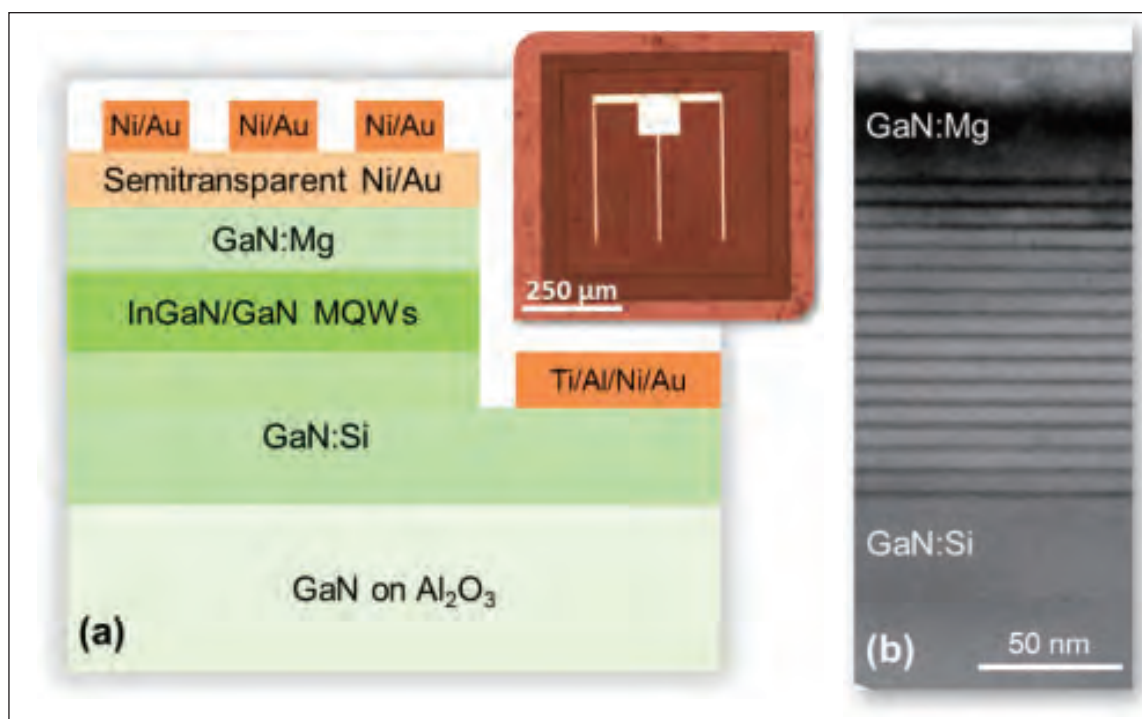


Figure 1. (a) Schematic description of InGaN/GaN MQW solar cell structure. Inset: top-view optical microscopy image of a solar cell with 0.5mm x 0.5mm mesa. (b) TEM image of n-GaN/i-MQW/p-GaN stack (S4 in Table 1).

Table 1. Structural characteristics of InGaN/GaN MQW structures: indium mole fraction in wells (x), number of MQWs, thicknesses of GaN barriers (d_B), InGaN wells (d_W), and Mg-doped GaN layer (d_{Mg}). Electrical performance is given in terms of open-circuit voltage (V_{oc}), short-circuit current density (J_{sc}), fill factor (FF), and overall conversion efficiency (η).

Sample	x	MQWs	d_B (nm)	d_W (nm)	d_{Mg} (nm)	V_{oc} (V)	J_{sc} (mA/cm ²)	FF (%)	η (%)
S1	0.10±0.01	15	8.5±0.2	1.3±0.2	60	1.5±0.1	0.13±0.01	57.8±0.1	0.11±0.01
S2		30	8.0±0.2	1.3±0.2	60	2.1±0.1	0.23±0.01	58.9±0.1	0.29±0.01
S3	0.19±0.01	15	9.0±0.2	2.0±0.2	60	1.7±0.1	3.00±0.01	39.3±0.1	2.00±0.01
S4		30	8.8±0.2	2.0±0.2	200	1.5±0.1	1.81±0.01	49.9±0.1	1.36±0.01

In addition to CEA-Grenoble, INAC/SP2M/NPSC, the team also included researchers from CEA, LITEN and CNRS-Institut Néel.

The devices (Figure 1) were grown using metal-organic chemical vapor deposition (MOCVD) on sapphire (Al_2O_3). The silicon-doped n-type gallium nitride (GaN:Si) buffer consisted of $3.2\mu\text{m}$ with $6 \times 10^{19}/\text{cm}^3$ carrier density and 10nm heavily doped to $2 \times 10^{19}/\text{cm}^3$ carrier density. The MQW consisted of 15 or 30 InGaN layers in GaN barriers. The magnesium-doped p-type GaN (GaN:Mg) was doped at $7 \times 10^{16}/\text{cm}^3$.

Four device types with varying structure of MQWs were produced (Table 1). The MQWs with 0.1 indium fraction (x) were grown at 750°C . The more delicate growth with 0.19 indium-content was performed at the lower temperature of 720°C .

Devices were fabricated with $0.5\text{mm} \times 0.5\text{mm}$ and $1\text{mm} \times 1\text{mm}$ mesas, etched using chlorine-based inductively coupled plasma. The n-GaN ohmic contact consisted of titanium/aluminium/nickel/gold. The p-GaN ohmic contact was a semi-transparent layer of annealed nickel/gold and a nickel/gold electrode grid with $5\mu\text{m}$ -wide fingers at $150\mu\text{m}$ pitch.

The spectral cut-offs for MQWs with 0.1 and 0.19 indium content were at wavelengths of 380nm and 465nm , respectively. The values are red-shifted from the 365nm cut-off of pure GaN. Increasing the number of wells from 15 to 30 boosts external quantum efficiency (EQE) by factors of 2–2.5 for either indium content.

Under 1-sun radiation corresponding to an AM1.5 solar spectrum, the conversion efficiency was highest at 2% for the 15-well 0.19-indium-content device. The lower-indium-content devices suffered from having a shorter wavelength cut-off, while the bulk of the solar

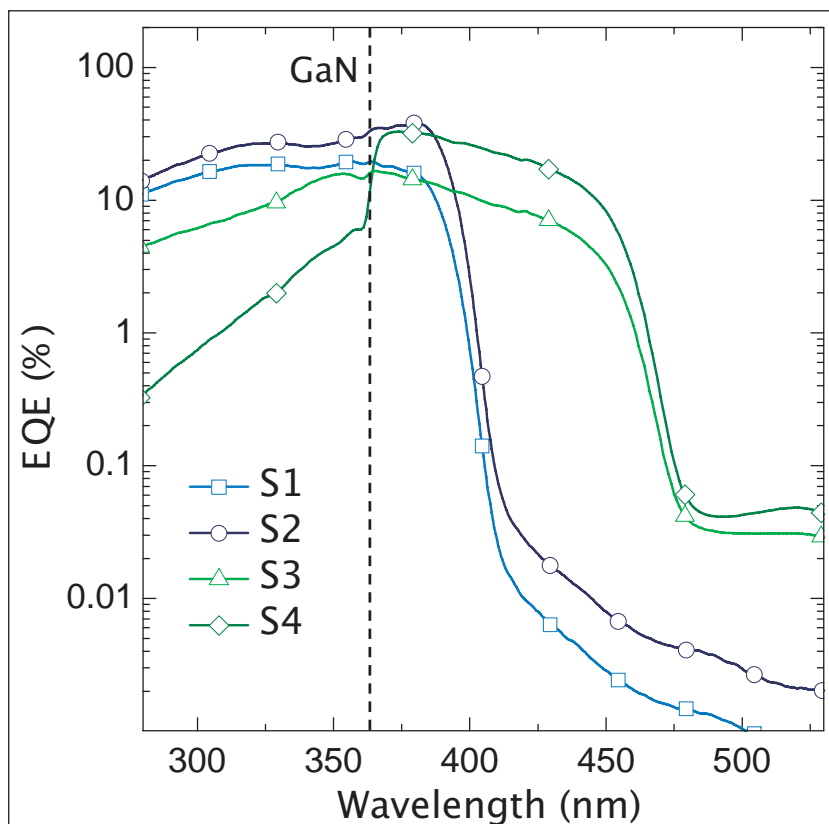


Figure 2. Spectral response of InGaN/GaN MQW samples (S1–S4 in Table 1). The dotted line corresponds to GaN spectral cutoff.

spectrum is weighted towards longer wavelengths. However, the higher-indium-content device suffers from $\sim 3\times$ higher series resistance and smaller shunt resistance for blocking leakage. Although the 30-well devices have higher EQE, the advantage is offset by the presence of a 200nm -thick photon-absorbing p-GaN layer (d_{Mg} in Table 1) in the case of higher indium content. ■

<http://iopscience.iop.org/1882-0786/7/3/032301/article>
Author: Mike Cooke

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Simplifying indium gallium arsenide growth on gallium arsenide substrate

Researchers in China investigate the process potential for replacing germanium in high-conversion-efficiency tandem solar cells.

Fangliang Gao and Guoqiang Li of South China University of Technology have developed a technique to grow high-quality indium gallium arsenide (InGaAs) on gallium arsenide substrates using an ultrathin amorphous buffer [Appl. Phys. Lett., vol104, p042104, 2014].

The researchers see their process as having applications to tandem solar cells, replacing the usual germanium layers in these structures. The germanium layer can lead to a large mismatch in photocurrent: in the case of gallium

indium phosphide/indium gallium arsenide/germanium (GaInP/InGaAs/Ge, 1.84eV/1.4eV/0.67eV bandgaps) multi-junction cells, the germanium photocurrent density is about two times that in the other two layers. Photocurrent mismatch leads to degradation of conversion efficiency.

A 1eV bandgap bottom layer would solve the mismatch problem and $\text{In}_{0.3}\text{Ga}_{0.7}\text{As}$ has a 1eV bandgap. However, such InGaAs films have a lattice mismatch of 2.3% with GaAs substrates. The usual approach to bridge such mismatches is to use compositionally graded buffer layers. "However," the researchers write, "it is always a big challenge to accurately control the composition, the thickness, and the crystal quality of each sublayer for the buffer layers, not to mention

the tedious procedures to grow so many sublayers." As-grown $\text{In}_{0.3}\text{Ga}_{0.7}\text{As}$ films on GaAs with compositionally graded buffers tend to have worse-than-expected quality.

Gao and Li grew their InGaAs films on semi-insulating GaAs (111) substrates using molecular beam epitaxy (MBE). The process began with an $\text{In}_{0.6}\text{Ga}_{0.4}\text{As}$ buffer layer grown on the substrate at 380°C. Different buffer thicknesses — 10nm, 4nm, 2nm, 1nm, 0nm — were tried to optimize the quality of the top 500nm $\text{In}_{0.3}\text{Ga}_{0.7}\text{As}$ grown at 540°C.

The resulting epitaxial structures were studied using high-resolution x-ray diffraction (HRXRD), high-resolution transmission electron microscopy (HRTEM), scanning electron microscopy (SEM), and atomic force microscopy

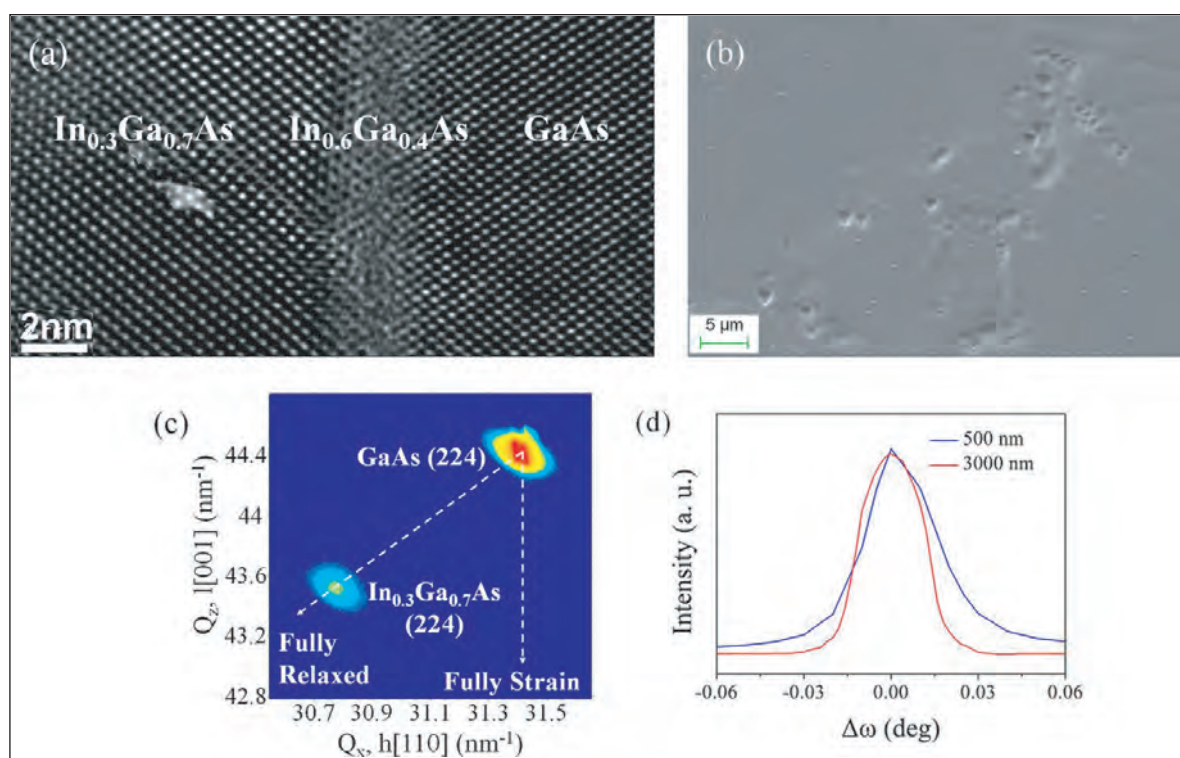


Figure 1. (a) Cross-sectional HRTEM image, (b) SEM image of etched surface, and (c) high-resolution reciprocal space mapping for (224) diffraction of 500nm-thick $\text{In}_{0.3}\text{Ga}_{0.7}\text{As}$ on 2nm-thick $\text{In}_{0.6}\text{Ga}_{0.4}\text{As}$ /GaAs heterostructure and (d) XRD rocking curves of 500nm (blue line) and 3000nm (red line) $\text{In}_{0.3}\text{Ga}_{0.7}\text{As}$ (111) films grown on 2nm $\text{In}_{0.6}\text{Ga}_{0.4}\text{As}$ amorphous buffer.

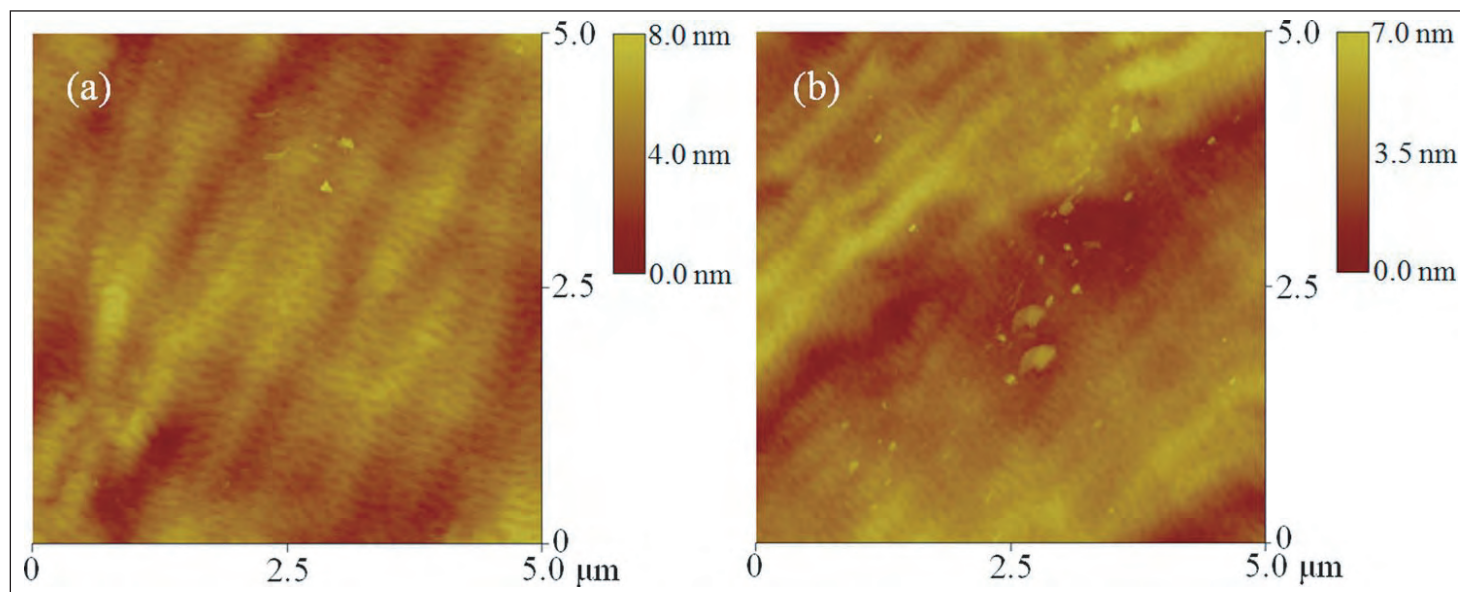


Figure 2. AFM images (5μm x 5μm) of $\text{In}_{0.3}\text{Ga}_{0.7}\text{As}$ epitaxial layers grown on GaAs substrates with buffer structures of (a) 2nm amorphous $\text{In}_{0.6}\text{Ga}_{0.4}\text{As}$ and (b) four-step-graded-composition layer.

(AFM).

The 10nm buffer layer was found to be amorphous due to the low growth temperature, the large 4.3% lattice mismatch with the GaAs substrate, and the large indium content, which has a much larger atomic radius (142pm) than gallium (122pm) or arsenic (119pm). With 10nm buffer, the top InGaAs layer is polycrystalline, as revealed using halo selected-area electron diffraction (SAED) performed with the TEM system.

Reducing the amorphous buffer to 4nm gave a single-crystalline $\text{In}_{0.3}\text{Ga}_{0.7}\text{As}$ layer, although there was a large density of dislocations. The HRXRD rocking curve full-width at half maximum (FWHM) of the $\text{In}_{0.3}\text{Ga}_{0.7}\text{As}$ (111) layer was 980arcsec.

Further improvement came with decreasing the buffer thickness to 2nm. "The as-grown $\text{In}_{0.3}\text{Ga}_{0.7}\text{As}$ epitaxial film is almost dislocation-free compared with the two previous samples with thicker $\text{In}_{0.6}\text{Ga}_{0.4}\text{As}$ buffer layers," the researchers write. The etch pit density, which reflects dislocation densities, was $3.3 \times 10^6/\text{cm}^2$.

High-resolution x-ray reciprocal space mapping indicated that the lattice parameter of the film was 0.57713nm, which is very close to the fully relaxed value of 0.57749nm (Figure 1). The XRD rocking curve FWHM was 108arcsec.

A comparison $\text{In}_{0.3}\text{Ga}_{0.7}\text{As}$ film was grown on a four-step-graded-composition $\text{In}_x\text{Ga}_{1-x}\text{As}$ buffer layer ($x \sim 0.09, 0.18, 0.27$, and 0.33 , respectively).

AFM studies on $5\mu\text{m} \times 5\mu\text{m}$ fields gave root mean square (RMS) roughness values of 1.1nm and 1.2nm for $\text{In}_{0.3}\text{Ga}_{0.7}\text{As}$ grown on 2nm amorphous $\text{In}_{0.6}\text{Ga}_{0.4}\text{As}$ and on four-step graded buffers, respectively (Figure 2). Also, the XRD rocking curve FWHM for the film on four-step-graded buffer was 116arcsec, compared with 108arcsec for $\text{In}_{0.3}\text{Ga}_{0.7}\text{As}$ on 2nm amorphous $\text{In}_{0.6}\text{Ga}_{0.4}\text{As}$.

The four-step-graded buffer process also gave similar

values for etch-pit density and lattice constant of $3.6 \times 10^6/\text{cm}^2$ and 0.57706nm, respectively.

The researchers comment: "Evidently, the proposed approach is at least competitive, if not better than the usually adopted way using step-graded-composition buffer layers. Given its simplicity, this approach shows a high potential as a replacement for the routine composition-graded buffer layer currently used to produce high-quality 1eV solar cell junctions."

The researchers believe that the 2nm amorphous layer traps threading dislocations and introduces a high density of defects at the $\text{In}_{0.6}\text{Ga}_{0.4}\text{As}/\text{GaAs}$ interface reducing residual strain, thus inhibiting nucleation of dislocations in the $\text{In}_{0.3}\text{Ga}_{0.7}\text{As}$ epi-layer.

The researchers write: "The ultrathin amorphous $\text{In}_{0.6}\text{Ga}_{0.4}\text{As}$ buffer layer is acting like an 'elastic layer' between $\text{In}_{0.3}\text{Ga}_{0.7}\text{As}$ epi-layer and GaAs substrate. This elastic layer contains a high density of point defects. As a result, dislocations can be easily nucleated. At the same time, point defects can promote dislocation glide and consequently block the penetration of dislocations into the following $\text{In}_{0.3}\text{Ga}_{0.7}\text{As}$ epi-layer. Clearly, this amorphous elastic layer can efficiently release misfit strain and trap dislocations."

Increasing the thickness of the $\text{In}_{0.3}\text{Ga}_{0.7}\text{As}$ film to 3000nm reduced the XRD FWHM to 90arcsec, indicating even better crystallinity. The researchers see this as indicating that their process can provide "favorable conditions for the subsequent epitaxial growth of $\text{In}_{0.3}\text{Ga}_{0.7}\text{As}$ solar cell layers".

Reducing the thickness of the amorphous layer below 2nm leads to deterioration in the $\text{In}_{0.3}\text{Ga}_{0.7}\text{As}$ layer with XRD rocking curve FWHMs of 556arcsec and 1292.9arcsec for 1nm and 0nm buffer thickness, respectively. ■

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Author: Mike Cooke

Pseudo-direct gaps for efficient light emission and absorption

Mike Cooke reports on recent research seeking to develop optoelectronic devices based on indirect-bandgap semiconductors with a nearby direct gap.

Light emission from semiconductors usually depends on the existence of a direct bandgap (Figure 1). This is because the wave properties of the emitted light have to match those of the electron and hole states that recombine. In particular, the sum of the wave-vectors (of magnitude $2\pi/\text{wavelength}$) of the incoming electrons and holes combines into that of the outgoing photon. The relevant wavelength for the photon is hundreds (UV, visible) or thousands (infrared) of nanometers. By contrast, the relevant electron/hole wavelengths are atomic scale – i.e. tenths of nanometers. Given the large difference of scale and the inverse proportional dependence on wavelength, the photon has near-zero wave-vector.

In terms of the band structure giving the relation between energy (E) and wave-vector (k) of the electron states, one is looking for transitions between electrons in the conduction band to hole states in the valence band directly beneath. In semiconductors, the electrons tend to populate the lowest lying states in the conduction band and the holes populate the highest states in the valence band. The peak of the valence band is usually at zero wave-vector, but sometimes the valleys of the conduction band can be away from zero, giving an indirect gap.

While the conditions of light absorption are less stringent, photodetector and photovoltaic energy conversion (solar cell) devices show improved efficiency when constructed from direct rather than indirect semiconductors.

Researchers hope that, by exploring the potential of pseudo-direct gaps, new opportunities for optoelectronic application will arise. Here we look at three recent contributions to the research literature.

Electrically pumped light emission in germanium

The Chinese Academy of Sciences Institute of Semiconductors has been studying a lateral light-emitting diode (LED) and waveguide structure (Figure 2) based on the

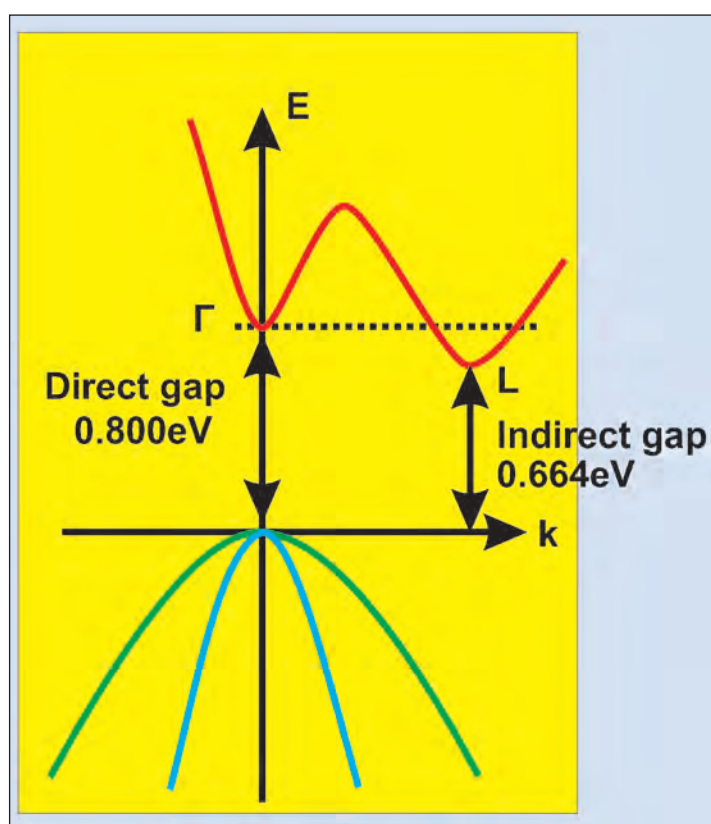


Figure 1. Rough sketch of germanium bandstructure along L direction showing direct and indirect valleys.

indirect-gap semiconductor germanium (Ge) [Zhi Liu et al, Appl. Phys. Lett., vol104, p191111, 2014]. The indirect gap should make efficient light emission difficult, but the band structure of Ge has a direct 'gamma' (Γ) valley in the conduction band that has a gap from the valence band only $\sim 140\text{meV}$ wider than the indirect gap of $\sim 660\text{meV}$. By contrast, silicon (Si) has an indirect gap of 1.12eV (the 6 'chi' or X valleys) and a direct Γ gap of 3.4eV .

The small difference between germanium's indirect and direct transitions raises the possibility for 'pseudo-direct' light emission through tweaking the band structure with strain and/or filling/doping the

four indirect 'L' valleys so that the Γ valley can become populated with electrons.

Fabricating effective Ge light emitters would have benefits for optoelectronics based on Si waveguides and silicon CMOS since Ge and SiGe alloys are already integrated in Si transistor mass-production processes, unlike the usual light emitters consisting of direct-gap III-V compound semiconductors.

The germanium film was grown on lightly-doped n^- -silicon (n^- -Si) substrates by cold-wall ultra-high-vacuum chemical vapor deposition (CVD). The precursor was pure germane (GeH_4). The 60nm buffer layer was grown at 290°C, and the main 740nm Ge layer at 600°C.

A 300nm silicon dioxide (SiO_2) film was grown by plasma-enhanced CVD (PECVD). The wafer was then annealed rapidly to improve crystal quality and to create tensile strain of between 0.20% and 0.22%. The Ge film was formed into $1\mu\text{m} \times 350\text{nm} \times 0.5\text{mm}$ ridge structures, with the SiO_2 forming a mask for the patterning process.

The regions by the ridge without SiO_2 mask were implanted with phosphorous and boron to create n^- - and p^- -type regions, respectively. The dopants were thermally activated and the SiO_2 mask removed. Between these steps a dilute solution of hydrogen peroxide and hydrochloric acid was used to smooth the sidewalls of the ridge. A new 700nm SiO_2 layer was applied using PECVD.

The metal electrodes were created and thermally activated for a good ohmic contact with the Ge film. The structures were cleaved across the $\langle 001 \rangle$ facet with waveguide lengths between 0.6mm and 1.3mm.

Using a lateral structure avoids the current having to cross the defect infested region of the Si/Ge interface. The researchers comment: "The device exhibited a good rectifying behavior and had excellent injection efficiency. The current density was about $100\text{kA}/\text{cm}^2$ with a 2V forward bias."

The waveguide peak emission wavelength of 1625nm at $30\text{kA}/\text{cm}^2$ injection current was significantly red-shifted compared with the 1590nm photoluminescence of 0.21% tensile-strained undoped Ge. The researchers suggest the red-shift could be due to

self-heating caused by the high injection current. The bandgap tends to shrink at high temperature. The halting of the red-shift trend beyond $110\text{kA}/\text{cm}^2$ is attributed to the low energy cut-off of the InGaAs detector that was used. Under $150\text{kA}/\text{cm}^2$ current injection, the light output power was around $1\mu\text{W}$.

The researchers also studied the emission from the top surface with a microscope at $10\text{kA}/\text{cm}^2$ (Figure 3). The emission peak in this case was 1587nm, consistent with the peak for 0.21% tensile-strained undoped Ge. The amount of emission was greatest near the n^- -contact region (position 'A' in Figure 2). The direct transition ' Γ ' valley is more likely to be populated near the n^- -type region than in the p^- -type region. As the current increased, the maximum emission region moved nearer to the intrinsic region.

The researchers believe that their results indicate the potential of Ge as a Si-based light-source. ▶

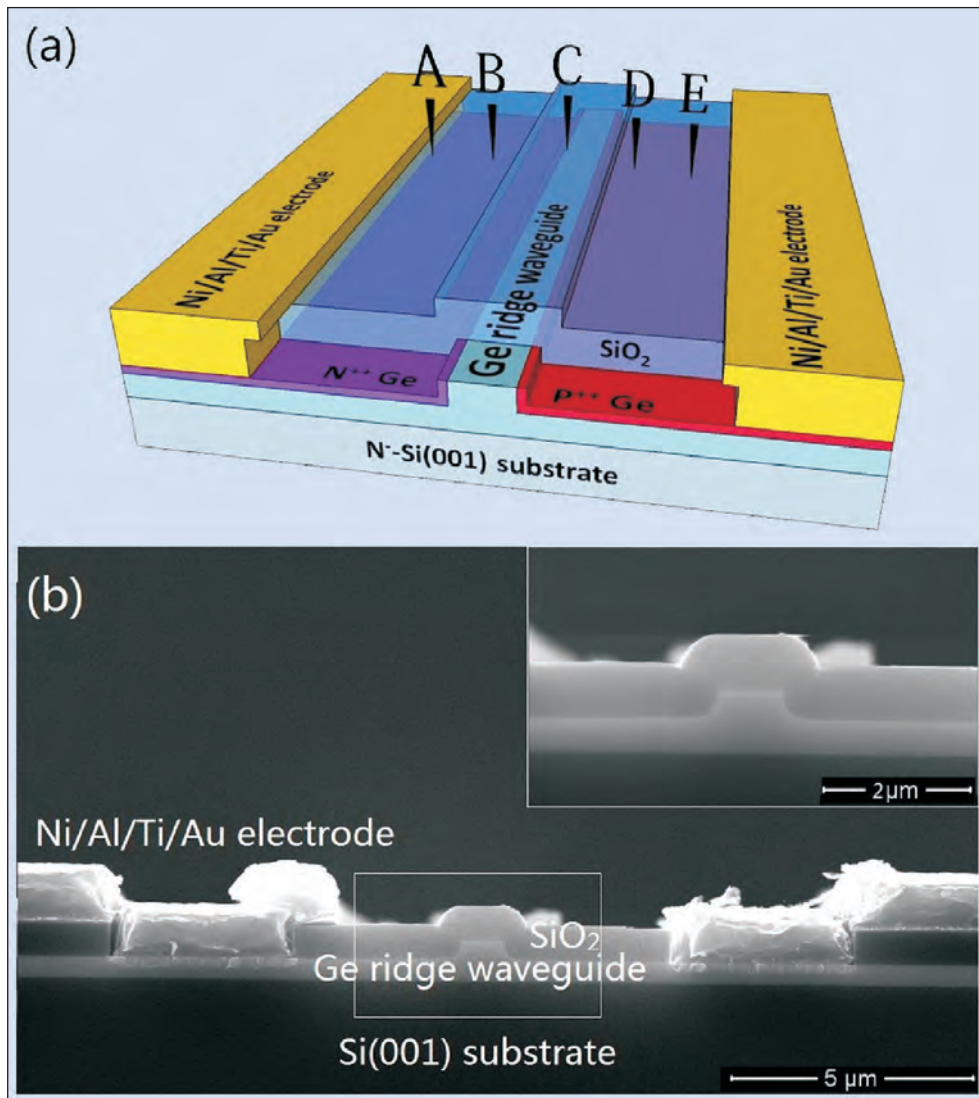


Figure 2. (a) Schematic of Ge p-i-n ridge waveguide LEDs on Si substrate. Top surface positions marked A to E for micro-electroluminescence measurement are shown. (b) Cross-sectional SEM of Ge p-i-n ridge waveguide LEDs and cleaved facet. Top width and height of the ridge waveguide are 900nm and 350nm, respectively.

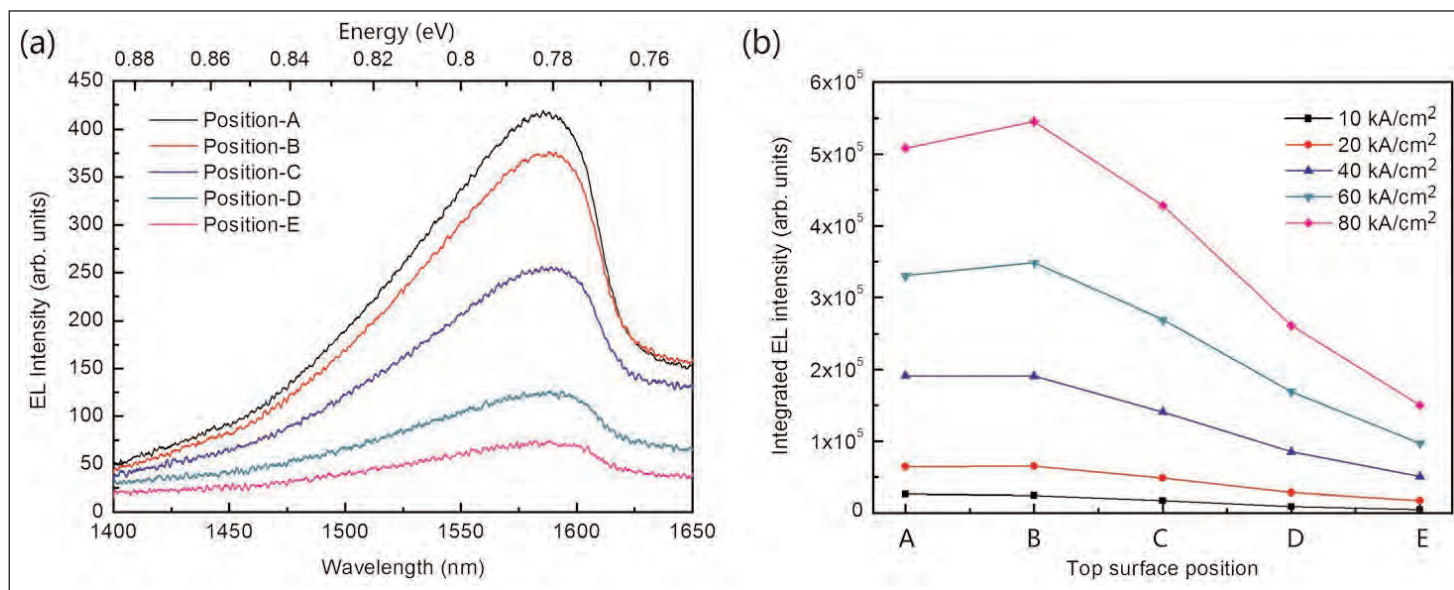


Figure 3. (a) Room-temperature top surface micro-electroluminescence spectra at various surface positions (Figure 2a) of Ge waveguide LED with fixed current density of 10 kA/cm². (b) Integrated top surface EL intensities at different top surface positions (A–E) with varying current density.

Solar energy conversion

Yale University in the USA has developed indium gallium phosphide (InGaP) solar cells on gallium phosphide substrate [S. Tomasulo et al, Appl. Phys. Lett., vol104, p173903, 2014]. The aim of the researchers' work was to create a top-cell option for multi-junction cells with four or more junctions in monolithic or spectrum splitting architectures. It is hoped that such arrangements will be able to achieve conversion efficiencies up to almost 60%.

Such top cells need an energy bandgap of around 2.0–2.4 eV. Gallium phosphide has such a bandgap, but unfortunately the 2.26 eV gap is indirect, leading to inefficient conversion of photons into electrical energy. The InGaP alloy system has a transition from indirect to direct bandgap when the indium fraction exceeds 30%. However, the increase of indium content also leads to a reduction in the bandgap.

In fact, there are two valleys in the GaP bandstructure – a direct Γ valley with a gap of 2.78 eV and an indirect 'chi' X valley. In InGaP, the Γ valley gap with the valence band decreases at the rate of 19 meV/% of indium. The X gap reduces more slowly at 1.7 meV/%.

The Yale group explored how moving the composition towards the crossover point increases conversion efficiency. In fact, the conversion efficiency improves even in the indirect region as the Γ valley comes in range of the X valley.

Previous work with InGaP has tended to grow the material on gallium arsenide (GaAs) substrate. Unfortunately, the InGaP is then placed under tensile strain, which, according to the researchers, "leads to faceted trenches and cracks, and extremely thick graded buffers are required to minimize these efficiency-diminishing defects". The Yale group chose GaP substrates so that the InGaP was under compressive strain to avoid these problems.

The epitaxial structures (Figure 4) were grown on p-GaP substrates in a Veeco Mod Gen II solid source

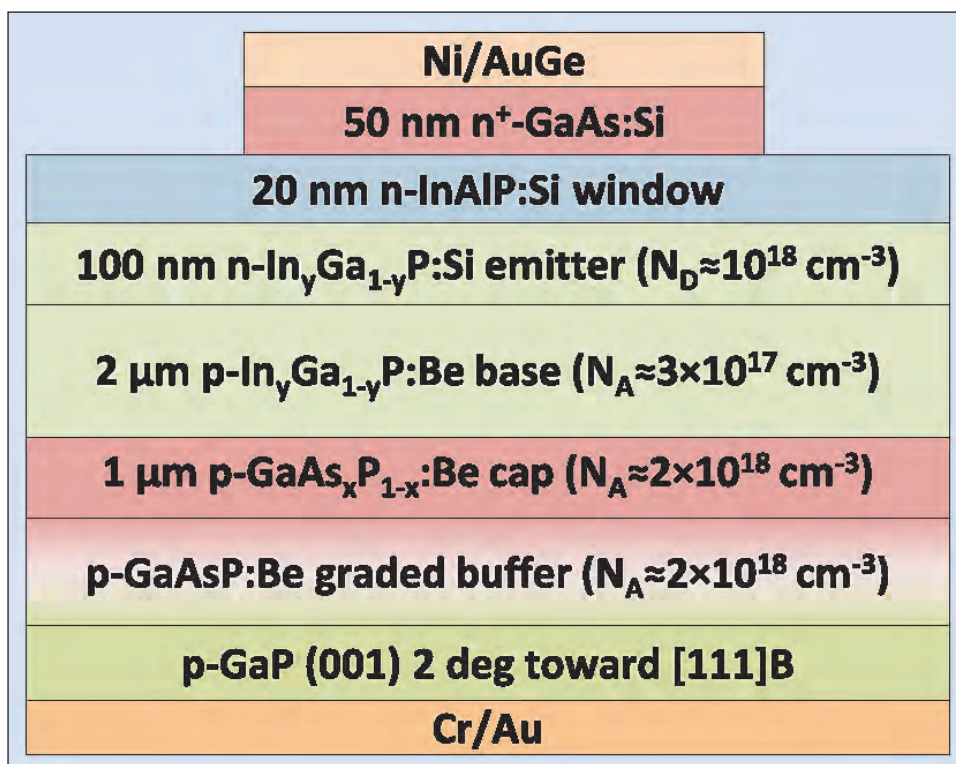


Figure 4. Schematic of InGaP solar cells.

Table 1. Summary results: bandgap energy (E_g), threading dislocation density (TDD), open-circuit voltage (V_{oc}), bandgap-voltage offset ($W_{oc} = E_g/q - V_{oc}$), short-circuit current density (J_{sc}), ratio of J_{sc} to theoretical maximum for infinite base and unity collection probability ($J_{sc, ratio}$), fill factor (FF), and conversion efficiency (η).

In fraction	E_g (eV)	TDD (/cm ²)	V_{oc} (V)	W_{oc} (V)	J_{sc} (mA/cm ²)	$J_{sc, ratio}$	FF	η
0%	2.26 ^a	. . .	1.46	0.80	1.64	17%	0.64	1.53%
18%	2.23 ^a	2.28x10 ⁶	1.46	0.77	2.29	23%	0.74	2.47%
24%	2.21	4.02x10 ⁶	1.43	0.78	2.75	26%	0.73	2.87%
30%	2.12	7.60x10 ⁶	1.42	0.70	3.65	30%	0.75	3.89%

^a Indirect gap.

molecular beam epitaxy (MBE) chamber. The use of a gallium arsenide phosphide (GaAsP) graded buffer reduced threading dislocations that arise from the lattice mismatch between the substrate and overlying epitaxial structure. The compressive grading was achieved using between 10 and 16 steps of 360nm thickness and increased arsenic molar fraction of four percentage points per step. The aim was a grading rate of stain over buffer thickness of 0.4%/μm. The indium aluminium phosphide (InAlP) window layer was lattice-matched to the InGaP active emitter/base material.

The epitaxial samples were formed into 1mmx1mm solar cells. The devices were patterned with photolithography and wet etched down to the n-InAlP window layer through the top n⁺-GaAs used to achieve good ohmic contact with the metal n-type electrodes. No anti-reflective coatings were used in any device. A reference GaP device with Al_{0.25}Ga_{0.75}P window was also produced.

The current and voltage characteristics were measured under AM1.5G solar simulation conditions (Table 1). Also, the threading dislocation density (TDD) was estimated using electron-beam induced current (EBIC) measurements. The TDD increased by 3x with indium fractions between 18% and 30% — a factor that Yale plans to address in future work.

Although the devices are in the ambiguous direct-indirect bandgap region, their external quantum efficiency (EQE) behavior is similar to that of a direct-gap In_{0.49}Ga_{0.51}P device with a sharp turn-on at the band edge. The bandgap-voltage offsets (W_{oc}) were higher than for InGaP on GaAs cells. The researchers comment: "We speculate that the wide- E_g solar cells presented here, as well as GaP devices, possess increased point defect densities, resulting in elevated W_{oc} . It is possible that as y decreases, the growth conditions that were chosen for $y = 0.49$ are no longer appropriate, suggesting that growth condition optimization should be performed for each composition."

The main improvement of the InGaP structure is an increase in short-circuit current density (J_{sc}), leading to a 2x improvement in conversion efficiency (η) over a GaP cell.

Wurtzite gallium arsenide nanowires

Researchers in Switzerland and Norway have used strain to alter the light-emitting properties of gallium arsenide (GaAs) nanowires [G. Signorello et al, Nature Communications, vol5, p3655, published online 10 Apr 2014]. The researchers from IBM Research-Zürich, Norwegian University of Science and Technology (NTNU) and CrayoNano AS found that different strain conditions cause a transition in the band structure from a direct to pseudo-direct gap.

The GaAs nanowires were grown in the wurtzite (WZ) rather than the zincblende crystal structure usual with

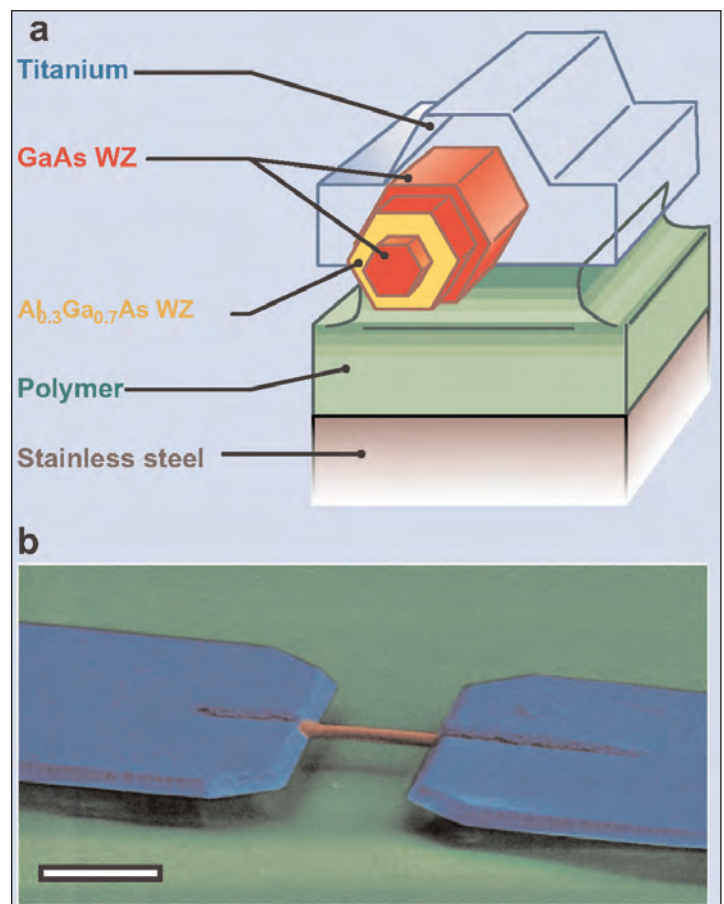


Figure 5. Wurtzite GaAs nanowire strain device. (a) Schematic cross-section of nanowire strain device. Device dimensions not to scale. (b) False-color scanning electron micrograph of nanowire strain device. Scale bar 1mm.

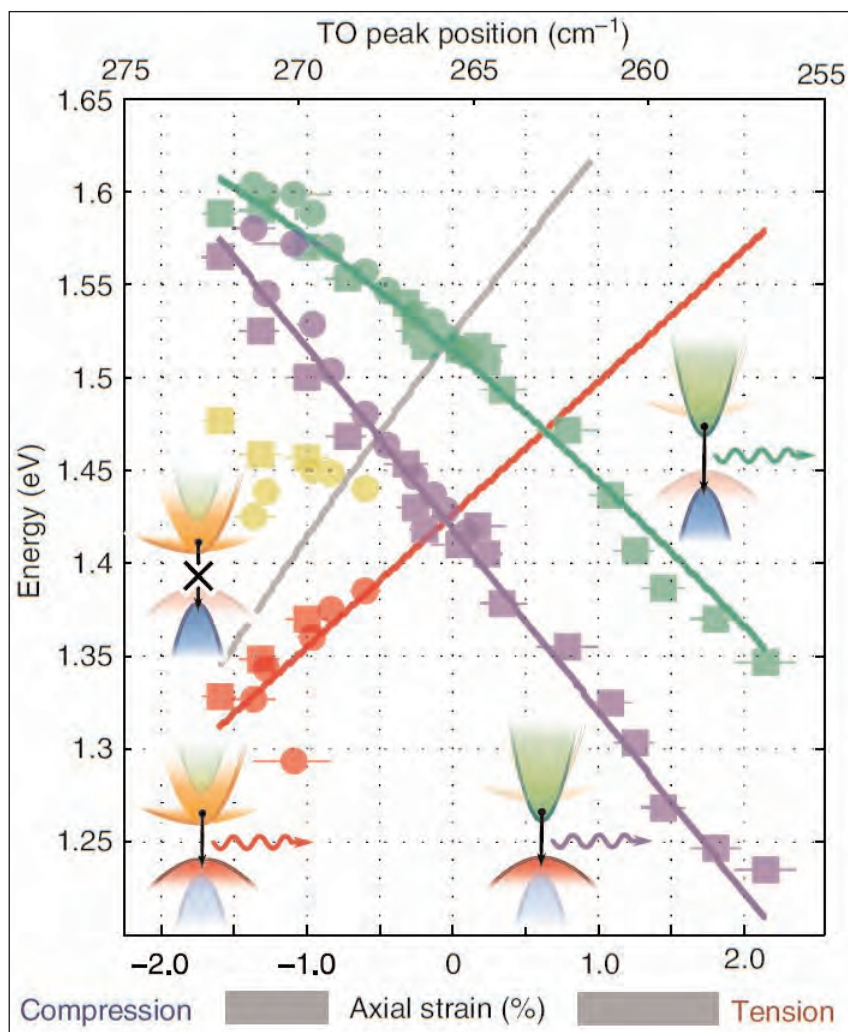


Figure 6. k.p model of uniaxial stress effects in wurtzite GaAs. Energy of optical transitions, extracted from fits of photoluminescence spectra are plotted as function of Raman transversal optical (TO) phonon peak position (top abscissa) and of inferred axial strain (bottom abscissa). Squares and circles represent values obtained from two different nanowire devices. Continuous lines correspond to uniaxial strain dependence of photon energy expected from k.p model. Transitions between bright conduction band and heavy- and light-hole states, purple and green, respectively. Transitions between dark conduction band and heavy-hole band are in red, whereas forbidden transitions between dark conduction band and light hole are represented by grey line. The researchers also found dark conduction band transition (yellow data points) that follows nonlinear energy shift that differs between the two nanowire devices, “whose origin is not yet clear”.

bulk GaAs. The researchers found bright photoluminescence under tension but decreasing brightness under compression. This is interpreted as signaling the transition between a direct to a pseudo-direct energy gap.

There are two conduction bands in WZ GaAs — one offering a direct gap with strong photon emission with transitions to the valence bands of heavy- and light-hole states and the other with simple photon emission to the light-hole band forbidden by symmetry considerations. The direct/pseudo-direct transition occurs

when one of these gaps becomes smaller in energy than the other.

The researchers see the use of such strain effects as being potentially useful to increase carrier lifetime and quantum efficiency of photodetectors, as well as to decrease dark currents and generation–recombination noise. Further, they comment: “These results pave the way for a new generation of devices that can simultaneously serve as efficient light emitters and efficient photodetectors by leveraging the uniaxial strain degree of freedom.”

The c-axis wurtzite (WZ) nanowires were produced in an MBE reactor using a gold-catalyzed vapour–liquid–solid method. The nanowires consisted of a ~40nm GaAs core, and further shells of ~40nm $\text{Al}_{0.3}\text{Ga}_{0.7}\text{As}$ and ~3nm GaAs. The core and AlGaAs shell are lattice-matched. The GaAs shell protects the structure from oxidation.

The nanowires were fabricated into free-standing structures clamped with titanium to a flexible substrate of stainless-steel covered in polymer (Figure 5). Bending the structure created tensile or compressive strain in the nanowire.

Under unstrained conditions, the researchers estimated an optical bandgap of $1.417\text{eV} \pm 8\text{meV}$ (~875nm near-infrared wavelength), by using a model that combines data from Raman spectroscopy and photoluminescence (PL) with a k.p model of the strain-dependent effects on the energy bands (Figure 6). The temperature of the measurement was estimated to be in the range 300–480K due to laser-induced heating on the relatively thermally isolated nanowire structure.

Lead author Giorgio Signorello comments: “The laser power was chosen to be as low as possible for compatibility with the measurement of the PL spectra and, especially, of the Raman spectra (which impose the tightest requirements in terms of laser power). I want to emphasize that using the same laser power for PL and Raman is very important to plot correlated Raman/PL data [as in Figure 6].”

The difference between the bright and dark conduction bands was estimated at $33\text{meV} \pm 47\text{meV}$. For comparison, zincblende (ZB) GaAs has a gap of $1.376\text{eV} \pm 15\text{meV}$ for temperatures of $398 \pm 32\text{K}$.

The researchers hope to combine these discoveries with nanowire growth methods on graphene developed by Crayonano to produce improved solar cells and LEDs. NTNU and Crayonano also plan to grow gallium nitride nanowires on graphene with a view to creating flexible, strong, lightweight white LEDs with better optical properties. ■

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Bipolar diffusion injection into indium gallium nitride quantum wells

Researchers in Finland develop current injection method with possible use in nanowire, near-surface and large-area light-emitting structures.

Aalto University in Finland has developed a new current injection method for nitride semiconductor light-emitting diodes based on bipolar diffusion [L. Riuttanen et al, Appl. Phys. Lett., vol104, p081102, 2014]. The active light-emitting multiple quantum well (MQW) region of the new device is placed under both the p- and n-type contact layers (Figure 1). This is in contrast to the usual arrangement of conventional LEDs where the indium gallium nitride (InGaN) MQWs are sandwiched between the n- and p-contacts.

The researchers believe that such work could lead to devices that could challenge conventional structures for selected applications. "In particular, it would enable a new way to inject current to nanowires and near surface structures as well as fabrication of large-area devices with improved current spreading."

Based on previous simulations and other preparatory design work, the team has now realized these diffusion-injected LEDs (DILEDs) experimentally. The DILED was grown by metal-organic chemical vapor epitaxy (MOVPE) on a 3µm unintentionally doped GaN buffer on c-plane sapphire. The MQW consisted of 5 InGaN wells in GaN barriers.

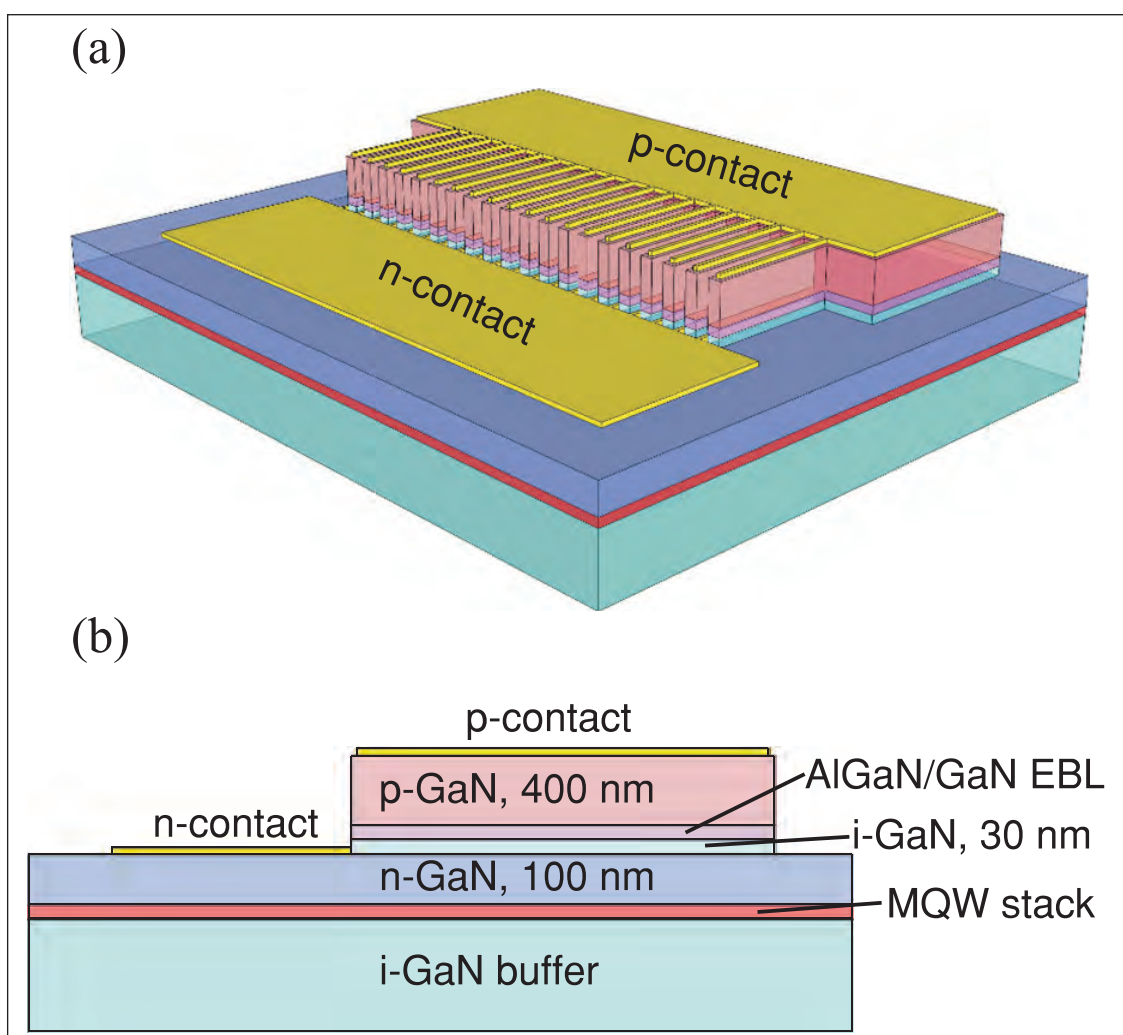


Figure 1. (a) Schematic of device and (b) layer structure and thicknesses. InGaN/GaN MQW stack is located under both p- and n-layers away from pn-junction.

The n- and p-type contact layers were patterned and etched down to the n-type contact layer to create a p-type mesa with a comb structure with 20µm x 300µm-long, 30µm-wide fingers/teeth. The n-type contact metals were titanium/gold. The pad extended in between the fingers/teeth of the p-type comb. The p-contact metals were nickel/gold/titanium/gold.

At low injection of 20mA, most of the electroluminescence (Figure 2) is in a broad yellow band. At high

injection, e.g. 160mA, the yellow band disappears, leaving the 450nm wavelength of the MQW. The measured output power was for light emitted through the back-side of the device.

The yellow band emission could be due to "shallow dopants in n-GaN, carbon impurities in i-GaN or gallium vacancy complexes in i-GaN". Microscopic inspection indicated that the yellow emission came from the mesa.

The blue emission was found to originate mostly from the finger/teeth regions. "Since the QWs are located far outside the pn-junction, this indicates that both electrons and holes are transported to the QWs from the same side of the active region through bipolar diffusion," the researchers write.

There was no blue-shift, which is normally observed in conventional MQW LEDs at increasing current. The researchers comment: "This suggests that the electric field inside the QWs is much less dependent on the external bias voltage than in conventional III-N LEDs."

The bias voltage at 20mA was 3.9V and at 160mA was 5.8V. "The relatively high bias voltages are expected to be mainly caused by the unoptimized metal contacts as well as the resistance of the thin n-GaN layer of the DILED structure," the researchers explain. They add that the current-voltage characteristics of the device were comparable with those of conventional InGaN/GaN MQW LEDs.

Using the area of the p-type mesa as the effective area of the device, an injection current of 250mA corresponds to $40\text{A}/\text{cm}^2$. Output power increases superlinearly, unlike conventional devices that begin to show efficiency droop effects at these injection levels. This is probably due to the low carrier densities in the MQW "caused by low injection efficiency of the unoptimized device structure".

The external quantum efficiency (EQE) was low at about 0.4% at 250mA injection. The EQE curve increases at high current. The researchers suggest that the usual degradation of internal quantum efficiency at the higher temperatures or higher current is counterbalanced by improved diffusion of carriers into the MQW active region. The back-side temperature at 250mA current was 70°C , due to Joule heating and non-radiative recombination effects. The estimated junction temperature was 80°C . A cooling flow of room-temperature nitrogen reduced the optical output power.

The researchers performed simulations on a simplified structure with a single quantum well of 10nm and 20nm p-AlGaIn electron-blocking layer. They report: "The hole concentration decreases as a function of depth as the holes diffuse deeper into the n-GaN. Despite the low hole concentration at the edge of the n-GaN region next to MQW stack, the MQW stack acts as a drain and both electron and hole concentrations

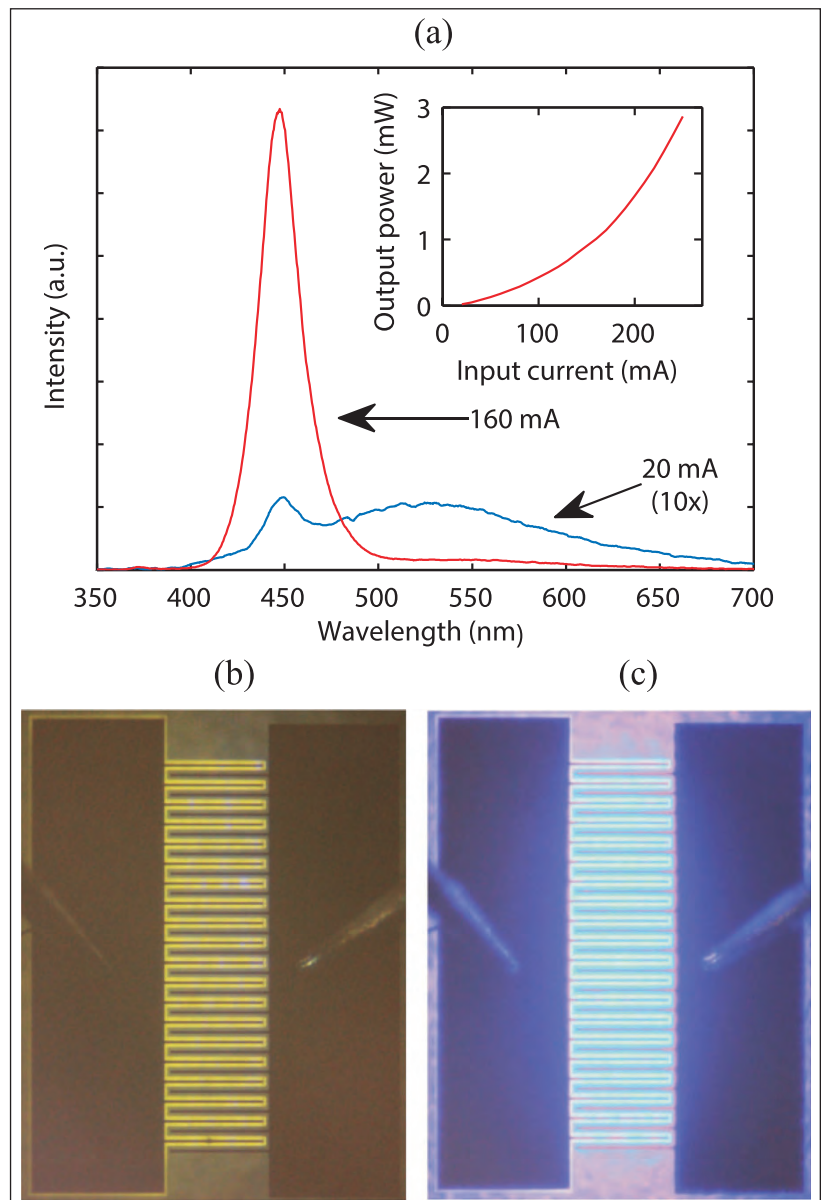


Figure 2. (a) EL spectra of DILED at injection currents of 20mA and 160mA at room temperature. Intensity of 20mA graph is scaled by factor of 10 to show spectrum line-shape. Inset: optical power for 400–500nm emissions versus input current. (b) Low and (c) high injection current DILED micrographs.

increase drastically in the active region. Additionally, just above the active region the electron concentration decreases because the active region efficiently captures electrons from the n-GaN layer."

A thick depletion region forms below the MQW active region with reduced electron and hole concentrations.

The low ~0.4% EQE measurement was reflected in a simulated injection efficiency of ~4%, the order of magnitude difference being attributed to light extraction efficiency problems. The researchers believe the injection can be improved with optimization of "layer thicknesses and doping levels as well as reducing finger widths closer to the diffusion lengths of the carriers". ■

<http://dx.doi.org/10.1063/1.4866343>

Author: Mike Cooke

Distributed Bragg reflectors for InGaN LEDs on silicon

Chinese researchers use DBRs to boost wall-plug efficiency by 24%.

Sun Yat-sen University in China has improved the wall-plug efficiency of indium gallium nitride (InGaN) light-emitting diodes (LEDs) grown on silicon by incorporating a distributed Bragg reflector (DBR) [Yibin Yang et al, Appl. Phys. Express, vol7, p042102, 2014].

Although the growth of nitride semiconductor LED structures on silicon promises production cost benefits, there are two technical barriers to be overcome. First, the growth of high-quality gallium nitride on silicon is more difficult than on alternative, more expensive substrates such as sapphire or silicon carbide. Second, light emitted into the silicon substrate is lost because its bandgap is narrower than that of the overlying active nitride semiconductor structures.

One way to avoid the second problem is to remove the silicon substrate from the LED layers. However, such techniques are complicated and result in low yields and high cost. Incorporating a DBR between the silicon substrate and active light-emitting layers avoids the need to remove the substrate by reflecting the light upwards through the wide-bandgap layers that do not significantly absorb the produced photons.

The Sun Yat-sen University epitaxial nitride layers (Figure 1) were grown on 2-inch n⁺-silicon (111) substrates in a Thomas Swann close-coupled showerhead metal-organic chemical vapor deposition (MOCVD) system.

The substrate was cleaned before deposition to remove surface oxidation. The 100nm aluminium nitride (AlN) nucleation/seeding layer was formed by first depositing aluminium and then introducing ammonia, preventing the formation of silicon nitride.

The AlN layer was also designed to prevent melt-back etching that occurs in the presence of gallium-silicon alloys. The next linear compositionally graded AlGaIn layer was constructed to compensate for tensile stress and thus avoid cracking in the overlying layers.

The researchers found that the AlN/GaN DBR layers reduced the threading dislocation density significantly,

Contact	p-GaN	240nm
Multiple quantum well	(InGaIn/GaN)x6	
Contact	n-GaN	800nm
Cap	GaN (102°C, 250mbar)	300nm
Distributed Bragg reflector	(AlN/GaN)x5 (106°C, 100mbar) (56nm/48nm)x	
Compositionally graded buffer	AlGaIn	660nm
Seeding	AlN	100nm
Substrate	n ⁺ -Si (111)	

Figure 1. Epitaxial structure of LEDs with DBR.

compared with that of the underlying AlGaIn and AlN.

The LED devices (Figure 2) were fabricated with through-hole connections to the n-contact layer using inductively coupled plasma reactive-ion etching (ICP-RIE). First, the n-GaN contact layer was exposed in a mesa etch. Further selective ICP-RIE drilled the holes down to the conductive n⁺-Si substrate.

The structure was then subjected to a 700°C anneal in nitrogen for 25 minutes to activate the magnesium-doping of the p-GaN contact. The researchers say that the annealing also partially repaired etch damage from the ICP-RIE process.

The p-GaN contact was covered with nickel/gold as a transparent conductor. Annealed chromium/palladium/gold was used as bonding pads for the p- and top n-electrodes. The same metal combination was used to fill the through-holes and thus short out the resistive DBR and AlGaIn buffer layers.

The Si substrate was thinned to 100µm and was coated with titanium/nickel/gold as a back-side n-electrode. The resulting LED structure measured 1mm x 1mm.

The peak reflectance of the DBR was 58% at 463nm, significantly short of the theoretical value of 83%. The researchers write: "This difference may result from structural imperfections such as deviations from the designed layer thickness and interface roughness between each epitaxial layer. Scattering loss and absorption in the film are other potential causes."

Even so, the photoluminescence was "significantly greater for the DBR-based LED", compared with a device without DBR. The full-width at half-maximum (FWHM) of the peak was 8.6nm with DBR, but 17.6nm without. The researchers attribute the narrower line-width to "higher light efficiency and better crystalline

Figure 2. Fabrication processes of vertical-conducting DBR-based LED chips with through-holes: (a) epitaxial layer deposited on Si substrate; (b) dry etching to expose n-GaN and form through-holes; (c) depositing metals as electrodes and current paths of vertical-conducting DBR-based LED with through-holes marked by curves with arrows. (d) Light-emitting image of the vertical-conducting DBR-based LED chip with through-holes at an injecting current of 100mA.

quality owing to reflectivity enhancement and suppression of dislocation formation by the DBRs".

The main peak for electroluminescence fell within the range 465-468nm for injection currents from 50mA up to 600mA.

The forward voltage at 20mA was 3.68V when the n-contact was made with the 'lateral' top n-GaN electrode and 3.96V when made with the bottom 'vertical' n-Si electrode. The corresponding series resistances were 5.5Ω and 7.7Ω. The greater series resistance with the vertical conduction scenario was attributed to the resistances of the top and bottom contacts with the silicon substrate and its bulk resistivity.

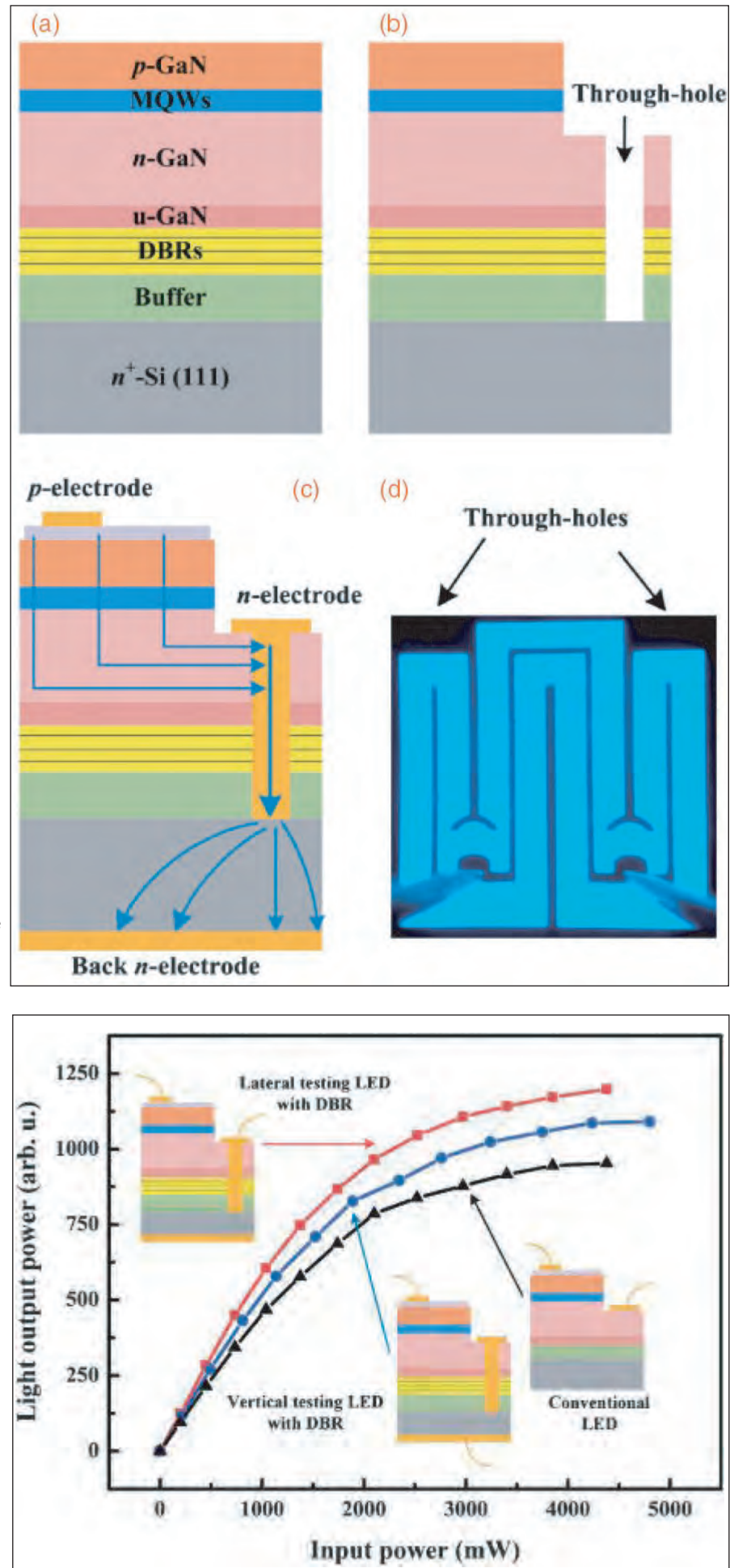
Without the through-hole structure, vertical conduction is limited with a current of 1.3μA even at 100V, giving a series resistance of the order of 107Ω. This reflects the insulating nature of the AlN seed, AlGaIn buffer, and DBR layers.

The wall-plug efficiency (WPE) for light output power of devices with DBRs for 2100mW input (350mA) increased by around 24% over the performance of conventional LEDs without DBRs (Figure 3). The DBR LEDs in the vertical conducting mode suffered from the higher series resistance, particularly at higher input power where self-heating effects led to performance degradation. Even so, the vertical DBR LED mode had greater WPE than conventional LEDs without DBRs. ■

<http://iopscience.iop.org/1882-0786/7/4/042102/article>

Author: Mike Cooke

Figure 3. Light output power versus input power of DBR-based LEDs with through-holes under lateral and vertical testing modes, and conventional LED.



Substrates shaping trends in LED front-end manufacturing

The impact of sapphire substrates will grow unless GaN-on-Si and GaN-on-GaN improves in performance and cost.

According to Yole Développement's market research report 'LED Front-End Manufacturing Trends' (which covers substrates, epitaxy, lithography, plasma etching & deposition, PVD and testing), the LED substrate is one of the key factors impacting the LED front-end industry.

This impact is manifested in the following ways:

- Increased demand for larger-diameter sapphire wafers, with big players (such as LG, Sharp or Osram) moving to 6" wafers and Taiwanese players moving to 4" wafers.
- Increased demand for patterned sapphire substrates (PSS), which have now become mainstream in the industry (87% share, as of first-quarter 2014) even if some questions remain concerning the strategies of key patent holders.
- The development of gallium nitride-on-silicon (GaN-on-Si) and GaN-on-GaN LEDs, with both technologies having begun mass production in some companies (such as Sora for GaN-on-GaN, or Toshiba for GaN-on-Si). However, market penetration of these

alternative substrates will be secondary to future improvements in terms of performance and cost.

Otherwise, GaN-on-Si and GaN-on-GaN LEDs will not be able to fully compete with sapphire-based LEDs.

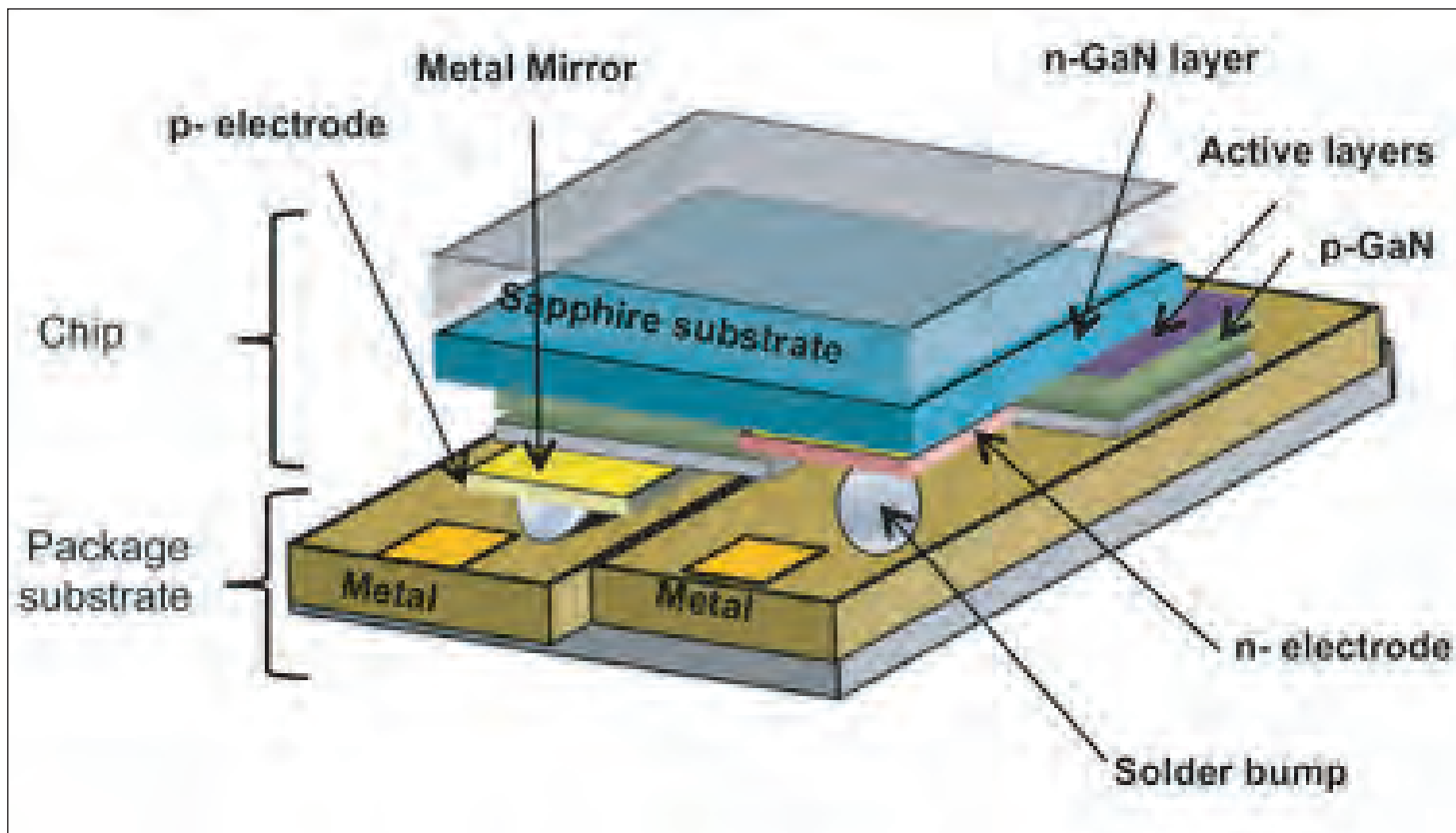
The impact of the sapphire industry on the LED sector is likely to grow in the future because of the partnership in fourth-quarter 2013 between GT Advanced Technologies Inc (GTAT) and Apple to set up a large (\$1bn) sapphire manufacturing plant which, with a capacity roughly doubling the industry's existing qualified sapphire capacity, could totally modify the structure and evolution of the sapphire and LED industries in the next few years, reckons Yole.

Increased competition to accelerate new LED MOCVD reactor development

Epitaxy has been of core interest to the LED front-end industry, and has seen the entry of several new players in the metal-organic chemical vapour deposition (MOCVD) reactor market since 2011/2012, notes Yole. Even if increased competition has not really affected



Commercial status of LEDs based on different substrates (as of Q1/2014).



Structure of flip-chip LED.

the market leaders (Aixtron, Veeco and Taiyo Nippon Sanso), it has forced them to accelerate development of the next generation of MOCVD tools to leverage market entry barriers. This generation of MOCVD reactors should focus on cost of ownership (CoO) and see the emergence of enhanced designs (with new heating systems, new gas-flow designs, and increased automation etc), says Yole.

Regarding lithography, plasma etching & deposition, PVD and testing, mostly incremental evolutions have occurred (such as improvements in throughput, and reductions in average selling price), reflecting saturation in technological development, notes Yole.

Flip-chip technology as the new battleground

As flip-chip gradually matures, LED makers are actively developing this technology as it provides several advantages, such as larger light-emitting area and highest luminosity, better heat dissipation, adjustable dimensions, and the elimination of wire-bonding.

While this technology has been in the hands mostly of a few big LED makers (such as Cree or Lumileds), in 2013 Taiwanese manufacturers (mainly Epistar, FOREPI and Genesis Photonics) also started to develop it.

In 2014, flip-chip technology should also make its way into the mid-power LED market. In third-quarter 2013, Lumileds announced plans to introduce flip-chip technology into the mid-power LED market, as devices in this sector have drawn the most attention from the

general lighting market in 2013. Indeed, following the industry overcapacity of 2011/2012, mid-power LEDs have become mainstream in interior lighting applications.

From technology-oriented to cost-oriented manufacturing

LED manufacturing still uses methods and practices — such as manual wafer handling, with operators moving wafers with tweezers in (not so) cleanrooms — that would be considered outdated in most semiconductor industries. However, the emergence of LED 'giants' (such as Cree, Osram, Lumileds, Samsung and LG) have facilitated and sped up the adoption of manufacturing paradigms from the IC industry in order to reduce overall manufacturing cost and increase product quality. These factors include the following:

- the transition from batch processing to single-wafer processing;
- automation, cluster tools, full cassette-to-cassette operation;
- statistical process control (SPC), defect management etc;
- a reduction of SKUs (stock-keeping units); and
- enterprise management systems (EMS).

As a result, the gap will widen between Tier-1 players and other players, pushing forward industry consolidation, forecasts Yole.

www.i-micronews.com/reports/LED-Front-End-Manufacturing-Trends-report/14/433

Improving electrically pumped external-cavity mode-locking

ETH Zürich and Philips Technologie claim shortest pulses and highest powers for 981nm passively mode-locked electrically pumped VECSEL.

ETH Zürich and Philips Technologie GmbH have developed 981nm-wavelength passively mode-locked electrically pumped vertical-external-cavity surface-emitting lasers (EP-VECSELs) with “the shortest pulses (2.5ps), highest average output power (53.2mW), highest repetition rate (18.2GHz), and highest peak power (4.7W) to date” [C. A. Zaugg et al, Appl. Phys. Lett., vol104, p121115, 2014].

Mode-locking is a technique to produce extremely short laser pulses. The researchers believe that EP-VECSELs could drastically reduce the complexity, footprint and cost of such devices, with potential applications in optical communication, sampling and clocking. The researchers comment: “If optimized for compactness, the laser could be built in a volume as small as 1cm³ with little effort, and even smaller if industrial packaging would be applied.”

An EP-VECSEL consists of a gain chip and semiconductor saturable absorber mirror (SESAM) arranged in V- or Z-shape cavity configurations. The V-shape configuration includes a curved output coupler (OC). The Z-shape configuration has an added curved high-reflectivity (HR) mirror (Figure 1).

The ETH/Philips team used both V- and Z-cavity setups. In the V-cavity configuration, the SESAM was placed about 3mm from the gain chip.

Philips Technologie fabricated the gain chip with an improved doping scheme for a better trade-off between electrical and optical losses, and implementing a smaller bottom contact than the top contact to strongly confine the current-injection profile in the center of the device.

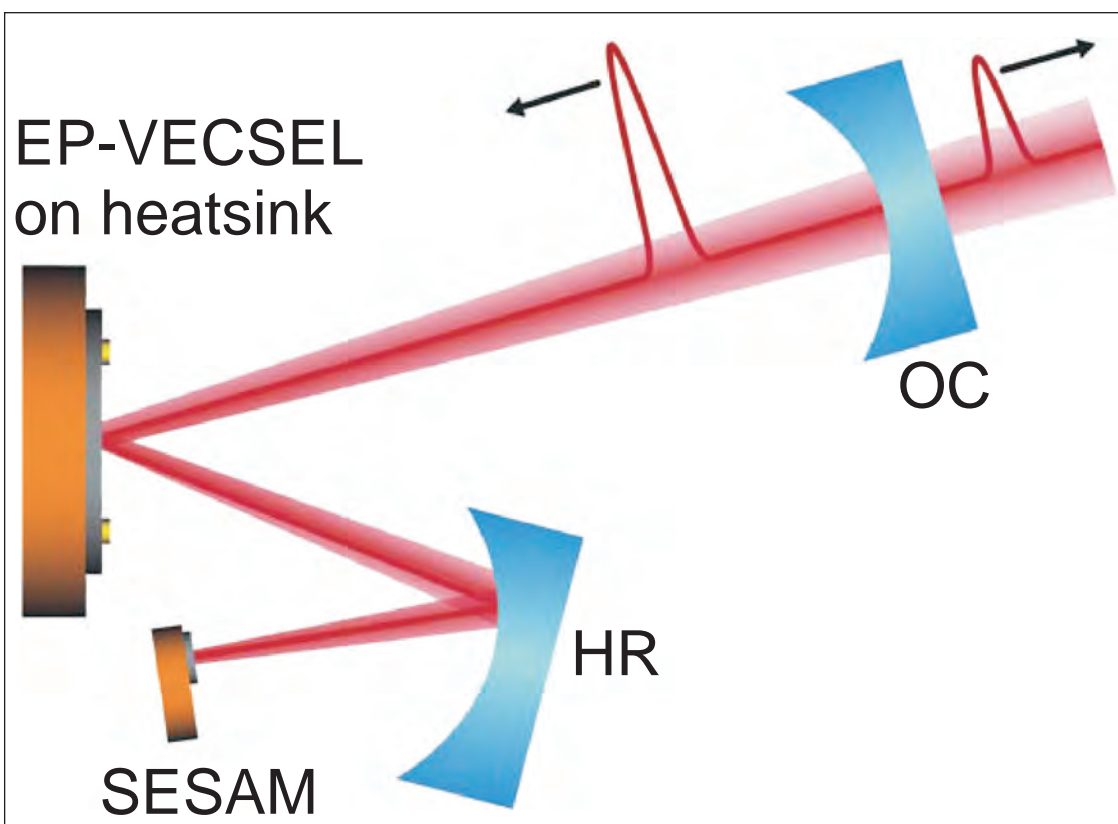


Figure 1. Z-cavity setup for EP-VECSEL.

These factors optimized the fundamental mode (TEM_{00}) of the cavity.

The gain chip was flipped so that the laser light was emitted through the growth substrate. The substrate was thinned to 100µm before flipping. The active light-emitting region consisted of three indium gallium arsenide (InGaAs) wells embedded in gallium arsenide (GaAs) barriers. The active region was sandwiched between distributed Bragg reflectors (DBRs). The bottom DBR (grown last) consisted of a 37-pair p-type structure. The top DBR was an 11-pair n-type structure.

The bottom contact was 60µm diameter. The chip was bonded to an aluminium nitride (AlN) heat spreader. The light-emitting oxide aperture was 100µm diameter with a ring electrode top contact. An anti-reflective coat was also applied.

The SESAM consisted of a 30-pair AlAs/GaAs DBR, single InGaAs quantum well in AlAs, and a thin GaAs cap. The InGaAs well was designed to be at an

Table 1. Overview of EP-VECSEL results.

P_{avg} (mW)	f_{rep} (GHz)	τ_{pulse} (ps)	P_{peak} (W)
53.2	9.2	2.91	1.74
10.1	18.2	9.48	0.05
15.9	2.2	2.47	2.62
35.0	2.2	3.03	4.73

anti-node of the electro-magnetic standing-wave field. Also, the semiconductor-air interface was at an electric field node (i.e. zero field). The SESAM was coated with silicon nitride and silicon dioxide using plasma-enhanced chemical vapor deposition (PE-CVD) to improve modulation depth and saturation fluence.

With a long V-cavity (13.3mm between gain chip and OC), the highest average output power of 53.2mW at 355mA injection current was achieved with mode-locking, resulting in a pulse repetition rate of 9.2GHz (Figure 2).

The pulse duration was 2.9ps. The gain chip heat-sink was maintained at 3°C while the SESAM was at 32°C.

A short-cavity (5mm gain chip to OC) mode-lock of 18.2GHz repetition rate of 9.7ps pulses achieved an average output power of 10.1mW at 265mA. The gain chip heat-sink was at 3°C and the SESAM was at 25°C. The dimensions of the essential elements of this EP-VECSEL cavity setup were 3cmx3cmx2cm.

In a Z-cavity configuration, the pulses were as small as 2.47ps at 282mA injection current (10.6°C gain chip, 55°C SESAM). The average output power was 15.9mW. The repetition rate was 2.17GHz.

Increasing the injection current to 288.7mA and reducing the gain chip temperature to 9.7°C increased the average output power to 35mW with 3ps pulses at 2.15GHz repetition. This configuration had the highest peak power of 4.7W (Table 1). ■

<http://dx.doi.org/10.1063/1.4870048>

Author: Mike Cooke

Mode-locking is a technique to produce extremely short laser pulses. The researchers believe that EP-VECSELs could drastically reduce the complexity, footprint and cost of such devices, with potential applications in optical communication, sampling and clocking. The researchers comment: "If optimized for compactness, the laser could be built in a volume as small as 1cm³ with little effort, and even smaller if industrial packaging would be applied."

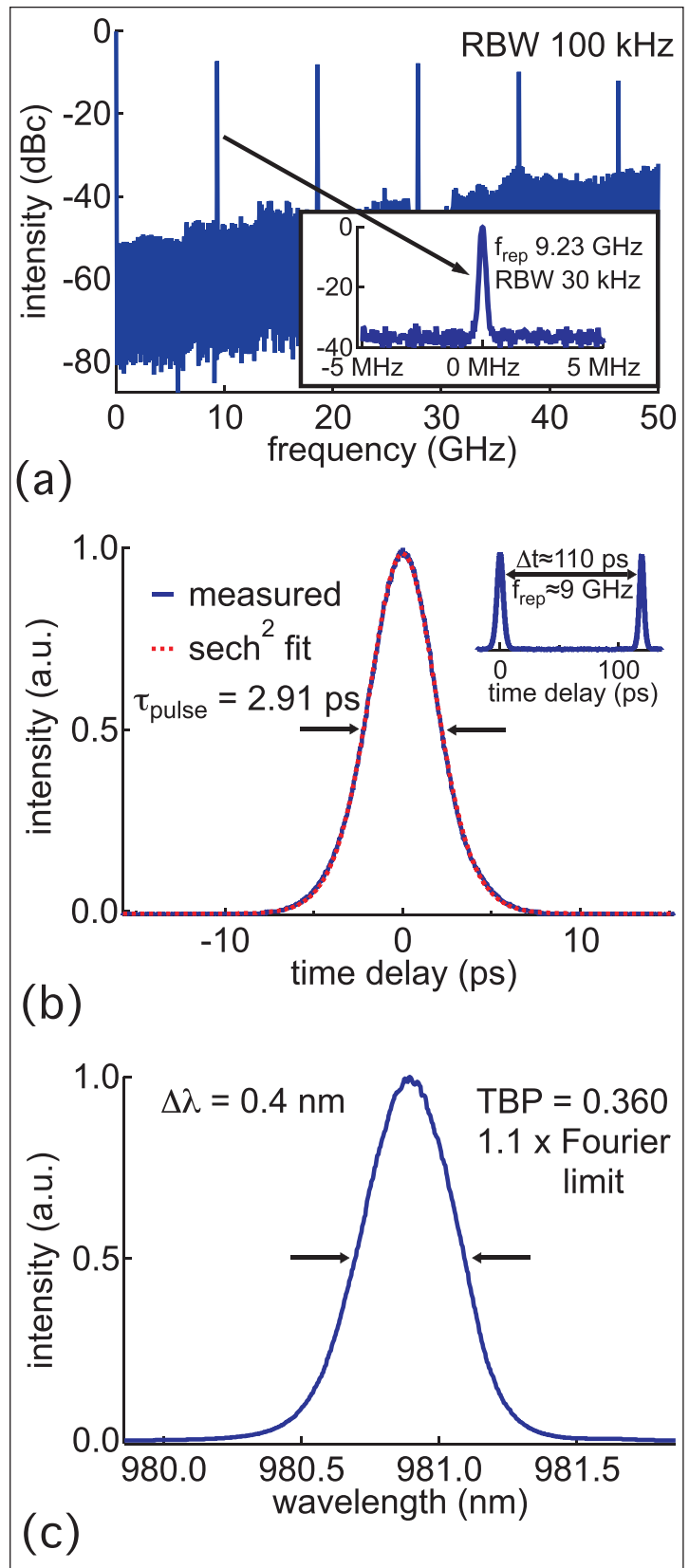


Figure 2. SESAM mode-locked EP-VECSEL with highest average output power of 53.2 mW. (a) Microwave spectrum of pulse train in wide span, zoomed in around fundamental pulse repetition frequency of 9.23GHz (inset). (b) Autocorrelation (blue) and sech²-fit (red dashed) revealing pulse duration of 2.9ps. Fundamental mode-locking with longer time delay (inset). (c) Optical spectrum. (TBP: time-bandwidth product.)

InP/GaAsSb DHBT with record more than 700GHz power-gain cut-off

Base contact resistance has been reduced by in-situ argon sputtering treatment of the GaAsSb base before metal deposition.

The Swiss Federal Institute of Technology (ETH-Zürich) has reported a record power-gain cut-off frequency, f_{MAX} , of 700GHz for a double heterostructure bipolar transistor (DHBT) based on indium phosphide (InP) and gallium arsenide antimonide (GaAsSb) [Ralf Flückiger et al, Appl. Phys. Express, vol7, p034105, 2014].

The epitaxial material structure (Figure 1) was achieved using metal-organic chemical vapor deposition (MOCVD) on 2-inch semi-insulating InP substrates. The heterostructure used staggered gap 'Type II' InP/GaAsSb junctions where the band discontinuities are in the same direction. Such structures allow the use of a simplified pure InP collector, giving good thermal conductivity and high breakdown voltages.

The transistors were constructed as 'triple-mesa' devices with 0.4 μm -wide emitter and base, achieved with inductively coupled plasma and wet etch processes. The emitter-base junction area was 0.3 μm x 4.4 μm .

The emitter and base electrodes consisted respectively of titanium/platinum/gold and palladium/nickel/platinum/gold. The surface of the

Emitter contact	$\text{Ga}_{0.75}\text{In}_{0.25}\text{As}$	5nm
Graded emitter contact	$\text{Ga}_z\text{In}_{1-z}\text{As}$	10nm
Emitter contact	$\text{Ga}_{0.47}\text{In}_{0.53}\text{As}$	20nm
Emitter	InP:Si	130nm
Emitter	InP:Si	5nm
Graded emitter	$\text{Ga}_y\text{In}_{1-y}\text{P:Si}$	10nm
Emitter	$\text{Ga}_{0.22}\text{In}_{0.78}\text{P:Si}$	5nm
Graded base	$\text{GaAs}_x\text{Sb}_{1-x}$	20nm
Collector	InP:S	125nm
Pedestal	InP:S	50nm
Etch stop	$\text{Ga}_{0.40}\text{In}_{0.60}\text{As:Si}$	20nm
Buffer	InP:S	300nm
Substrate	Semi-insulating InP	

Figure 1. Epitaxial layer sequence. The gradings in the upward direction were $x = 0.41\text{--}0.59$, $y = 0.22\text{--}0.00$, and $z = 0.47\text{--}0.75$.

Figure 2. (a) Schematic representation of emitter and base contact. The emitter contact acts as a mask for argon sputtering and protects base access region. (b) Scanning electron micrograph of focused-ion-beam cross section of representative DHBT. Arrow indicates residuals of Teflon planarization.

GaAsSb base was treated using an in-situ argon sputtering process before metal deposition (Figure 2). The treatment is found to reduce contact resistivity from $\sim 10^{-6}\Omega\text{-cm}^2$ to $\sim 10^{-9}\Omega\text{-cm}^2$. The process removed about 10nm of GaAsSb, including oxidation layers. The emitter was protected by the metal contact electrode layers that acted as a self-aligned mask.

Passivation of the emitter and base sidewalls was provided by plasma-enhanced chemical vapor deposition (PECVD) of silicon nitride. A low-temperature Teflon-based etch-back process was used to planarize the devices before the deposition of probe pads.

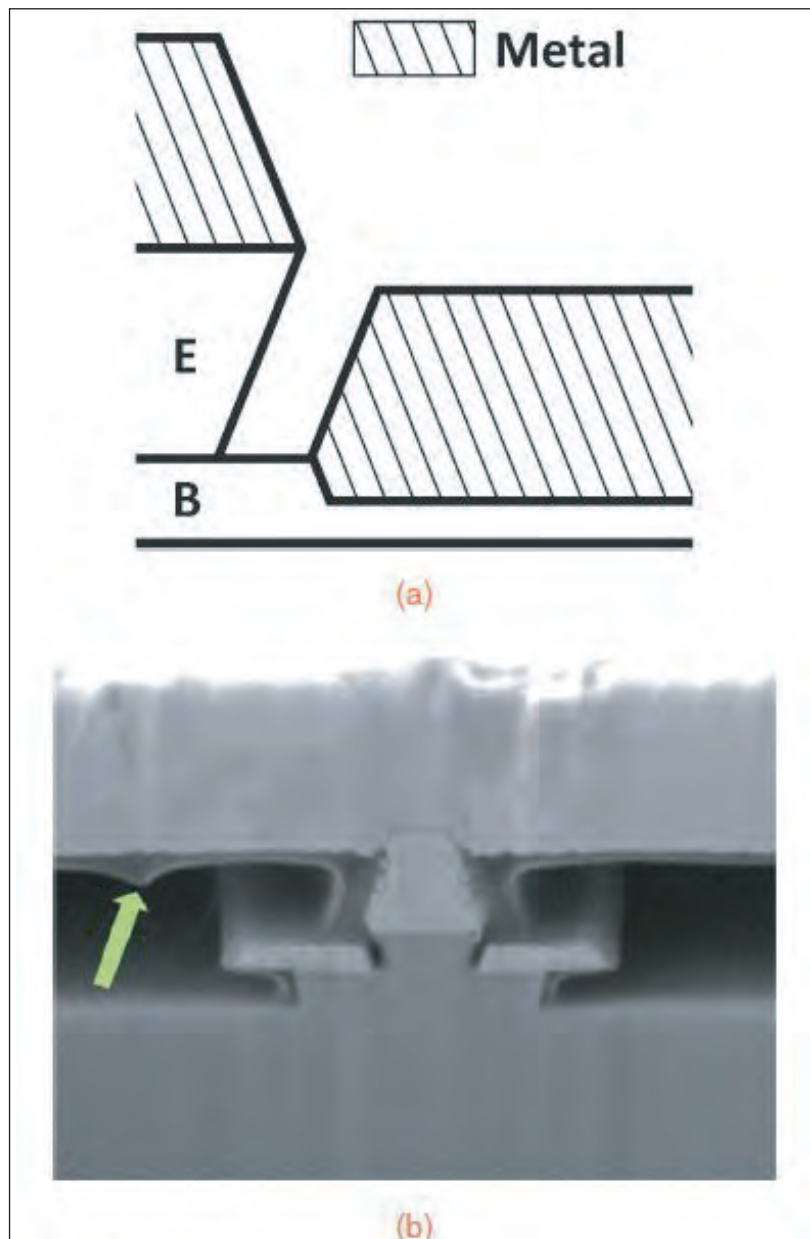
The RF performance was measured between 0.2GHz and 40GHz, giving estimated current- (f_T) and power-gain (f_{MAX}) cut-offs of 442GHz and 701GHz, respectively, at a collector-emitter voltage (V_{CE}) of 1.2V. With a higher V_{CE} of 1.6V, the corresponding estimates were 429GHz and 715GHz.

The researchers write: "The present devices show a $\sim 100\text{GHz}$ higher f_{MAX} than those previously reported with the same epitaxial layer structure."

The DC gain of the device was 11 and the common-emitter breakdown voltage (BV_{CEO}) was over 5V. ■

<http://iopscience.iop.org/1882-0786/7/3/034105/article>

Author: Mike Cooke



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Pushing high-power, high-frequency performance of GaN HEMTs on silicon

Singapore researchers claim a record Johnson figure of merit of 8.32THz-V for conventional AlGaIn high-electron-mobility transistors.

Singapore's Nanyang Technological University has developed conventional aluminium gallium nitride (AlGaIn) high-electron-mobility transistors (HEMTs) with record-breaking figures-of-merit (FOMs) for frequency and breakdown performance [Kumud Ranjan et al, Appl. Phys. Express, vol7, p044102, 2014].

The Johnson FOM is defined as the product of the unity current gain cut-off frequency and the off-state breakdown gate-drain voltage ($f_T \times BV_{gd}$). The J-FOM is designed to reflect the needs of high-power microwave devices. The Nanyang device achieved 8.32THz-V, which is claimed as a record for conventional T-gate AlGaIn/GaN HEMTs on silicon substrates (Figure 1). Using much more expensive silicon carbide (SiC) substrates, researchers in Japan produced HEMTs with 12.9THz-V J-FOMs.

The conventional AlGaIn/GaN HEMT structures (Figure 2) were grown on 100mm high-resistivity (111) silicon substrates using metal-organic chemical vapor deposition (MOCVD). The resulting two-dimensional electron gas (2DEG) channel had a carrier density of $0.87 \times 10^{13}/\text{cm}^2$ with mobility of $1940 \text{ cm}^2/\text{V-s}$.

In more detail, the layer structure consisted of 100nm AlN nucleation, 1400nm transition, 800nm GaN buffer/channel, 1nm AlN spacer, 8nm $\text{Al}_{0.26}\text{Ga}_{0.74}\text{N}$ barrier, and 2nm GaN cap. The AlN spacer improved the mobility of the 2DEG to allow higher frequencies and transconductance. The thin AlGaIn barrier reduced

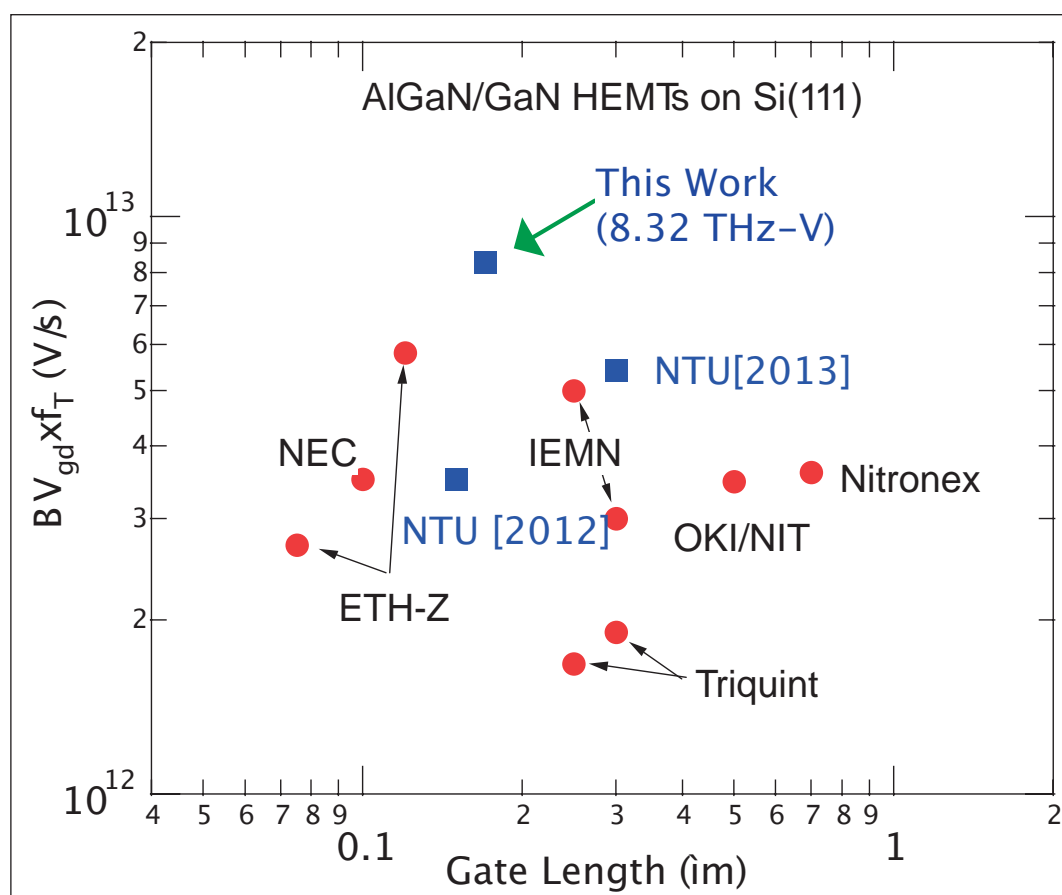


Figure 1. Benchmarking with state-of-the-art J-FOMs ($BV_{gd} \times f_T$) versus L_g for AlGaIn/GaN HEMTs on Si substrates.

short-channel-effect performance degradation.

The HEMT fabrication used plasma etch for mesa isolation, annealed titanium/aluminium/nickel/gold for ohmic source-drain contacts, ammonium sulfide ($(\text{NH}_4)_2\text{S}_x$) treatment, T-gate formation, titanium/gold transmission lines, and silicon nitride passivation. The T-gate footprint measured $0.15 \mu\text{m}$. The T-head was $0.5 \mu\text{m}$. Further device dimensions were $0.8 \mu\text{m}$ source-gate, $2 \times 75 \mu\text{m}$ gate width, and $3 \mu\text{m}$ gate-drain.

The maximum DC current of the device was 800 mA/mm . The peak extrinsic transconductance was 346 mS/mm . The threshold voltage was -1.7 V . The drain-induced barrier lowering (DIBL) was "negligibly small" at

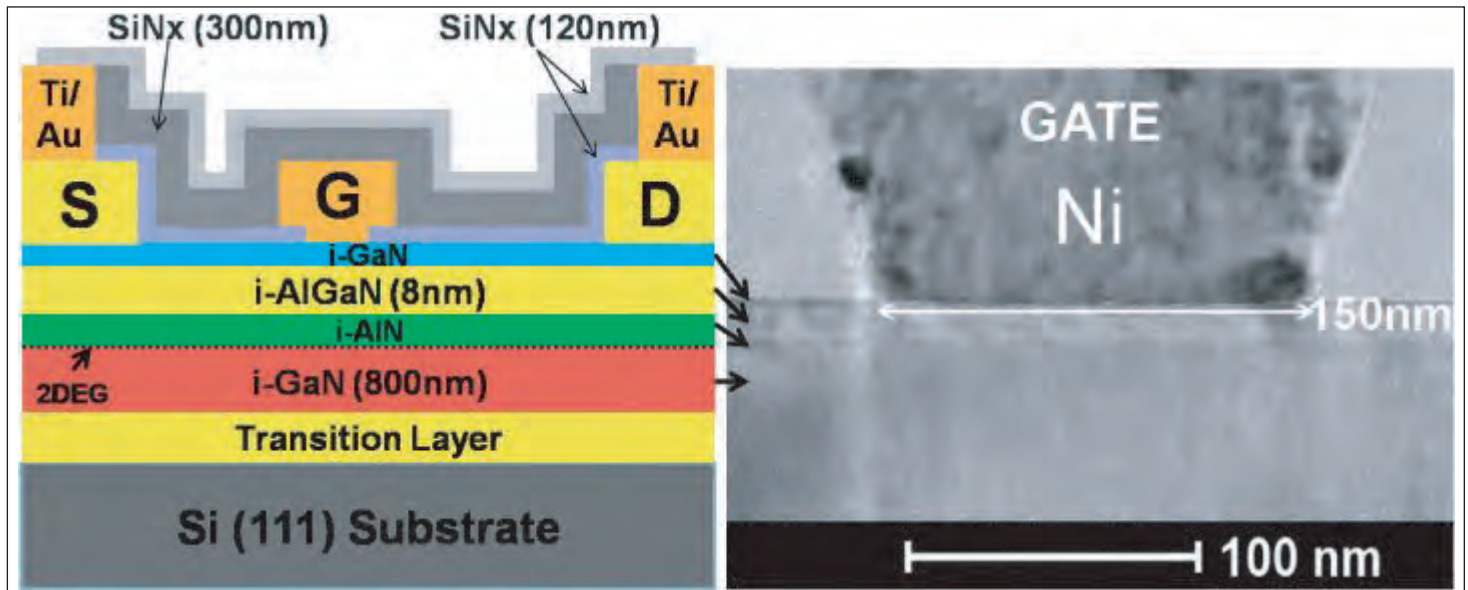


Figure 2. Schematic cross-section and high-resolution cross-sectional transmission electron micrograph (TEM) (gate region) of Nanyang AlGaIn/GaN HEMTs on Si substrates.

1.5–3.0mV/V. This compares with DIBL values an order of magnitude greater achieved with $\sim 0.15\mu\text{m}$ gates and InGaIn or AlGaIn back barriers. The researchers comment on their device: “The observed low DIBL is due to the large gate-to-channel aspect ratio ($L_g/d_{gc} \sim 15$).”

Small-signal high-frequency measurements gave estimates for the cut-off frequency (f_T) of 63.1GHz and the maximum oscillation/unity power gain (f_{max}) of 124GHz for 6V drain and -0.8V gate biasing. The three-terminal off-state 1mA/mm breakdown (BV_{gd})

occurred at 132V.

Current collapse under gate- and drain-lag pulsed operation was 6% and 8%, respectively. The researchers comment: “These values are closely matched with or even better than those in other reports on AlGaIn/GaN HEMTs on Si substrates. The suppression of current collapse is mainly due to the ammonium sulfide treatment plus SiN passivation.” ■

<http://iopscience.iop.org/1882-0786/7/4/044102/article>

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GaN to grow at 9% CAGR to over 18% of RF device market by 2020

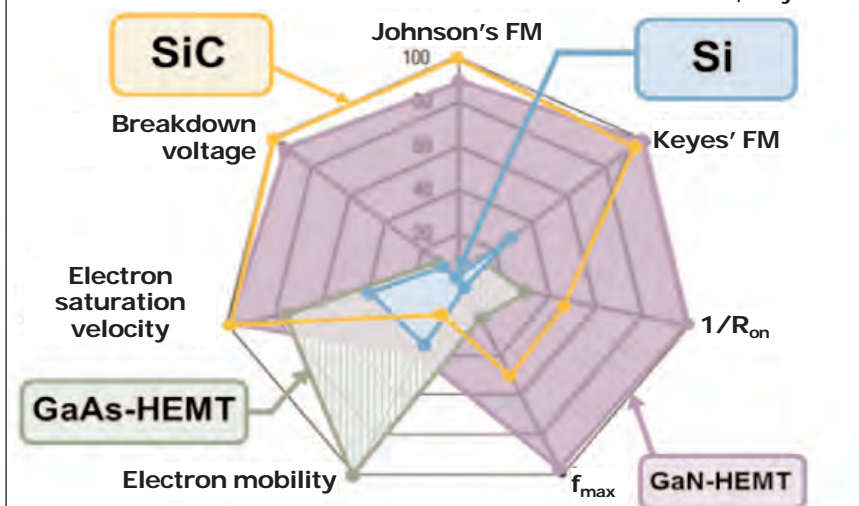
GaN-on-Si to challenge Si-LDMOS under 3.5GHz?

The need for high-power, high-frequency transistors is increasing steadily, commensurate with the huge demand for wireless telecommunications, notes market research firm Yole Développement in its report 'RF GaN Technology & Market Analysis: Applications, Players, Devices & Substrates 2010–2020'. More power, more frequency bands, better linearity and improved efficiency are still driving the development of RF semiconductor devices, since the market needs devices able to handle all of these specifications at a reasonable price.

Recent mergers and acquisitions are a concern for the overall RF market and silicon LDMOS, gallium arsenide (GaAs) and gallium nitride (GaN)-based devices, says Yole. The overall RF market does not seem large enough for so many players, hence companies are trying to gain scale in order to increase profitability, which has stagnated. "We expect that commercial wireless telecom, CATV [cable television] and defense applications will be the main applications affected," says Yole.

Although significant improvements have been achieved in RF GaN-based devices (performance and yields), Yole believes that there is still a barrier preventing gallium nitride on silicon carbide (GaN-on-SiC) from entering mainstream applications (i.e. in wireless telecom base-stations or CATV). In applications below 3.5GHz, GaN-on-SiC is not cost-effective enough versus Si-LDMOS, resulting in low market penetration rates, adds the firm. M/A-COM Technology Solutions Inc of Lowell, MA, USA and epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK believe they will enter mass production using 6" and 8" GaN-on-Si substrates in two years. IQE will offer MACOM a significant mass-production level due to its existing production for

Comparison of GaN/SiC/Si/GaAs high-power RF transistors
OKI Semiconductors, May 2014



other applications. "Our analysis shows that GaN-on-Si could be implemented in 2-5 years within telecom base-stations, MilCom [military communications] and CATV," says Yole. "In this optimistic scenario, RF GaN-based devices could see an increased penetration rate and reach more than 20% of the overall RF device market by 2020," it adds.

From defense to mainstream – RF GaN technology continues to be adopted for commercial applications

Over the last several years, silicon LDMOS' share of high-power RF amplification applications in the 2GHz+ frequency range has fallen from 92% to 76%; the remaining 24% market share is addressed mainly by technologies such as GaAs pHEMT or GaN HEMTs. This equilibrium continues to be turned around by GaN HEMT implementation, says Yole. The GaN HEMT in wireless telecoms is a higher-power and higher-frequency transistor alternative. From a system point of view, GaN is cost-competitive in applications over 3.5GHz. GaN devices continue to challenge the dominant

RFMD and TriQuint to combine, creating a new player in RF solutions			New company not yet named
Macom acquired Nitronex's GaN-on-Si growth technology, making IP deals and transfer with IQE			Partnership with 
Hittite bought Keragis's GaN and GaAs based power amplifiers assets			

Recent mergers and acquisitions in the RF market (2014).

position of silicon in an industrial playground in which a power amplifier (PA) market of \$1600m+ is forecasted for 2020.

Today, several firms (i.e. Cree, Triquint/RFMD, Sumitomo, RFHIC, MACOM/Nitronex, Mitsubishi, NXP, Microsemi) have GaN device portfolios covering a wide range of applications. GaN has progressed significantly

over the last five years; several thousand devices have been developed and implemented in applications such as radar, CATV, space applications with satellite communication, counter-IED jammers, CATV modules, 3G/4G base-stations, WIMAX/LTE PAs and general-purpose applications.

"In our nominal case, RF GaN-based devices could reach more than 18% of the overall RF device market by 2020 (i.e. a 9% CAGR [compound annual growth rate] from 2013-2020)," says Yole.

GaN devices offer added values over incumbent Si-LDMOS and GaAs HEMT

Yole notes that GaN offers better power capability and linearity compared with commonly used pure silicon or GaAs-based technologies, enabling higher performance and lower overall system costs, such as:

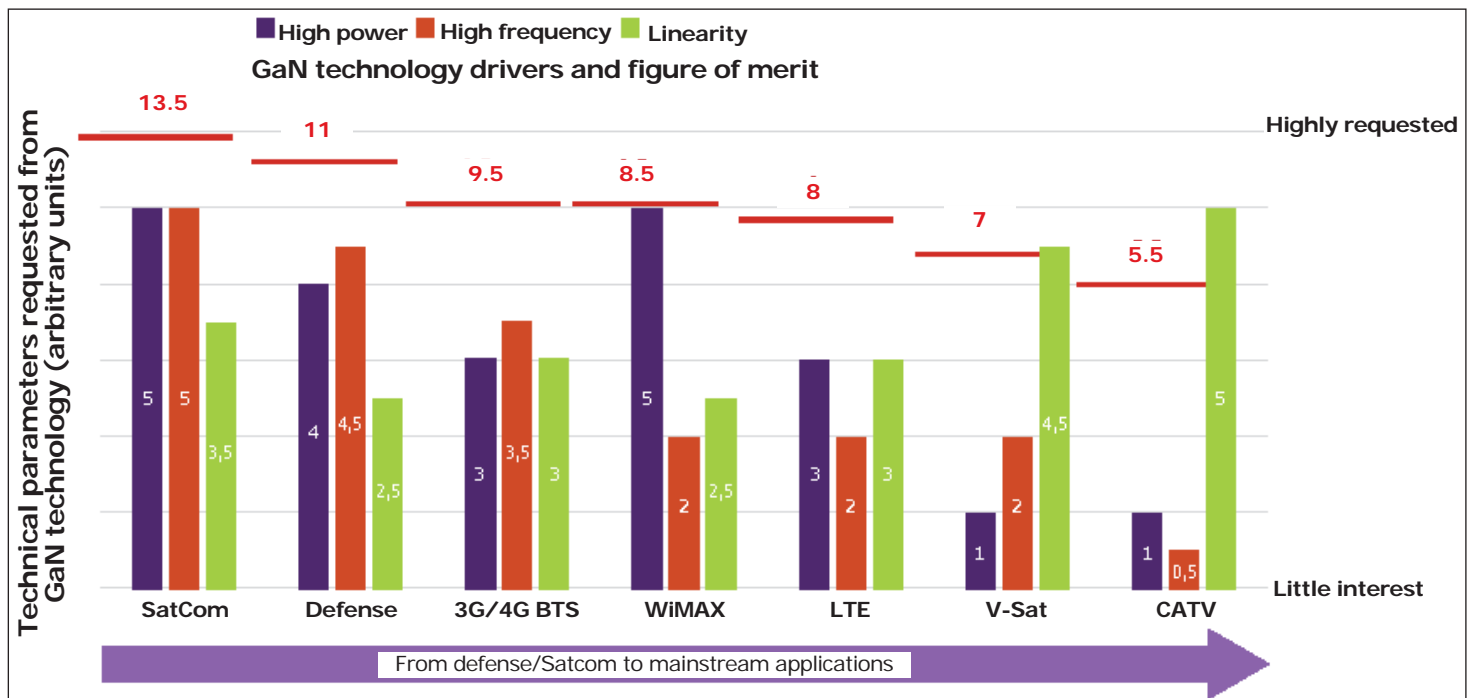
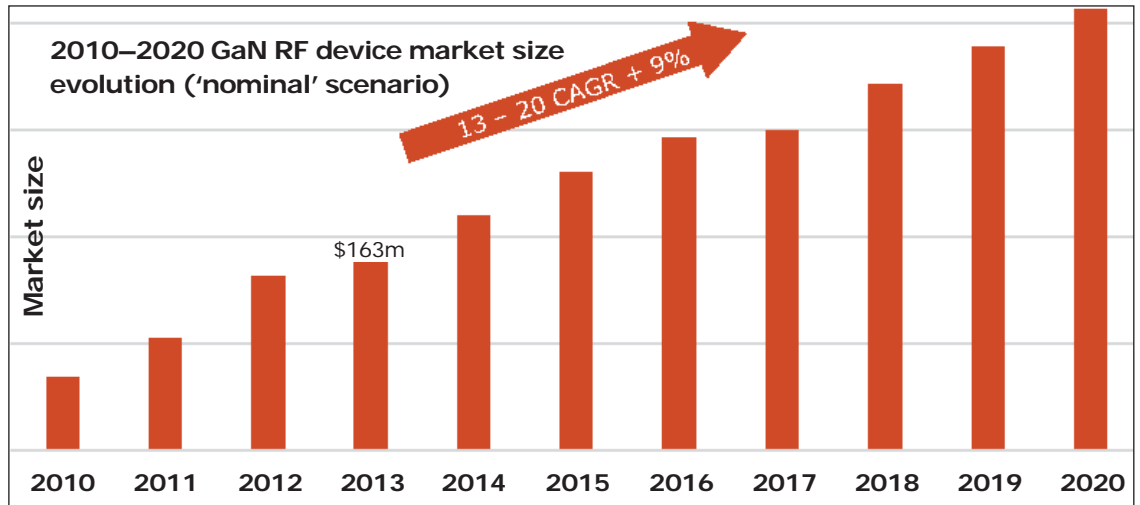
- higher efficiency (lower operating costs; improved module power density and size; and reduced cost of ownership);
- higher bandwidth and linearity (more versatile

devices; fewer devices needed to cover the entire frequency spectrum; and cost savings at the development stage);

- higher polarization voltage (lower current level for the same power output; and fewer losses from the Joule effect, leading to cost savings in thermal management); and
- higher junction temperature (more robust devices, leading to improved expected lifetime and mean time to failure [MTTF]; and reduced cooling system demands, leading to cost savings at the system level [BTS]).

The report evaluates such added value, in addition to the production cost of GaN-based devices today and within 5 years. The production cost impact at the system level of the use of RF GaN devices is also analysed in detail, in order to understand the added costs at the device level and the cost savings at the system and module levels. ■

www.i-micronews.com/reports/RF-GaN-Market-Analysis-Applications-Players-Devices/3/438



Millimetre-wave SiGe IC design – a technology overview

Increasing consumer demand for high-data-rate wireless applications has resulted in accelerated development activity to exploit the millimeter-wave frequency range, where large amounts of spectrum are available. The ISM band around 60GHz (V-band) and the light-licensed spectrum at E-band (71–76GHz and 81–86GHz) are both of particular interest. While commercial millimeter-wave ICs have traditionally been realised using III-V based technologies, the increasing availability of SiGe processes with very high f_T values offers an alternative solution that benefits from the potential for lower unit costs in volume production. Stuart Glynn and Liam Devlin of [Plextek RF Integration](#) explore in detail the design considerations for exploiting SiGe technology in millimeter-wave applications.

Silicon germanium (SiGe) technology uses heterojunction bipolar transistors (HBTs) to provide impressive transistor performance up to high millimeter-wave frequencies. One of the main features of the SiGe HBT that allows superior performance compared to a silicon bipolar junction transistor (BJT) is a base with a graded germanium (Ge) concentration. The resulting transistors have higher β , higher f_T and f_{max} and lower NF_{min} , making the more advanced SiGe processes potentially suitable for millimeter-wave applications.

A number of vendors now offer on a commercial foundry basis SiGe processes that are suitable for the realisation of circuits operating at V-band and E-band. One such vendor is IHP, a European foundry with a range of high f_T SiGe processes. Figure 1 shows the preparation and processing of SiGe wafers in the IHP pilot line.

While transistors with adequate f_T are a necessary requirement for developing millimeter-wave SiGe ICs, there are many other issues that complicate the design process and must be adequately addressed:

- substrate losses;
- grounding inductance;
- breakdown voltage (which reduces with increasing f_T);
- thermal issues (e.g. self heating, particularly when biased for highest f_T).

This technology overview investigates the realization of analogue circuits for V-band and E-band applications using appropriate IHP SiGe processes. It considers the design of amplifiers as a vehicle for assessing the



Figure 1: Preparation and processing of SiGe wafers in the IHP pilot line (courtesy R.Weisflog/IHP).

achievable performance, the implementation issues, and the appropriate design approaches. Process selection, device and bias selection, and the choice of circuit architecture required to demonstrate strong performance at millimetre-wave frequencies, are also considered.

V-band IC design

Process selection: When considering the design of millimeter-wave silicon circuits, it is tempting to select the process with the highest available f_T . However, considerations such as breakdown voltage, cost and current consumption led to the selection of the SG25H3 process for V-band operation. It is a 0.25 μ m technology, which features high-performance npn HBTs offering a good compromise between breakdown voltage

($BV_{CEO} = 2.3V$) and high frequency operation ($f_T/f_{max} = 110/180GHz$).

Bias point: For peak f_T the current density of high performance npn HBTs on this process is around $6mA/\mu m^2$. However, simulations of G_{max} and NF_{min} at different values of V_{be} were carried out, to gauge the bias point that would allow a suitable trade off between gain and noise figure.

These plots of G_{max} and NF_{min} , as a function of V_{be} , for a device in common emitter configuration, are shown in Figures 2 and 3.

At this stage zero emitter grounding inductance was assumed. A V_{ce} bias of 1.7V was used to optimise linearity. The emitter area is $0.22\mu m \times 6.72\mu m$.

The selected bias point was a collector current density of $3mA/\mu m^2$, corresponding to a typical V_{be} of 0.87V, as this offers a good compromise between G_{max} and NF_{min} . The choice of V_{ce} bias of 1.7V was made considering linearity, voltage swing and device breakdown voltage. Under these quiescent conditions, the HBT dissipates $5.1mW/\mu m^2$, which is relatively low, meaning that performance degradation due to thermal issues is less of a concern.

This allows an HBT of a given emitter area to be implemented with fewer parallel devices (a lower value of M) and hence with a reduction in the associated interconnect parasitics being introduced in layout.

The selected device in common emitter configuration is unconditionally stable above 49GHz at the chosen bias point. This is evident from the inflection in the G_{max} characteristic at this frequency, showing where the device moves from a region of potential instability to a region of unconditional stability. Being unconditionally stable across the band of interest (57–65GHz) is an attractive feature, as a conditionally stable device would need additional stabilising circuitry, which would cause a drop in gain.

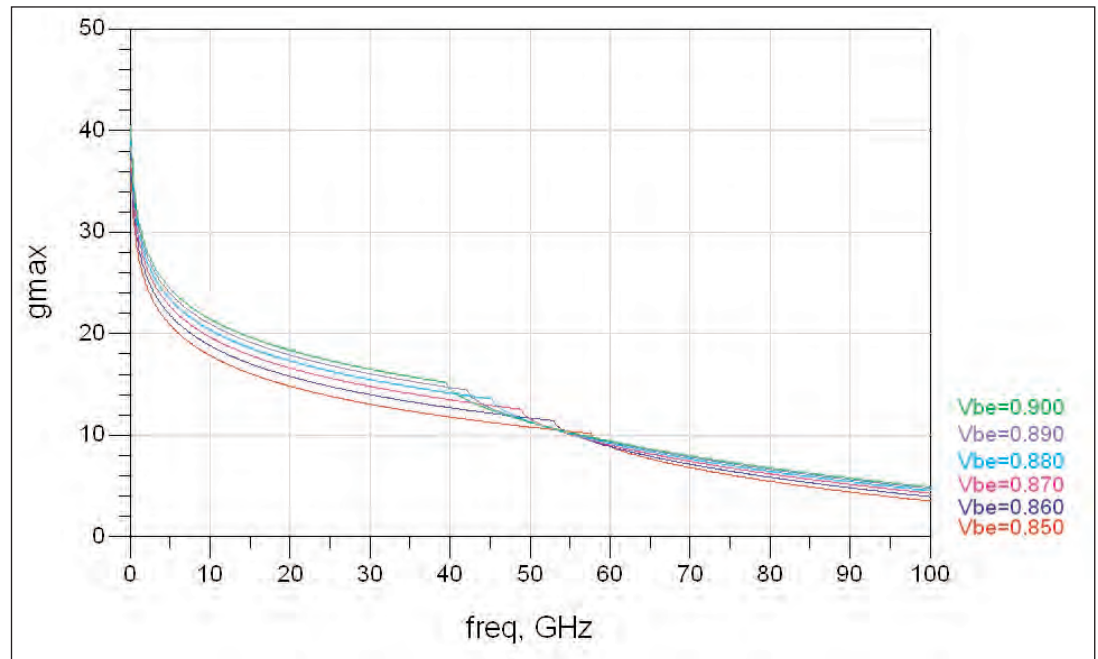


Figure 2: G_{max} versus frequency for different bias points, SG25H3 transistor.

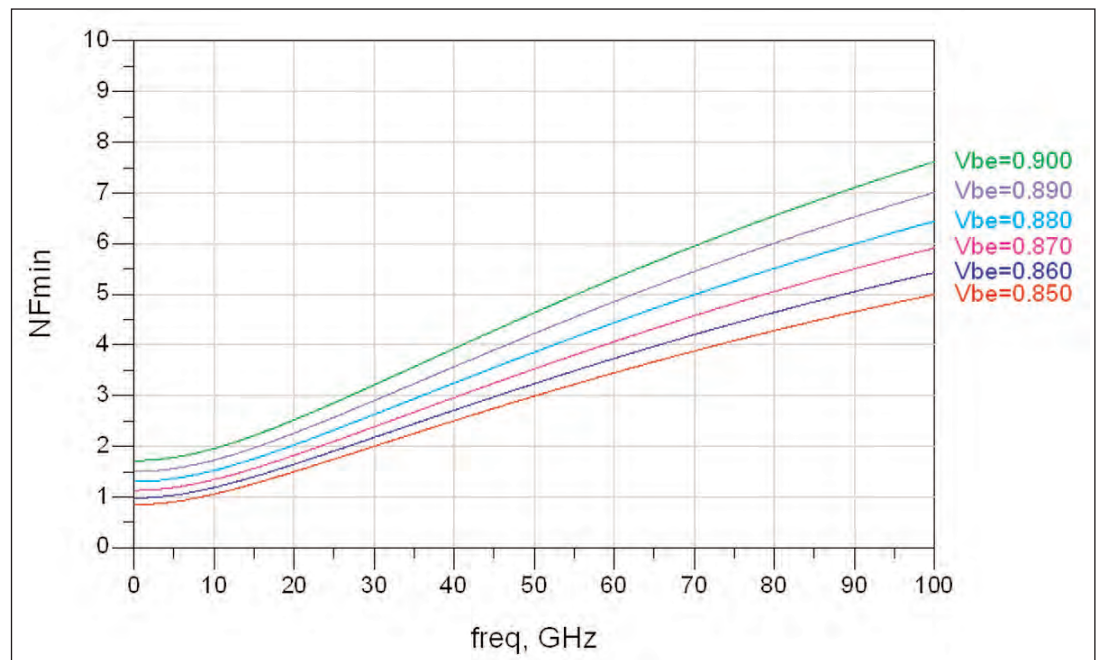


Figure 3: NF_{min} versus frequency for different bias points, SG25H3 transistor.

V-band amplifier architecture: Assuming the amplifier is to be used in a real application, then the practical issues of assembly and packaging must be considered from the outset. In particular the expected grounding inductance can be problematic. Regardless of the approach taken to minimise grounding inductance it will still be significant at millimeter-wave frequencies. Overlooking this will result at best in an amplifier with lower gain, and most likely in an unstable amplifier. Interestingly many publications on millimeter-wave SiGe amplifiers ignore this inductance, choosing to only mention performance when measured on a RF-on-wafer (RFOW) probing station, which allows for an effective grounding inductance approaching zero.

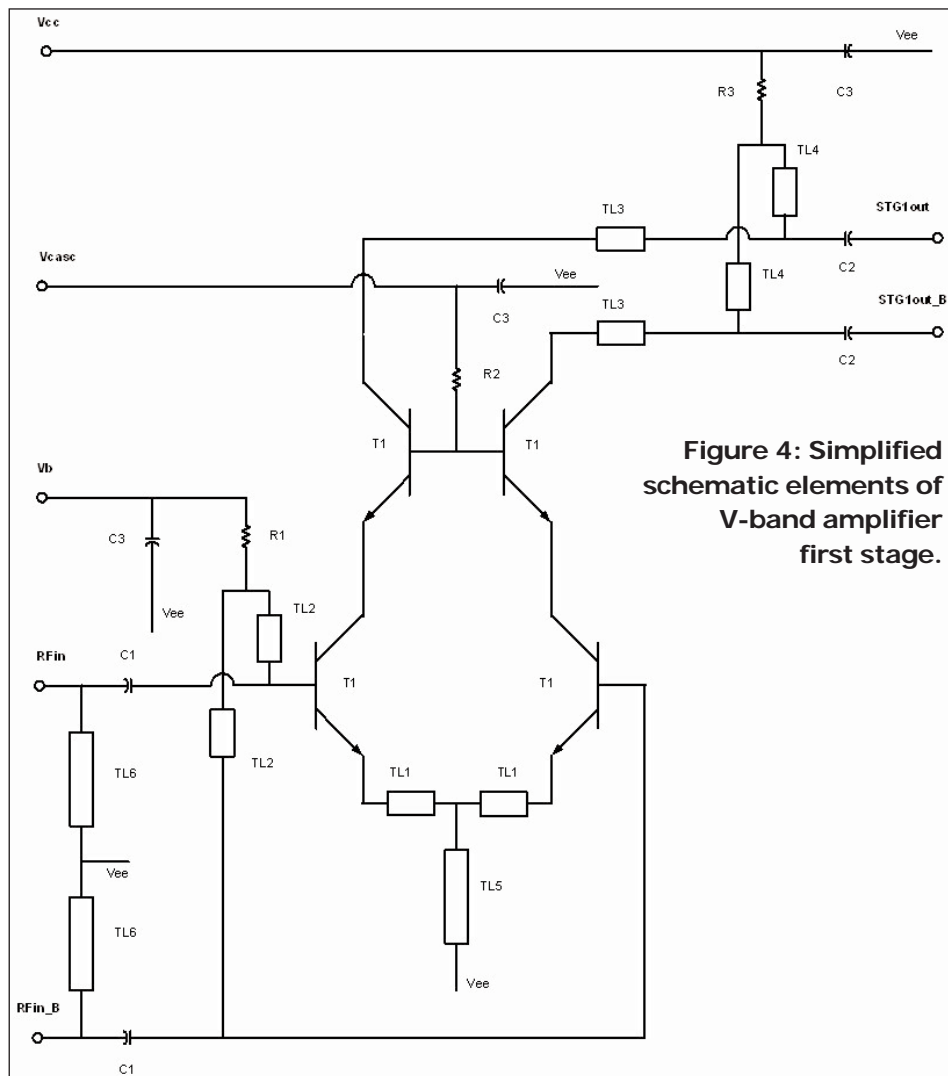


Figure 4: Simplified schematic elements of V-band amplifier first stage.

Packaging and assembly of V-band and E-band ICs is a complex matter in its own right, and a detailed discussion of the subject is beyond the scope of this text. However, consideration has been given to providing tolerance to a reasonable level of grounding inductance. The design was therefore progressed with the assumption that the grounding inductance due to assembly/package could be as high as 50pH, which is realistic for processes without low inductance through vias. A differential architecture benefits from a virtual earth, and this was selected to provide tolerance to the grounding inductance. It also provides rejection of common mode signals, which gives other advantages including improved second harmonic performance and higher dynamic range.

V-band amplifier stability: Although the use of a differential topology means that the grounding inductance no longer has any effect on the wanted signal, it is still very significant in common mode and can cause instability. During the design of the amplifier, measures were taken to ensure stability in differential mode, common mode and mixed mode for all frequencies up to the f_{\max} of the

transistors, for a grounding inductance of up to 50pH.

A cascode architecture was adopted for the amplifying transistors. This has several benefits for millimetre-wave amplifiers implemented on SiGe, including increased voltage handling, reduced Miller capacitance, and higher isolation between input and output, making impedance matching easier and improving stability.

To achieve adequate gain a two-stage design was progressed, each stage comprising a cascode transistor arrangement. All devices were biased at $3\text{mA}/\mu\text{m}^2$, with the devices in the second stage having twice the emitter area of those in the first. This approach ensures an adequate drive

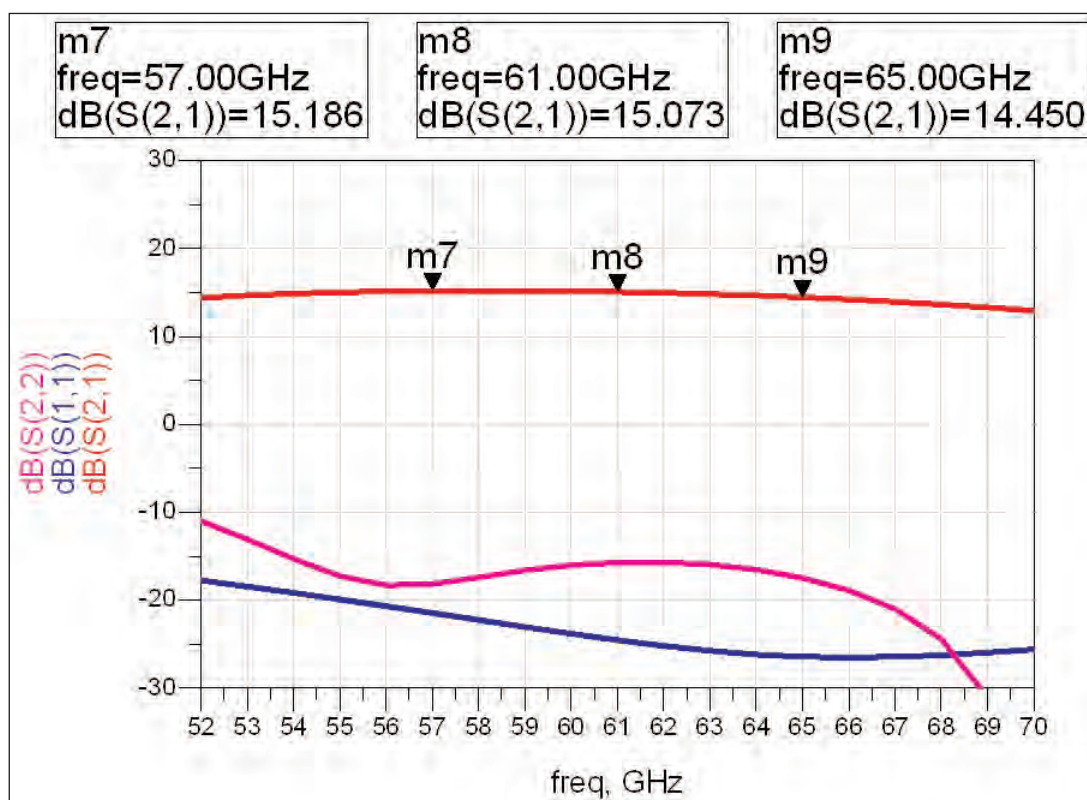


Figure 5: Small-signal performance of V-band amplifier.

ratio between stages, which is required for linearity.

V-band amplifier schematic: A simplified schematic showing the main elements of the first stage of the V-band amplifier is shown in Figure 4. All components are from the SG25H3 process design kit (PDK). The design makes good use of microstrip transmission lines which use a lower metal layer (metal 1) as the ground plane and an upper metal layer (top metal 2) as the conductor. Substrate losses are minimised by connecting the metal 1 ground plane to the substrate with an adequate number of p-taps in the layout. In this design the microstrip lines are essentially being used as low-value inductors. Note the use of a length of microstrip line in the tail of the differential pair — this helps to increase common mode rejection. The tail current source, traditionally used to bias differential amplifiers, was avoided, as this can lead to common mode stability problems.

Series resistors are used in the bias paths. These only affect common mode signals, and in fact contribute to providing common mode rejection and ensuring stability. The bases of the common base stage of the differential cascode are joined to form a virtual earth. Stage 2 uses a very similar topology to stage 1, with the addition of matching circuitry to transform the output impedance to 50Ω. The overall two-stage amplifier runs off a 3.3V supply and draws a total quiescent current of 24mA.

V-band amplifier

performance: Typical V-band amplifier simulated performance is shown in Figures 5 and 6. The small signal gain is 14.8dB \pm 0.4dB across the band 57–65GHz. The output return loss is better than 15dB across the band, and the input return loss is better than 20dB across the band. The output power at 1dB gain compression is 9.5dBm \pm 1dB across the band.

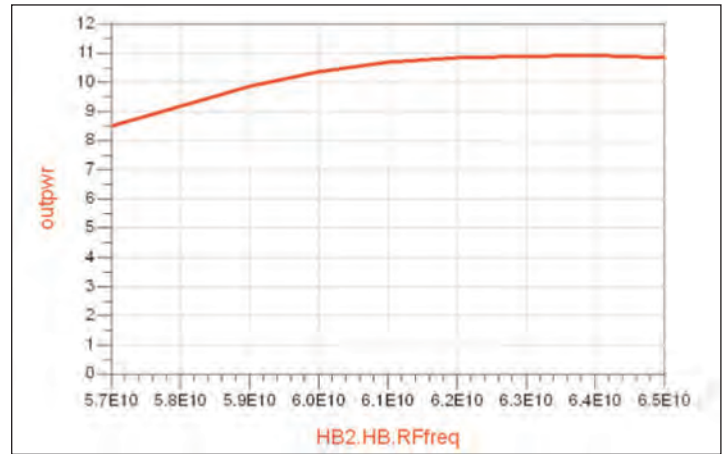


Figure 6: Output P1dB of V-band amplifier across band.

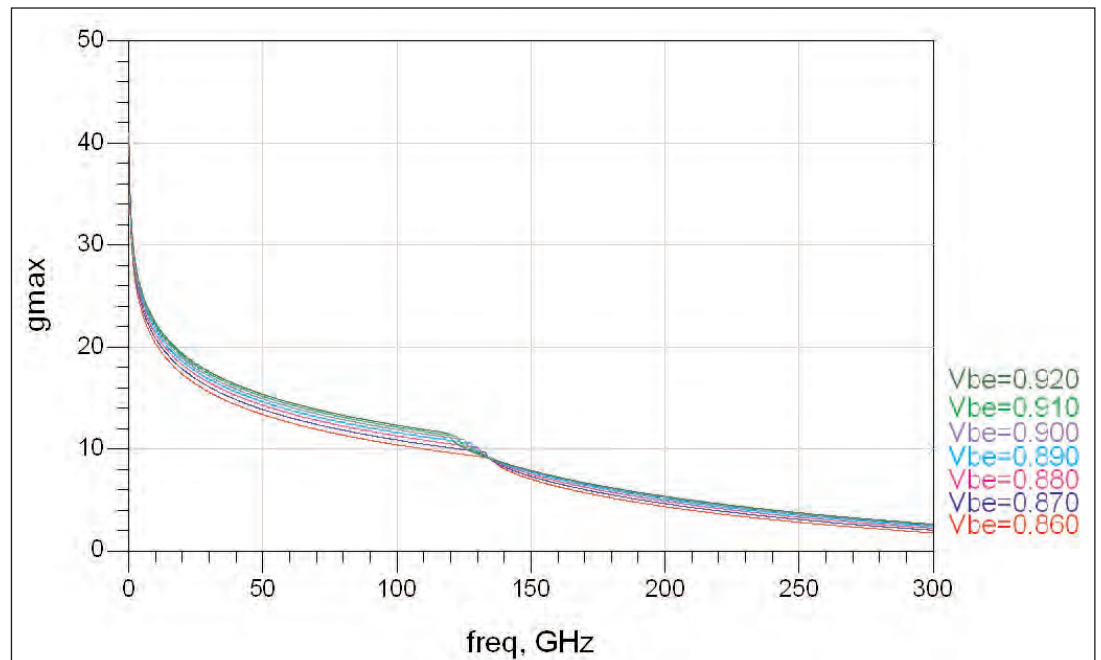


Figure 7: G_{\max} versus frequency for different bias points, SG13G2 transistor.

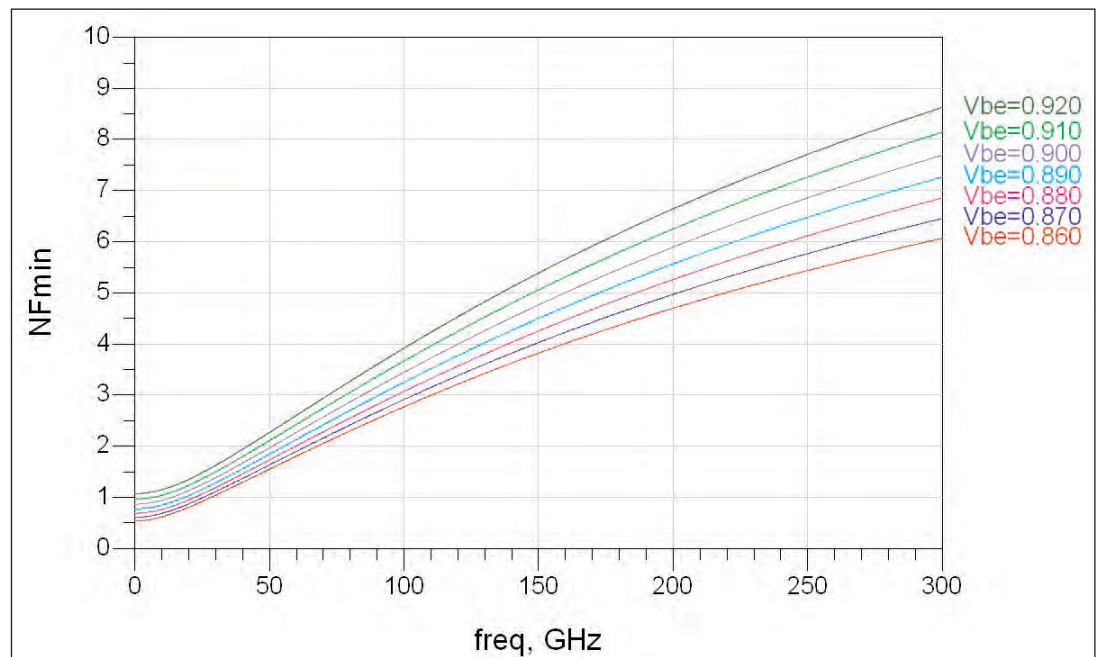


Figure 8: NF_{\min} versus frequency for different bias points, SG13G2 transistor.

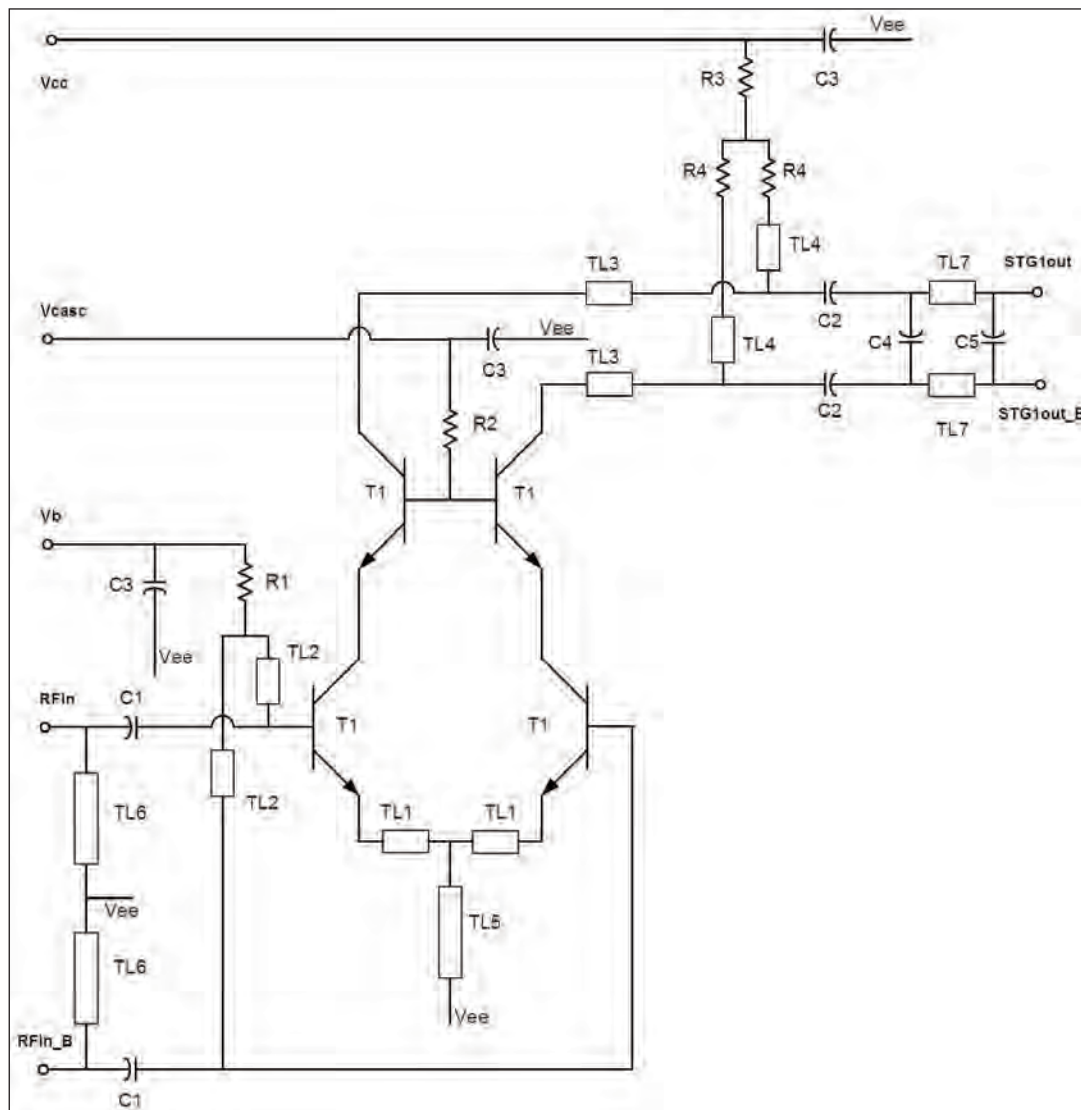


Figure 9: Simplified schematic elements of E-band amplifier first stage.

E-band IC design

Process selection: Although SG25H3 demonstrated good performance at V-band, IHP's higher f_T processes were considered more appropriate for an amplifier working at E-band (71–86GHz). After due consideration the selected process was SG13G2 which is a high performance 0.13 μm technology. This offers an npn HBT with very high frequency performance ($f_T/f_{\text{max}} = 300/500\text{GHz}$) with a slightly lower breakdown voltage ($BV_{\text{CEO}} = 1.7\text{V}$).

Bias point: For peak f_T the current density for this device is around $30\text{mA}/\mu\text{m}^2$, however, simulations of G_{max} and NF_{min} as a function of bias were carried out to gauge the bias point that would provide the best trade-off of gain for noise figure at E-band. Plots of G_{max} and NF_{min} , as a function of V_{be} , for a device in common emitter configuration with $V_{\text{ce}} = 1.2\text{V}$ are shown in Figures 7 and 8 respectively. The emitter area is $0.07\mu\text{m} \times 7.2\mu\text{m}$.

A current density of $14\text{mA}/\mu\text{m}^2$ was selected (corresponding to a typical V_{be} of 0.88V) as providing a good compromise between G_{max} and NF_{min} . The choice of V_{ce} bias of 1.2V was made considering linearity, voltage

swing and device breakdown voltage. Under these quiescent conditions, the HBT dissipates $16.8\text{mW}/\mu\text{m}^2$ which is a higher power density than that of the transistors of the V-band amplifier ($5.1\text{mW}/\mu\text{m}^2$) and requires the HBT to be implemented with a higher number of parallel devices in layout.

The $0.07\mu\text{m} \times 7.2\mu\text{m}$ emitter area device is potentially unstable at E-band so gain must be sacrificed to ensure stability. As G_{max} for this device at the chosen bias point is high enough at the top of the band (12dB at 86GHz), this reduction in gain can be afforded.

E-band amplifier architecture: As for the V-band amplifier, the E-band amplifier was assumed to have to tolerate 50pH grounding inductance. This should provide sufficient tolerance for assembly and packaging in a real application. A similar two stage cascode architecture was adopted using a differential topology. All

devices were biased at $14\text{mA}/\mu\text{m}^2$, with the devices in the second stage having twice the emitter area as those in the first. This is to ensure an adequate drive ratio between the stages which is required for linearity.

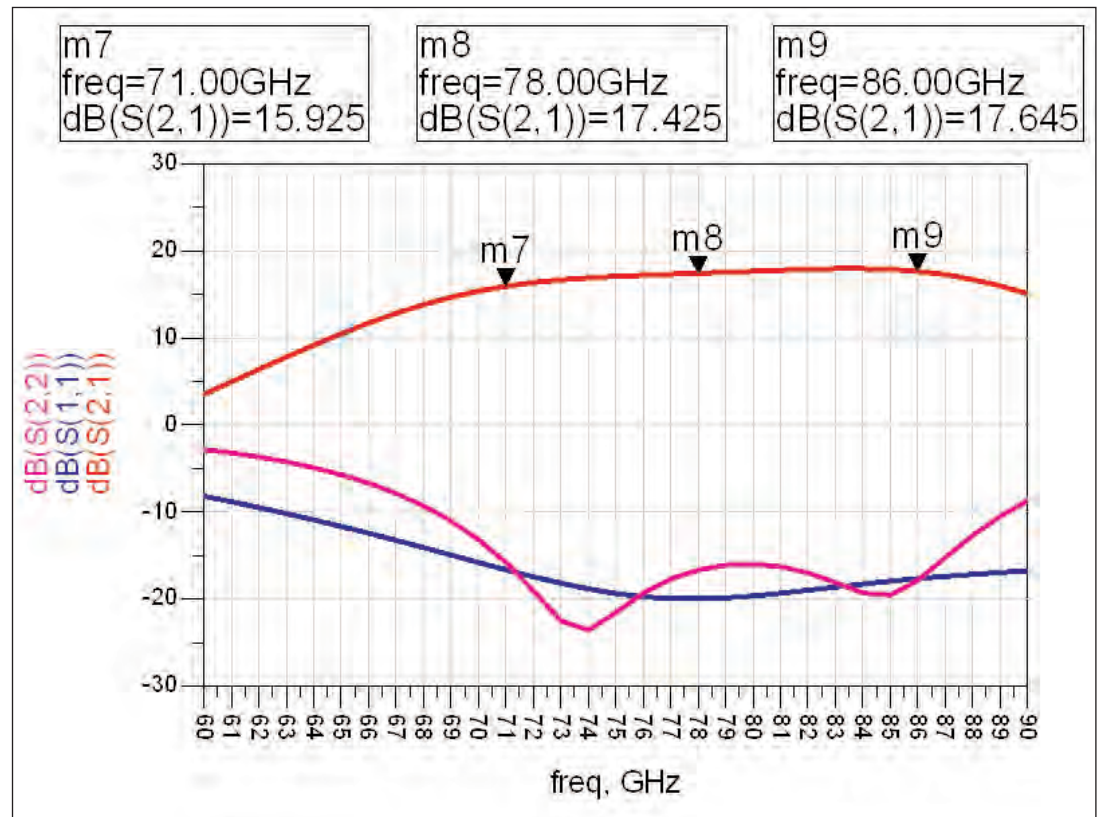
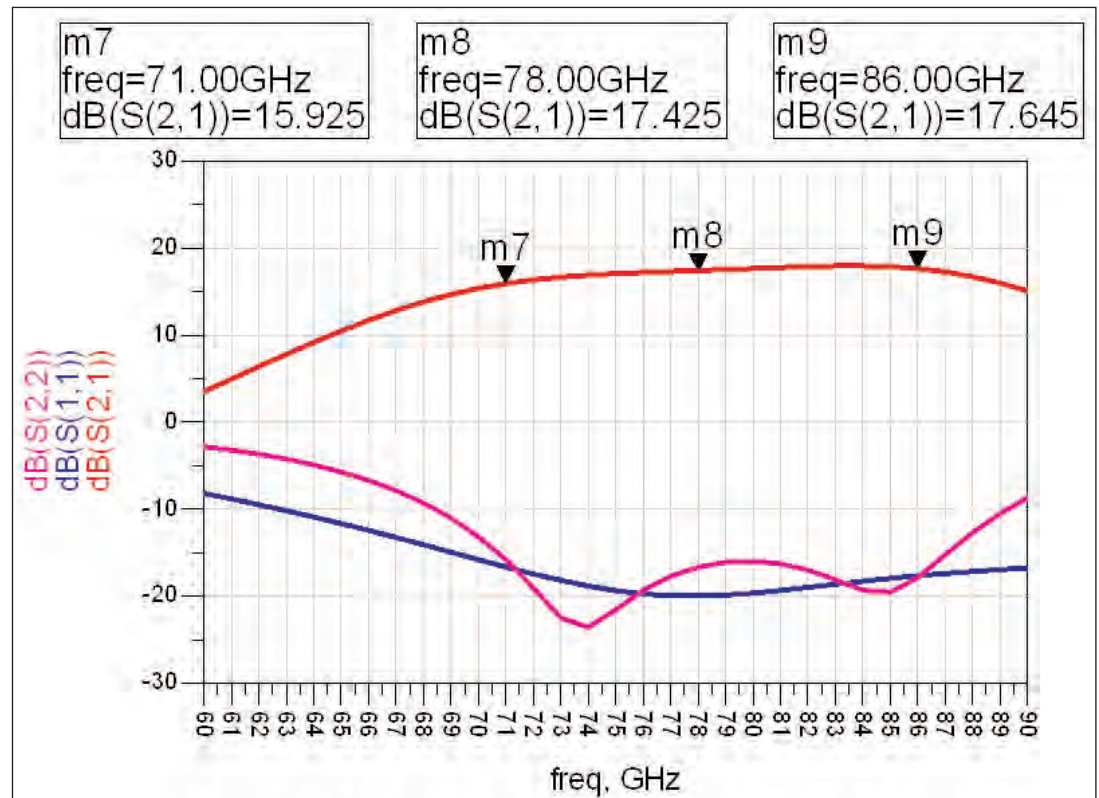
E-band amplifier schematic: A simplified schematic showing the main elements of the E-band amplifier's first stage is depicted in Figure 9. All components are from the SG13G2 PDK. The use of the same architecture as the V-band design means that the design incorporates many similar features, including the use of microstrip transmission lines and series resistors in the bias paths. In the E-band design, however, extra loss was required differentially in the output match by means of resistors R4. As well as stabilising the stage, this loss allows for a good wideband impedance match. Although not strictly necessary, it was convenient to match the output of stage 1 to 50Ω . Stage 2 uses a very similar topology to stage 1. The E-band amplifier runs off a 2.5V supply and draws a total quiescent current of 42mA. It is stable in differential mode, common mode and mixed mode for all frequencies up to f_{max} , for up to 50pH of grounding inductance.

E-band amplifier performance:

Typical E-band amplifier simulated performance is shown in Figures 10 and 11. The small-signal gain is $16.8\text{ dB} \pm 0.9\text{ dB}$ across the band 71–86 GHz, and it exhibits a slight positive gain slope which is often a desirable feature. The output return loss is better than 16 dB across the band and the input return loss is better than 17 dB across the band. The output power at 1 dB gain compression is $7.5\text{ dBm} \pm 1\text{ dB}$ across the band. Noise figure is between 4 dB and 4.25 dB across the band.

Conclusion

The use of SiGe technology to realize millimeter-wave ICs has been reviewed, using the examples of V-band and E-band amplifiers designed on IHP's SiGe processes to explore the implementation issues and to assess the achievable performance. Issues such as substrate loss, grounding inductance, breakdown voltage and thermal performance become more problematic at high millimeter-wave frequencies. These issues were addressed during design by appropriate choice of process, bias point and circuit architecture. It has been noted that the potential problems that may be caused by practical levels of grounding inductance resulting from assembly and/or packaging are often inadequately covered in existing literature. The designs presented are tolerant to grounding inductances of up to 50 pH, which is considered as a realistic level for a practical implementation and mandates the choice of a differential architecture. It is also vitally important to ensure amplifier stability in differential mode, common mode and mixed mode. After careful

**Figure 10: Small-signal performance of E-band amplifier.****Figure 11: Output P1dB of E-band amplifier.**

consideration of the main implementation issues, this article has demonstrated that strong performance at millimeter-wave frequencies can be achieved using IHP's SiGe processes. ■

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(see section 6 for full contact details)

Plasma-Therm LLC

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SAMCO International Inc

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Tel: +1 408 734 0459

Fax: +1 408 734 0961

www.samcointl.com**SPTS Technology Ltd**

Ringland Way,
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Tel: +44 (0)1633 414000

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www.spts.com**SUSS MicroTec AG**

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Tel: +49 89 32007 0

Fax: +49 89 32007 162

www.suss.com**Veeco Instruments Inc**

(see section 6 for full contact details)

9 Materials & metals**Goodfellow Cambridge Ltd**

Ermine Business Park, Huntingdon,
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**10 Gas and liquid handling equipment****Air Products and Chemicals Inc**

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Cambridge Fluid Systems

12 Trafalgar Way, Bar Hill,
Cambridge CB3 8SQ, UK

Tel: +44 (0)1954 786800

Fax: +44 (0)1954 786818

www.cambridge-fluid.com**CS CLEAN SYSTEMS AG**

Fraunhoferstrasse 4,
Ismaning, 85737,
Germany

Tel: +49 89 96 24 00 0

Fax: +49 89 96 24 00 122

www.cscleansystems.com**SAES Pure Gas Inc**

4175 Santa Fe Road,
San Luis Obispo,
CA 93401,
USA

Tel: +1 805 541 9299

Fax: +1 805 541 9399

www.saesgetters.com**11 Process monitoring and control****k-Space Associates Inc**

2182 Bishop Circle
East, Dexter,
MI 48130, USA

Tel: +1 734 426 7977

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www.k-space.com

k-Space Associates Inc specializes in
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USA

Tel: +1 408 875 3000

Fax: +1 408 875 4144

www.kla-tencor.com**LayTec AG**

Seesener Str.
10-13,

10709 Berlin,
Germany

Tel: +49 30 89 00 55 0

Fax: +49 30 89 00 180

www.laytec.de

LayTec develops and manufactures
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OpTIC Technium,
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St Asaph, LL17 0JD,
UK
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www.ors-ltd.com

WEP (Ingenieurbüro Wolff für Elektronik- und Programmentwicklungen)

Bregstrasse 90, D-78120
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Tel: +49 7723 9197 0
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www.wepcontrol.com

12 Inspection equipment**Bruker AXS GmbH**

Oestliche Rheinbrueckenstrasse 49,
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13 Characterization equipment**J.A. Woollam Co. Inc.**

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www.jawoollam.com

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575 McCorkle Boulevard,
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Fax: +1 614 818 1600
www.lakeshore.com

14 Chip test equipment**Keithley Instruments Inc**

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Cleveland, OH 44139,
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www.keithley.com

15 Assembly/packaging materials**ePAK International Inc**

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Austin, TX 78759,
USA
Tel: +1 512 231 8083
Fax: +1 512 231 8183
www.epak.com

Gel-Pak

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Hayward, CA 94544,
USA
Tel: +1 510 576 2220
Fax: +1 510 576 2282
www.gelpak.com

Wafer World Inc

(see section 3 for full contact details)

Williams Advanced Materials

2978 Main Street,
Buffalo, NY 14214,
USA
Tel: +1 716 837 1000
Fax: +1 716 833 2926
www.williams-adv.com

16 Assembly/packaging equipment**Ismeca Europe Semiconductor SA**

Helvetie 283, La Chaux-de-Fonds,
2301, Switzerland
Tel: +41 329257111
Fax: +41 329257115
www.ismeca.com

Kulicke & Soffa Industries

1005 Virginia Drive,
Fort Washington,
PA 19034,
USA
Tel: +1 215 784 6000
Fax: +1 215 784 6001
www.kns.com

Palomar Technologies Inc

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Carlsbad, CA 92010,
USA
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Fax: +1 760 931 5191
www.PalomarTechnologies.com

TECDIA Inc

2700 Augustine Drive, Suite 110,
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USA
Tel: +1 408 748 0100
Fax: +1 408 748 0111
www.tecdia.com

17 Assembly/packaging foundry**Quik-Pak**

10987 Via Frontera,
San Diego, CA 92127,
USA
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Fax: +1 858 674 4681
www.quikicpak.com

18 Chip foundry**Compound Semiconductor Technologies Ltd**

Block 7, Kelvin Campus,
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Scotland G20 0TH,
UK
Tel: +44 141 579 3000
Fax: +44 141 579 3040
www.compoundsemi.co.uk

United Monolithic Semiconductors

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BP46, Orsay, 91401,
France
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Fax: +33 1 69 33 02 92
www.ums-gaas.com

19 Facility equipment**MEI, LLC**

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Albany, OR 97322-7014,
USA
Tel: +1 541 917 3626
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www.marlerenterprises.net

20 Facility consumables**PLANSEE High Performance Materials**

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Ansoft Corp
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 Pittsburgh, PA 15219, USA
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 Fax: +1 412 471 9427
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 Burnaby, BC, V5C 6P8,
 Canada
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 Fax: +1 604 320 1734
www.crosslight.com

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 Research Inc**
 10404 Patterson Ave., Suite 108,
 Richmond, VA 23238, USA
 Tel: +1 804 740 8314
 Fax: +1 804 740 3814
www.semitech.us

22 Used equipment

Class One Equipment Inc
 5302 Snapfinger Woods Drive,
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25 Resources

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Moscone Center, San Francisco, CA, USA

E-mail: semiconwest@semi.org

www.semiconwest.org

9–10 July 2014

UK Semiconductors 2014

Sheffield UK

E-mail: info@uksemiconductors.com

www.uksemiconductors.com

13–18 July 2014

17th International Conference on Metalorganic Vapor Phase Epitaxy (ICMOVPE XVII)

Lausanne, Switzerland

E-mail: icmovpe2014@epfl.ch

<http://icmovpe2014.epfl.ch>

14–16 July 2014

2014 IEEE Photonics Society Summer Topical Meeting Series

Delta Montreal Hotel, Montreal, Quebec, Canada

E-mail: i.donnelly@ieee.org

www.sum-ieee.org

17–21 August 2014

SPIE Optics + Photonics 2014

San Diego Convention Center, CA, USA

E-mail: customerservice@spie.org

<http://spie.org/optics-photonics.xml>

24–29 August 2014

International Workshop on Nitride Semiconductors (IWN2014)

Wrocław, Poland.

E-mail: contact@iwn2014.pl

<http://iwn2014.pl>

27–29 August 2014

IEEE Photonics Society's 11th International Conference on Group IV Photonics (GFP-2014)

Cité Internationale Universitaire de Paris, France

E-mail: m.figueroa@ieee.org

www.gfp-ieee.org

3–5 September 2014

SEMICON Taiwan

TWTC Nangang Exhibition Hall, Taipei, Taiwan

E-mail: nsun@semi.org

www.semicontaiwan.org

16–18 September 2014

The LED Show

Los Angeles Convention Center, CA, USA

E-mail: registration@pennwell.com

www.theledshow.com

22–24 September 2014

LEDs and the SSL Ecosystem 2014: Lighting in the Information Age

Hyatt Cambridge in Cambridge, MA, USA

E-mail: jcarter@smithers.com

www.ledsconference.com

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22–25 September 2014

SPIE Security+Defence 2014

Amsterdam RAI Exhibition and Convention Centre,
The Netherlands

E-mail: info@spieeurope.org

http://spie.org/security-defence-europe.xml

5–9 October 2014

Mid-IR Optoelectronics: Materials and Devices (MIOMD-XII)

CORUM convention center, Montpellier, France

E-mail: miomd2014@miomd2014.org

www.[miomd2014.org](http://www.miomd2014.org)

5–10 October 2014

226th Electrochemical Society (ECS) Meeting

Moon Palace Resort, Cancun, Mexico

E-mail: meetings@electrochem.org

www.[electrochem.org/meetings/biannual/fut_mtgs.htm](http://www.electrochem.org/meetings/biannual/fut_mtgs.htm)

7–9 October 2014

SEMICON Europa

Alpexpo, Grenoble, France

E-mail: eweller@semi.org

www.[semiconeuropa.org](http://www.semiconeuropa.org)

7–9 October 2014

Solar Power International (SPI '14)

Las Vegas Convention Center

E-mail: plangdon@solarenergytradeshows.com

www.[solarpowerinternational.com](http://www.solarpowerinternational.com)

9–10 October 2014

Invest in Photonics

Bordeaux, France

E-mail: pitch@invest-in-photonics.com

www.[invest-in-photonics.com](http://www.invest-in-photonics.com)

12–16 October 2014

IEEE Photonics Conference (IPC) 2014

Hyatt Regency La Jolla, San Diego, CA, USA

E-mail: i.donnelly@ieee.org

www.[ipc-ieee.org](http://www.ipc-ieee.org)

15–17 October 2014

LED Japan/Strategies in Light

Pacifico Yokohama, Japan

E-mail: registration@pennwell.com

www.[sil-ledjapan.com](http://www.sil-ledjapan.com)

21–23 October 2014

Strategies in Light Europe

M.O.C. Event Centre, Munich, Germany

E-mail: registration@pennwell.com

www.[sileurope.com](http://www.sileurope.com)

11–13 November 2014

Avionics Fiber-Optics and Photonics Conference 2014 (AVFOP)

Hyatt Regency Atlanta, Georgia, USA

E-mail: m.figueroa@ieee.org

www.[avfop-ieee.org](http://www.avfop-ieee.org)

15–17 December 2014

IEEE International Electron Devices Meeting (IEDM 2014)

Hilton San Francisco, CA, USA

E-mail: iedm@his.com

www.[ieee-iedm.org](http://www.ieee-iedm.org)

7–12 February 2015

SPIE Photonics West 2015

Moscone Center San Francisco, CA, USA

E-mail: customerservice@spie.org

http://spie.org/photonics-west.xml

24–26 February 2015

Strategies in Light

Sands Expo & Convention Center, Las Vegas, NV, USA

E-mail: registration@pennwell.com

www.[strategiesinlight.com](http://www.strategiesinlight.com)

2–5 March 2015

LED China 2015

China Import and Export Fair Complex, Area B,

Pazhou, Guangzhou, China

E-mail: led-trust@ubm.com

www.[LEDChina-gz.com](http://www.LEDChina-gz.com)

22–24 April 2015

SEMICON Southeast Asia 2015

SPICE Arena, Penang, Malaysia

E-mail: skoh@semi.org

www.[semiconsea.org](http://www.semiconseas.org)

18 May 2015

2015 ROCS:

Reliability of Compound Semiconductors Workshop

Hyatt Regency Scottsdale Resort, AZ, USA

Abstract deadline: 2 March 2015

E-mail: Peter.Ersland@macomtech.com

www.[jedec.org/home/gaas](http://www.jedec.org/home/gaas)

18–21 May 2015

CS MANTECH 2015:

International Conference on Compound Semiconductor Manufacturing Technology

Hyatt Regency Scottsdale Resort & Spa at Gainey,

Scottsdale, AZ, USA

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