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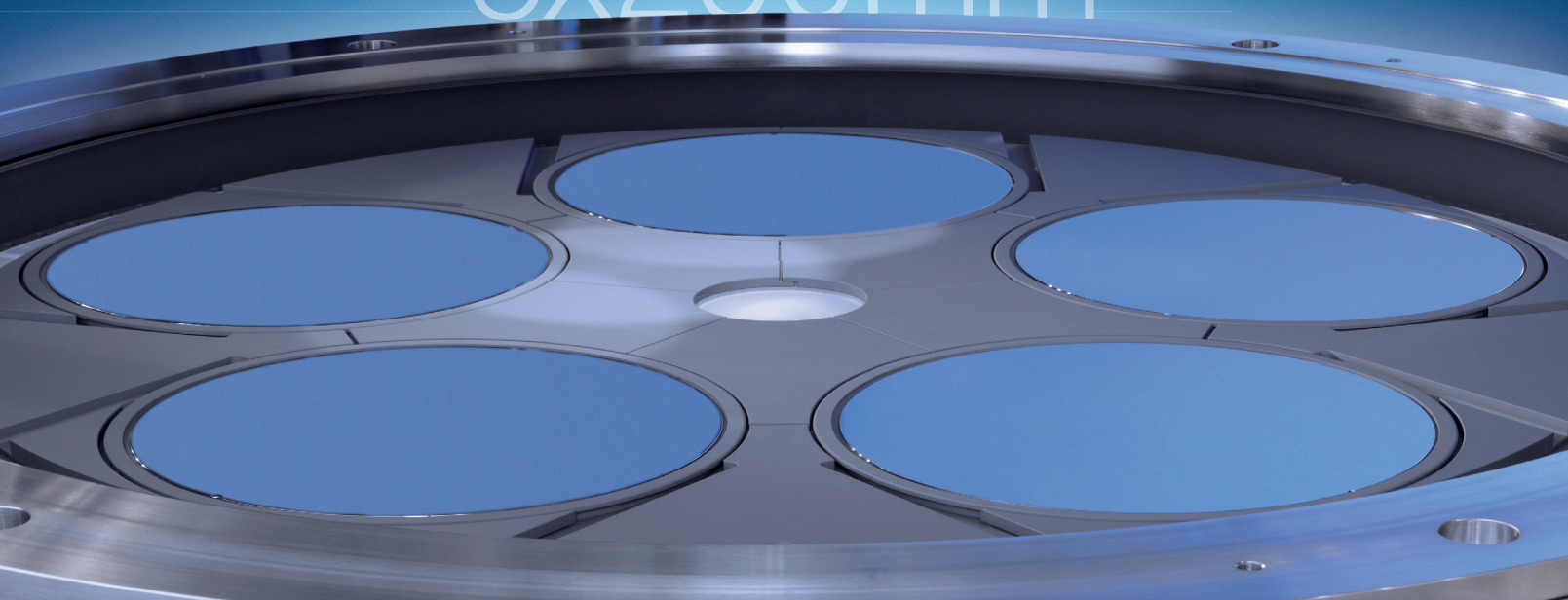
200mm GaN-on-Si Batch Reactor

5x200mm



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COMPOUNDS & ADVANCED SILICON

Vol. 7 • Issue 6 • July/August 2012

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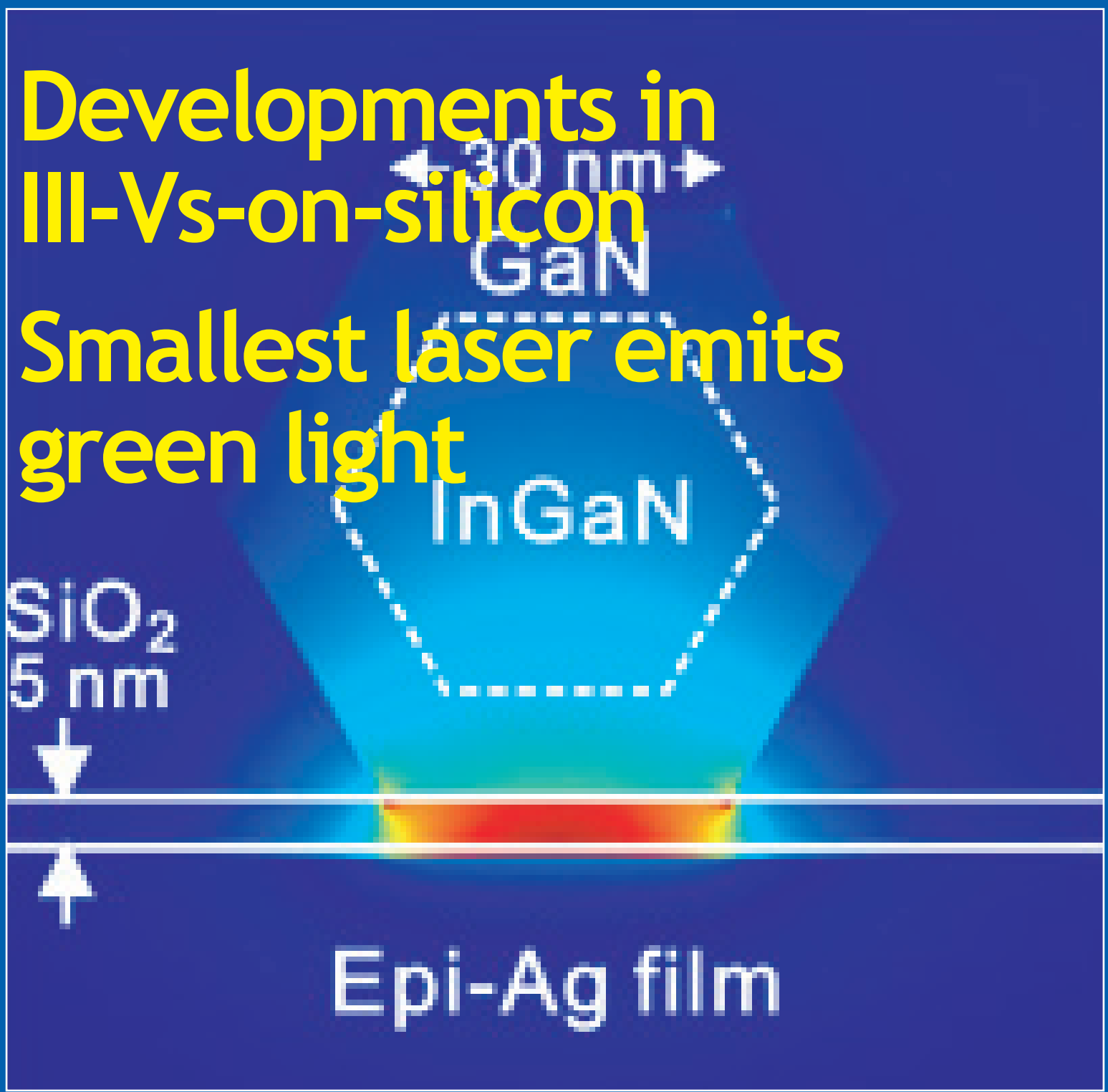
Developments in III-Vs-on-silicon

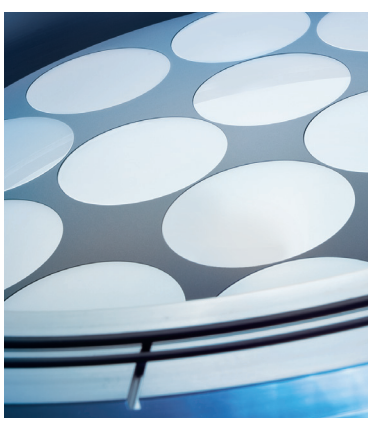
Smallest laser emits green light



Albemarle expanding Korea plant • Osram & Samsung settle
Emcore consolidates CPV into Suncore • MiaSolé reorganizes

Light Up a Brighter World

Introducing MaxBright MHP MOCVD System



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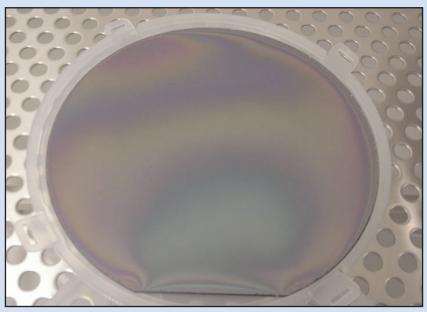
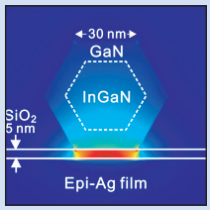
p20 Rohm's TO-247-packaged 1200V SCH2080KE, first SiC power MOSFET with an internal Schottky barrier diode.

p46 Groundbreaking ceremony for Osram's new back-end LED assembly plant. on a 100,000m^2 site in China, which will accommodate 1600 staff.



p82 AZZURRO Semiconductors' 150mm GaN-on-silicon template wafer, ready for shipment.



Cover: The University of Texas at Austin, Taiwan's National Tsing-Hua University and National Chiao-Tung University, and the Chinese Academy of Sciences have developed what is claimed to be the world's smallest semiconductor laser. An InGaN/GaN core–shell rod on a silver film emits CW green light. **p48**

editorial

Grafting and restructuring

This issue includes articles on III-V semiconductors on silicon substrates, focusing on nitride transistors for high-power and high-frequency microelectronics applications (see pages 74–83), with an emphasis on making fabrication compatible with silicon wafer processing.

In addition, we cover the growth of nitride LEDs on silicon wafers, targeting the economies of scale of larger-diameter substrates as well as existing silicon manufacturing infrastructure and processes. In particular, the article on page 82 from AZZURRO Semiconductors covers the provision of GaN-on-Si templates, enabling subsequent overgrowth of LED makers' existing LED epilayer structures. This follows last issue's report of AZZURRO ordering a Veeco MOCVD system for 6" GaN-on-Si production, as well as a European grant to scale epiwafer development up to 200mm.

Also, on page 84 we report research in China on grafting nitride LEDs grown on silicon substrates onto copper submounts with higher electrical and thermal conductivity (as well as less light absorption).

Following reports in the last few issues of Japan's Toshiba and China's Lattice Power planning to start production of GaN LEDs on 150–200mm silicon, this issue sees news of US-based Albemarle expanding its metal-organic precursor materials production capacity in Korea to meet demand for MOCVD growth of LEDs (see page 24). Meanwhile, Germany's Osram Opto Semiconductors has broken ground on construction of its new LED back-end assembly plant in China (page 46), supplementing its existing back-end capacity in Malaysia. Also, after last issue's report of the USA's Cree and Taiwan's SemiLEDs settling their LED patent lawsuits, on page 47 we report Osram and Korea's Samsung settling their LED patent litigation.

Expansion of LED manufacturing in Asia comes amid reports of a crisis-induced slump in LED lighting sales in Europe in May–July (down 18% year-on-year in the UK), whereas Japan showed growth of 15% (page 6). Market research firm LEDinside notes that lighting firms Osram and Philips are hence starting to shift their focus to the Asian market.

A sector undergoing greater restructuring is thin-film photovoltaics, impacted by not only falling costs for silicon solar modules and low pricing of Chinese PV manufacturers but also macroeconomic and political factors in Europe and the USA. News came in our April/May issue of First Solar's plans to close its German plant, and in our June/July issue of fellow US CdTe PV maker Abound Solar suspending operations as it filed for bankruptcy protection. Meanwhile, Emcore is consolidating its CPV system business into its China-based Suncore Photovoltaics joint venture with San'an Optoelectronics (see page 57), and North American firm OPEL is negotiating to sell its CPV business.

More turbulent still, in the CIGS PV sector, Global Solar Energy is consolidating its German operation into its Tucson headquarters while seeking investors and MiaSolé is restructuring as it negotiates with potential partners (pages 64–66), while Germany's Soltecture is seeking a buyer during insolvency. Although the success of CIGS giants such as Japan's Solar Frontier suggests a natural shakeout as the sector matures, the existing partnerships between US CIGS firms Ascent Solar and Stion with larger Asian firms suggests a general geographical trend, especially in the aftermath of the failure of US government-funded CIGS firm Solyndra and in the run up to the US presidential election.

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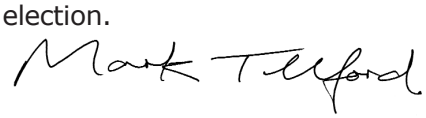

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***Semiconductor Today* covers the R&D and manufacturing of compound semiconductor and advanced silicon materials and devices** (e.g. GaAs, InP and SiGe wafers, chips and modules for microelectronic and optoelectronic devices such as RFICs, lasers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

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

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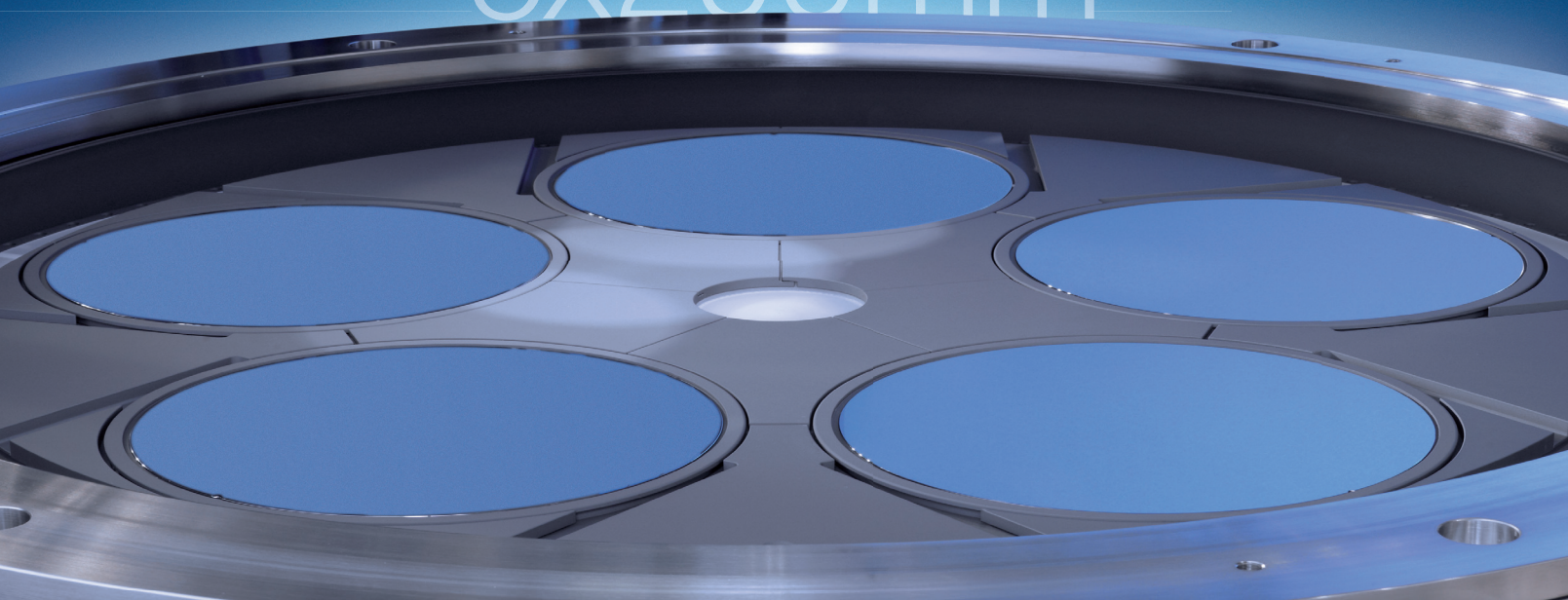

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news

Focus of LED lighting market shifting to Asia during European debt crisis

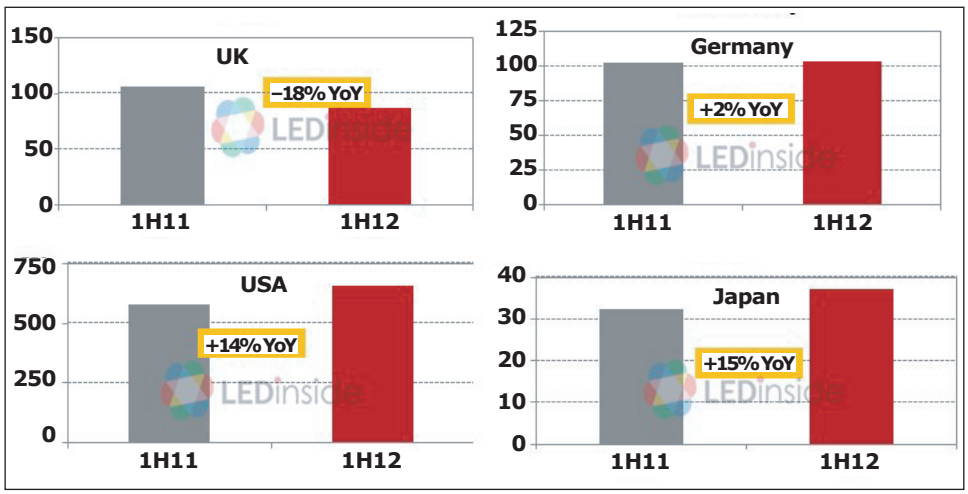
Restart of bidding process for China LED subsidies to boost industry

Major lighting markets around the world have been affected by the European debt crisis to varying degrees, says LEDinside (the LED research division of TrendForce). Certain Chinese LED firms whose business relies heavily on overseas markets have seen a decline in orders, which is particularly pronounced in the European lighting market. As a result, many LED firms are starting to shift their focus to the Chinese LED bidding market, says the market research firm. In fact, in July China restarted the bidding process for LED subsidies, providing hope for many LED firms.

Regarding the outlook for second-half 2012, with the stagnant global economy dampening the end market and many large-scale lighting projects coming to a halt, most export companies have turned to on-going mid-scale and small-scale lighting projects and the commercial lighting market. On the other hand, large-scale LED lighting market demand will depend on the bidding project market in China in second-half 2012, says the report.

According to LEDinside, orders for LED lighting firms with primarily European clients fell by over 20% sequentially in third-quarter 2012. European orders saw the biggest downturn during May–July. Given the murky outlook for second-half 2012, European distributors have reduced their orders placed in the Asian market. Moreover, due to the payment delay, large-scale lighting projects in Europe have come to a halt. Looking towards second-half 2012, the mid-scale and small-scale lighting projects are expected to continue as scheduled, but pricing competition is going to be fierce.

Aside from the European LED market, LED lighting demand in the US market (especially for LED light bulbs and light tubes) has been picking up on a monthly basis in 2012 due to the increase in new housing projects, according to LEDinside's report. The second half of the year is usually the peak season for the residential lighting market, and so far the US market has been performing better than the European market, despite the still uncertain global market outlook.



January–May light bulb and lighting fixtures shipments (unit: millions).

Due to the slump in the European and US markets, global lighting giants such as Philips and Osram have started to place more emphasis on the Asian market. For example, benefiting from the summer energy-saving policy, people in Japan are more willing to buy LED light bulbs, contributing to a strong surge in LED demand in the Japanese market for Q3/2012.

Furthermore, the LED lighting project market in China will be the target of most LED companies. In early 2012, due to drastic differences in product quality between the winning bidders, the bidding process for the 2012 Solid-State Lighting Product Subsidy was restarted in July for the 2012/2013 period, with outdoor lighting products such as LED street lamps, LED tunnel lights and indoor lighting products such as LED down-lights, and self-ballasted LED reflector lamps included in the subsidy scheme. The Chinese government has established new standards for the bidding process in order to increase the product quality of the winning bidders.

Although China's LED subsidy bidding process in first-half 2012 did not go as smoothly as planned, causing many projects to be placed on hold, the new standards added to the new bidding process will help to raise product quality and establish the threshold for companies planning to bid, says the report. Even though the amount of subsidy has not yet been announced, support from the government will undoubtedly aid the development of the LED industry, reckons the report. Commercial, industrial and household lighting markets will gradually take off as the governments start to increase related subsidies and as market acceptance begin to grow, it concludes.

www.LEDinside.com

Backlight LED prices fall 2-3% in Q3/2012

Inventory adjustment remains an issue

Despite the rush orders during second-quarter 2012 that kept LED chip and package makers' utilization rates high, the Q3/2012 outlook for the LED backlight market has turned murky due to the European debt crisis and weak demand in China, according to LEDinside (the LED research division of TrendForce). Due to the weakened market confidence and the conservative attitude of LED companies, no demand surge is in sight, it adds. Whether or not brand vendors will cut orders in Q3 depends on the sales of end-market products.

As for the TV backlight market in Q3, the prices of LED packages such as 7030 and 3528 saw a decline of 5–6% after they entered mass production and reached economies of scale. In contrast, the price of LEDs for other backlight applications saw limited price drops, averaging 2–3%.

Demand for smartphones and tablet PCs fell; notebook shipments flat

Affected by the lukewarm economic outlook, smartphone and tablet PC makers have revised their shipment forecasts. For smartphones, global shipments for 2012 are forecasted to be 660 million units, which is 55 million less than forecasted in early 2012. The forecast of orders for high-brightness (HB) side-view LEDs has also been lowered to 425 million units. Although the second-half 2012 LED backlight market remains uncertain, the price of LEDs for mobile phones applications still fell by 2–3% quarter-to-quarter due to demands from mobile phone makers for higher backlight brightness.

In addition, TrendForce estimates that global shipments of notebooks in 2012 will see no growth, which will affect LED backlight market growth in the notebook sector. On the other hand, demand for tablet PCs remains strong in 2012, with global shipments forecast to see year-on-year growth of 52%. However, as Apple has 60% of the tablet PC market, Apple's LED backlight demand is supplied by two Japanese package makers. The price for 0.8t side-view LEDs fell by 3% in Q3/2012, while 3014 packages for notebook PCs are sold at cost, with the price dropping by 2% in Q3.

LED backlight penetration rate for TVs to reach 73% in 2012

The end of Q2 and the beginning of Q3 is usually the time for TV makers to start develop new models. Aside from Japanese TV vendors, Korean TV makers are still going through LED patent cases. Korean firms have hence adopted Taiwanese package makers' LED product, TrendForce says. So, certain Taiwanese package makers may see booming growth in their orders by the end of 2012, it is reckoned.

Although direct-type LED TV sales in first-half 2012 fell short of expectations, 3528 prices fell by 6% in Q3 as sales rose, while 7030 prices dipped by 5%. Moreover, the LED usage of direct-type LED TVs will be reduced by 30% in 2013. For example, the current for 3528 LEDs will be increased to 400mA, and only 21 LEDs will be required instead of 32.

Also, since Korean companies have stopped production of cold-cathode fluorescent lamp (CCFL) TVs, TrendForce estimates that LED backlight penetration in the TV market will rise further to 73% in 2012.

New LED package to hit TV backlight market in 2013

According to TrendForce, given the uncertain outlook for second-half 2012, if the market remains stagnant and LED inventory for the backlight market remains high in Q3, then LED users may start to cut orders.

Hence, if LED companies can seek strategic alliances with other firms and continue to improve their products (i.e. increasing their brightness — even under lower-voltage operation — and reducing the number of LEDs needed), then it will be harder for them to be replaced in the LED industry, says TrendForce. Additionally, new LED packages for TV backlights will start to impact the market in 2013, the firm forecasts.

www.LEDinside.com

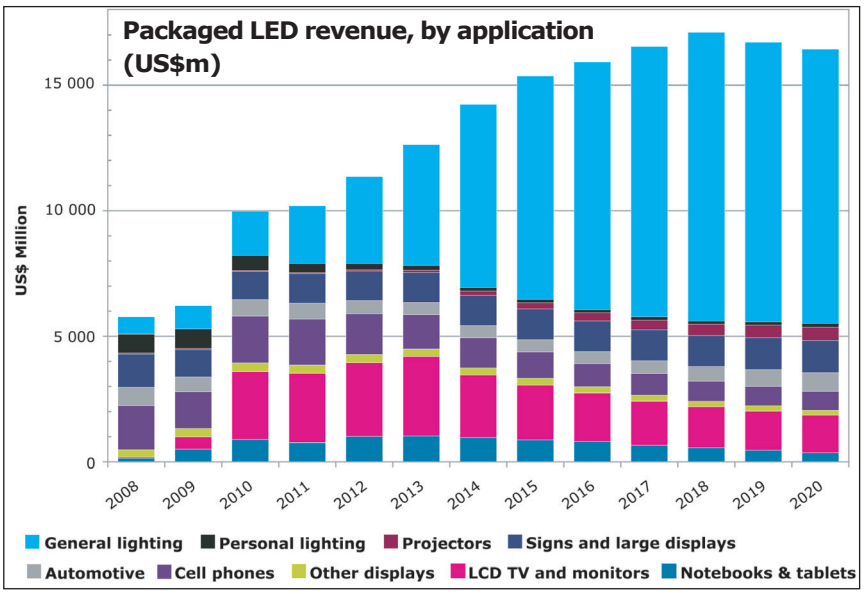
AP	Type	Current (mA)	VF(Typical)	Luminous// Efficacy (lm)	2012 Q3 Price (US$)		
					High	Low	Change
TV	7030	120	6.8	55-70	0.21	0.15	-5%
	3228/3528	250	3.75	50-60	0.38	0.32	-6%
Monitor	3020	20	3.2	5.3-7.0	0.05	0.03	-2%
	4014	60	3.4	15~20	0.08	0.06	-2%
NoteBook	0.8t	20	3.2	5.5-6.8	0.07	0.04	-3%
	3014	20	3.2	5.9-7.0	0.06	0.03	-2%
Mobile phone	0.6t	20	3.2	6.0-7.5	0.09	0.04	-2%
	0.6t	20	3.2	7.5-8.7	0.14	0.08	-3%
High Power	Cool white	350	3.2	90-100	0.56	0.33	-1%
	Cool white	350	3.2	100-120	0.68	0.44	-3%
	Cool white	350	3.2	120-140	0.85	0.62	-5%

LEDinside

White LED price (in US$) in Q3/2012 for various types for various backlighting applications.

LED market to grow from $11.4bn to $17.1bn in 2018

General lighting to drive 26% annual growth in substrate volume



While LED industry growth came initially from small display applications and was boosted by LCD display applications, lower-than-expected adoption of LEDs in the TV market and the entry of several new players (mostly from Asia) in 2011 created a climate of overcapacity, price pressure and strong competition, summarizes the report 'Status of the LED Industry' from market research firm Yole Développement and the European Photonics Industry Consortium (EPIC). Packaged LED volume was hence about 30% lower than expected and revenue shrank due to strong pressure on average selling prices (ASPs).

"In 2012, most companies have moved to the new 'El Dorado' of LED business, general lighting, which represents the next killer application for LEDs," says Pars Mukish, market & technology analyst, LED at Yole. "But enabling massive adoption of the technology for such an application still requires a large decrease in the cost of LED-based products."

Yole and EPIC estimate that the packaged LED market will $11.4bn in 2012 and peak at $17.1bn in 2018. Growth will be driven both by display (LCD TV) and general lighting applications, until the mass adoption of LEDs in lighting. From 2014, the third growth cycle in the LED business will accelerate, with general lighting representing more than 50% of overall packaged LED revenue. In terms of volume, LED die surface area will increase from 22.5 billion to 80 billion square millimeters from 2012 to 2018. This will prompt growth in substrate volume at a compound annual growth rate (CAGR) of 26% from 8 million to 39.5 million x 2"-equivalent (TIE) wafers from 2011 to 2018.

Packaged LED cost needs to fall 10x for mass adoption in lighting

However, the adoption of LEDs for general lighting applications strongly depends on improvements in technology and manufacturing, reckons the report. This is required to drive the performance and cost of LED solutions to a trigger point where mass adoption can start. Industry consensus indicates that the cost per lumen for packaged LEDs needs to fall by a factor of 10x.

The report suggests this can be achieved via a combination of manufacturing efficiency and performance improvements, including access to larger-size wafers; improvements in LED epitaxy cost of ownership through yield and throughput; and improved packaging technologies (e.g. phosphors, optics etc). Also, improved package and luminaire design will also enable significant cost reduction ('design for manufacturability').

China's GaN MOCVD reactor capacity up 20-fold in last 3 years

GaN LED epi capacity rose greatly in 2010 and 2011 across all regions, but most dramatically in China (up 20-fold from Q4/2009 to Q1/2012).

However, "Most emerging Chinese LED epiwafer and die manufacturers are still lagging significantly behind their competitors in term of technology maturity and LED performance," notes Dr Eric Virey, senior analyst, LED.

The bulk of those new companies are not yet capable of manufacturing LEDs to address the large display and general lighting applications that are currently driving the market, reckons the report. In the mid-term, consolidation of the Chinese LED industry will occur (as per the scenario in the central government's new five-year plan), and China should become a major player in the LED industry.

New business models needed to capture added value of lighting

Ultimately, the long life-span of solid-state lighting technology will change the lighting market by greatly increasing the length of replacement cycles, says the report. The replacement market (after-market) will be strongly impacted, pushing traditional players in the lighting industry to define new strategies to capture profit (e.g. intelligent lighting, lighting solutions).

"In addition, as value is moving to the top of the value chain (module and luminaire levels), several players that were originally involved only at LED device levels will develop strategies of vertical integration in order to capture more value," adds EPIC's general secretary Tom Pearsall.

However, accessing distribution channels represents a big challenge for those players that develop new approaches (such as e-commerce, new distributors etc) to sell their lighting products. The rise of LED lighting will hence depend on appropriate combining of the emerging LED industry with the traditional lighting industry.

www.yole.fr

GaAs bulk substrates return to normal demand growth and price declines in 2012

Revenues rose in 2011 due to increased pricing, despite lower demand

Coupled with a shift away from GaAs technology for handset switches, slow growth in the GaAs device market reduced demand for semi-insulating GaAs bulk substrates by 4% in 2011, according to the report 'Semi-insulating GaAs Substrate Markets: 2011–2016' from Strategy Analytics' GaAs and Compound Semiconductor Technologies Service (GaAs).

"Growth in the GaAs device market slowed noticeably in the second half of 2011, and this slowdown was one of several factors causing GaAs bulk substrate demand to decline", notes Eric Higham, director of the Strategy Analytics GaAs and Compound Semiconductor Technologies Service (GaAs).

"The other notable trend that has slowed growth in GaAs substrate demand is the rapid conversion of handset switches to technologies other than GaAs," he adds.

However, the 2011 earthquake and tsunami in Japan disrupted the entire GaAs bulk substrate supply chain, resulting in increased substrate pricing and higher overall revenue. The market research firm hence estimates that total demand for semi-insulating (SI) GaAs bulk substrates from manufacturers such as Freiberger Compound Materials (FCM), Hitachi Cable, AXT, Sumitomo and Dowa reached slightly more than 32100 kilo square inches (ksi) in 2011, resulting in nearly $230m in revenue.

"These disruptions have increased substrate prices in the short-term but, as they diminish, we expect modest market growth and substrate price declines will return," says Asif Anwar, director in the Strategy Analytics Strategic Technologies Practice (STP).

The report forecasts that demand and revenues will return to slow growth, with demand reaching nearly 39000ksi and revenue growing to just over $240m by 2016.

www.strategyanalytics.com

Power semi market to grow $9bn to $26.2bn in 2016

The power discrete and module market will grow by almost $9bn to $26.2bn in 2016, forecasts the 15th edition of an annual report from IMS Research, which this year includes more comparisons of wide-bandgap (silicon carbide and gallium nitride) power semiconductor sales with silicon sales. Following good growth in first-half 2011, the market fell away in the second half to finish with only 9% growth over the full year. Although market conditions have remained flat in first-half 2012, the longer-term prospects remain positive, says the firm.

With revenues growing 9% from 2010, it is clear that 2011 was, at best, an average year for the power semiconductor market. This follows the dramatic market fall in 2009 and spectacular recovery in 2010, so perhaps the industry was ready for a 'normal' year, says IMS. However, with business confidence uncertain and the recovery stalling, what are the prospects for the future? According to IMS Research's report 'The World Market for Power Semiconductor Discretes & Modules 2012' (to be published in August), there remains cautious long-term optimism, with the market projected to grow at a compound annual growth rate (CAGR) of 8% over 2011–2016, to $26.2bn.

According to IMS, in 2011 the market for power semiconductor modules again grew faster than the market for discrete power semiconductors, increasing by 32% to nearly $4.6bn. Despite slowing demand as reduced business confidence is felt in industrial market sectors, the power module market is continuing to grow in 2012. "Power module revenues are predicted to grow by 14% in 2012, and to be 80% higher than in 2011 in 2016" says senior analyst and report author Richard Eden.

The power discrete market was worth an estimated $12.9bn in 2011, having grown by just over 2% from 2010. Continued high demand for discrete IGBTs (insulated-gate bipolar transistors) accounted for nearly all the growth. "The sudden surge in discrete IGBT demand was fuelled by sales of domestic appliances such as room air-conditioning and variable-speed washing machines in the Chinese market," adds Eden. "In contrast, sales of standard power MOSFETs and thyristors actually declined slightly in 2011."

A high proportion of discrete power semiconductors are used in relatively fast-moving commodity items such as flat-screen TVs, notebook computers and mobile phone adapters. Sales of these products depend heavily on consumer confidence and the health of the global economy. Sales of power semiconductors in those sectors either declined or achieved negligible growth in 2011, and are not forecast to deliver much growth in 2012. Power semiconductor market growth will hence be driven by increased content, either to improve power conversion efficiency or add functionality. In contrast, growth is forecast to accelerate in the automotive, renewable energy and transportation sectors. Overall discrete power semiconductor market growth is predicted to remain below 5% in 2012; IMS forecasts the market will reach almost $18bn in 2016.

www.imsresearch.com

Power electronics device market to reach $20bn this year

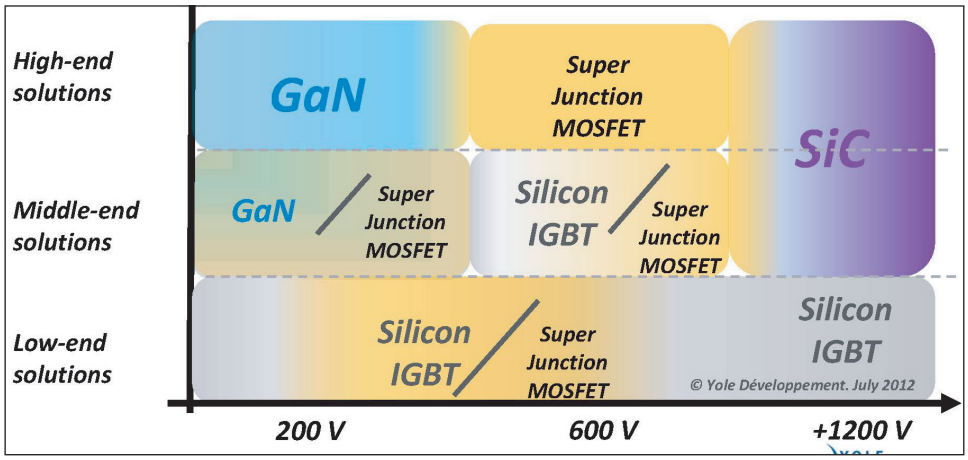
SiC to be dedicated to high-power/voltage applications; GaN becoming more globalized

The total market for semiconductor devices (discretes, modules and ICs) dedicated to the power electronics industry will reach $20bn in 2012, according to the report 'Status of the Power Electronics Industry' from market research firm Yole Développement. With applications as diversified as hybrid cars, photovoltaic (PV) inverters, lighting, and energy — and with a voltage ranging widely from a few volts to a few thousands volts — power electronics will remain one of the most attractive branches of the semiconductor industry for the next decade, the firm expects.

The power electronics industry is now addressing applications involving conversion and motion, and requires lighter/smaller, cheaper and more efficient systems, notes Yole. This evolution starts with improvements at the semiconductor level, and there are four technologies that are the best candidates for handling these new system requirements: silicon IGBTs (insulated-gate bipolar transistors), super-junction (SJ) MOSFETs, gallium nitride (GaN)- and silicon carbide (SiC)-based devices.

Already well established in the market, IGBTs account for $1.6bn in the medium- to high-voltage range. However, Yole says that there is a trend to decrease the voltage range in order to access more segments by targeting consumer applications such as TVs, computer adapters and cameras. At the same time, SJ MOSFETs present in these applications offer faster switching frequencies and competitive cost. Yole forecasts that the SJ MOSFET market will reach $567m by the end of 2012.

GaN and SiC also look promising to surpass silicon's performance and enhance inverter capabilities, notes Yole. However, these materials are still expensive and the technology is not yet ready, the firm reckons.



Technology positioning, depending on voltage range and system requirements.

On the other hand, both of these materials can benefit from their developed status in the LED industry, and plenty of LED players have been paying attention to the opportunity that power electronics represent, it adds.

Each technology faces development issues

In the report, Yole identifies the needs for using the four main technologies. Nevertheless, all still have issues in offering ideal solutions for each application in every power/voltage range. There are two consequences:

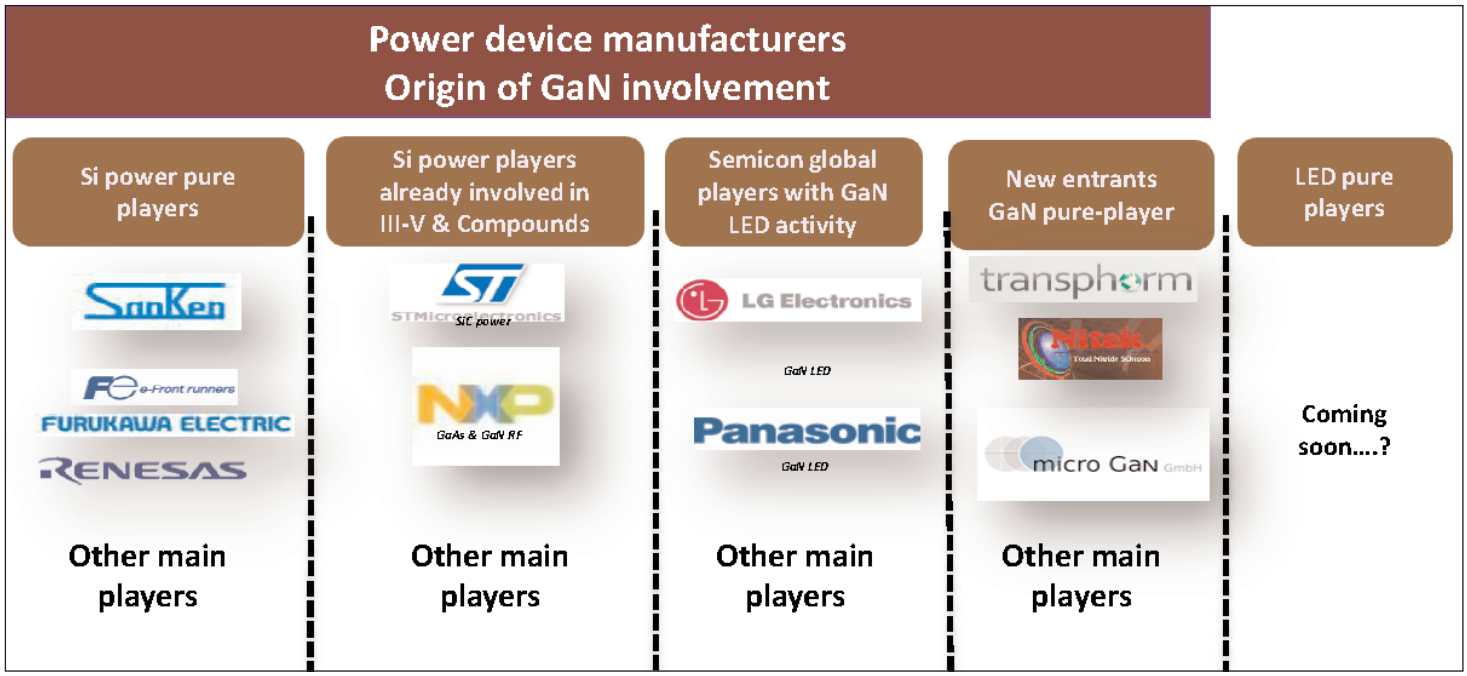
- GaN and SiC are not yet mature enough for the power electronics market: GaN needs technical enhancements in the manufacturing process, especially for epitaxy thickness, and SiC is an expensive material that precludes implementation in consumer sectors.
- Segmentation between technology and power/voltage range will take place, so some segments will adopt only one 'best' technology, reckons Yole.

Each technology has a particular industry structure

While SJ MOSFETs are seeing new players and foundry service suppliers, the IGBT chip industry is becoming consolidated by the presence of large players — such as Infineon, Mitsubishi Electric and Fuji — involved in many application sectors. However, the IGBT (and SJ MOSFET) modules business is growing and new players are entering the sector to provide solutions for cooling, interconnections, substrates, packaging, and gel.

On the other hand, the SiC industry, which has been led so far by Cree Inc, is now an interesting playground for new players, says Yole. With access to lower-cost material, the SiC industry now has the possibility of ramping up in volume and becoming more established. However, apart from the PFC (power factor correction) business, the capabilities of SiC technology show that it will almost certainly be dedicated to high-power/high-voltage applications. Last but not least, SiC companies have arisen in China, which will present competition and tougher access to local markets.

At the moment, the GaN industry is mostly US-based, says Yole. International Rectifier, EPC, Transphorm, Microsemi and GaN Systems have now presented fully off-the-shelf or customized products. However, some pioneers such as MicroGaN, NEC and Powdec are showing that there is a trend towards globalization in the GaN manufacturing industry. At the same time, the market is still soft, ►



Interaction between power GaN industry and related industries leading semiconductor firms to enter power GaN.

and LED players are considering using their technology base to enter the power electronics market, which will be very much low-power/voltage-oriented, notes Yole.

The power electronics industry has great potential for growth, reckons the firm, driven mostly by energy-related applications (production, distribution, consumption), which presents an open and accessible market, even for small players.

Technology & cost requirements, driven by inverter industry

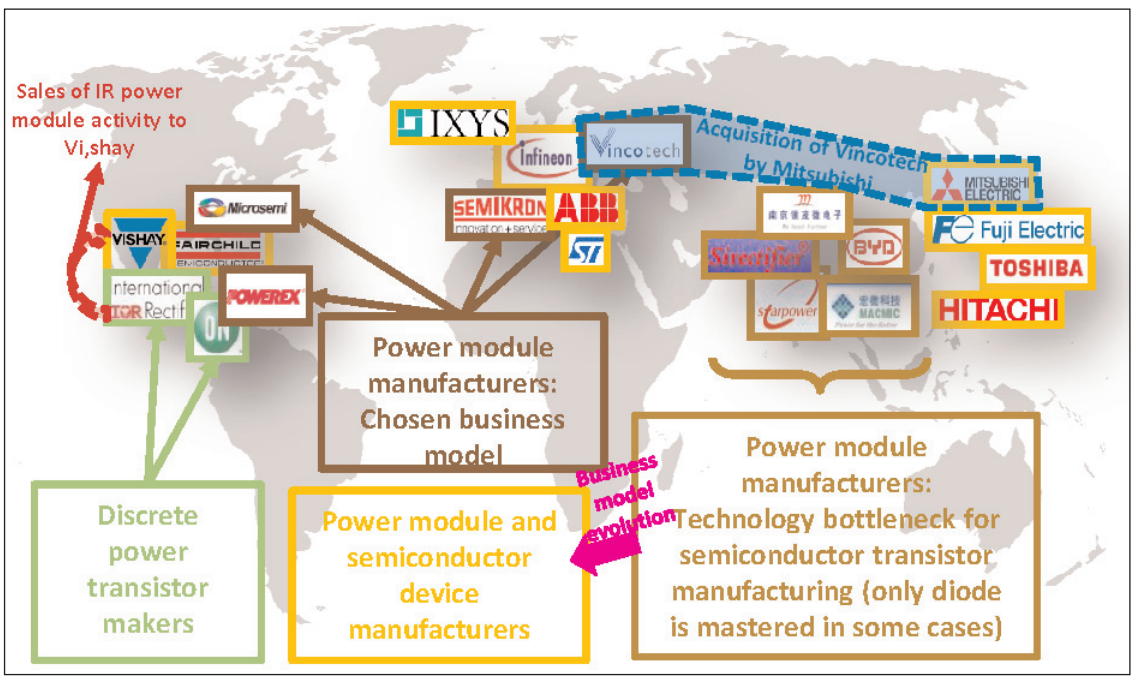
Because it comprises just part of the power electronics industry, the power semiconductor industry must meet the demands of a bigger system: the inverter. For example, some expensive solutions have still not been implemented, even if the device and module performances are much higher than the existing output.

The report therefore provides an analysis of the inverter market and the players, as well as the industry evolution, in order to illustrate the role of power semiconductors and to analyze which drivers will be key for various applications.

In addition, the report underlines the expected technical developments of an inverter — depending on the applications — and how power semiconductors can contribute to these improvements. Indeed, power devices ameliorations will be useful only if they fit with passive and connective devices, as defined by the needs of the inverter, Yole notes.

Geographical positioning is also critical in the power electronics area, especially with the boom in China and other emerging countries, but also because several applications (PV, wind, electric vehicles) are supported by local governments, comments the market research firm. Yole therefore also provides a geographical and supply chain analysis for the power electronics industry, from semiconductors and passive devices to the inverter stage.

www.i-micronews.com



Supply chain integration and diversification.

Anadigics' revenue falls 12% in Q2 to $25.1m

Losses rise, but transition from legacy to new products to drive growth

For second-quarter 2012, GaAs-based broadband wireless and wireline communications component maker Anadigics Inc of Warren, NJ, USA has reported net sales of $25.1m, down 11.7% on $28.4m last quarter and 29.5% on $35.6m a year ago.

Revenue for Infrastructure (formerly termed Broadband) was $7.1m, down 4% on $7.4m last quarter, after supplying pent-up demand in Q1/2012. Of Infrastructure revenue, about $4.5m came from CATV and the rest from WiFi, WiMax etc.

Wireless revenue was $18m, down 14% on $21m last quarter (falling further from 75% to 72% of total revenue). This was due mainly to an anticipated reduction of $2m with Blackberry-maker Research In Motion (to just over $500,000), as well as smaller declines for China OEMs who saw their market shares drop as Apple and Samsung increasingly dominate smartphone sales.

Anadigics again had three greater-than-10% customers (Samsung, ZTE and Huawei) and another five in the 5–10% range (Cisco, LG, two distributors Richardson and World Peace Group, and Sierra Wireless, which replaced Research In Motion this quarter). Just over a year ago (in Q1/2011) RIM had contributed $16.6m (38% of total revenue).

On a non-GAAP basis, gross margin has fallen further, from +6.7% last quarter to negative 7.7%. Capacity utilization was only about 40%, while additional costs had to be absorbed during the introduction and ramp-up of new technologies, processes, and products.

R&D expenses were cut from $11.6m last quarter to $11.3m, but remain high as Anadigics continues to bring more products to market and accelerate new product introductions. Selling & administrative expenses were cut from $6.8m to $6.3m after staff reductions, as the firm reduces non-critical expenses.

Nevertheless, net loss has risen further, from $9.4m a year ago and $14.9m last quarter to $17.9m. Depreciation expense was $4.2m (roughly level with last quarter), while capital expenditure (CapEx) has halved from $1.4m to $0.7m. During the quarter, cash, cash equivalents and short- and long-term marketable securities fell further, from $84m to $73.1m.

"During the second quarter, Anadigics made tremendous strides in executing to its product strategy, exemplified by the introduction of several new products," says president & CEO Ron Michels. These included the launch in mid-June of the ProEficient power amplifier family, as well as expanding its family of small-cell wireless infrastructure power amplifiers to support extra bands and power levels (for Band 5 WCDMA and LTE applications). "The commercial success of these new products has been validated by several new design wins and ramping production volumes," he adds.

"With the successful market introduction of MMPAs [multi-mode multi-band power amplifiers], outstanding design-win activity with ProEficient power amplifiers [for Band 1], continued traction with our penta-band PA, and dual-band design wins in flagship products such as [Samsung's] Galaxy S3, we believe Anadigics' wireless mobile device portfolio is positioned for strong growth," says Michels.

"Revenues have stabilized as new products and wireless ramp and offset the decline in legacy business," believes chief financial officer Terry Gallagher. "We are pleased with the traction we continue to see in the development of our new products."

"We continue to aggressively execute on our market strategy with new product introductions that drive expansion of our served available market," says Michels. "Specifically, we're addressing the front-end areas of wireless mobile devices with dual-band power amplifiers and MMPAs, ProEficient power amplifiers [for Bands 2, 4, 5 and 8] as well," he adds. "We are also utilizing expertise in power amplifier design to take the leadership position in the enterprise small-cell market, which is expected to follow a steep growth trajectory in 2013. Lastly, we are leveraging our differentiated technology and IP to address the WiFi market trend toward higher data rates in mobile devices," Michels continues.

"Over time, margin headwinds will ease as revenues recover and we complete the transition from legacy to new products," says Gallagher. "We remain focused on streamlining our cost structure and, on that front, we recently took additional actions that further reduced annualized expenses by over $1m."

Anadigics' dual-band PAs power Samsung Galaxy S III smartphone

Anadigics says it is shipping production volumes of its dual-band High-Efficiency-at-Low-Power (HELP3E) power amplifiers (AWC6323, AWC6325, ALT6725) to Samsung Electronics for the new Galaxy S III smartphone.

The AWC6323 is in the S III available through Verizon Wireless, and the AWC6325 and ALT6725 are in the S III available through Sprint.

The compact 3mm x 5mm dual-band devices incorporate two independent PAs, RF couplers, control logic and an internal voltage regulator in a single package, reducing printed circuit board (PCB) space requirements by more than 20% compared with single-band discrete solutions.

www.anadigics.com

Kopin's Q2 revenue growth suppressed awaiting launch of next-generation iPhone

...but Skyworks supply deal extended to end-2013

For second-quarter 2012, Kopin Corp of Taunton, MA, USA, a supplier of III-V semiconductor products and microdisplays for mobile applications (including smartphones, tablet PCs, military thermal weapons sights and wearable computers), has reported total revenue of $22.8m, down 9.5% on $25.2m last quarter and 27% on $31.4m a year ago.

Revenue from III-V products was $15.8m, down slightly from $16m a year ago but up 10% on $14.3m last quarter. Revenue from display products was $7m, down 36% on $10.9m last quarter and less than half the $15.4m a year ago.

"Display product revenues were down in the second quarter due to decreased US military spending, while III-V revenues were essentially flat as the market awaits the launch of the next-generation iPhone in the second half of the year," says president & CEO John C.C. Fan.

Although down from $31m a year ago, operating expenses have risen from $27.6m last quarter to $28.3m. Of this, R&D expenses have fallen further, from $7.1m a year ago and $5.1m last quarter to $5m.

Compared with net income of $0.8m a year ago, net loss has risen from $2.2m last quarter to $5.9m. During the quarter, cash and marketable securities fell further, from $102m to $96.3m.

During the quarter, Kopin's III-V product purchase and supply agreement with Skyworks Solutions Inc of Woburn, MA, USA (which manufactures analog and mixed-signal semiconductors) was extended through December 2013 under terms similar to previous agreements. "Skyworks has been an outstanding customer and partner for many years, and we look forward to continuing to supply them," says Fan.

"Our renewed purchase and supply agreement with Skyworks, combined with our strong relationships with other customers, positions our III-V business well for the future," Fan reckons. "While the growth trajectory of the wireless handset market may not be as steep as anticipated at the beginning of 2012, the market remains strong," he adds.

"In our military display business, the decline in defense spending has prompted one customer to review various options to reduce costs, which is currently affecting an existing program," notes Fan. "Orders we had anticipated in our 2012 guidance likely will not occur this year." Consequently, Kopin is cutting its full-year 2012 revenue guidance from $110–120m to $90–100m.

www.kopin.com

TriQuint adds ex-AT&T 3G network developer as independent director

RF front-end component maker and foundry services provider TriQuint Semiconductor Inc of Hillsboro, OR, USA has expanded its board of directors by adding Roderick Nelson as a new independent director.

Nelson's career in telecoms spans over 25 years, ranging from AT&T Wireless to a number of start-up companies. He served as executive VP & chief technology officer of AT&T Wireless Services, based in Redmond, WA, where he led the Technology Development Group responsible for the development and deployment of the first 3G networks in the USA. His role was to define the future wireless network architecture and technology direction.

During his career, Nelson has worked closely with both national and international regulators and standards bodies on the creation of 3G specifications and standards. TriQuint says that, regarded as a spokesperson and industry leader on the direction of wireless technologies, he has developed strategies to make radio spectrum available for successful 3G deployments.

Currently, Nelson is a founding partner at Tritech Sales and Services LLC, which provides business and technology strategy consulting as well as business development and distribution strength to accelerate clients' growth in the wireless ecosystem. Nelson and Tritech have positioned new technology solutions and vendors with leading operators in the USA and internationally, taking previously unknown vendors and solutions to carrier approval, resulting in scaled revenue generation, says TriQuint.

www.triquint.com

RFMW design & sales support for 2W high-linearity amplifier

RF and microwave component distributor RFMW Ltd of San Jose, CA, USA has announced design and sales support for TriQuint's TQP7M9106, a high-linearity driver amplifier with frequency coverage from 50MHz to 1.5GHz.

At 0.9GHz, the TQP7M9106 offers gain of 20.8dB, output IP3 of 50dBm, and compressed 1dB power of +33dBm, while drawing just 455mA from a 5V supply.

Available in a 4mm x 4mm QFN surface-mount package, the device suits applications such as 3G/4G wireless infrastructure, small-cell base-station transceivers (BTS), boosters, high-power amplifiers, repeaters, defense communications, and general wireless applications in the 50–1500MHz range.

www.rfmw.com

IN BRIEF

RFMD shipping PAs for Galaxy S3 LTE smartphone

RFMD has begun production shipments of power amplifiers (PAs) to Samsung in support of its next-generation Galaxy S3 4G LTE smartphone.

RFMD expects to supply the majority of the 3G and 4G power amplifiers in Samsung's highest-volume smartphones this calendar year. It already supports multiple feature phones, smartphones and tablets for Samsung with a broad range of products, including PowerSmart power platforms, ultra-high-efficiency PAs, and other critical high-performance components. This most recent 4G LTE smartphone to be supported by RFMD features a dual-core multi-mode 3G/LTE modem.

"These shipments of RFMD's ultra-high-efficiency 3G/4G power amplifiers to Samsung underscore our strong design momentum in next-generation mobile devices and our early market share leadership in the rapidly growing LTE market," says Eric Creviston, president of RFMD's Cellular Products Group. "We currently forecast robust growth in LTE in calendar 2012, as LTE devices grow from approximately 20 million units in calendar 2011 to greater than 100 million units in calendar 2012."

RFMD claims that its ultra-high-efficiency 3G and 4G LTE PAs enable increased battery life in smartphones while reducing the thermal impact of advanced data-based applications, including web surfing, video calling and internet radio. The product family covers WCDMA bands 1, 2, 3, 4, 5 and 8, and LTE bands 3, 4, 7, 11, 13, 17, 20 and 21, addressing the most common UMTS/HSPA+ and LTE frequency bands and band combinations.

www.rfmd.com

RFMD launches 4.9–5.85GHz front-end module for 802.11a/n WiFi

RF Micro Devices Inc of Greensboro, NC, USA says that its new RF5836 provides a complete integrated solution in a single front-end module (FEM) for WiFi 802.11a/n systems.

The RF5836 integrates a 5GHz power amplifier (PA), single-pole double-throw (SP2T) Tx/Rx switch, and a power detector coupler for improved accuracy. Provided in a low-profile 3mm x 3mm x 0.5mm, 16-pin package, the device is suited to SiP (system-in-package) and CoB (chip-on-board) designs. RFMD says that the ultra-small form factor and integrated matching minimizes the layout area in the customer's application and greatly reduces the number of external components.

Features include a single supply voltage of 3.0–4.8V, and a low control voltage of >1.6V. Output power (P_{OUT}) is 15.5dBm (11a, 54Mbps at 4% EVM) and 14.5dBm (11n, 65Mbps at 2.8% EVM). The module meets or exceeds the RF front end needs of IEEE 802.11a/n WiFi RF systems.

Applications include cellular handsets, mobile devices, tablets, consumer electronics, gaming, netbooks/notebooks, and TV/monitors/video.

www.rfmd.com

Shareholders approve all proposals at annual meeting

RF Micro Devices says that all agenda items at its 2012 Annual Meeting of Shareholders were approved by the shareholders.

The proposals approved included:
(1) the election of eight directors to serve a one-year term;
(2) executive compensation (approved on an advisory, non-binding basis);
(3) the 2012 Stock Incentive Plan;
(4) an amendment to RFMD's Employee Stock Purchase Plan to increase the number of shares authorized for issuance; and
(5) the appointment of Ernst & Young LLP as RFMD's independent registered public accounting firm for the fiscal year to end-March 2013.

RFMD launches 0.25W, 50–2700MHz InGaP HBT power amplifier

RFMD has launched a new single-stage indium gallium phosphide heterojunction bipolar transistor (InGaP HBT) power amplifier (PA) operating at frequencies of 50–2700MHz, designed specifically for wireless infrastructure applications.

The RFPA2089 offers high-gain linear operation (17.6dB gain at 2.65GHz) at a comparably low DC power, suiting next-generation radios requiring high efficiency. Its external matching allows for use across various radio platforms.

Features include: –60dBc adjacent channel power ratio (ACPR) at 13dBm WCDMA; 0.25W of output power at 1dB gain compression point (P1dB); what is claimed to be excellent linearity-to-DC power ratio; single-supply 5V operation; and electrostatic discharge (ESD) protection up to Class 2 (2000V) human body model (HBM).

Applications include driver amplifiers for base-station transceivers; PA stages for commercial wireless infrastructure; IF amplifiers; and 2G, 3G and LTE transceiver applications.

Pricing begins at $1.84 each for 750-unit quantities.

Hittite's revenue and profit continue recovery in Q2

For second-quarter 2012, Hittite Microwave Corp of Chelmsford, MA, USA (which designs and supplies analog, digital and mixed-signal RF, microwave and millimeter-wave ICs, modules and subsystems as well as instrumentation) has reported revenue of $65.4m, down 4.6% on $68.5m a year ago but up 3.3% on $63.3m last quarter as revenue continues to recover from the low of $60.2m in Q4/2011.

Of total revenue, 46.7% ($30.5m) came from customers in the USA (down from 48.8% last quarter) and 53.3% ($34.9m) came from outside the USA (up from 51.2% last quarter).

Gross margin has risen again, from 72.7% a year ago and 73.7% last quarter to 74.5%. Although down on $32m (46.8% of revenue) a year ago, operating income of $26.2m (operating margin of 40.1% of revenue) is up on $25.5m (40.2% of revenue) last quarter.

Although still down on $20.8m a year ago, net income has risen from $16m last quarter to $17.2m. However, this includes a $0.7m tax benefit related to the resolution of a tax audit.

During the quarter, total cash and cash equivalents rose by $1.5m, from $373.9m to $375.4m.

For third-quarter 2012, Hittite expects stable revenue of $65–67m and net income of $16–16.9m ($0.52–0.55 per diluted share).

Digi-Key signs global distribution agreement with Hittite

Internet-based electronic components distributor Digi-Key Corp of Thief River Falls, MN, USA has signed a global distribution agreement with Hittite Microwave, which supplies MMIC-based solutions for communication and military markets.

Founded in 1985, Hittite designs and develops ICs, modules, subsystems and instrumentation for digital, RF, and microwave applications.

"Microwave and RF technologies are widespread in numerous industries today," says Mark Zack, VP, global semiconductor product at Digi-Key. "The broad selection of high-performance products offered by Hittite will add a unique dimension to our line card," he adds.

Hittite's digital integrated circuit (IC), radio-frequency integrated circuit (RFIC) and monolithic microwave integrated circuit (MMIC) products use GaAs, GaN, InGaP/GaAs, InP, SOI, SiGe, CMOS and BiCMOS semiconductor processes to form MESFET, HEMT, pHEMT, mHEMT, HBT and PIN devices. The firm's product portfolio covers 35 product lines and includes over 1025 standard products.

www.digikey.com

Hittite launches wideband LNA & PAs for high-linearity microwave radio, EW/ECM, radar and test

Hittite Microwave has launched two new power amplifiers suited to microwave radio, electronic warfare (EW), electronic counter measures (ECM) and radar applications to 28GHz. Also released is a unique wideband low-noise amplifier (LNA) that operates from 300MHz to 20GHz and is suited to wideband multi-chip-module (MCM) and subsystem applications.

The HMC994LP5E is a GaAs MMIC pHEMT distributed power amplifier that operates between DC and 28GHz. The amplifier provides 13dB of gain, +29dBm of saturated output power, and 23% power-added efficiency (PAE) from a +10V supply. With up to +38dBm output IP3, the device suits high-linearity applications in military and space as well as point-to-point and point-to-multi-point radios.

The HMC998LP5E is a GaAs MMIC pHEMT distributed power amplifier that operates between 100MHz and 20GHz. The amplifier provides 11dB of gain, +41dBm output IP3, and +31dBm of output power at 1dB gain compression while requiring only 500mA from a +15V supply.

The device suits high-linearity applications in military and space as well as point-to-point and point-to-multi-point radios

Both the HMC994LP5E and the HMC998LP5E exhibit very flat gain from 4 to 16GHz and from 3 to 17GHz respectively, suiting EW, ECM, radar and test equipment applications. Both are supplied in leadless QFN 5mm x 5mm surface-mount packages and feature I/Os that are internally matched to 50Ω.

The HMC1049 is a GaAs MMIC pHEMT low-noise amplifier die that operates between 300MHz and 20GHz and employs a novel topology that maintains a low noise figure of 1.7dB at low frequencies. The amplifier also delivers 16dB of small-signal gain and output IP3 of +27dBm, while requiring only 70mA from a +7V supply. The P1dB output power of +16dBm enables the LNA to function as an LO driver for balanced, I/Q or image reject mixers. The device is internally matched to 50Ω for ease of integration into MCMs.

Die samples, SMT product samples and evaluation PC boards for all SMT-packaged products are available from stock.

www.hittite.com

IN BRIEF

DOE announces fiscal 2013 SBIR/STTR funding opportunity

The US Department of Energy (DOE) Office of Science has released its DE-FOA-0000760 funding opportunity announcement for the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs, seeking applicants for funding directed toward fiscal 2013 Phase I and Fast-Track (combined Phase I and Phase II) projects, starting in February 2013.

About $34m is expected to be available under this FOA for up to a total of about 162 awards. The maximum amount for individual SBIR and STTR awards will be $150,000, $225,000 or $450,000 for Phase I projects (running for up to 9 months) and $1,150,000, $1,725,000 or $3,450,000 for Fast-Track projects (running for up to 33 months), depending on the topic.

Of the 43 topics for the funding opportunity, 14 fall under the Office of Basic Energy Sciences' program area overview, including the following two: 'Radio Frequency (RF) Devices and Components for Accelerator Facilities (Phase I, $150,000/Phase II, $1,000,000)'; 'Wide Bandgap Semiconductors for Energy Efficiency and Renewable Energy (Phase I, $150,000/Phase II, $1,000,000)'.

Qualified small businesses with strong research capabilities in science or engineering in any of the research areas sought in the announcement are encouraged to apply.

Applicants must submit a letter of intent by 4 September in order to be eligible to submit a full application by 16 October.

http://science.energy.gov/sbir/funding-opportunities

Northrop Grumman demonstrates record 850GHz integrated receiver

Phase 2 of DARPA's Terahertz Electronics Program raises frequency from 670GHz

US defense contractor Northrop Grumman Corp has demonstrated an 850GHz integrated receiver that brings the firm much closer to being first to reach a US Department of Defense goal for developing transistor-based electronics that can operate at center frequencies beyond 1 terahertz (THz).

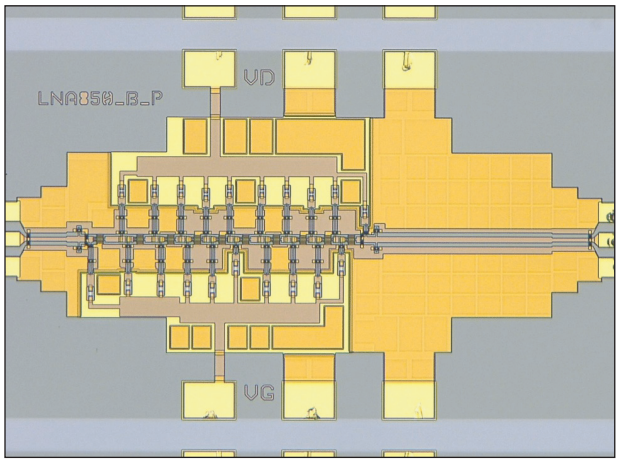


Image of 850GHz low-noise amplifier circuit.

Under Phase 2 of the Defense Advanced Research Project Agency's (DARPA's) Terahertz Electronics program, company engineers report that they have scaled the frequency to a record 850GHz. Under Phase 1, in 2010 they developed a Terahertz monolithic integrated circuit that operated at 670GHz.

"Integrated circuits operating at frequencies past 1THz will enable submillimeter-wave technology for covert, small-aperture communications, high-resolution imaging and leap-ahead advancements in explosive detection spectroscopy," says Dr William Deal, Terahertz Electronics program manager for Northrop Grumman's Aerospace Systems sector. "This unprecedented increase in integrated circuit operating speed is especially important for emerging applications in military communications and radar," he adds. "The amplifiers and receivers we are demonstrating will enable more sensitive radar and produce sensors with highly improved resolution."

In addition to demonstrating low-noise integrated receivers under the DARPA program, the firm has developed and tested low-noise amplifiers and power amplifiers. "Success in the initial phase led to a $12.5m contract, bringing the total value of the program to $28m," Deal notes.

The goal of DARPA's Terahertz Electronics program is to develop the critical device and integration technologies necessary to realize compact, high-performance electronic circuits that operate at center frequencies exceeding 1THz. The program focuses on two areas: THz high-power amplifier modules and THz transistor electronics.

"The ability to coherently process signals at 0.85THz provides a means to generate and radiate the high-frequency signals needed for applications such as DARPA's Video Synthetic Aperture Radar (ViSAR) program," says DARPA program manager John Albrecht. "VISAR seeks to develop and demonstrate a targeting sensor which operates through clouds as effectively as today's infrared (IR) sensors operate in clear weather," he adds. "This revolutionary advance would give US warfighters an advantage in an especially challenging portion of the RF spectrum."

ICs operating at frequencies past 1THz will enable submillimeter-wave technology

www.northropgrumman.com
www.darpa.mil/Our_Work/MTO/Programs/THz_Electronics.aspx

GigOptix launches power detector for high-capacity E-band transmitters

GigOptix Inc of San Jose, CA, USA (a fabless supplier of analog semiconductor and optical components enabling high-speed end-to-end information streaming over optical fiber and wireless networks) has released engineering samples of the EXE8602-DNT power detector die for high-capacity wireless point-to-point E-band radios.

The EXE8602-DNT is a small-form-factor gallium arsenide MMIC die power detector designed to operate over 71–76GHz and 81–86GHz E-band frequencies for applications requiring power detection over a wide RF power range. Features include consistent performance over temperature and output load variations from the typical 50Ω system impedance. Operating with very low DC power consumption, the monolithic microwave integrated circuit (MMIC) produces reference and detector output voltages which can be compared to determine the RF power and which can be further processed to provide RF power in decibel units. The MMIC provides high-capacity-radio manufacturers with an E-band power detector featuring low insertion loss, flat frequency response over each band and high RF power dynamic range with excellent sensitivity. The detector may be used to monitor transmitter operation, or to enable closed-loop control of the transmitter's output power to ensure consistent operation.

"The EXE8602-DNT enables E-band radio output power monitoring and control to best suit the conditions and the modulation scheme being utilized," says Padraig O'Mathuna, VP/general manager of GigOptix's RF/MMIC product line. "In light of the growing demand for mobile data due to the advent of cloud computing, the migration of data services to the web and with the mass adoption of smartphones and tablets, E-band offers a much less congested frequency spectrum compared to existing legacy 6-38GHz mobile backhaul bands along with 13GHz of allocated frequency spectrum that enables very economical multi-Gigabit per second communication links," he adds. "Indeed we believe that speeds of 10Gbps and beyond commonly seen in optical interconnects will shortly be enabled in metro areas by E-band links."

In its most recent report, market analyst firm EJL Wireless Research forecast E-band point-to-point radio links to be one of the fastest-growing segments in the wireless mobile backhaul market, with a compound annual growth rate (CAGR) of more than 100% to 2016.

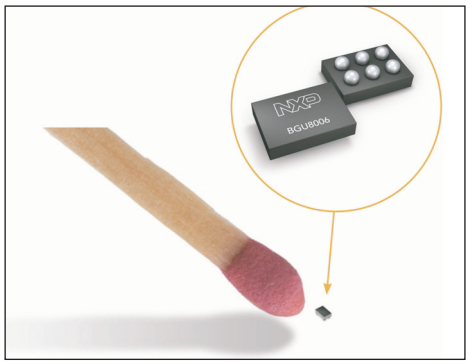
www.gigoptix.com

NXP's 0.65mm x 0.44mm x 0.2mm SiGe:C GPS low-noise amplifier offer 0.60dB noise figure

NXP Semiconductors N.V. of Eindhoven, The Netherlands, which provides mixed-signal and standard product solutions, has unveiled the BGU8006 low-noise amplifier, which is claimed to be the smallest GPS low-noise amplifier (LNA) on the market, designed for very small portable devices.

Available in a wafer-level chip-scale package (WLCSP), the latest GPS LNAs have a footprint of just 0.65mm x 0.44mm x 0.2mm and need just two external components, saving 38% in PCB space compared to the smallest solution on the market, it is reckoned. With a very low noise figure of 0.60dB, the LNAs aid reception for weak GPS signals by dynamically suppressing strong cellular and WLAN transmit signals. NXP showed the BGU800x series LNAs at June's 2012 IEEE MTT-S International Microwave Symposium (IMS) in Montreal, Canada.

"Smartphones, tablets, personal navigation devices and automotive telematics applications all suffer from communication delays when network reception is poor, and have to wait for data to refresh as the GPS searches for satellite signal," says Erick Olsen, marketing director, RF small signal product line. "Our new BGU8006 LNA helps to maintain optimal GPS signal reception for as long as possible — on a chip that is so small, it isn't even visible to the naked eye," he adds. "As GPS functionality becomes ubiquitous, the ability to deliver better accuracy and faster Time to First Fix will vastly improve user experience and enable operators to provide more sophisticated Location Based Services down the line."



The BGU8006, next to a match head.

The BGU8006 LNA uses adaptive biasing techniques — enabled by NXP's QuBIC4Xi SiGe:C BiCMOS process technology — to instantly detect any output power from jammers, and compensate by temporarily increasing the current. Adaptive biasing dynamically suppresses strong cellular, WLAN and Bluetooth signals, which can drive typical GPS LNAs into compression, lowering gain, generating intermodulation and harmonics that can overpower weak signals, and causing poor GPS reception. With the BGU8006, adaptive biasing improves linearity with a 10dB better IP3 under −40 to −20dBm jamming conditions and provides effective GPS output with jammer power up to −15dBm.

As well as suiting space-constrained applications, the BGU8006's WLCSP technology minimizes parasitic inductance because there are no leads, bond wires or interposer connections, and optimizes package size, cost and thermal characteristics. NXP also offers the BGU8007 LNA in a 1.45mm x 1.0mm x 0.5mm 6-pin leadless SOT886 package. Both LNAs require only one external matching inductor and one external decoupling capacitor for easy design-in and savings in component costs and PCB area, says NXP.

The BGU800x series LNAs are suited to a range of applications using GPS technology, including smartphones, feature phones, tablets, personal navigation devices (PNDs), digital still cameras (DSCs), digital video cameras (DVCs), RF front-end modules for phones, and complete GPS chipset modules. For automotive telematics applications such as emergency call (eCall) and toll collection systems, NXP also offers the BGU7004 and BGU7008, which are AEC-Q100 qualified.

The BGU8007 LNA is currently available. Qualification samples of the BGU8006 are being made available in Q3/2012, for volume production during Q4/2012.

www.nxp.com/pip/BGU8006

TowerJazz announces reverse share split ratio

The board of directors of specialty foundry TowerJazz (which has fabrication plants at Tower Semiconductor Ltd in Migdal Haemek, Israel, and at its subsidiaries Jazz Semiconductor Inc in Newport Beach, CA, USA and TowerJazz Japan Ltd) has approved a 1-for-15 reverse split of its ordinary shares, reducing the number of outstanding ordinary shares to about 22 million shares (rounding up fractional shares as a result of the reverse split to the next whole number). Proportional adjustments were made to outstanding convertible securities.

The reverse split was intended to enable TowerJazz to regain compliance with the minimum bid requirement to keep its listing on NASDAQ.

Ordinary shares began trading on a split-adjusted basis on NASDAQ on 6 August and on the Tel Aviv Stock Exchange on 5 August, after shareholder approval on 2 August.

"The reverse split action is intended to enable continued US investment and analysts' coverage by regaining our listing on NASDAQ, while continuing to be traded on the Tel Aviv Stock Exchange," says CEO Russell Ellwanger. "We also expect this action to create new opportunities for us with large-size institutional investors and analysts."

www.towerjazz.com

Peregrine raises $79m in IPO

Peregrine Semiconductor Corp of San Diego, CA, USA, a fabless provider of radio-frequency (RF) integrated circuits (ICs) based on silicon-on-sapphire (SOS) founded in 1990, has closed its initial public offering (announced on 7 August) of 5,500,000 shares of common stock on the NASDAQ Global Market (under the ticker symbol PSMI) priced at $14 per share (the low end of the targeted range of $14–16).

Of the shares offered, 5,340,780 were offered by Peregrine and 159,220 shares by selling stockholders (eight employees of the firm).

Also, on 13 August the underwriters (led by Deutsche Bank Securities Inc and J.P. Morgan Securities LLC, together with RBC Capital Markets LLC, Needham & Company LLC, Oppenheimer & Co Inc, and Pacific Crest Securities LLC) exercised in full their 30-day option to purchase an additional 825,000 of common stock at the public offering price of $14 per share.

The full exercise of the option raised the total number of shares sold in the IPO from 5,500,000 to 6,325,000. Of the shares in the offering, Peregrine hence sold a total of 6,165,780. Peregrine did not receive any proceeds from the sale of the 159,220 shares by the selling stockholders. Total net proceeds received by the firm were hence about $79.2m, after underwriting discounts and commissions and estimated offering expenses payable by the firm.

The firm intends to use net proceeds for working capital and other general corporate purposes, e.g. funding growth; developing new products; asserting and defending intellectual property rights; and funding capital expenditures. It may also repay its loan facility with Silicon Valley Bank or expand its current business through acquisitions of other businesses, products, or technologies. The loan facility provides a revolving line of credit as well as an equipment line.

Peregrine originally filed an IPO prospectus with the US Securities and Exchange Commission (SEC) in November 2010, pointing out several risks for its business, including a reliance on a few large customers for most of its revenue. In 2011, 68% of sales came from its three largest customers.

Since 2006, Peregrine has shipped more than 1 billion RF chips based on UltraCMOS, which is a patented variation of silicon-on-insulator (SOI) technology that incorporates an ultra-thin layer of silicon on a highly insulating sapphire substrate. Revenue grew 18% from $91.1m in 2010 to $107.8m in 2011, although the firm also went from net income of $3.8m to a net loss of $9.7m. However, for first-half 2012, revenue has grown 76% year-on-year to $80.3m while net loss has been cut to $3.1m. As of end-June, accumulated deficit was $231.3m.

www.psemi.com

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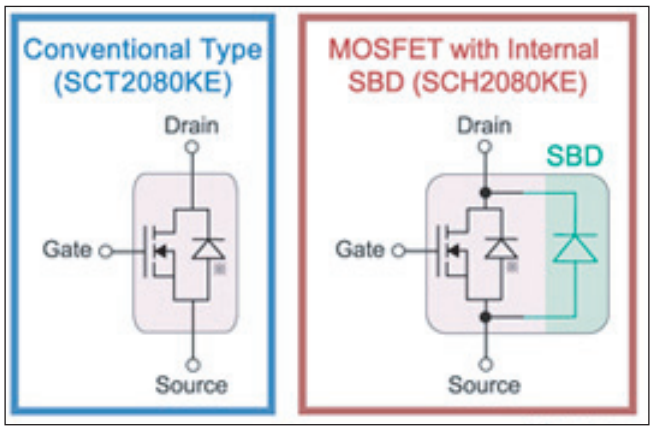
Rohm develops first SiC power MOSFET with internal Schottky barrier diode

Switching power loss and component count reduced for inverters

Rohm Co Ltd of Kyoto, Japan has launched the SCH2080KE, a second-generation high-voltage (1200V) silicon carbide (SiC) power MOSFET designed for inverters and converters in power conditioners for industrial devices and photovoltaic power generation. Features include low power loss and high reliability, reducing power consumption and enabling support for smaller peripheral components.

Existing silicon insulated-gate bipolar transistors (IGBTs) commonly used in 1200V-class inverters and converters cause power switching loss due to tail current or recovery of the external FRD, creating a need for SiC power MOSFETs capable of operating with low switching loss at high frequencies. However, conventional SiC power MOSFETs have been plagued with reliability problems, including characteristic degradation due to body diode conduction (e.g. increased ON resistance, forward voltage, and resistance degradation) and failures of the gate oxide film, making full-scale integration impossible.



SiC power MOSFET integrating Schottky barrier diode.

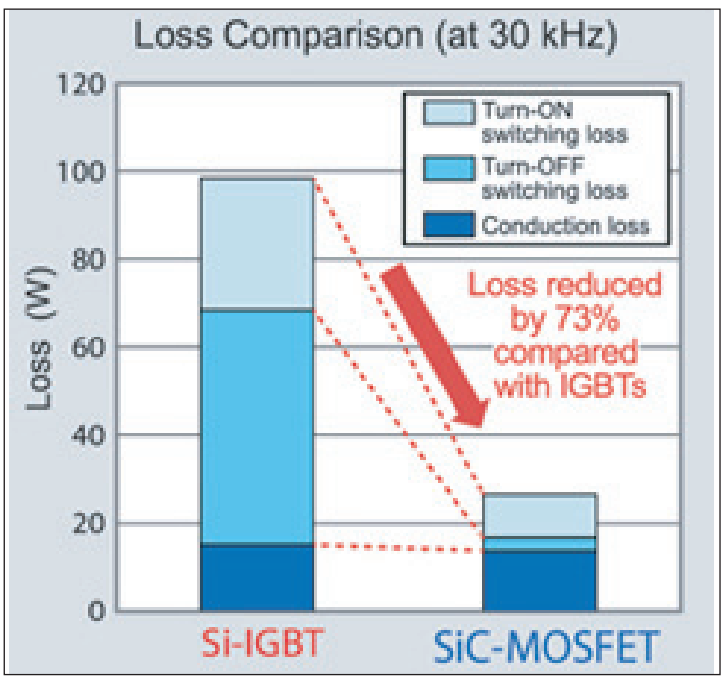
Also, due to the characteristics of silicon carbide, SiC power MOSFET body diodes typically feature a higher rise voltage (2.5V or more), possibly resulting in increased switching loss during inverter operation.

Rohm says that it has overcome these problems by improving processes related to crystal defects and device structure and reducing ON-resistance per unit area by about 30% compared to conventional, first-generation products, leading to increased miniaturization. The new SiC power MOSFETs do not feature the voltage rise common with Si IGBTs, ensuring low switching loss even in low-load operation.

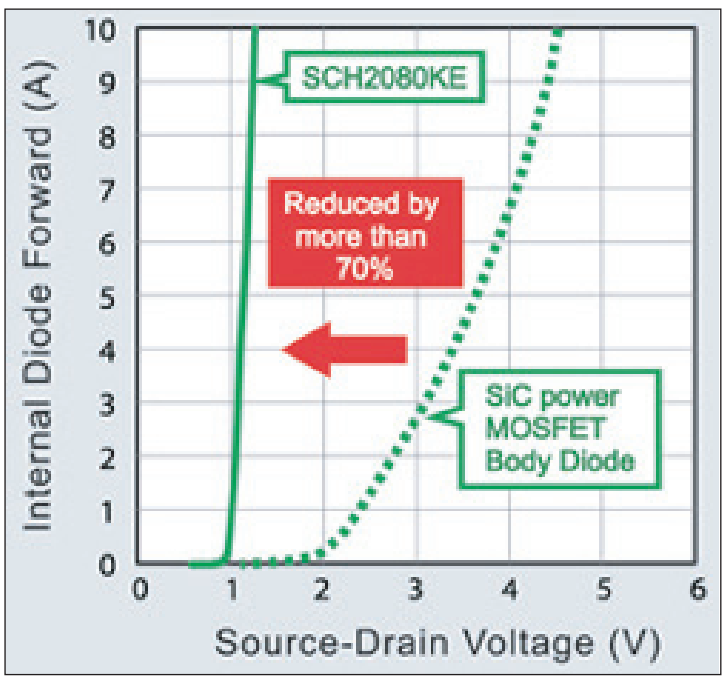
By using proprietary mounting technology, the SCH2080KE is the first SiC power MOSFET to integrate a SiC Schottky barrier diode (SBD) — conventionally externally mounted — into the same package. This reduces forward voltage (V_F) by at least 70% compared with silicon-based insulated-gate bipolar transistors (IGBTs) used in general inverters, so operating power loss is reduced by 70% or more, says the firm. This not only minimizes switching loss, but enables compatibility with smaller, lightweight peripheral components by supporting frequencies above 50kHz. Also, fewer external components are required, saving space.

Rohm also offers the SCT2080KE, an SiC power MOSFET with no internal SiC Schottky barrier diode.

www.rohm.com



Reduced power loss for SiC MOSFET vs silicon IGBT.

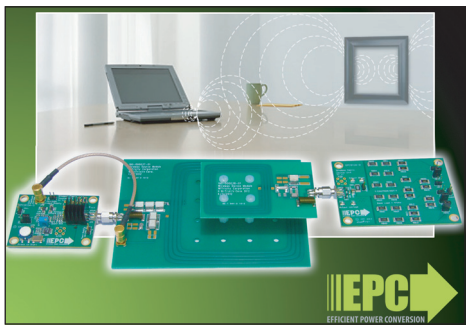


Forward voltage for MOSFET-SBD vs conventional MOSFET.

EPC launches WiTricity demo system featuring high-frequency 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) used in power management applications, has launched a high-efficiency wireless power demonstration system using the high-frequency switching capability of gallium nitride transistors. EPC says that its eGaN FETs suit these systems because of their ability to operate efficiently at high frequency, voltage, and power.

Highly resonant wireless power transfer was invented by the founders of WiTricity, which licenses its intellectual property to firms seeking to build products based on the technology. Capable of transferring power over distance, WiTricity technology enables a wide range of consumer, medical, industrial and automotive applications. Products



Wireless power transfer with eGaN FETs.

using highly resonant wireless power transfer can meet stringent regulatory guidelines, and is safe for people and animals, says the firm.

Many wireless charging products now in the market use traditional magnetic induction coils with operating frequencies of 100–300kHz, and Class E, F and S amplifier converter topologies. Recently, organizations such as the Consumer Electronics Association and A4WP (Alliance for Wireless Power) have called for a higher-frequency standard (6.78MHz) for wireless charging systems. At higher frequencies, traditional silicon-based power transistors (MOSFETs) approach the limit of their switching capability. EPC says that eGaN FETs offer higher efficiency compared to MOSFETs at these higher frequencies.

The wireless power demonstration system jointly developed by EPC and WiTricity is a class-D power system operating at 6.78MHz, and capable of delivering up to 15W to a load. The purpose of the system is to simplify the evaluation process of the wireless power technology. It includes all the critical components in a single system that can be easily connected to demonstrate the powering of a device with wireless energy transfer.

www.epc-co.com
www.witricity.com

Comtech contract for high-power solid-state RF switches

Comtech Telecommunications Corp says its subsidiary Comtech PST in Melville, NY, USA has been awarded a $3.1m contract for solid-state, high-power RF switches from a major domestic prime contractor.

The firm says that the switches provide very broad frequency coverage and are key components in an integrated electronic countermeasures system used by the US military.

"This significant order demonstrates Comtech's technical strength in delivering solid-state, broadband high-power RF switches for military applications," says Comtech Telecommunications' president & CEO Fred Kornberg. "The market for our high-power RF switch products remains strong," he believes.

Comtech PST supplies broadband, high-power, high-performance RF microwave amplifiers and switches using gallium nitride (GaN) transistor technology for applications including defense, medical, satellite communications systems and instrumentation. Parent company Comtech Telecommunications conducts business through three complementary segments: telecommunications transmission, RF microwave amplifiers and mobile data communications.

www.comtechtel.com

All American extends distribution deal with GeneSiC

All American Semiconductor has extended its distribution agreement with GeneSiC Semiconductor Inc of Dulles, VA, USA, which develops silicon carbide and silicon-based devices for high-temperature, radiation and power grid applications.

Founded by Dr Ranbir Singh as president in 2004, GeneSiC's silicon carbide products feature a high operating temperature range, small heat-sink requirements and fast switching speeds. They are also inherently radiation resistant and offer a higher voltage and current capability. The firm's products — which include rectifiers, field-effect transistors (FETs), bipolar devices and particle and photonic detectors — are used in industries, such as aerospace, alternative energy, commercial, industrial and military. Applications include solar inverters, electric vehicles, wind power, medical power supplies, down hole oil drilling and motor drives.

www.genesicsemi.com

IQE expects revenue growth in second-half 2012 following Q2 recovery

RFMD and Solar Junction deals to help meet full-year revenue targets and return to free cash generation

According to an interim trading update for first-half 2012, epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK expects to report first-half revenue of about £34m and EBITDA (earnings before interest, tax, depreciation and amortization) of £4m with net debt of less than £8m.

IQE's board says it remains confident of meeting its full-year expectations, given the notable second-half bias in revenues this year as a consequence of the destocking in second-half 2011 and first-quarter 2012, and the transfer of the in-house molecular beam epitaxy (MBE) epiwafer manufacturing operation of RF Micro Devices Inc of Greensboro, NC, USA to IQE in July.

The inventory correction related to market share swings at two major wireless customers in the latter part of 2011 impacted first-quarter 2012. However, sales and customer order patterns returned to normal in Q2/2012, and IQE exited the half-year strongly. Customer qualifications have progressed well, says IQE, and the outlook for wireless remains strong, driven largely by the increasing penetration of smartphones and 4G/LTE technology.

Major developments during first-half 2012 were the completion of two strategic transactions: an exclusive supply contract and strategic investment in Solar Junction Corp of San Jose, CA, USA, which manufactures III-V multi-junction solar cells for concentrating photovoltaic (CPV) modules, together with the acquisition of the RFMD's in-house epitaxial business.

In February, IQE made a strategic investment and exclusive wafer supply agreement with Solar Junction, marking a significant step in its strategy to become a supplier of CPV wafers for the solar power markets, the firm says.

Following the Solar Junction deal, project announcements include a 450MW installation in Mexico, confirming that the CPV market is rapidly gaining traction, reckons IQE. Solar Junction and IQE have received initial production orders and expect to capture a substantial share of this emerging market. The installation of tools at IQE is progressing in line with the board's expectations, and will be followed by a technology transfer. Once qualified, the tools will be used to meet existing production orders.

As well as acquiring RFMD's in-house MBE epitaxy manufacturing unit, IQE also secured a seven-year wafer supply agreement with RFMD. This is expected to deliver a step increase in IQE's revenue and profitability in second-half 2012. It also complements the Solar Junction investment by bringing spare capacity to service the high-growth CPV market, says IQE.

IQE adds that it continues to make good progress across its optoelectronics and electronics businesses in development projects spanning emerging high-growth opportunities.

"The deals with Solar Junction and RF Micro Devices represent significant milestones in the execution of our growth strategy and will significantly enhance both our short- and long-term growth," says chief executive Dr Drew Nelson. "They are highly complementary, extending our critical mass and global leadership in wireless and bringing spare capacity to service the emerging high-growth CPV market," he adds.

"The outlook for the group's core wireless markets continues to look strong and, with our capacity expansion program nearing completion, we are well positioned to deliver strong sales growth and return to free cash generation," Nelson concludes.

IQE will report full interim results in the week beginning 24 September.

www.iqep.com

Accel-RF changes name to Accel-RF Instruments to reflect expanded product offerings

Accel-RF Corp of San Diego, CA, USA (which produces turn-key RF reliability testing systems for compound semiconductor devices) says its shareholders and board of directors has approved a change of company name to Accel-RF Instruments Corp.

"There is no change to our mission, which continues to be to enable our customers to accelerate the introduction of new semiconductor products into the market", says chairman & CEO Roland Shaw.

"We are leveraging our Automated Accelerated Reliability Test System [AARTS] technology into new products. These products enable advancements in the engineering, quality-assurance, and production test communities with the development of innovative instruments which dramatically decrease cost and schedule constraints associated with characterization and performance verification testing," he adds. "This name change best communicates our objective to provide solutions contributing to reducing product time-to-market."

www.accelrf.com

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Albemarle expanding Korea facility to electronic-grade metal organics

TMG, TEG and TMA capacity to be added to planned catalyst plant

Specialty chemical manufacturer Albemarle Corp of Baton Rouge, LA, USA says that its board of directors has authorized the expansion of its facility in Yeosu, Korea, which is currently in the final stages of construction and will produce commercial quantities of finished catalysts and components used in the polymer industry.

The additional capacity will be dedicated to manufacturing Albemarle's PureGrowth products, including high-purity trimethyl gallium (TMG), triethyl gallium (TEG) and trimethyl aluminum (TMA) used in metal-organic chemical vapor deposition (MOCVD) for processing semiconductor, LED and opto-electronic devices. The Korean expansion will complement the firm's existing capacity for these products, as well as trimethyl indium (TMI), at its facility in Baton Rouge.

"These new assets will enable us to meet both existing and future demand in the rapidly expanding electronic chemicals market," says Amy H. Motto, VP of Albemarle's Catalysts global business unit (which encompasses the Performance Catalyst Solutions division).

Over 80% of the global demand for LED products is in Asia. Expansion of our Korea facility will ensure security of supply in this high-growth region while reducing transportation risks

"Over 80% of the global demand for LED products is in Asia," notes Jenny S. Hebert, global product manager for Electronic Materials. "Expansion of our Korea facility will ensure security of supply in this high-growth region while reducing transportation risks," she adds. "These state-of-the-art facilities will also allow us to consistently maintain the high purity standards required of electronic-grade metal organics."

Property for the expansion has been acquired and infrastructure plans have already been finalized and approved. The project is due for completion in 2013.

www.albemarle.com

Banner's representation of Johnson Matthey expanded to California, Oregon and Washington

Johnson Matthey Gas Purification Technology (GPT) group of West Chester, PA, USA, which designs and manufactures hydrogen purifiers, has appointed Banner Industries of Danvers, MA, as sales distributor in California, Oregon and Washington for its line of PureGuard gas purification equipment.

"Banner is a perfect fit for Johnson Matthey, with its 25-plus years of industry experience and vast knowledge of the semiconductor market," comments GPT's business manager Jeff Lucht, citing their reputation for customer support, stocking capabilities and field service.

The firms have worked together for more than 10 years. "Banner has very successfully represented us on the East Coast, as well as in Colorado, Idaho and Utah," says Lucht. With full service sales offices in Malta, NY, Allentown, PA, Manassas, VA, Orlando, FL, Richardson and Pflugerville, TX, Lehi, UT, and Singapore, Banner also represents Johnson Matthey in Singapore and Malaysia through its Singapore office.

Banner serves semiconductor manufacturers and a number of other industries, providing sales, service, distribution, support and marketing. It has been offering solutions to thousands of customers since 1985, says Lucht.

www.bannerindustries.com
www.pureguard.net

IN BRIEF

Reactant injector temperature effect on III-nitride deposition

Veeco Instruments exhibited and presented at the 4th International Symposium on Growth of III-Nitrides (ISGN4) in St. Petersburg, Russia in July, organized by the Ioffe Physical-Technical Institute of Russian Academy of Sciences.

Dr Alex Gurary, Veeco's senior director, MOCVD Hardware Test, presented 'Reactants injector temperature effect on III-Nitrides materials deposition in the high speed vertical rotating disc MOCVD reactor'.

Gurary has a Ph.D. in Material Science and over 20 years of experience with MOCVD equipment.

www.ioffe.ru/ISGN4
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5N Plus' revenue falls 14% in Q2/2012

5N Plus Inc of Montreal, Quebec, Canada, a producer of specialty metal and chemical products, has reported results for second-quarter 2012, with numbers for the comparable period to end-May 2011 restated to reflect changes resulting from the implementation of IFRS (International Financial Reporting Standards) and the adoption of the US dollar as the firm's functional and reporting currency.

5N Plus focuses on specialty high-purity metals such as tellurium, cadmium, selenium, germanium, indium and antimony and also produces related II-VI semiconducting compounds such as cadmium telluride (CdTe), cadmium sulphide (CdS) and indium antimonide (InSb) as precursors for the growth of crystals for electronic applications, including solar photovoltaic, radiation detector and infrared markets. In addition, in mid-April 2011, 5N Plus paid $317m to acquire MCP Group SA of Tilly, Belgium, a producer and distributor of bismuth and bismuth chemicals (with a 50% global market share) as well as other specialty metals (including gallium, indium, selenium and tellurium).

5N Plus' revenue for second-quarter 2012 of $140.1m was up 15% on $122m for the quarter to end-May 2011, but down 14% on $162.2m last quarter.

"In our Electronic Materials business unit, although sales of gallium and indium products were somewhat softer than in the previous quarter, partly because of the relocation of some of the production activities previously located at our Fairfield offices [in Connecticut, formerly MCP], sales to our main customers for solar products increased and we also made progress in our germanium-related activities," says president & CEO Jacques L'Ecuyer. "In our Eco-Friendly Materials business unit, we continued to increase market share, with strong sales of bismuth-related products in a market which is continuing to grow, as efforts to replace lead accelerate," he adds.

"Unfortunately, these positive developments were overshadowed from an earnings and revenue standpoint by two main factors," continues L'Ecuyer. "On the one hand, the quarter was characterized by sharp decreases in the prices of almost all of our underlying commodities, especially in the back-end of the quarter, which led to decreases in average selling prices and further impairment charges on our inventories at the end of the quarter. On the other hand, we also sold to our main customer in the solar market [CdTe PV module maker First Solar Inc of Tempe, AZ, USA] at lower margins than normal, such sales having been made from previously impaired units in accordance with the terms of our new agreement with the customer," he adds. "Both factors severely impacted our earnings and revenue levels, providing a somewhat distorted picture of the company's overall performance."

Excluding impairment charges, adjusted net earnings yielded a loss of $2.1m. This compares with net earnings of $5m last quarter and $8.5m for the quarter to end-May 2011. Adjusted EBITDA (earnings before interest, taxes, depreciation and amortization) was $5.6m, compared with $16.9m last quarter and $20m in the quarter to end-May 2011.

"We saw relatively strong demand for most of our products during the quarter, which enabled us to continue reducing working capital and debt levels through significant cash flow generation," says L'Ecuyer. During Q2, net debt was cut by $56.4m to $175.8m. Total debt fell by $90.5m to $187.6m.

During the quarter, the backlog of orders expected to translate into sales over the following 12 months fell from $215.6m to $189m.

"We believe a more appropriate assessment would be that we are holding our ground and doing better than most of our competitors in a challenging environment," says L'Ecuyer. "We expect earning levels to be more reflective of the company's actual performance once both the underlying commodity pricing stabilizes and the inventory of impaired units has been used up, especially with respect to our contract with our main customer in the solar market," he adds.

On 6 June, the firm issued 12,903,613 stock units for net proceeds of $37.1m. "Our decision to further strengthen our balance sheet through an equity raise of CDN$40m on 6 June 2012 was largely determined by the relative uncertainty in the global economic environment and the company's exposure to the solar and European markets," says L'Ecuyer. "Regardless of its short-term impact, we are confident that this financing will deliver long-term shareholder value by enabling us to execute more effectively on our strategic growth plan, which calls for further deleveraging and redeployment of capital into less volatile and higher-value-added opportunities. The current year is thus key in many respects as we gradually transition the entire company towards this business model and complete the full integration of former MCP activities, realigning the company towards greater sustainability in our commercial practices and greater efficiencies throughout the group," he adds.

"Outlook for the rest of the year and corresponding financial performance will be largely determined by underlying commodity pricing and the performance of the European economy," cautions L'Ecuyer. "We remain committed to a further reduction in our working capital requirements and a corresponding decrease in our debt levels. Although we may continue to experience short-term volatility in our financial performance, we are confident that our company remains well positioned to continue growing."

www.5nplus.com

GaAs growth of 22% drives AXT's revenue up 7% in Q2 despite drops in InP, Ge and raw materials

For second-quarter 2012, AXT Inc of Fremont, CA, USA has reported revenue of $25.2m, up 7% on $23.5m last quarter but down 16% on $30m a year ago.

Gallium arsenide (GaAs) substrate revenue was $14.9m, up 22% on $12.2m last quarter (although still down 20.8% on $18m a year ago). Indium phosphide (InP) substrate revenue was $1.3m, down 13% on $1.5m last quarter and 18.8% on $1.6m a year ago. Germanium (Ge) substrate revenue was $2.4m, down 7.7% on $2.6m last quarter and 11% on $2.7m a year ago. Raw materials sales were $6.5m, down 9.7% on $7.2m last quarter and 15.6% on $7.7m a year ago.

Gross margin has fallen further, from 34.9% last quarter to 29.8%, due largely to a new People's Republic of China value-added tax (VAT) levied on foreign enterprises that import materials that do not form part of the final product. AXT recently received notice of the retroactive VAT, which applies for the period 1 July 2011 to 30 June 2012 and amounted to $1.27m expense in Q2/2012, resulting in a 505 basis point impact to gross margin. Excluding the effect of this VAT tax, gross margin would have remained steady at 34.9%. Going forward, the firm expects that this new VAT will negatively impact gross margins by about 150 basis points per quarter.

Operating expenses have risen further, from $4.4m a year ago and $4.6m last quarter to $4.9m. Correspondingly, net income has fallen further, from $7.1m a year ago and $1.6m last quarter to $1.3m. During the quarter, cash and cash equivalents rose slightly from $31.2m to $31.3m.

"As we move into Q3, the demand environment appears to be more challenging, particularly in certain geographies," says CEO Morris Young. "We are continuing to approach the current business environment with measured conservatism, based on mixed industry data points, and expect to see weaker-than-normal seasonal performance as a result," he adds.

"However, we have worked diligently to improve our operating structure and efficiency and are well positioned with key customers in each of our markets," Young continues. "We continued to make good progress with new customer qualifications, and are hopeful that we will begin to layer on additional revenues from new qualifications later this year and into 2013," he adds. "We view improving market conditions, new customer qualifications and a bottoming of raw material pricing as key catalysts for our growth later this year and beyond."

www.axt.com

Veeco's MOCVD revenue falls 8% in Q2

Orders expected to recover in second-half 2012; OpEx to be cut while maintaining R&D

For second-quarter 2012, epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA has reported revenue of $136.5m, down 2% on $139.9m last quarter and 48% on $264.8m a year ago.

Of total Q2 revenue, 36% came from record Data Storage revenue of $49.8m, up 12% on $44.3m last quarter (32% of revenue). The other 64% comprised LED & Solar revenues of $86.8m, down 9.2% on $95.6m last quarter (68% of revenue) and down 60% on $219.1m a year ago. This included revenue from molecular beam epitaxy (MBE) systems of $12m (down 14% on $14m last quarter) and revenue from metal-organic chemical vapor deposition (MOCVD) systems of $75m (down 8% on $82m last quarter).

However, Veeco reckons that its MOCVD market share has continued to rise, from 29% in 2009 to 44% in 2010 and 51% in 2011 to 62% in first-half 2012, becoming the number 1 supplier to six out of the 10 LED makers with the most merchant MOCVD tools. Also, after reaching revenue of nearly $100m in full-year 2011, in Q2/2012 Veeco's Services business achieved record quarterly bookings and revenue ($33.5m). "Veeco continues to deliver solid results in a soft market," comments chairman & CEO John R. Peeler.

Gross margin was 45%, falling back from 46.7% last quarter (which had been helped by a favorable mix in larger revenue from final acceptances). Although down from $51.1m a year ago, operating expenses (OpEx) have risen from $43m last quarter to $45m (impacted by salary increases that became effective earlier in the quarter, as well as equity compensation expense). R&D spending remained roughly flat sequentially, at about $24m.

Excluding certain items, earnings from continuing operations before interest, income taxes and amortization (adjusted EBITA) were $20.3m (15% of sales), down from $25m last quarter and $88m a year ago. Specifically, LED & Solar EBITDA fell from $17.5m last quarter to $9.6m (due mainly to lower revenue, lower margins and higher OpEx), while Data Storage EBITDA rose from $9m to $12.1m (due to higher sales volumes).

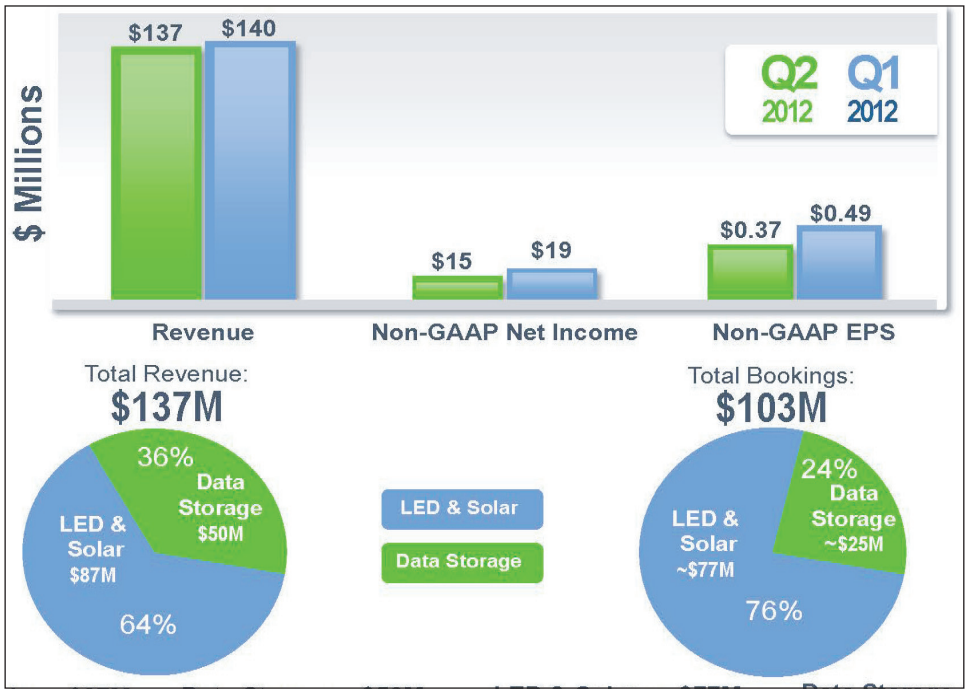
"What Veeco has done really well was to plan for the downcycle," notes Peeler. "Over four years ago, we started building our operations strategy around a variable cost structure. We can go from $300m of revenue in an upcycle quarter to a $137m of revenue in a downcycle quarter and still make 15% EBITDA," he adds.

On a non-GAAP basis, net income has fallen from $63.4m a year ago and $19m last quarter to $14.5m. Operating cash flow fell again, more than halving from $42m last quarter to about $19m. Free cash flow was about $10m. During the quarter, cash and short term investments rose from $524m to $540m.

"As anticipated, we experienced a challenging bookings environment in Q2," says Peeler. Total orders were $102.5m, down 10% on $113.4m last quarter and 67% on $310.8m a year ago.

Of total Q2 bookings, Data Storage orders remained weak, down 12% on $28.8m last quarter to $25.2m (24% of total bookings). The other 76% of bookings comprised LED & Solar orders of $77.3m, down 8.6% on $84.6m last quarter and 72% on $273.3m a year ago. Of LED & Solar bookings, MOCVD orders were flat sequentially at $70m (albeit coming from more than a dozen customers) and MBE roughly halved from $15m to $7m. However, MBE business tends to be 'lumpy', says Veeco, often impacted by production buys from wireless customers, and there were no production buys in Q2/2012.

"Across our markets, macroeconomic concerns and weakness in TV, PC and consumer electronics



Veeco revenue, income and earnings per share for Q2/2012 versus Q1 (top), and revenue and orders by application sector for Q2/2012 (bottom).

sales are delaying customers' capex purchases," says Peeler. "MOCVD orders appear to be bumping along the bottom and we have not yet seen a meaningful inflection in customer buying."

During the quarter, total order backlog fell from $305m to $241m. However, this was after a $30m adjustment (involving five customers). "We took a prudent action to remove certain MOCVD systems from backlog that no longer meet our backlog criteria," says chief financial officer & executive VP David D. Glass. "These backlog adjustments were primarily, although not exclusively, on Chinese deals. These were not order cancellations… we're still working with these customers," he stresses. Specifically, MOCVD backlog has fallen to $158m (with about 80% still destined for China customers).

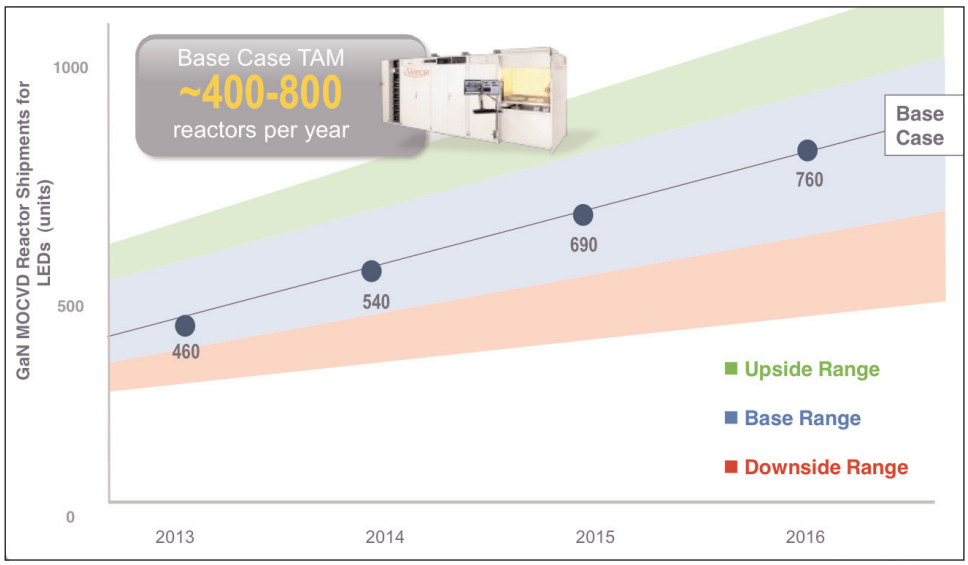
For third-quarter 2012, Veeco expects revenue of $120–140m and gross margin of 44–45%. Operating expenses should be steady at $44–46m. Adjusted EBITA is expected to be $11.8–20.6m (10–15% of revenue, in line with the target model). Non-GAAP net income should be $8.6–14.9m.

However, utilization rates are up at key customer facilities in Taiwan [80–95%], Korea [65–80%], and even in China [under 50% overall, but more than 80% at top players]. "We have seen a pick-up in quoting activity as customers plan future capacity expansions to ensure their position in LED lighting for 2013 and beyond," Peeler says. "We continue to win in the market due to our low-cost-of-ownership solutions that drive customers' yield and productivity, most recently through our new TurboDisc 'M' and 'HP' product suite."

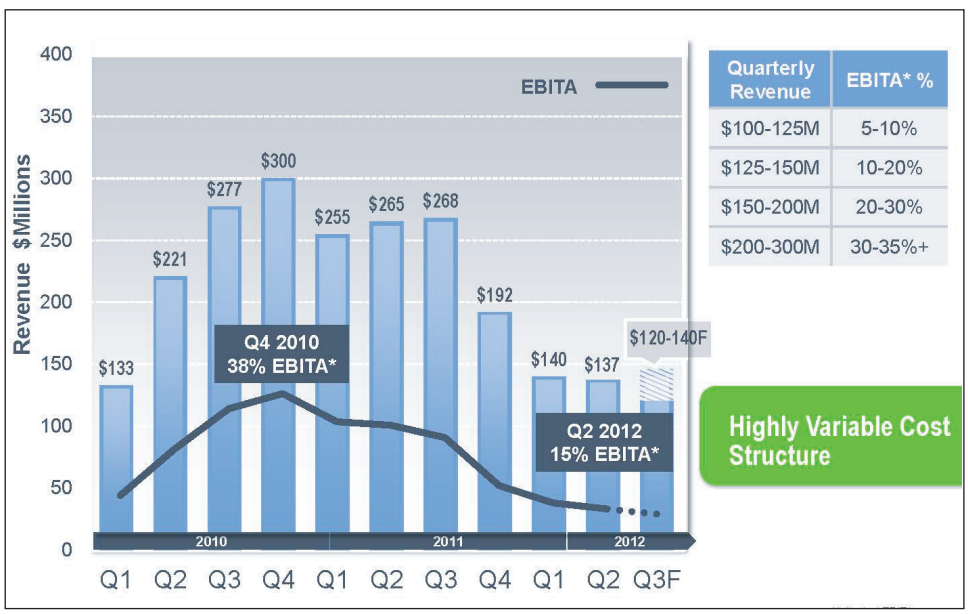
"Second-half orders will improve gradually," expect Glass. "However, given the overall weak environment and customer uncertainty, we think it's prudent to dial back our [sales, general & administration] spending as we head into the remainder of the year. We're implementing some additional belt-tightening measures, particularly in fixed-cost areas, to drive OpEx lower," he adds. Veeco's aim is to get OpEx down to Q1 levels (about $43m) by Q4/2012. "This should put us in good shape to continue to remain solidly profitable, while at the same time, not giving up on any of our strategic priorities," reckons Glass. "Despite the business slowdown, we're keeping the R&D spending rate at about the same pace as 2011 levels, maintaining our accelerated product development programs," he adds.

"We are executing on our plan to deliver solid profitability in a down revenue year while investing for future growth," says Peeler. "At the mid-point of the year, we are tightening our 2012 revenue guidance to $520–560m [implying adjusted EBITDA of 13–16% of revenue]. Assuming macro-economic conditions do not worsen, we currently anticipate a gradual order recovery in the second half of 2012," he adds. Also, with 400 MOCVD reactors due to go 'off-warranty' in 2012 (prompting the sale of extended warranty plans) and Veeco's Asia service centers enabling customer training and process development support — together with the new VCE (Veeco Certified Equipment) business re-selling refurbished tools with Veeco warranties — Veeco's Services business is targeting 40% revenue growth for full-year 2012.

www.veeco.com



Veeco's estimate for accelerating MOCVD system demand from 2013.



EBITA operating profit, maintained through cycles by Veeco's flexible model.

Aixtron's revenue rebounds by 10%

Increased order intake and profitability to return during second-half

Deposition equipment maker Aixtron SE of Herzogenrath, Germany says that, for second-quarter 2012, its revenues and orders have stabilized at the levels of Q1/2012.

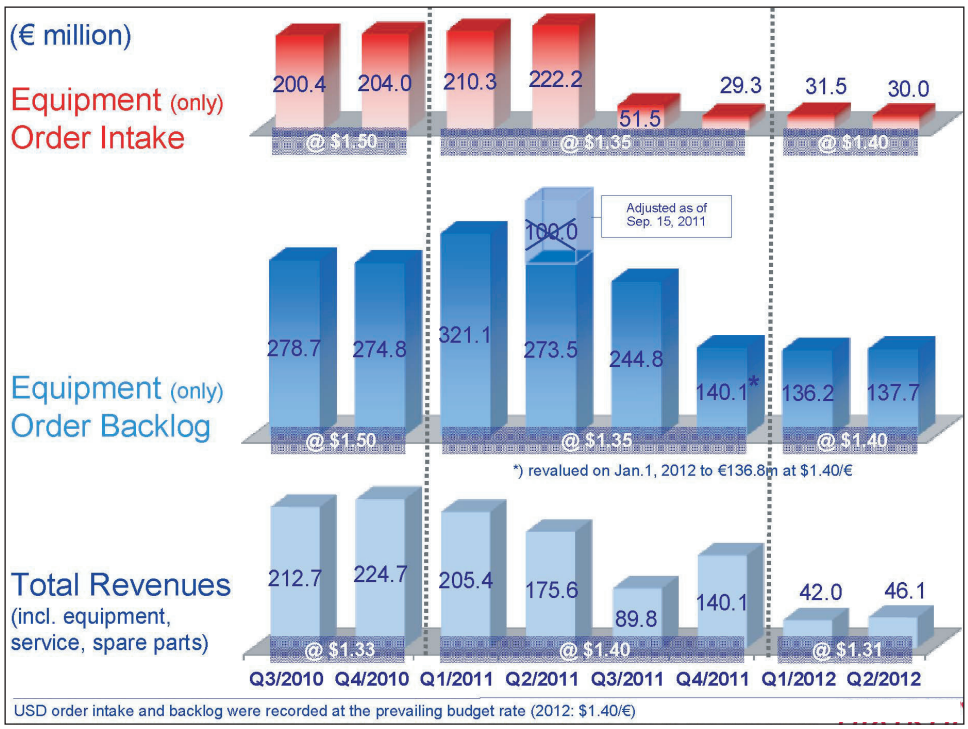
Q2 revenue was €46.1m, up 10% on €42m in Q1. However, for first-half 2012, revenue was €88.1m, down 77% (€292.9m) on €381m on H1/2011, due mainly to the drop in demand for metal-organic vapor phase deposition (MOCVD) reactors for LED production. Asia has slumped from 90% of total revenue in full-year 2011 to 77% in H1/2012, while the USA has risen from 6% to 16% and Europe from 4% to 7%.

Gross margin rose from 25% in Q1 to 32% in Q2, due mainly to a favorable product mix and currency effects. Nevertheless, H1/2012 gross margin of 28% is down from 48% in H1/2011, due to the decline in sales volume and the disproportionately lower percentage decrease in cost of sales resulting from the fixed cost effect of ongoing facility, production and service costs.

The earnings before interest and taxes (EBIT) operating result remained negative, but improved by 10%, from –€18.3m in Q1 to –€16.5m in Q2. The H1/2012 EBIT fell from €129.2m in H1/2011 to –€34.7m in H1/2012, due mainly to significantly reduced gross profit (resulting from the lower sales volumes) coupled with an increasing absolute operating cost base (driven mainly by higher investments into R&D and currency effects).

Free cash flow was –€31.9m in Q2, down from –€5.6m in Q1. Correspondingly (and after a dividend payment of €25.4m), cash & cash equivalents (plus cash deposits) fell 19% during the quarter, from €288.9m to €234.6m.

In line with expectations, order intake volume remained stable in Q2. New orders amounted to €30m, down 5% on Q1's €31.5m, possibly marking the trough in the current investment cycle. Total



Aixtron's 24-month business development, showing upturn in revenue and expected trough in orders.

H1/2012 order intake was €61.5m, down 86% on H1/2011's €432.5m. Correspondingly, equipment order backlog of €137.7 m at the end of H1/2012 is down 63% on €373.5m a year ago but down just 2.1% on €136.2 at the end of Q1/2012.

Aixtron says that, as well as the sequential improvement in financial results, there is also evidence of improved capacity utilization among LED producers. In particular, spare parts & services grew from Q1 to Q2, comprising 29% of total revenue in H1/2012 (up from 8% in H1/2011), representing higher demand from consumables in production. Also, current quotation levels suggest that a bottom in the order intake cycle may have been reached.

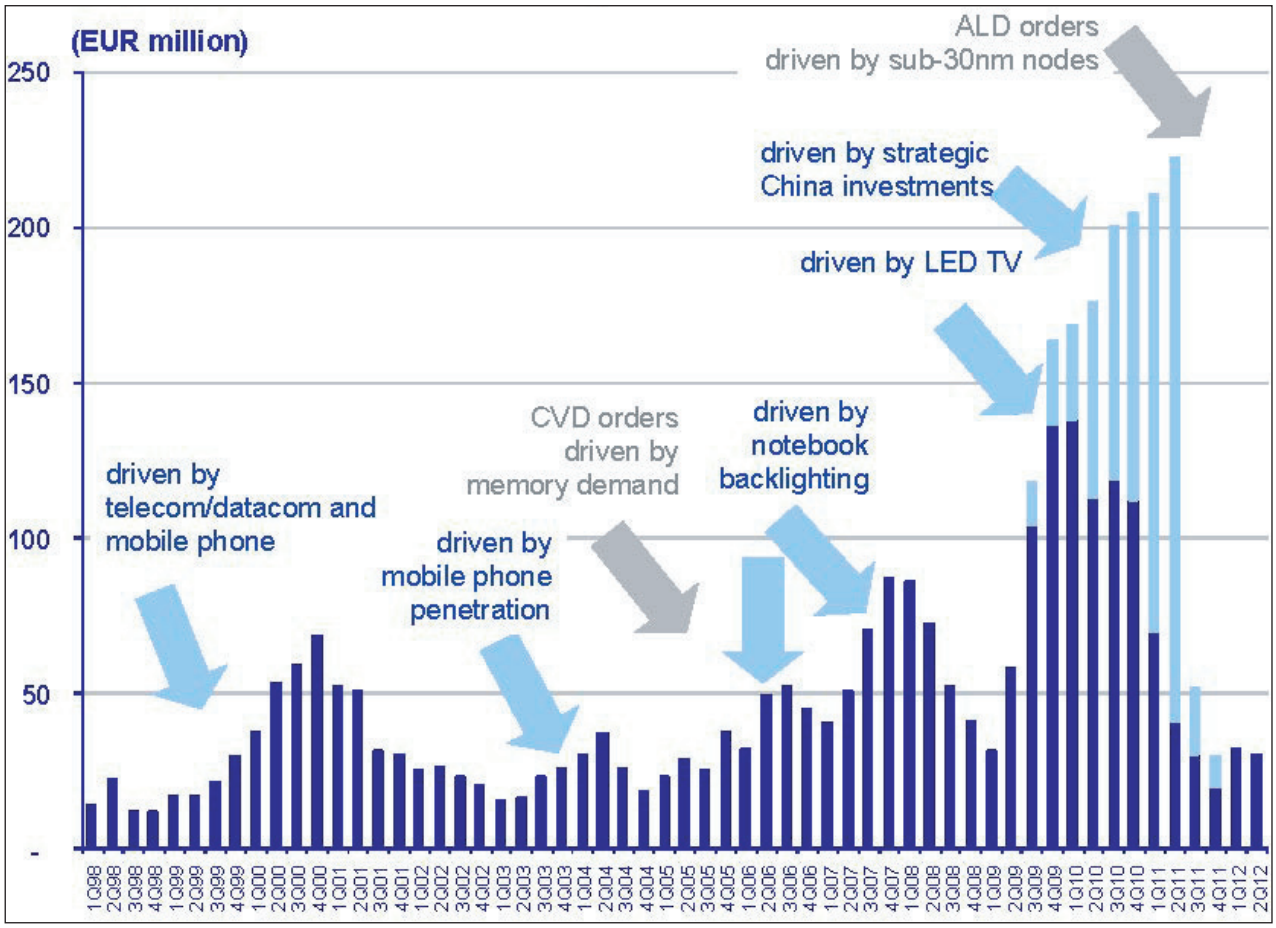
In addition, Aixtron is seeing its non-LED business gaining traction. The firm recorded an increase in silicon equipment orders during H1/2012, strongly influenced by a major order placed by a leading Korean DRAM manufacturer for the next-generation QXP-8300 atomic-layer deposition (ALD) system. The firm also recorded several orders

Next-gen ALD system shipped to Korea

Aixtron has received a multi-tool order for its next-generation QXP-8300 ALD system from a leading Korean DRAM maker. The production system for sub-30nm DRAM technology nodes will help to accelerate high-volume manufacturing of the most advanced DRAM technology node available.

"The Aixtron QXP-8300 was chosen over other competitive ALD products based on its superior film quality, excellent defect control and best-in-class productivity," says Dr Sasangan Ramanathan, chief technical officer at Aixtron Inc.

"We look forward to supporting their ramp-up in production," adds Dr Bernd Schulte Aixtron's executive VP & chief operating officer.

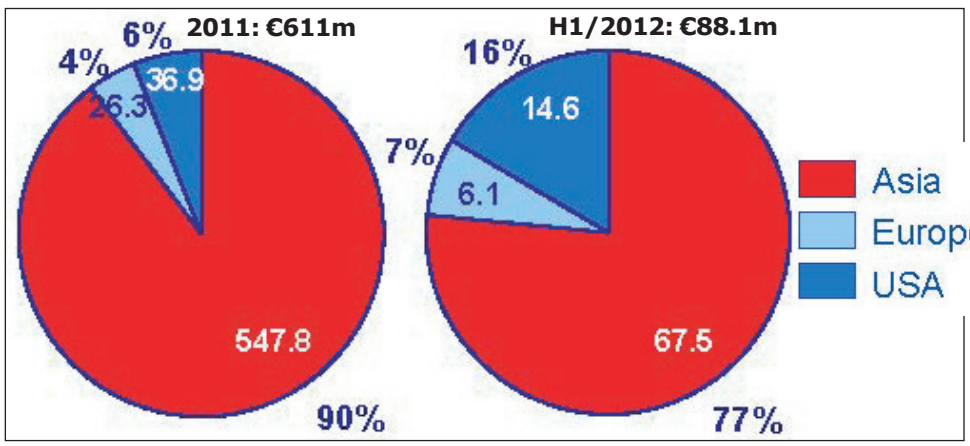


Aixtron's quarterly equipment orders, with Q2/12 down 5% on Q1/12 but expected to be the trough.

from the potentially huge power electronics market for both R&D and production tools.

President & CEO Paul Hyland also remains confident that Aixtron will benefit from the next major LED investment cycle: "Recent reports from lighting companies confirm the increased growth dynamics of the LED lighting market, which we believe will trigger significantly higher demand for LED production equipment in the coming years."

He reiterates the importance of strong R&D, for which expenses rose 41% from €24m in H1/2011 to €34m in H1/2012, while selling expenses fell 25% and general & administrative expenses fell 38%. Meanwhile, R&D staffing has risen from 32% of total staffing to 35%. "As part of our long-term strategy to retain Aixtron's technology market leadership, we continue to pursue our focused R&D programs, which are not just limited to the development of next-generation MOCVD tools, they also include technologies for other promising growth markets," says Hyland. "As a result of these activities, we are today gaining traction in new emerging MOCVD applications and other technology markets, including silicon semiconductor and organic material applications, which include OLEDs."



Aixtron's total revenue by region, showing decline of Asian contribution.

Management continues to believe that orders and revenues in second-half 2012 will pick up compared to the first half. However, the recent perceived higher short-term macroeconomic risks in the end markets that Aixtron addresses has made the magnitude and timing of the equipment demand pick-up still difficult to forecast with any certainty. Since order intake and shipment commitments in Q3 and early Q4 will largely determine the full extent of the year-end performance, this may also affect the firm's aim to be EBIT profitable in fiscal 2012. The firm nevertheless expects to return to profitability in the course of second-half 2012.

Meanwhile, Aixtron says that it will continue to review and implement appropriate cost-saving measures to optimize year-end results. The firm notes however that it expects to see significantly higher demand and growth in 2013, driven by a significant increase in demand from LED lighting manufacturers.

www.aixtron.com

IN BRIEF

Finisar orders another Aixtron G4 MOCVD system for InP lasers and detectors

Deposition equipment maker Aixtron SE of Herzogenrath, Germany says that it has received a repeat order for an AIX 2800G4-TM automated metal-organic chemical vapor deposition (MOCVD) system — dedicated to the growth of indium phosphide materials for lasers and detectors — from fiber-optic communications component and subsystem maker Finisar Corp of Sunnyvale, CA, USA.

The new order has been placed after the first AIX 2800G4-TM system was installed and qualified at Finisar's facility in Allen, TX, USA. Aixtron's local support team will install and commission the new reactor at Finisar's plant in Fremont, CA, targeting later this year.

"There are several key features we look for in an automated MOCVD system, and they are well addressed by Aixtron," says Charles Roxlo Ph.D., Finisar VP & general manager, Active Devices. "The AIX 2800G4-TM reactor provides the best means to create high-performance optical device products that fulfill the necessary requirements of our customers," he adds.

"As a manufacturer of world class lasers and photodetectors for use in their broad product line of transceivers and transponders, Finisar is another prized customer with whom we will enjoy working with in the coming months," comments Dr Bernd Schulte Aixtron's executive VP & chief operating officer.

www.finisar.com

University of Stuttgart orders Aixtron CCS system for III-V-on-Si lasers

Aixtron says that in first-quarter 2012 the University of Stuttgart placed a repeat order for a CCS (Close Coupled Showerhead) MOCVD system that is capable of handling three 2-inch (3x2") substrates at a time. For delivery in third-quarter 2012, the system will be used by the University of Stuttgart's Institute of Semiconductor Optics and Functional Interfaces (Institut für Halbleiteroptik und Funktionelle Grenzflächen, IHFG) research group.

IHFG researchers specialize in semiconductor optics and epitaxy. The new system will be used to expand their work in gallium arsenide (GaAs)-based optoelectronics, in particular producing material for solid-state lasers.

"We want to use the CCS 3x2" in two ways: on the one hand we want to produce our GaAs-based laser structures on GaAs, but we also want to transfer them to Si substrates," says Dr Michael Jetter. "As a specialist in semiconductor optics, the Institute's main research areas are semiconductor lasers and low-dimensional structures such as quantum wells (QWs) and quantum dots (QDs)."

One focus of the work will be quantum cryptography and single-photon emitters. However, the researchers also foresee opportunities arising from their efforts in automotive electronics. In particular, they plan to grow III-V materials on silicon (Si) substrates using Aixtron's MOCVD technology. "We would like to give Si electronics an optic touch, which means that we want to monolithically integrate III/V optoelectronic devices (lasers and LEDs, either QW- or QD-based) into CMOS-compatible Si substrates," says Jetter. "These can then be used for the optical data interconnects either on-chip, chip-to-chip or as board-to-board connectors."

The Aixtron equipment will be also used by the Stuttgart Research Center of Photonic Engineering (SCoPE), which aims to improve interdisciplinary collaborations between scientists and engineers at the Universität Stuttgart. IHFG and Aixtron further plan to work together on joint research and to cooperate on other scientific programs in the Stuttgart region, focusing on III-V growth on silicon.

www.ihfg.uni-stuttgart.de
www.aixtron.com

Jilin University orders Aixtron reactor for GaN UV and white LED research

Aixtron has received an order from existing customer Jilin University of Changchun, China for a Close Coupled Showerhead (CCS) MOCVD system in 3x2"-wafer configuration, which will be dedicated to the growth of GaN materials for ultraviolet and white LEDs. One of Aixtron's local support teams has installed and commissioned the reactor.

"We already have experience and a very good understanding of Aixtron systems, and we were particularly impressed with the reactor's ergonomics and security," comments Dr Zhang of the Jilin University, State Key Laboratory on Integrated Optoelectronics. "Our intention is to develop exciting new material structures that will lead to greater understanding and to production of gallium nitride materials for UV and white LEDs," he adds. "The combination of the process technology capabilities of the CCS reactor and strong backing from the local Aixtron support team will enable us to achieve our aims quickly and efficiently."

http://en.jlu.edu.cn

Plessey receives Aixtron reactor for GaN-on-Si HB-LED production line

UK-based Plessey Semiconductors Ltd has taken delivery of a CRIUS II-XL MOCVD reactor (in 7x6"-wafer configuration) from Aixtron (which announced the order in mid-June). The procurement is the first part of a multi-million pound investment by Plessey to create a production line for its new HB-LED products at its Plymouth facility. These will use Plessey's MaGIC (MAnufactured on Gan ICs) technology of GaN on 6" silicon substrates.

"We use a much thinner GaN layer, at only 2.5µm, compared to 6–8µm in other GaN-on-Si technologies," says Plessey's HBLED product line director Neil Harper. "This means less deposition time, so that we can do multiple production cycles in the reactor in 24 hours to achieve higher throughputs and lower costs."

Plessey claims to be one of the first firms to make working GaN-on-Si LEDs, with the first samples producing the correct wavelength output from Plessey's 6" IC production line.

Plessey is using standard, readily available 6" silicon, offering significant cost reductions of about 80% compared to existing technologies using silicon carbide (SiC) or sapphire, which are expensive and difficult to scale up, the firm notes.

Plessey aims to move to 8" silicon in future to yield greater cost savings. Efficiencies in the new technology should enable outputs in excess of 150lm/W to be achieved (much brighter than anything commercially available), it is reckoned. Typical MaGIC HB LEDs are yielding at 95%, providing over 14,000 1mm^2, 1W MaGIC HB LEDs per 6" wafer.

"MaGIC and EPIC [Plessey's sensor technology] are two unique, disruptive technologies that are instrumental in our plan to rapidly grow Plessey into a major electronics company producing smart lighting solutions," says chief operating officer Barry Dennington.

Plessey develops and manufactures semiconductor products used in sensing, measurement and controls applications for markets including communications, medical, defense, aerospace and automotive. Earlier this year, it announced its plan to bring to market low-cost MaGIC HB-LED products (initially for the replacement incandescent bulb market) within the next six months. It also plans to develop a range of smart-lighting products incorporating Plessey's existing sensing and control technologies.

www.plesseysemiconductors.com

Reactor for NCU's GaN-on-Si power devices

Aixtron has received an order from existing customer National Central University (NCU) in Taiwan for a 1x6"-wafer Close Coupled Showerhead MOCVD system. The reactor will be dedicated to growing GaN epitaxial structures on 6" silicon for R&D on power management devices.

Aixtron's local support team has installed and commissioned the reactor at NCU's Microwave and Optoelectronic Devices Laboratory.

"Demand for low-cost GaN-based power devices in high-efficiency and high-power systems continues to increase," says Jen-Inn Chyi, chair professor of Electrical Engineering at NCU. "We therefore plan to transfer our specially developed semiconductor materials technology to industry, for a pilot initially, and then for large-scale production. This system is an excellent match for the heteroepitaxial growth of GaN structures on large-area silicon wafers, with a view to providing high-performance devices as cost-efficiently as possible."

www.ee.ncu.edu.tw

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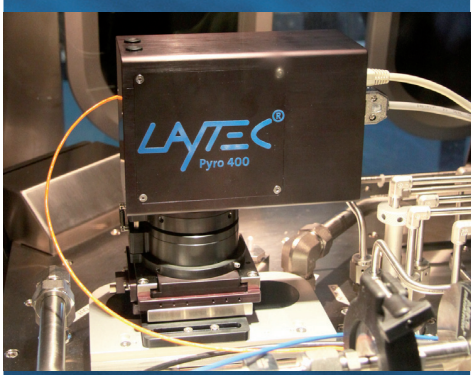

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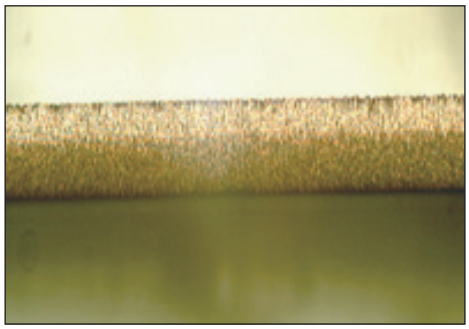
JPSA launches metal dicing system for high-power LED die singulation

JP Sercel Associates Inc (JPSA) of Manchester, NH, USA, which makes laser-based materials processing workstations for wafer processing and micromachining, has launched the IX-6100-MD for scribing and dicing metal layers such as Mo, Cu, Ni, Au, Ag and Zn, as well as their alloys, used in LED manufacturing. The system is equipped with the firm's latest proprietary vision and scribe placement technology, allowing a reduction in die street size and enabling more LED die per wafer.

In third-quarter 2012, JPSA will ship several IX-6100-MD systems to a leading LED manufacturer in Asia, where they will be used for the singulation of high-power LED devices that use the metal substrate to assist in LED heat dissipation. JPSA says that the IX-6100-MD was selected because of its high throughput, increased



Cross section of 60µm-thick copper after singulation.

die yield and low cost of ownership of the system.

JPSA says that the key technology in the IX-6100-MD is its proprietary beam delivery system, which allows the shape of the laser beam to be independently adjusted in two dimensions. This allows for optimization of laser energy used for cutting, and enables a minimal kerf width of 20µm to be achieved while minimizing the heat-affected zone.

"The IX-6100-MD combines JPSA's proprietary scribing technique with laser processes designed to achieve full singulation of metal devices," says CEO Jeffrey Sercel. "The IX-6100-MD can be configured by JPSA with a range of lasers and options to optimize production performance for each customer's specific material combinations," he adds.

The IX-6100 series of micromachining systems can be equipped with JPSA's IAP (Integrated Automation Platform) for automated wafer handling in production environments. The IX-6100 is similar to the firm's IX-6600 platform, which is claimed to be the industry-standard tool used for laser lift-off (LLO) of LED devices in an associated manufacturing process.

www.jpsalaser.com

Tiger Optics launches compact trace gas analyzer for 200ppt contaminant detection in UHP gas

At July's Semicon West 2012 tradeshow in San Francisco, laser-based trace gas analyzer manufacturer Tiger Optics LLC of Warrington, PA, USA unveiled the HALO-KA, which can detect traces of contaminants to 200 part-per-trillion levels in an ultra-high-purity (UHP) gas stream.

The HALO-KA has what is claimed to be the smallest footprint of any high-purity analyzer on the market, providing cost savings. With a low detection limit of 500ppt H_2O in nitrogen (200ppt in helium), two of the new instruments can fit in a 19" rack. Also, its patented continuous-wave cavity ring-down spectroscopy (CW CRDS) principle of operation requires no moving parts or calibration, saving on down-time, labor, and consumables, the firm adds.

The HALO-KA is the latest addition to a platform that debuted in 2006 as the HALO, a 'mini' device measuring moisture in a range from 2ppb to 20ppm, offering the speed, specificity and reliability of the original Tiger tools but at about half of the price and a quarter of the size. The original HALO was conceived by Dr Farhang Shadman, director of the NSF/SRC Engineering Research Center for Environmentally Benign Semiconductor Manufacturing at the University of Arizona.

Tiger Optics' HALO-KA

The HALO+ analyzer, introduced at Semicon West 2007, provided detection limits down to 400ppt for fields as diverse as gas manufacturing, semiconductor fabrication, and national metrology institutes. When a user requested an analyzer with an extended upper detection limit, Tiger Optics responded in 2010 with the HALO-500-H_2O, providing the widest detection range of any Tiger product.

"Our newest HALO is unique in its ability, as an all-in-one device, to monitor extremely low levels of contamination in a UHP gas stream," claims founder & chief executive Lisa Bergson. "Not only can the HALO-KA monitor moisture, but we also have systems available to monitor a wide variety of analytes in both inert and corrosive gases," she adds.

www.tigeroptics.com

FBH orders Oxford Instruments' Optofab3000 ion beam deposition tool for laser bar facet coating

UK-based etch, deposition and growth system maker Oxford Instruments Plasma Technology (OIPT) says that the Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik (FBH) in Berlin, Germany has ordered an Optofab3000 ion beam deposition tool for laser bar facet coating to further expand its capability in optoelectronics research and pilot production.

The Optofab3000 tool will be used to deposit optical thin films for high-power and high-brightness laser diodes based on III-V semiconductor layer structures and emitting at wavelengths of 0.63–1.12μm.

"We have chosen the Optofab3000 ion beam deposition tool because of its capability to deposit high-quality optical films as well as its advanced in-situ optical monitor," says Dr Götz Erbert, head of FBH's Optoelectronics Department. "Another key factor in making our decision was the twin benefits of a tool that can achieve our high-specification requirements with a small footprint. While we are primarily an R&D institute, we also undertake pilot production and consequently need to achieve the highest-quality end-product possible," he notes.

System similar to the one for FBH

The tool will be used to deposit optical thin films for high-power and high-brightness laser diodes

"We are extremely pleased to have the opportunity to work with a prestigious research institution like FBH," says Mark Vosloo, director of sales, marketing & customer support at Oxford Instruments Plasma Technology. "Their decision to order an Optofab3000 for laser bar facet coating from Oxford Instruments further establishes our ion beam products in the field of opto-electronics research & production," he adds.

The Optofab3000 ion beam tool is scheduled for delivery by the end of 2012.

www.fbh-berlin.com
www.oxford-instruments.com

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Soraa to lead ARPA-E project on bulk GaN substrates

Soraa Inc of Fremont, CA, USA, which develops solid-state lighting technology built on 'GaN on GaN' (gallium nitride on gallium nitride) substrates, has been selected by the US Department of Energy's (DOE) Advanced Research Projects Agency-Energy (ARPA-E) to lead a project on the development of bulk GaN substrates.

Currently, this is the only ARPA-E funded LED substrate project, says Soraa. Specifically, Soraa will continue development of ammonothermal technology for bulk GaN substrates.

Soraa says that such an advance in a commercially viable new substrate technology promises higher efficiency and performance. GaN-on-GaN LEDs are of interest because they have demonstrated much higher performance than traditional lighting technologies and hence offer the potential for major energy savings.

Most white, blue and green LEDs are made by depositing GaN on non-native substrates, typically sapphire or silicon carbide (SiC). In contrast, Soraa claims to be the only LED maker shipping products based on GaN-on-GaN LEDs. To date, the adoption of native-substrate GaN-on-GaN technology for large-scale applications has been inhibited by high costs due partly to the absence of inexpensive native GaN substrates. Soraa reckons that creating a US-made solution to the challenges of bulk GaN production will benefit the firm, the LED industry, and the US consumer with more energy-efficient, less expensive and more readily available components.

LEDs lend themselves well to the new substrate because it greatly enhances performance — in terms of the quality of light — in addition to benefiting energy efficiency. Because of innate physical properties of the compound, GaN-on-GaN LEDs can withstand higher power densities than diodes made with other substrates, leading to a much brighter diode and allowing the use of just one LED light emitter per lamp. Other substrates necessitates the use of three, four or more LEDs to achieve the same brightness, claims Soraa. Multiple sources of light within a lamp produce fuzzy shadows instead of the crisp light required of an MR-16 lamp for best use in commercial, museum or high-end consumer applications. The MR-16 bulb represents Soraa's first commercially available product.

ARPA-E, which invests exclusively in transformational energy technologies, began funding Soraa as a consortium member for the project in 2011. ARPA-E's recent decision to make the firm the lead organization on the project means that Soraa will become the prime contractor working with ARPA-E to commercialize GaN substrate technology. The firm says that applications for GaN substrates have the potential to reduce US energy consumption by over 30%. These applications represent potential markets (including laser diodes and power electronics) of more than $50bn annually, according a DOE study.

"Soraa's system design and capabilities represent a breakthrough path toward the development of high-quality, low-cost GaN substrates," says ARPA-E program director Mark Johnson, who adds that the project is supporting Soraa's process development, crystal quality improvements, and device characterization.

"DOE's recognition and support of this transformational technology is expected to accelerate a more energy-efficient, higher-performing US-based technology for LEDs and a host of additional applications," comments Mark D'Evelyn, Soraa's principal investigator on the project.

"This level of funding, combined with the vote of confidence from the Department of Energy, is a significant step forward to a future of lighting technology based on large-area, high-quality, low-cost GaN substrates," reckons the firm's chief technology officer Mike Krames.

www.soraa.com

Rudolph appoints head of Inspection business unit

Rudolph Technologies Inc of Flanders, NJ, USA, which makes defect inspection, process control metrology, and data analysis systems and software for semiconductor device manufacturing, process characterization equipment and software for microelectronic manufacturers, has appointed Dr Michael Jost as VP & general manager of its Inspection business unit.

Jost has over 20 years of experience with scientific products, initially in development, and most recently as VP & general manager of the Molecular Spectroscopy business unit at Thermo Fisher Scientific. He joined Rudolph in April as supply chain vice president and assumes general manager responsibilities immediately. Jost replaces Nathan Little, who will work on special corporate-wide growth initiatives.

"Inspection business continues to exceed expectations and now accounts for 60% of our total revenue," says chairman & CEO Paul McLaughlin.

"In addition to managing a broad product portfolio for both front- and back-end semiconductor manufacturing, Mike will lead the R&D of Rudolph's next-generation inspection solutions — a critical, ongoing effort that is required to address today's diverse and emerging process requirements," he adds. "In addition, he will oversee the company's centralized manufacturing operations located in Bloomington, MN."

www.rudolphtech.com

GT revenue falls 53% in Q2 due to solar & LED headwinds

For second-quarter 2012, GT Advanced Technologies Inc of Nashua, NH, USA (a provider of polysilicon production technology plus sapphire and silicon crystalline growth systems and materials for the solar, LED and other specialty markets) has reported revenue of $167.3m, down 53% on $353.9m last quarter and 28% on $231.1m a year ago (yet exceeding guidance).

Revenue by segment was $121.5m in polysilicon (down from $153.9m last quarter), $9.4m in photovoltaic (down from $34.4m last quarter), and $36.3m in sapphire (down from $168.6m last quarter), most of which was from advanced sapphire furnace (ASF) equipment revenue.

"We exceeded expectations, a notable accomplishment given the continued headwinds in the solar and LED markets that we serve," says president & CEO Tom Gutierrez. "Our PV and sapphire businesses performed in line with our expectations, while our polysilicon business out-performed," he adds.

Gross margin has fallen further, from 49.1% a year ago and 43% last quarter to 36%. Non-GAAP net income has hence also fallen further, from $56.1m a year ago and $83.9m last quarter to $19.2m. During the quarter, cash and cash equivalents fell from $350.9m (including $75m of debt) to $332.4m (including $145m of debt).

New orders have fallen from $34.6m last quarter to $13.8m. This included $0.4m in polysilicon (down from $4.2m), $8.5m in PV (up from $6.9m) and $4.9m in sapphire (down from $23.5m). However, backlog was downgraded by $31.9m after termination of a single ASF sapphire contract due to the customer's failure to perform.

Including about $149.3m of deferred revenue, order backlog has fallen from $1.8bn to $1.6bn. This includes $758.6m in polysilicon (down from $879.7m), $137.8m in PV (down slightly from $138.7m) and $697.5m in sapphire (down from $760.9m). "Our assessment of backlog risk remains unchanged from our analysis one quarter ago," notes Gutierrez.

"We remain committed to investing in next-generation technologies and product innovations in our core businesses to solidify our market leadership and develop new opportunities," says Gutierrez. "We continue to explore ways to further diversify the company's portfolio into new high-growth areas. During the quarter we added $70m of debt in anticipation of several potential investments that are under discussion."

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Rubicon's revenue rebounds in Q2, driven by 6" sapphire

For second-quarter 2012, Rubicon Technology Inc of Bensenville, IL, USA, which makes monocrystalline sapphire substrates and products for the LED, RFIC, semiconductor and optical industries, has reported revenue of $17m, down 60% on $43m a year ago but rebounding by 67% from $10.2m last quarter due to strong demand for both the LED and silicon-on-sapphire (SOS) markets.

Revenue from the optical market fell by a third from $1.8m to $1.2m. But revenue from the LED market more than doubled from $3.9m to $8.4m, due to higher sales for both 6" wafers and smaller-diameter 2–4" cores. Specifically, 2–4" cores doubled to $5.3m as LED demand strengthened via increased utilization rates at most LED chip makers. As expected, substrate pricing stayed low in Q2, particularly for 2–4" cores. LED demand has improved, but the industry is below full utilization in all regions, notes Rubicon. More notably, at the major sapphire wafer makers (to which Rubicon sells its cores) inventory levels are being reduced but remain higher than normal, which continues to keep pricing low.

Nevertheless, revenue from 6" wafers for the LED market tripled from $0.9m to $2.7m. In particular, toward the end of the quarter Rubicon resumed shipping 6" wafers to its largest LED customer after a pause in their purchases due to excess inventory. The down-cycle in the LED market has delayed broader adoption of 6" substrates among LED chip makers, notes Rubicon. While most of the major LED chip makers continue development work on 6", the focus recently has been on improving utilization of their existing platform.

However, overall 6" wafer revenue rose 84% sequentially to $10.1m (59% of total revenue). In particular, 6" sales to the silicon-on-sapphire (SoS) RFIC market continued to rise, growing 62% sequentially to $7.4m.

"We saw the beginning of a recovery of the LED market in the quarter along with continued strong demand from the SoS market," summarizes president & CEO Raja Parvez.

Gross margin was break-even, up 33 percentage points on last quarter, driven by increased revenue from higher-margin, large-diameter wafer sales and hence an improvement in utilization of polishing operations (also, in Q1 Rubicon incurred extra scrap and rework expenses associated with changes to specifications for its largest 6" LED customer). However, utilization is still only 30–40% for polishing operations, and 80–85% for crystal growth. The weak pricing environment, particularly for 2–4" sapphire cores, continues to be a drag on margins but pricing is expected to improve once inventory levels at sapphire producers are reduced further.

Operating expenses have been cut further, from $3.9m a year ago and $3.2m last quarter to $3.1m. Operating loss was more than halved to $3.1m from $6.6m last quarter (although the latter included $1.8m of scrap expenses). Likewise, loss per share has been cut from $0.15 last quarter to $0.06 (better than the forecast $0.10–0.14), though still down on the profit of $0.41 a year ago. Cash consumption was $3m during the quarter. In addition, capital expenditure was $1.8m and inventory balance rose by $6.5m, of which $5m was due to building a safety stock of raw material. Cash and short-term investments has fallen further, from $55m to $52m.

Pricing for 2–4" cores will likely remain low for another quarter or two as sapphire inventory levels continue to be worked down at a slower pace than originally expected. However, Parvez expects additional growth in 6" wafer business in second-half 2012. "Utilization rates have been gradually improving and we expect to see one or two more of the major chip manufacturers begin using 6" substrate in production in the next year," he adds. "We are still in the early days of adoption of 6" wafers for the LED market and specifications for these wafers continue to develop as LED chip manufacturers gain more experience with these substrates and production."

For Q3/2012, Rubicon expects revenue to rise to $18–21m, with a heavier mix of 6" wafers. Although it will most likely still not cover all operating expenses, gross margin should continue to improve. Likewise, loss per share should improve further, to $0.02–0.05.

"It has been a difficult cycle for the LED industry but the market is improving. This, along with the strength of the SOS market, has enabled us to resume growth and improve margins," says Parvez. "We expect continued improvement in the second half of this year as our utilization improves [expecting 60–65% for polishing operations in Q3]… We continue to work on reducing cost, particularly in our polishing operation, through process improvement and relocating our US polishing to Malaysia," he adds.

"During this cycle, we continue to focus on extending our vertical integration and refining our processes," Parvez says. "The strength of our technology in crystal growth, fabrication and large-diameter wafer polishing has allowed us to earn a leadership position in supporting emerging technologies like SoS and in the progression of the LED market to larger substrates," he continues. "We continue to focus on enhancing our existing platforms and developing new products. Projects like our in-house raw material production and the in-situ crystal alignment, which has just been patented, will allow us to improve quality while reducing cost," Parvez adds. "We continue to extend our vertical integration upstream by rolling out our raw material preparation process and downstream by moving forward with our development of patterning capability… Our development of pattern capability is on track and we expect to be the first to offer large-diameter patterned sapphire substrates next year."

www.rubicon-es2.com

Rubicon orders Zeta optical profilers

Zeta Instruments Inc of San Jose, CA, USA, which provides optical profilers for micron-scale surface analysis, says that Rubicon Technology Inc of Bensenville, IL, USA has ordered multiple units of the Zeta-300 series optical profiler for its sapphire substrate production aimed at the high-brightness light-emitting diodes (HB-LED) market.

Rubicon says that, being sensitive to the LED maker's costs of wafer failure late in the production cycle, it will use the Zeta-300 series optical profilers for inspection and metrology of its sapphire substrates to help improve wafer yield and to lower costs for LED customers.

Zeta says that, known for cost-effective advanced functionality, its high-precision metrology systems have gained strong traction across the LED industry. The latest in its suite of optical profilers, the Zeta-300 series was designed specifically to address the stringent specifications of the patterned sapphire substrate (PSS) market. It combines PSS metrology and defect review in a system that is claimed to be unique in the sapphire industry, enabling detailed measurement of PSS structure

Zeta-300 series optical profiler.

dimensions as well as wafer defect inspection on the same system.

"We have evaluated many tools for the production environment and the Zeta 300 series delivers the best combination of speed and accuracy for precision metrology applications," comments Rubicon's president & CEO Raja M. Parvez. "Zeta's systems are integral to assuring our products meet and surpass our own internal quality specifications and those of our customers," he adds.

The Zeta-300 series leverages patented Z-Dot technology to deliver high repeatability and accuracy for the measurement of LED-patterned/etched substrates, photo-resist and stacked structures on transparent surfaces. Due to its combination of optics and algorithms, it provides what is claimed to be rapid and reliable data acquisition and analysis.

Coupled with application-specific software and a companion automated wafer handler, the Zeta-380 in particular provides imaging and measurement capabilities that are claimed to be superior to those of laser confocal microscopes. It measures and detects defects falling outside the industry certification levels that may not be detected by competing offerings, it is claimed. The firm reckons that its system design also offers greater ease of use while lowering overall cost of ownership.

"Having one of the world's largest and most esteemed PSS wafer suppliers select the Zeta-300 series as integral to its manufacturing process is powerful validation of our product strategy and development efforts," reckons Zeta's president Rusmin Kudinar. "We look forward to an ongoing trusted partnership with Rubicon."

www.zeta-inst.com
www.rubicon-es2.com

Rubicon patent allowed for in-situ crystal orientation

Rubicon Technology Inc of Bensenville, IL, USA, which makes monocrystalline sapphire substrates and products for the LED, RFIC, semiconductor and optical industries, says that the US Patent and Trademark Office (USPTO) has allowed Rubicon's patent application 'Intelligent Machines and Process for Production of Monocrystalline Products with Goniometer Continual Feedback'. The patent covers Rubicon's equipment and process developed to perform in-situ orientation of its sapphire crystals within the various fabrication tools used by the firm.

Rubicon says that its customers in the LED, silicon-on-sapphire (SoS)/RFIC (radio-frequency integrated circuit) and optical markets all have specific and distinct requirements for the crystal planar orientation of the sapphire products used in their applications. The new patented orientation technology provides greater precision in sapphire planar orientation and eliminates time-consuming steps by performing the orientation at the fabrication tool. The resulting efficiencies will ultimately translate into savings for customers, reckons Rubicon.

The patented orientation technology provides greater precision in sapphire planar orientation

"Rubicon is known by many for its expertise in crystal growth technology, but our technological leadership extends from raw material through finished sapphire wafers," says president & CEO Raja M. Parvez. "This patent reflects one of many technological innovations we've put in place to meet our customers' exacting and evolving requirements."

IN BRIEF

Innolume launches next generation of quantum-dot diode lasers

Innolume GmbH of Dortmund, Germany, which manufactures quantum-dot (QD) diode lasers covering the 1064–1320nm spectrum, has launched the next generation of its LD-12XX-series laser diode.

While keeping output characteristics the same — i.e. 350mW of kink-free output power and a fiber Bragg grating (FBG)-stabilized spectrum in the 1180–1270nm wavelength range — the new LD-12XX-series of lasers has substantially improved wall-plug efficiency.

Compared with the previous generation, the main differentiation is a higher operating temperature of the laser chip, which has allowed the maximum wall-plug efficiency to be shifted to higher environmental temperatures.

As a result, the wall-plug efficiency of the butterfly-packaged laser, which includes a TEC (thermo-electric cooler), exceeds 16% at a case temperature of 40°C — typical for the environment in PON (passive optical network) equipment racks — hence leading to a significant reduction in power consumption, it is reckoned.

"This optimization supports our customers in further improving their products already introduced to the market, and by that bring even more benefits of Raman-based Gigabit passive optical network (GPON) reach extension to network operators compared to conventional reach extenders based on semiconductor optical amplifiers (SOAs)," says managing director Guido Vogel.

www.innolume.com

ONR awards SETi $1.6m to develop portable UV LED water purification

Ultraviolet light-emitting diode (UV LED) maker Sensor Electronic Technology Inc (SETi) of Columbia, SC, USA has been awarded a program from the US Office of Naval Research (ONR) to develop a self-contained portable water purification system incorporating UV LED technology for water quality monitoring and disinfection.

The program's goal is to develop a portable unit that can provide a small team of warfighters with a self-sustainable source of potable water from any fresh water source.

Stand-alone UV LED water disinfection efficacy has already been demonstrated at SETi through a program funded by the National Science Foundation. However, this demonstration has been designed for commercial use and will not meet the needs of the warfighter. To achieve compliance with the rigorous standards of NSF P-248, SETi has teamed up with Cascade Designs Inc (CDI) of Seattle, WA to combine novel mechanical filtration technologies with the effective disinfection of UV LEDs.

The system will also use SETi's UV LEDs to monitor the water quality, optimizing system efficiency and effectiveness. SETi says that, through funding the program, ONR has demonstrated commitment to a new type of water purification system that will benefit from the advantages of UV LEDs, making it smaller, more robust and lower power than anything now available and reducing the need for chemical disinfectants such as chlorine and iodine.

SETi says that the system has major implications for improving the self sufficiency of warfighters in mobile operations. "Modern warfighters assume many risks on the battlefield; drinking contaminated water should not be a concern," says Cody Reese, program manager at ONR. "UV LEDs have the potential to revolutionize water disinfection at all scales, with a marked improvement to safety, durability, and energy consumption — from the mouth-piece of an individual drink tube, all the way to commercial-scale water treatment plants."

Via a DARPA development program, SETi recently announced eight-fold efficiency improvements in LEDs operating at germicidal wavelengths. "It will lead on from our successes in DARPA and other military programs to develop a military application based on this new technology," says president & CEO Remis Gaska.

During the project CDI will be focusing on designing novel filtration techniques to complement SETi's UV LED disinfection reactor. CDI provides water treatment systems and, with its hydration product brands MSR and Platypus, is also a supplier of portable water treatment systems to the military. "UV LEDs will become a compelling disinfection technology component in the creation of safe drinking water both for our troops and the general public," believes the firm's president Joe McSwiney.

Other members of the development team include the University of Colorado's department of Civil, Environmental and Architectural Engineering (led by professor Karl Linden) and the Institute of Applied Research at Vilnius University, Lithuania (led by professor Arturas Zukauskas). The Colorado team is focused on research related to advanced treatment technologies for water and, with a rich history in UV systems, will assist in modeling water flow and light distribution from the LEDs to optimize the efficacy of the UV chamber. With a history of integrating SETi LEDs into optical monitors and spectrometers, Vilnius University will assist in developing an optical water quality monitor that will measure the microbial level in the water and adjust the system accordingly.

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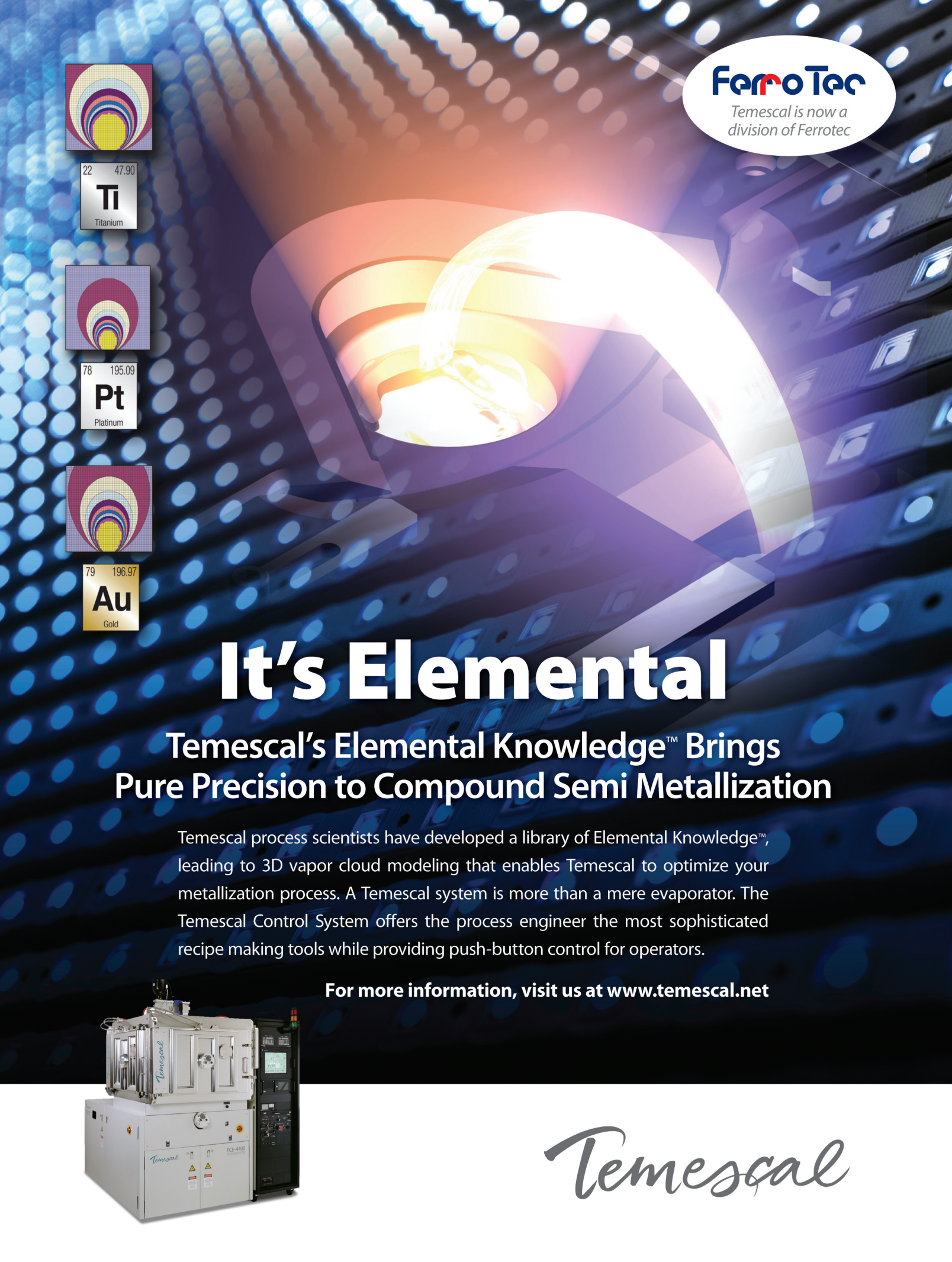
www.cascadedesigns.com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Logwin providing logistics services to Optogan

Logwin AG of Grevenmacher, Luxembourg, which provides procurement, warehousing, distribution and valued-added services, has been chosen to manage the logistics of LED chip and luminaire maker Optogan.

Founded in Helsinki, Finland in 2004 by Russian entrepreneurs and scientists from Ioffe Institute in St Petersburg, Optogan is a vertically integrated manufacturer of LED chips, components, lamps and lighting equipment for applications including general lighting. As well as having an R&D facility in Helsinki, since founding Optogan GmbH in Germany in 2005 it has established epitaxy and chip R&D plus a pilot line in Dortmund and its Fab1 chip fabrication plant in Landshut. Also, after founding CJSC Optogan in Russia in 2009, in 2010 it acquired an industrial facility in St Petersburg, where it established LED component and luminaire production lines.

Optogan opened its production site in Landshut in Bavaria at the end of 2011. The firm commissioned Logwin to manage its global supply chain. "Our entire goods handling is now in Logwin's hands," says Optogan's general manager Markus Zeiler. "This challenge can only be met with international presence and powerful networks," he adds.

Logistics for Optogan are centred on the Logwin warehouses in Karlsfeld near Munich, Germany and Taipei, Taiwan. Each site serves as the distribution centre for its region. Up to 7600 pallet storage positions are available in Karlsfeld and in Taipei for the storage of Optogan products on a non-mixed basis. Logwin says that, since LEDs are highly sensitive, high standards regarding equipment, cleanliness, fire protection and security apply in the warehouses and while the goods are being handled. Besides storage and transportation, Logwin will be providing incoming goods checking and quality inspections, assembly of lighting units, and returns processing. "Optogan is particularly interesting for us," explains Marc Styrnal, manager sales & key accounts solutions. "First, because it is a company undergoing dynamic growth whose development we can accompany constructively. Second, because Optogan's products fit in well with our striving for sustainability."

Logwin stores finished and semi-finished goods from Optogan in Karlsfeld, and handles order picking and distribution throughout Europe. The logistics specialist organizes the shipment of smaller quantities using CEP services and distributes other consignments via its own networks.

Logwin's Taipei site is responsible for distributing LEDs within Asia. At the same time, it is from here that the firm organizes Optogan's entire air freight operations, together with its location in Munich. Whether global import and export of finished goods or international shipments with semi-finished goods between Germany, Russia and Taiwan, Logwin organizes air freight transportation, arranges insurance and takes care of customs formalities. "Optogan relies on fast and flexible solutions in procurement and distribution, which is why air cargo is the right choice," says Eva-Maria Jackermeier, senior sales manager Air + Ocean at Logwin. "In the further course of the project we will develop additional concepts together with Optogan and thus play an active role in setting up logistics structures."

Logwin is now also a customer of Optogan, since a section of the warehouse in Karlsfeld is being equipped with LED lighting. "Logwin will benefit from energy savings and the lower maintenance effort involved," says Zeiler. The average lifespan of LEDs is about 10 years. Whereas in the past lighting elements suspended from the high warehouse ceilings had to be replaced on a regular basis, this work will in future be reduced to a minimum. "We hope the installation of Optogan LEDs will lead to improvements in the working conditions of our employees, because LEDs provide a more pleasant light, consistent brightness and they do not flicker," says Styrnal.

www.optogan.com
www.logwin-logistics.com

Digi-Key to distribute Luminus' LEDs globally

Internet-based electronic components distributor Digi-Key Corp has signed a global distribution agreement with Luminus Devices Inc of Billerica, MA, USA, which makes PhlatLight (photonic lattice) LEDs for solid-state lighting applications.

"Demand for Luminus 'Big Chip' LEDs is accelerating rapidly," says Luminus' president & CEO Keith T.S. Ward, who reckons that Digi-Key's global reach will help it to better serve customers by driving its technology into the marketplace.

"Solid-state lighting is one of the fastest-growing segments in today's fast-paced market," says Mark Zack, Digi-Key's VP, global semiconductor product. "Luminus' products, with their value-added and module-like offerings, support our full solution approach. High-efficiency, reliable LED lighting products have seen exponential expansion in recent years," he adds.

"High-flux-density LEDs allow solid-state devices to replace traditional lighting technologies in applications previously not thought possible," says David Rubin, Luminus' director of sales for North America. "Digi-Key has created an infrastructure that enables the lighting community to find the products that meet their needs in developing exciting new lighting solutions, and then deliver those products to the market immediately."

www.digikey.com
www.luminus.com

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Cree's quarterly revenue grows 8%

Growth returns after transition to new sales agents for lighting products

For full-year fiscal 2012 (ended 24 June), Cree Inc of Durham, NC, USA has reported revenue of $1.16bn, up 18% on $988m for fiscal 2011. This consisted of $757m for LED products (components, chips and materials), $335m for lighting products (indoor and outdoor LED lighting products, plus traditional lighting systems), and $73m for power & RF products.

Fiscal fourth-quarter 2012 revenue was a record $306.8m, up 26% on $243m a year ago and 8% on $284.8m last quarter. "Revenue was slightly higher than the midpoint of our target range [$295–315m] as LEDs, lighting and power & RF delivered solid growth," says chairman & CEO Chuck Swoboda.

Revenue from Power & RF products was $21m (up 21% on $17.3m last quarter), driven by growth in both product lines. Revenue from LED products was $185m (up 23% on $180.9m), driven LED components. Revenue from lighting products was $101m (up 16% on $86.5m) after seeing the initial benefits of new product launches and after regaining momentum with sales agents.

In fiscal Q3, Cree transitioned to new agents during the integration with Ruud Lighting Inc of Racine, WI, USA (acquired in August 2011), causing greater-than-expected disruption to the project pipeline). Nevertheless, in Q4 Cree enabled the largest municipal street lighting project in China, as the Beibei district of Chongqing completed installing 20,000 street lights featuring 1.9 million Cree LEDs.

Also during fiscal Q4, Cree launched its CS Series LED linear luminaire (to deliver fast payback to low-bay lighting applications) and expanded its CR Series LED downlights (offering high performance and low prices for mainstream residential and commercial lighting applications). The firm also introduced the XLamp XP-G2 LED to deliver luminaire makers up to 20% more lumens per watt and 2.5 times the lumens-per-dollar over the original XP-G LED.

"We finished the year strong in our fiscal Q4 with record revenue and non-GAAP earnings per share on the high end of our target range," says Swoboda.

Although still down on 38.8% a year ago, gross margin has risen from 35.6% last quarter to 36.3% (above the targeted 36%), driven by slightly higher factory utilization, factory cost reductions, and lower-cost new products. Nevertheless, full-year gross margin has fallen from 44.7% in fiscal 2011 to 36.1% in fiscal 2012 (30.9% for lighting products, 38.4% for LED products, 43.9% for Power & RF products).

Operating expenses have risen from $76.9m last quarter to $81.4m. In particular, R&D expenditure rose $900,000 to $34.3m, while SG&A (selling, general & administrative) expenditures rose $3m to $45.7m. But, while down on 13.5% a year ago, operating margin has rebounded from 8.6% last quarter to 9.8%.

Net income was $29.2m, down on $30.6m a year ago but rebounding from $23.3m last quarter and on the high-end of the targeted range. Full-year income fell from $187m for fiscal 2011 to $109m for fiscal 2012.

Cash flow from operations has recovered from $48.3m last quarter to $72m. Capital expenditure has been cut from $26m to $25m. Hence, free cash flow has more than doubled, from $22m to $47m. Also during the quarter, Cree repurchased 500,000 shares at $23.98 per share. Cash and investments hence rose by $34m to $745m.

"We had good success in fiscal 2012 with lower-cost LEDs and lighting systems that doubled the lumens per dollar," says Swoboda. "We are currently building sales momentum for these new products, while we work on next-generation designs to deliver even higher performance and better value." In fiscal Q4, Cree unveiled a 170lm/W prototype LED light bulb that aims to optimize performance, lower cost, and drive LED lighting adoption.

"As our new lighting products close the price gap with conventional lighting, and we expand our sales & marketing reach for these products, we target faster paybacks to drive increased adoption, sales growth and incremental improvement in product margins," says Swoboda.

"Both the LED and lighting product lines are operating with short lead times, which is similar to the previous few quarters, and adds additional variability to our forecasts," says Swoboda. "The macroeconomic environment has also made some of our customers more cautious in the near term, which is in line with what some of the major electronic component distributors have recently stated," he adds.

For fiscal Q1/2013 (ending 23 September 2012), Cree targets revenue of $305–325m, consisting of solid growth in lighting (driven by indoor and outdoor product sales); flat LED product sales (with strength in new products offset by macroeconomic weakness as customers continue to maintain low inventory levels); and Power & RF sales in line with fiscal Q4.

"We target incremental margin improvement through factory cost reductions, process improvements and lower-cost new product designs," says Swoboda. Building on the last two quarters by delivering higher revenues on a similar cost base, Cree expects gross margin to rise to 37%. Operating expenses should rise by $1m (with increased R&D spending supporting expanded new product development. Net income should be $27–33m.

"We target similar levels of investment as Q4 to support our strategic priorities to lead the market, drive adoption of LED lighting, accelerate cost reductions, and support incremental capacity," says interim chief financial officer Mike McDevitt.

www.cree.com

Cree unveils 170lm/W prototype LED bulb

Less than a year after showcasing the 152 lumens-per-watt concept LED bulb, Cree Inc of Durham, NC, USA has unveiled a 170 lumens-per-watt (LPW) prototype LED light bulb. The firm says the 170LPW LED bulb enables much higher efficacy and lower cost for its luminaire portfolio, as it aims to accelerate the adoption of LED lighting by addressing the key barriers of initial cost and payback.

Cree says that LED lighting at this level of performance is only enabled by advances across all elements of the LED lighting system — lighting-class LEDs, optics, drivers and thermal management. The firm says its latest R&D lighting result has been enabled by its SC^3 Technology Platform, which is based on Cree's silicon carbide (SiC) technology as well as advances in the LED chip architecture and phosphor.

"Optimizing each LED design element was critical in achieving the performance reached by Cree's new prototype LED bulb," says Nick Medendorp, VP of research and development, Cree lighting. "The technology embodied in the new 170LPW concept LED bulb is enabling us to develop higher-performance and lower-cost Cree LED luminaires," he adds.

Third-party testing by independent lab OnSpeX confirmed that the new 170LPW prototype LED bulb delivered more than 1250 lumens and consumes just 7.3W. The bulb uses Cree TrueWhite Technology to deliver a color rendering index of 90+. By comparison, a traditional 75W incandescent light bulb produces 1100 lumens, i.e. just 14.6LPW.

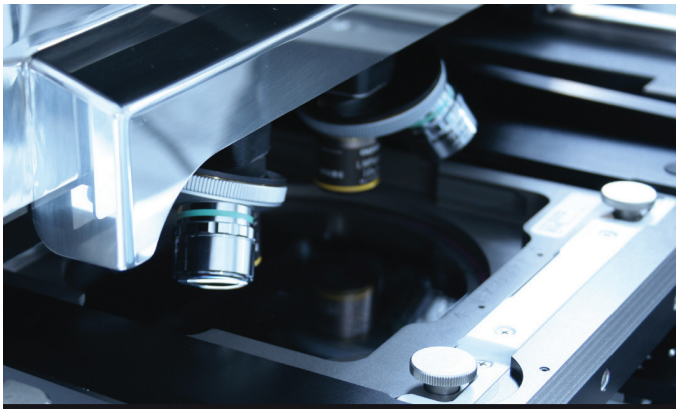
www.cree.com/lighting.

Cree's LED exterior luminaires illuminate schools in Virginia

Newport News Public School District has become the first Virginia school district in the area with a significant LED lighting installation by installing more than 185 LED exterior luminaires made by Cree. The district selected Cree's THE EDGE security, area and parking structure luminaires to illuminate the exteriors of seven schools.

In 2008, Newport News School District spent $5.6m on energy costs. In the past four years, it has implemented energy-saving projects including the installation of the LED luminaires. Officials estimate the lighting upgrade resulted in annual energy savings of 139,000kWh and a reduction in annual lighting energy costs by 65%. They also estimate a payback of three years.

Cree's THE EDGE area, parking and security luminaires replaced 189 high-pressure sodium and 150 incandescent fixtures, illuminating the exterior corridors, walkways and entryways and providing increased visibility around the building perimeters. The parking lots now meet the sustainable illumination requirements of each school. The lights also provide added safety and security for students, parents and staff for night-time activities and events.



Osram breaks ground on China back-end assembly plant

Completion due by end of 2013; 100,000m² site to employ 1600

In the presence of representatives of Jiangsu Province, Germany's Osram AG has laid the foundation of its new plant in the Chinese city of Wuxi, taking the next step in expanding its activities in the world's largest single lighting market. Scheduled for completion by the end of 2013, the back-end facility will package LED chips. Front-end production of the LED chips will continue in the plants in Regensburg, Germany and Penang, Malaysia of Osram Opto Semiconductors GmbH.

"China is already today the biggest sales market with significant future potential. The new assembly plant enables us to better participate in the strong market growth in China and further extend our solid position in Asia," says Osram's CEO Wolfgang Dehen. "Growing at a remarkable rate, Jiangsu Province's LED industry is at the forefront in China," adds Jiangsu Province's governor Xueyong Li. "We will fully support Osram's development in Wuxi with the highest-quality service, and we also hope Osram can expand its investment in Wuxi to have the plant up and running as soon as possible."

Contracts for the new Wuxi location were only signed in May. Groundbreaking now marks the start of construction of the 100,000m² compound. Osram intends to invest a low three-digit million euro figure over the next five years while also securing comprehensive support from its Chinese partners. In the final completion stage, the new plant will be able to accommodate up to 1600 employees.

Osram says that, with the new plant, it is responding to increasing demand for LED-based products in the fast-growing Asian market. This comes against the backdrop that LED back-end capacity at Osram's plant in Penang, where chips are both produced and packaged, is expected to reach its limits within the next few years. So, in addition to its two front-end plants, Osram will in future have two back-end sites. "With highly skilled personnel, a good infrastructure and experienced partners, Wuxi provides the best conditions for our new LED assembly," believes Osram Opto's CEO Aldo Kamper.

Groundbreaking ceremony for Osram's new back-end LED assembly plant.

The Asian region already accounts for about 35% of today's global general lighting market, and is expected to rise to 45% by 2020, according to recent studies. The Chinese lighting market alone, which is worth over €8bn, is predicted to more than double by 2020. In fiscal 2011, Osram generated about a fifth of its revenue in the Asia-Pacific region, where it employs over 16,000 staff. This workforce is larger than that of any other region worldwide, and roughly half of the firm's Asian staff is employed in China. Osram has marketed products in the region for about 80 years, covering all major stages in the value chain from development and production to sales.

www.osram-os.com

Model of planned Osram's plant new back-end LED assembly plant.

Osram and Samsung settle all LED lawsuits, including license agreements for patent portfolios

MoU signed to explore co-developing LED-based products

Osram AG (a subsidiary of Siemens AG of Munich, Germany and the world's second largest lighting manufacturer) and South Korea's Samsung Electronics Co Ltd (the world's largest maker of TVs, memory chips and smartphones) have agreed to settle all patent infringement lawsuits between them worldwide. The patent suits had been filed in various countries including Germany, South Korea and the USA.

In the USA in particular, Samsung had filed a case against Osram with the US International Trade Commission (ITC) in Washington, and that was scheduled for trial on 13 August. Osram's case against Samsung went to trial in July, and the judge had been expected to release findings in October.

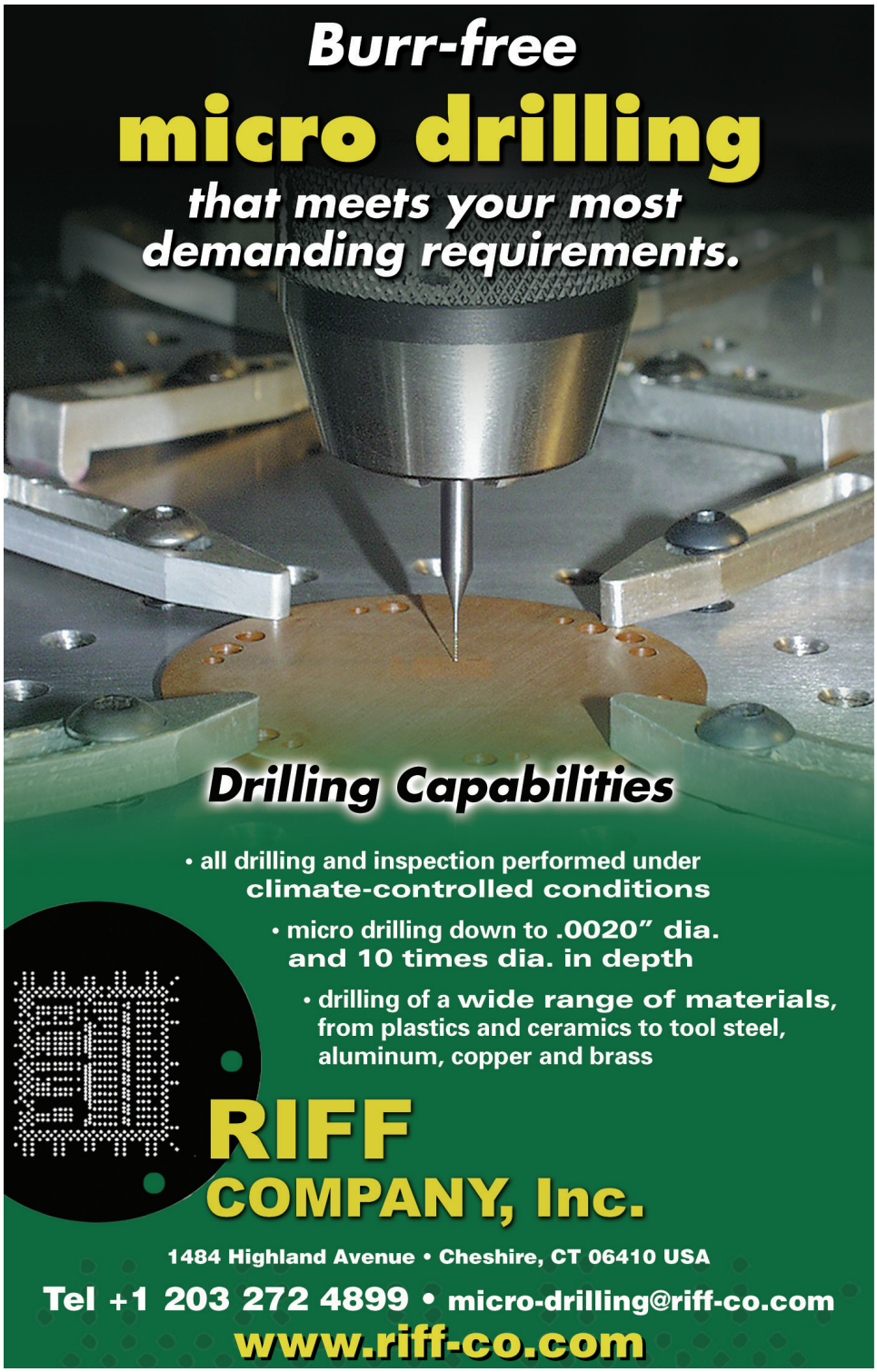
The parties now say that they will dismiss all suits as expeditiously as possible, with a settlement consequently expected to be finalized by the end of August.

As part of the settlement, the parties have reached license agreements for their respective LED patent portfolios. The parties have also signed a separate memorandum of understanding (MoU) to explore the possibilities of jointly developing future LED-based products.

"We are glad to enter with Samsung in a new area of partnership-based competition. We respect the intellectual property rights of other companies and it is our ongoing policy to reach license agreements with other manufacturers of LED products. Along these lines, we appreciate this out-of-court settlement with Samsung," says Osram's CEO Wolfgang Dehen.

"With the patent suits now behind us, we look forward to building a strategic relationship with Osram on a number of different fronts. There is a great deal of respect and also competition between the two companies. We believe the two companies now have an opportunity to significantly contribute to the LED industry and offer better products to our customers," says Namseong Cho, executive VP & general manager of Samsung Electronics' LED business.

www.osram.com
www.samsung.com



Smallest semiconductor laser emits CW green light below 3D diffraction limit

InGaN/GaN core-shell rod on silver film yields plasmon-based nanolaser

Physicists at The University of Texas at Austin, in collaboration with colleagues at Taiwan's National Tsing-Hua University and National Chiao-Tung University and at the Beijing National Laboratory for Condensed Matter Physics and Institute of Physics, Chinese Academy of Sciences, have developed what is claimed to be the world's smallest semiconductor laser, with photonic applications ranging from computing to medicine (Y.-J. Lu et al, 'Plasmonic Nanolaser Using Epitaxially Grown Silver Film', July 27 issue of Science).

The researchers say that miniaturizing semiconductor lasers are key to the development of faster, smaller and lower-energy photon-based technologies, such as ultrafast computer chips; highly sensitive biosensors for detecting, treating and studying disease; and next-generation communication technologies. Such photonic devices could use nanolasers to generate optical signals and transmit information, and have the potential to replace electronic circuits. However, the size and performance of photonic devices have been restricted by the three-dimensional optical diffraction limit (limiting the ability to distinguish between two objects separated by a distance of less than about half the wavelength of the light).

"We have developed a nanolaser device that operates well below the 3D diffraction limit," says Chih-Kang 'Ken' Shih, professor of physics at The University of Texas at Austin. "We believe our research could have a large impact on nanoscale technologies," he adds.

Shih and his colleagues have reported the first continuous-wave (CW) operation of a low-threshold laser below the 3D diffraction limit. When operated, the nanolaser emits green light. The laser is also too small to be visible to the naked eye.

The device is constructed from a gallium nitride (GaN) nanorod that is partially filled with indium gallium nitride (InGaN), both commonly used materials in LEDs. The single InGaN/GaN core–shell nanorod gain medium is placed on top of a thin (5nm-thick) insulating layer of silicon dioxide that in turn covers a 28nm-thick atomically smooth layer of silver film deposited by molecular beam epitaxy (MBE).

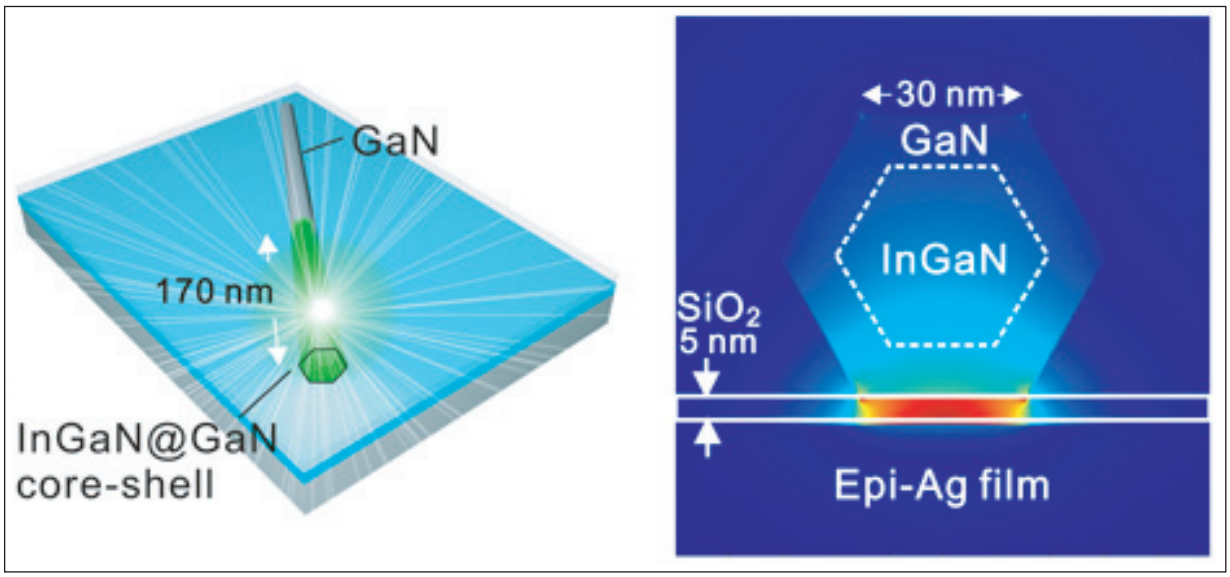
Shih's lab has been developing the material for more than 15 years. The atomic smoothness is key to building photonic devices that do not scatter and lose plasmons (waves of electrons that can be used to move large amounts of data). "Atomically smooth plasmonic structures are highly desirable building blocks for applications with low loss of data," says Shih.

Nanolasers such as this — i.e. a SPASER (surface plasmon amplification by stimulated emission of radiation) — could provide for the development of chips where all processes are contained on the chip, which could prevent heat gains and information loss typically associated with electronic devices that pass data between multiple chips, the researchers say.

"Size mismatches between electronics and photonics have been a huge barrier to realize on-chip optical communications and computing systems," says Shangjr Gwo, professor at Taiwan's National Tsing Hua University and a former doctoral student of Shih's.

Shih and Gwo's colleagues include Gennady Shvets, professor of physics at The University of Texas at Austin, and Lih-Juann Chen, professor at National Tsing Hua University.

www.ph.utexas.edu/~nemrg



Nanoscale structure used for demonstrating ultralow-threshold nanolaser. A single nanorod is placed on a 28nm-thick silver film. The resonant electromagnetic field is concentrated at the 5nm-thick silicon dioxide gap layer sandwiched by the nanorod and the atomically smooth silver film.

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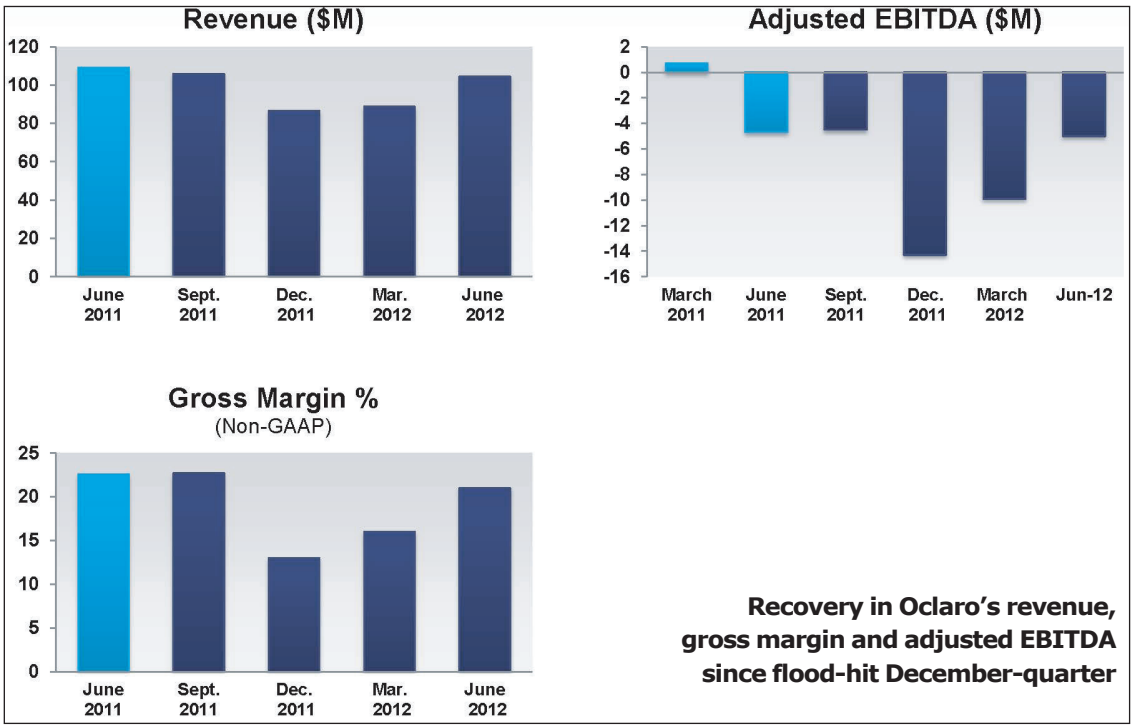
Oclaro's revenue almost back to pre-flood levels

Post-Opnext merger cost-saving plan accelerated to counter flat market in second-half 2012



Recovery in Oclaro's revenue, gross margin and adjusted EBITDA since flood-hit December-quarter

For its fiscal fourth-quarter 2012 (to end-June), optical communications and laser component, module and subsystem maker Oclaro Inc of San Jose, CA, USA has reported a second consecutive quarter of growth as it continues to recover from October's flooding at Thailand-based primary contract manufacturer Fabrinet Co Ltd (which made 30% of Oclaro's total finished goods). After the low of $86.5m in the December 2011 quarter, revenue has grown by 18% from $88.7m last quarter to $104.4m (although this is still down 4.4% on $109.2m a year ago).

Production capability is back to pre-flood levels. But revenue has not necessarily returned fully because customers had to go to alternate sources and are hence still giving some business to them, notes chairman & CEO Alain Couder. However, over time, Oclaro expects to recover that revenue.

After dipping to $12.2m in the December quarter due to high-power laser production being flood hit and vertical-cavity surface-emitting laser (VCSEL) revenue for consumer applications being seasonally down, revenue from Industrial & Consumer products has continued its recovery, growing for a second consecutive quarter, by 14% from $13.3m last quarter to $15.2m (and up 4% on $14.6m a year ago).

Although still down 11.6% on $41.2m a year ago, revenue from Amplification, Filtering and Optical Routing (amplifiers, micro-optics, dispersion compensation, wavelength select switching (WSS) modules and subsystems and ROADM line-cards) has grown again, by 54% from $23.6m last quarter to $36.4m, due mainly to increased production output on flood recovery product lines.

While also down 11.6% on $31.1m a year ago, revenue from Telecom Components (lasers, modulators, laser pumps, receivers, and integrated lasers and modulators) has grown again, by 17% from $23.5m last quarter to $27.5m.

However, after peaking at $31.4m in the December quarter, revenue from Transmission Modules (10G and 40G transponders and transceivers) has fallen for a second consecutive quarter, by 10.6% from $28.3m last quarter to $25.3m (although still up 14% on $22.2m a year ago).

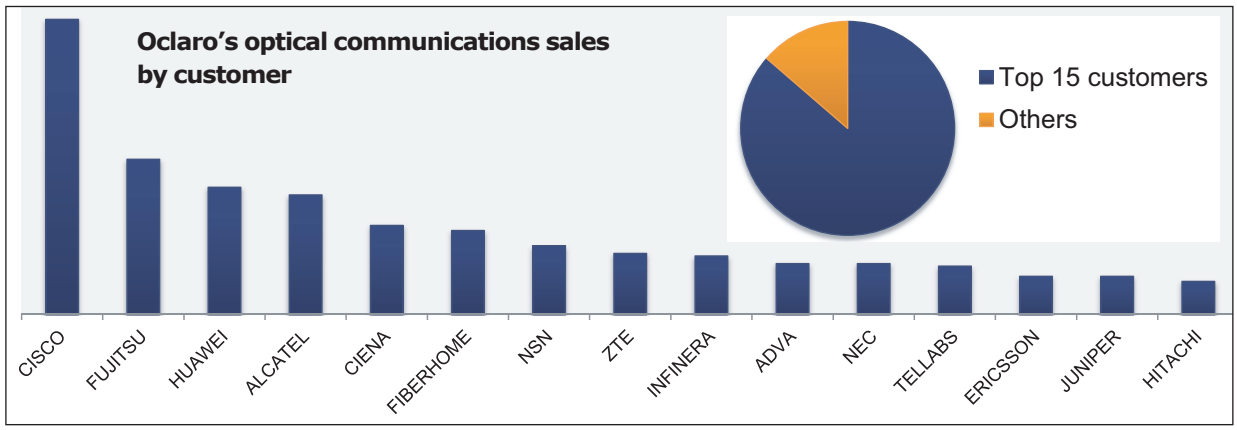
Non-GAAP gross margin has continued to recover, from 13% in the December quarter and 15.9% last quarter to 20.9% (though still down on 22.9% a year ago).

R&D expenses have risen from $14.7m last quarter to a more usual $16.9m, selling, general & administrative (SG&A) from $14m to $14.8m, and restructuring, acquisition & related costs have tripled from $2.2m to $6.7m. However, a gain on the sale of property and equipment of $11.6m led to overall operating expenses (OpEx) falling from $29.6m to $25.4.

Adjusted EBITDA (earnings before interest, taxes, depreciation and amortization) has been halved from a loss of negative $9.9m last quarter to negative $5m, and is almost back to the negative $4.7m of a year ago.

Oclaro received $19m in net proceeds from the sale of its back-end assembly building in Shenzhen, China and $4.6m in additional insurance advances associated with flood-related losses. During the quarter, cash, cash equivalents and restricted hence cash rose from $51.1m to $62.4m.

Full-year fiscal 2012 financial results were materially impacted by the floods in Thailand. Revenue was $385.5m, down on$466.5m in fiscal 2011. Non-GAAP gross margin fell from 26.8% to 18.6%. Adjusted EBITDA was negative $33.7m ($1.21 per diluted share), compared with positive $17m ($0.04 per diluted share) in fiscal 2011.



For fiscal first-quarter 2013 (ending 29 September 2012), Oclaro expects revenue of $154–168m, non-GAAP gross margin of 17–21% and adjusted EBITDA of negative $17–8m. However, this includes financial results of optical component, module and subsystem maker Opnext Inc of Fremont, CA, USA since its merger (announced in late March) was finalized on 23 July. Separately, demand for both Oclaro and Opnext is expected to be relatively flat on the June quarter. No real synergies of the merger will come into play in the quarter in terms of gross margin in particular, says Oclaro, so there will not be much change from a margin point of view from the two predecessor firms.

The merged company has now reorganized into three business units, combining all former Oclaro and Opnext business units: the Photonic Component business unit (PCBU, managed out of Europe but with R&D and new product introduction in China); the Module & Devices business unit (MDBU, managed out of Japan, combining Opnext's Japan team and California business unit plus some Oclaro products from Europe); and the Optical Network Solutions business unit (ONSBU, managed out of North America, but with new product introduction in China). In particular, since Opnext did not have a strong presence in Europe and Oclaro did not have a strong presence in Japan, the merged company creates a stronger global footprint, reckons the firm.

"With the close of our merger with Opnext, we are well positioned as the number 2 player in the optical components, modules and subsystems market," says chairman & CEO Alain Couder. "Moving forward we are focused on accelerating the synergies of our combined business and capitalizing on the strengths of our customer relationships, comprehensive product portfolio and technologies," he adds.

The original synergy plan (announced in March) targeted annualized savings of $35–45m after 18 months. However, the firm says that, compared with when the merger was announced in March, the market for second-half 2012 is now weaker (flat on first-half 2012), despite a pick up from some customers in North America and Japan. "Since March, we have seen the Chinese market slow down [in telco build-outs] while the European situation is not recovering," says Couder.

Oclaro has therefore now accelerated its synergy plan to target savings of $9m ($35m annualized, mostly in OpEx) as soon as the December 2012 quarter, rising to more than $45m (annualized) after 18 months. Actions to achieve the December-quarter target include the following:

- the firm is now one public company instead of two;
- reductions in workforce (related to the merger) have been triggered;
- a new organizational structure eliminating R&D and product management overlap has been implemented;
- R&D has been structured to approach the firm's investment model run rate of 13% of revenue exiting the December quarter.
- sales & marketing organizations have been aligned; and
- SG&A expenses (excluding information systems) to be cut by nearly 20%.

According to Couder, improvement in profit margins will be primarily the result of two things: (1) component 'in-feed' (i.e. in-house use of Oclaro components in Opnext products, and of a couple of Opnext components in Oclaro products, whereas previously those components had to be bought in); and (2) moving manufacturing to low-cost regions and to contract manufacturers.

Specifically, regarding manufacturing strategy, Oclaro intends to focus on front-end wafer and chip fabrication by retaining it in-house (a long-term differentiator, and a "key opportunity to profit on leading-edge technology"). However, over the next two years, all back-end assembly & packaging will be moved to contract manufacturers. As well as the divesting of Oclaro's Shenzhen final assembly & test plant to the Malaysia facility of Singapore-based Venture Corporation Ltd (announced in late March), this outsourcing strategy now involves both the firm's Japanese and California back-end operations, as well as the move of Oclaro's back-end operations in Zurich, Switzerland to a combination of Venture and Fabrinet, and moving WSS assembly in New Jersey to Fabrinet.

Full integration is expected to take 18–24 months, so during calendar 2013 the firm reckons it should see a gradual improvement in margins. "We will also be refining the synergies and the related action plans beyond December and into calendar 2013," notes chief financial officer Jerry Turin.

www.oclaro.com

JDSU's quarterly revenue rises 7.4%, driven by growth in North America

...but carrier spending still cautious for rest of 2012

On a non-GAAP basis, for fiscal 2012 (to end-June), JDSU of Milpitas, CA, USA has reported net revenue of $1682.7m, down 7.4% on fiscal 2011's $1816.2m. Fiscal fourth-quarter revenue was $439.3m, down 7% on $472.3m a year ago but up 7.4% on $409.2m last quarter (and above the expected $415–435m). The increase was driven by strength in Communications Test & Measurement (CommTest) and continuing growth and demand for Communications & Commercial Optical Products (CCOP), particularly in North America.

For fiscal Q4, Americas' customers contributed $236.3m (54% of revenue), up from $191.2m (47%) last quarter, due to seasonally higher demand from service providers and higher demand from network equipment manufacturers. Europe, Middle-East and Africa (EMEA) contributed $98.8m (22% of revenue), down from $102.2m (25%) last quarter, as macroeconomic concerns continued to drive cautious spending behaviour. Asia-Pacific contributed $104.2m (24% of revenue), down from $115.8m (28%), due to reduced revenue from a CommTest customer and lower fiber-laser revenue (after a record March quarter).

By segment, Advanced Optical Technologies (AOT) revenue was $58.1m (13.2% of total revenue), flat on last quarter and a year ago.

CommTest revenue was $196.2m (44.7% of total revenue), down 7.1% on $211.3m a year ago but up 10.3% on $177.8m last quarter due to strength in field test instruments (particularly for metro, Ethernet and cable applications).

CCOP revenue was $185m (42.1% of total revenue), down 8.6% on $202.3m a year ago but up 6.9% on $173.1m last quarter. Within CCOP, Commercial Lasers revenue was $29.6m, roughly flat on last quarter but up 6.5% on $27.8m a year ago. Optical Communications revenue was $155.4m, down 10.9% on $174.5m a year ago but up 8.5% on $143.2m last quarter. In particular, nine out of 12 Optical Communications product lines grew sequentially, with significant growth in pluggables and circuit packs. Tunable XFP modules fell from 16% to 11% of Optical Communications revenue, but revenue for reconfigurable optical add-drop multiplexers (ROADMs) grew by just over $2m from last quarter to 23% of Optical Communications revenue, while Super Transport Blade revenue also grew.

New products accounted for 58% of revenue in the firm's core networks market, consisting of Optical Communications and CommTest (including a record high 62% for CommTest). "We are pleased with the progress we have made on disruptive new products, particularly those addressing next-generation networks and enterprise-class datacom markets," says CEO & president Tom Waechter regarding Optical Communications.

We expect global carrier CapEx spending to be up only moderately as they continue to be cautious for the balance of calendar year 2012, driven by lingering economic concerns in Europe and other regions

"Revenue from 40G and 100G components is growing rapidly. We have multiple high-speed modulators and receivers and high-volume production, with many additional customer programs in the development pipeline," notes Waechter.

"We also continue to make solid progress with our TrueFlex product suite designed for next-generation networks of 100G and faster. WSS [wavelength-selectable switch] samples have been delivered to customers, while TrueFlex and next-gen blade design activities is steadily progressing," he adds.

"We have received orders for tunable SFP+, and shipment has started this quarter. As with our tunable XFP, we expect the introduction this quarter of tunable SFP+ to have a significant time-to-market advantage to our competitors," Waechter asserts.

"We are increasing market share and penetration into key accounts with our broad range of client-side pluggable transceivers to address enterprise LAN/SAN needs and the cloud," says Waechter. "Our focus on collaborative innovation continues to resonate with customers, resulting in sequential revenue growth at eight of our top ten Optical Communication accounts."

For fiscal Q4, gross margin has fallen from 46.7% a year ago and 45.5% last quarter to 45%. In particular, CommTest gross margin has fallen from 61.6% last quarter to 60.3%, impacted mainly by inventory-related charges. CCOP gross margin fell slightly from 28.1% last quarter to 27.8%. Specifically, Optical Communications gross margin fell from 24.9% to 24.5% (due to lower overhead absorption as JDSU reduced inventory levels), counteracting Commercial Lasers' gross margin rising from 43.2% to 45.1%. AOT gross margin rose from 47.8% last quarter to 48.3% (driven by product mix).

However, while still down on 12.3% a year ago, operating margin has risen from 7.3% last quarter to 8.7% (on the high end of the forecast 7.5–9%) due to the higher revenue, despite operating expenses rising by $3.4m from last quarter to $159.5m.

In particular, CommTest operating margin grew from 11.3% to 13.3%, while operating margin grew slightly from 8.1% to 8.5% for CCOP and from 33.1% to 33.4% for AOT.

Full-year net income has fallen from $216.7m for fiscal 2011 to $137.3m for fiscal 2012. However, although down on $53.9m a year ago, fiscal Q4 net income was $35.3m, up on $25.3m last quarter on a non-GAAP basis (excluding a $23.7m impairment charge of certain long-lived assets and $10.5m of insurance proceeds associated with October's flooding at contract manufacturer Fabrinet in Thailand).

"JDSU's execution on its strategic priorities is leading to market share gains and financial leverage despite challenging economic conditions," says Waechter. During fiscal Q4, JDSU generated $38m of cash from operations (almost tripling from $13.2m last quarter). Capital expenditure was $15.3m (down slightly from $16.1m). During the quarter, JDSU repurchased $14m of outstanding convertible debt. Overall, total cash and investments hence rose from $749.8m to $752.7m. In addition, after the end of the quarter, the firm retired an additional $50m of debt.

During fiscal Q4, Optical Communications order bookings grew for the fourth consecutive quarter to their highest level in six quarters. However, Waechter cautions: "Although demand drivers continue to increase significantly, we expect global carrier CapEx spending to be up only moderately as they continue to be cautious for the balance of calendar year 2012, driven by lingering economic concerns in Europe and other regions".

For fiscal first-quarter 2013 (ending 29 September 2012) JDSU expects normal seasonality in CommTest demand, and that the current macroeconomic environment will continue to impact customers. CommTest revenue is hence expected to fall seasonally by 9–14% sequentially. CCOP revenue should rise by 3–7%. Taking into consideration the historical September-quarter segment revenue mix (which includes more CCOP and less CommTest as a percentage of total revenue), JDSU hence expects overall company revenue to fall to $415–435m. This includes the AOT segment, which has now been realigned by separating out the bank-card hologram and newly created Optical Security & Performance (OSP) business units. The firm expects revenue to be up 2–5% for OSP and flat for holograms.

Driven mainly by investments in R&D (given the current product investment cycle), operating expenses should rise by $1–2m. Operating margin is expected to fall to 6.5–8.5%. In particular, JDSU expects operating margins of 8–10.5% for CommTest, 9.5–11% for CCOP, about 36% for OSP, and breakeven for the hologram business.

- After more than eight years as a member of JDSU's leadership team, Dave Vellequette is to step down as CFO at the end of August and leave the firm on 29 September. Effective 1 September, senior VP of business services Rex Jackson will assume the role of acting CFO. Since joining JDSU in January 2011, Jackson has been a member of the executive team in key roles, and recently served four years as CFO at public technology companies Symyx Technologies and Synopsys.

www.jdsu.com

Kotura launches SFP variable optical attenuator module integrating optical power monitor function

Expanding the application space for silicon photonics, Kotura Inc of Monterey Park, CA, USA, which designs and makes silicon photonics application-specific integrated circuits (ASICs) for the communications, computing, sensing and detection markets, has launched a new Ultra Variable Optical Attenuator module in a pluggable small form package (SFP-VOA). The new product integrates an optical power monitor function to provide feedback to the Ultra VOA in a control loop design.

The Ultra VOAs have response times of typically less than 1μs. The high-speed performance enables functions such as signal modulation, transient suppression and fast power control in wavelength-division multiplexing (WDM) agile networks. Kotura adds that its VOAs have no moving parts and have logged more than 1 billion device hours in optical networks around the world.

Kotura's new Ultra VOA module.

"Customers like the option of an industry-standard pluggable package," notes VP of product marketing Xavier Clairardin. "Our Ultra VOAs are already among the most widely used in the industry," he claims. "The 20-pin SFP package means that designers can better utilize board space by moving the attenuation function to the front panel. Our new product meets the growing trend towards pluggable optics in telecommunications equipment designs."

The SFP-VOA has lead times of 8–10 weeks for quantities up to 100. It works over the entire C-band range of 1525–1570nm and supports an attenuation range of 0–25dB. The module implements the control loop and feedback circuit using a 5% tap and photodetector.

www.kotura.com

GigOptix's revenue grows 5% in Q2 to record $9.6m

Enters net profit as it extends optical and RF/MMIC product ranges

For second-quarter 2012, GigOptix Inc of San Jose, CA, USA (a fabless supplier of semiconductor and optical components including modulator and laser drivers and transimpedance amplifier ICs based on III-V materials) has reported an 11th consecutive quarter of sequential growth in product revenue, to a record $9.6m. This is up 5% on $9.2m last quarter and 26% on$7.6m a year ago.

On a non-GAAP basis, net income was $385,000, compared with net loss of $409,000 last quarter and $928,000 a year ago. Compared with a loss of $414,000 a year ago, adjusted EBITDA (earnings before interest, taxes, depreciation and amortization) has more than doubled from $515,000 last quarter to $1.2m. During the quarter, the firm purchased about 702,000 shares of its common stock through its Dutch auction tender offer at a cost of $2.2m. Cash and cash equivalents fell from $15.8m to $12.9m.

"Our product lines continue to drive our top line growth as we extend our optical product offerings from telecom to datacom and consumer electronics; further strengthen our RF/MMICs product offering by working with key partners such as our new IBM relationship to expand our presence in the E-band market; and combine the efforts of our optical and ASIC engineering lines," says chairman & CEO Dr Avi Katz.

"We continue to execute on our mission of establishing the company as a leading provider of all devices enabling end-to-end high-speed information streaming over the network, by enhancing our position in the E-band back-haul point-to-point wireless market, and our entry into consumer electronics," says Katz. "In our RF/MMIC business, we were pleased to announce our strategic licensing agreement with IBM to leverage their silicon germanium (SiGe) millimeter-wave transceiver technology that complements our E-band gallium arsenide (GaAs) power amplifier solutions and further drives us into the wireless business," he adds.

"Separately, we also announced the first deployment of one of our optical interconnect chipsets in the consumer electronics market. Those components are now in full production with a leading Japanese manufacturer to enable their high-speed data interconnect module used for HDTV and next-generation HD information transfer on professional studio cameras," continues Katz.

"In addition to these new initiatives, we have continued to productize our 40G and 100G drivers, modulators and transimpedance amplifiers offerings and enhance production access with global Tier-1 datacom and telecom customers," says Katz. "We also introduced our first 400G Mach-Zehnder modulator driver," he adds. "Overall, this quarter we continued to make solid steps to uniquely address the needs of our customers and diversify our business."

"During the first half of fiscal 2012, we made good progress toward our stated goal of achieving $40m of revenue, which reflects growth of approximately 30% for the fiscal year," says GigOptix's senior VP & chief financial officer Curt Sacks. "We are optimistic about the large opportunity in front of us," he adds.

www.gigoptix.com

Advanced Photonix reports quarterly revenue down 23% year-on-year

For its fiscal first-quarter 2013 (ended 29 June 2012), Advanced Photonix Inc of Ann Arbor, MI, USA (which designs and makes silicon, InP- and GaAs-based APD, PIN, and FILTRODE photodetectors, HSOR high-speed optical receivers, and T-Ray terahertz instrumentation) has reported net sales of $6.2m, down 4% on $6.5m last quarter and down 23% on $8.1m a year ago.

However, although still down on 41.6% a year ago (due to lower volumes and price pressures in the HSOR product line prior to cost reduction efforts), gross margin has rebounded from 34.2% last quarter to 36.1%.

Operating expenses were $3.2m (51.8% of revenue), down 15% on $3.8m (46.9% of revenue) a year ago, with R&D spending down from $1.69m to $1.37m.

Adjusted EBITDA (earnings before interest, taxes, depreciation, amortization and stock compensation) was negative $456,000, worsening slightly from negative $416,000 last quarter and +$206,000 a year ago. Cash reserves remain about $3.2m.

"Our fiscal 2013 will have a restrained first half," says chairman & CEO Richard Kurtz. "Recent orders in the telecommunications market, combined with increasing adoption of our T-Ray products, leads us to reaffirm that revenues in the second half of our fiscal 2013 should be approximately 35% higher than the first half, assuming our supply chain can respond accordingly," he adds. "We are seeing an increasing number of opportunities for us to grow in existing markets and expand into new markets."

www.advancedphotonix.com

NeoPhotonics reports higher-than-expected record revenue in Q2/2012

Growth driven by demand for high-speed coherent & access products

For second-quarter 2012, 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, exceeded its financial projections for revenue, gross margin and profitability.

Exceeding the forecast $55–61m, revenue was a record $63m, rebounding by 16% on $54.2m last quarter and up 24% on $52.1m a year ago. "We continued to see positive growth and demand drivers for our Speed and Agility products, which include 100G and coherent technologies, and Access products, which support fiber-to-the-home deployments around the globe," says chairman, president & CEO Tim Jenks.

On a non-GAAP basis, gross margin was 26.5%, up on 23.9% last quarter and 26.4% a year ago, and exceeding the expected 23–25%.

Loss from continuing operations was $1.7m ($0.06 per diluted share, exceeding the expected $0.14–0.22), an improvement on $5.4m ($0.22 per diluted share) last quarter, although still down on income of $0.2m ($0.01 per diluted share) a year ago.

During the quarter, total cash, cash equivalents and short-term investments rose from $83.8m to $107.1m, primarily reflecting the sale of common stock in a private placement transaction, partially offset by growth in accounts receivable and scheduled repayment of notes payable and debt.

For Q3/2012, NeoPhotonics expects revenue of $60–66m, and gross margin of 26–28% (depending mainly on volume and product mix). Non-GAAP diluted loss per share should be $0.02–0.10, excluding expected amortization of intangibles and other assets of about $1.6m and the impact of stock-based compensation of about $2m, of which $1.2m is estimated to relate to gross margin.

www.neophotonics.com

Imec demos nanophotonics components on 300mm silicon photonics wafers using optical lithography

In conjunction with the SEMICON West 2012 event in San Francisco, CA, USA (10–12 July), the nanoelectronics research center Imec of Leuven, Belgium announced what it claims is the first realization of functional sub-100nm photonics components with optical lithography on 300mm silicon photonics wafer technology. Using 193nm immersion lithography, it has achieved the lowest propagation loss ever reported in silicon wire waveguides, and patterned simpler and more efficient fiber couplers.

Imec's industrial affiliation program on optical I/O explores the use of photonics solutions for realizing high-bandwidth I/O in high-performance computing systems. The program is developing silicon photonics processes, devices and circuits using CMOS fabrication processes. Until now, many nanophotonics components have only been demonstrated using lab-scale techniques such as electron-beam lithography. Imec says that it has demonstrated functional Si nanophotonics devices on industry-compatible 300mm wafers using 193nm immersion lithography and 28nm CMOS processes. Imec says that its achievement is a key step in bringing silicon photonics technology into line with CMOS industry standards and hence industry adoption.

The optical waveguides on 300mm wafers have a very low propagation loss, well below 1dB/cm. Moreover, Imec patterned sub-wavelength features and demonstrated optical fiber-chip couplers using 193nm immersion lithography. By applying 193nm immersion lithography for patterning waveguides as well as fiber couplers, Imec eliminated one patterning step in the processing of photonics devices, resulting in a significant reduction in processing cost, it is claimed. By demonstrating low phase errors on 450nm arrayed waveguide gratings (AWGs), Imec says that its patterning platform using 45nm mask technology and 193nm immersion lithography has proved it can yield a very uniform waveguide width within a device.

"Our achievement with 193nm immersion lithography and 28nm CMOS processes on 300mm wafers is an important step in Si photonics development to demonstrate the manufacturability of highly integrated components," reckons Philippe Absil, director of the optical I/O program at Imec. "Possible applications are next-generation short-reach interconnects, which we expect to go into manufacturing by 2015," he adds.

The results were obtained in cooperation with INTEC (Imec's associated lab at Ghent University) and Imec's key partners in its core CMOS programs (Globalfoundries, Intel, Micron, Panasonic, Samsung, TSMC, Elpida, SK Hynix, Fujitsu, Toshiba/Sandisk, and Sony).

www.imec.be

Emcore reports higher-than-expected quarterly growth of 9%, as Fiber Optics revenue recovers by a further 18%

For its fiscal third-quarter 2012 (to end-June), Emcore Corp of Albuquerque, NM, USA has reported revenue of $41.1m, down 17% on $49.5m a year ago but up 9% on $37.8m last quarter (and slightly above guidance of $38–41m), due to higher Fiber Optics revenue offset by a reduction in Solar business.

Photovoltaics has fallen further, by 4% on $15.8m last quarter (41% of revenue) to $15.3m (37%), with the space power business declining slightly. However, PV revenue has historically fluctuated significantly due to the timing of program completions and product shipments of major orders.

While still down 22% on $33.3m a year ago (67% of total revenue), after falling to $18.3m in the December quarter Fiber Optics has continued its recovery, rising 18% from $21.9m last quarter (58% of total revenue) to $25.8m (63%), driven mainly by flood recovery. In October 2011, flood waters severely impacted inventory and production operations at primary contract manufacturer Fabrinet Co Ltd in Thailand (which normally accounts for half of Emcore's Fiber Optics revenue). Impacted areas included product lines for the telecom and CATV market segments.

For fiscal 2012, the flood has resulted in higher manufacturing overhead as a percentage of revenue. Manufacturing of certain fiber optics components was moved to Emcore-owned facilities in the USA, involving higher labor and other related costs. Instead of completely rebuilding all flood-damaged manufacturing lines, the firm decided to realign its fiber-optics product portfolio and focus on business areas with strong technology differentiation and growth opportunities.

After recovering from just 9.3% in the December quarter to 14.2% last quarter, gross margin has fallen back to 10.7%, down on 19.1% a year ago. In particular, PV gross margin has fallen further, from 20.9% last quarter to 13% (down on 18.6% a year ago), impacted by higher losses in terrestrial business, losses from power outage at the Albuquerque site, and lower yields. After recovering from –4.8% in the December quarter to +9.4% last quarter, Fiber Optics gross margin fell back, but only slightly, to 9.3% (down on 19.4% a year ago). This was due mainly to higher margin from increasing revenue being offset by higher excess and obsolete charges, losses on purchase commitments, and yield variances associated with ramping up manufacturing on new products. Also, Fiber Optics products typically have lower margins than PV products, so the swing in revenue mix from PV back to Fiber Optics is unfavorable to margins.

Operating loss has been cut slightly, from $8.9m last quarter to $8.8m. Although down on $11.2m a year ago, it is due mainly to a $2.8m gain recorded in May on the sale of the Fiber Optics segment's enterprise product lines — consisting of vertical-cavity surface-emitting laser (VCSEL)-based products — to Sumitomo Electric Device Innovations USA Inc of San Jose, CA (a subsidiary of Japan's Sumitomo Electric Ltd).

In May, Emcore settled a patent infringement lawsuit (in exchange for a release of all related claims), resulting in a charge of $1.05m. Also, it recorded a $1.4m impairment charge related to long-lived assets associated with its concentrated photovoltaic (CPV) product lines as it announced consolidation of activities into its Suncore Photovoltaics CPV joint venture with China's San'an Optoelectronics.

Excluding flood-related charges, the gain on sale of assets, legal settlements and impairment charges, operating expenses have been cut from $19.2m a year ago and $14.1m last quarter to $13.8m. In particular, selling, general & administrative (SG&A) expenses have been cut from $9.7m a year ago to $8.8m due to cost reductions (including a cut in discretionary spending on staffing and infrastructure, plus lower stock-based compensation expense). R&D expenses have been cut from $9.5m a year ago and $5.8m last quarter to $5m due to cost reductions, as well as lower expense incurred related to developing fiber-optics products.

Non-GAAP net loss was $7.5m, up on $6.3m a year ago and $5.4m last quarter. During the quarter, cash, cash equivalents and restricted cash fell from $25.4m to $20.8m. This was due to increased inventory levels to meet the ramp up in production, equipment purchases associated with the rebuild of the fiber-optics production line, and operating losses (offset partially by proceeds from the sale of the enterprise product lines).

Order backlog for PV has fallen by 17% from $55.7m at the end of March to $46.2m at the end of June (which included $10.1m and $5.1m, respectively, of terrestrial solar cell orders from Suncore). Fiber Optics revenue is still limited by rebuilding production capacity. "We are not using backlog as a measure of the strength of our fiber-optics business," notes chief financial officer Mark Weinswig.

For fiscal Q4/2012 (to end-September) Emcore expects revenue of $46–49m (up 12–20% sequentially), with growth from both the PV and Fiber Optics segments.

"Our results will continue to improve in future quarters as we ramp up our fiber-optics manufacturing lines and increase our revenues in our solar segment and reduce our R&D investment levels in the CPV product lines," believes Weinswig. The Suncore CPV deal is expected to close in fiscal Q4 and result in a reduction in expenses of more than $1.5m per quarter.

www.emcore.com

Emcore completes business & management realignment

Emcore Corp of Albuquerque, NM, USA (which makes components, subsystems and systems for the fiber-optic and solar power markets) has completed both a business and a management realignment in a company-wide restructuring that changes its corporate business and management structure.

In May, Emcore closed the sale of its Enterprise product lines to Sumitomo Electric Device Innovations USA Inc of San Jose, CA (SEDU, a subsidiary of Japan's Sumitomo Electric Industries Ltd, or SEI). The firm has also just signed a definitive agreement that, upon closing, will consolidate its terrestrial concentrator photovoltaics (CPV) business into its joint venture Suncore Photovoltaics Technology Co Ltd. Emcore says that these two transactions mark the completion of its business realignment and allow it to focus its portfolio more effectively on areas where its technology and product solutions have strong differentiation in the marketplace. Losses from these product lines over the past four quarters were about $15m.

"In this complex market environment, it is vital to focus our business scope on those areas with the highest potential for growth and profitability," says executive chairman Reuben Richards Jr, who describes the firm's current business portfolio as a combination of solid sustaining businesses and high-growth areas with sought-after technology. "Emcore is determined to drive its business to achieve profitability."

As a part of this restructuring, Richards proposed to Emcore's board of directors to eliminate the post of executive chairman, retiring from this position on 30 September. However, he will continue to be chairman providing strategic guidance and governance oversight.

With Richards' retirement and the firm's focused business scope and operations, Emcore will realign its management responsibilities accordingly.

www.emcore.com

Emcore consolidates CPV business into US subsidiary of Suncore JV

Emcore has entered into a definitive agreement, subject to closing conditions, to consolidate its terrestrial concentrating photovoltaic (CPV) system engineering and development efforts into its joint venture Suncore Photovoltaics Technology Co Ltd, which has a site in the High-Tech Development Zone of Huainan City, Anhui Province, China.

Emcore has engaged in research, development, and manufacturing of CPV technology and products since 2005, and has been providing cells, receiver assemblies, and complete turn-key CPV systems to the market for both grid-tied utility applications and commercial rooftop solar power applications. In July 2010, Emcore formed Suncore with San'an Optoelectronics Co Ltd of Xiamen, China (which designs and makes products including full-wavelength-range high-brightness LED chips and wafers, solar cells and PIN photodiodes) in order to engage in high-volume manufacturing and business development in China. Suncore Photovoltaics is owned 40% by Emcore and 60% by San'an.

To streamline development and engineering effort for CPV systems, Emcore and Suncore have entered into a definitive agreement to consolidate intellectual property and development efforts for both ground-mount and rooftop terrestrial CPV products — including key engineering, and sales and marketing personnel — to a subsidiary of Suncore in the USA. Suncore's subsidiary will fund all ongoing R&D, marketing, sales and business development related to terrestrial CPV systems. Emcore says it will continue to own all of its intellectual property related to solar cell technology and maintain investment activities to advance CPV cell performance to serve a broader customer base within the CPV industry.

Staff engaged in product and business development for terrestrial CPV will be transferred to Suncore

"This announcement will allow Emcore to focus its efforts on our core competency of multi-junction solar cell technology for both space and terrestrial power applications," says chief operating officer Christopher Larocca. "Emcore will continue to support Suncore through supply of advanced CPV solar cell products and maintain its presence in the terrestrial CPV systems market through our ownership in Suncore," he adds.

"This transaction provides Suncore with strong R&D capability on top of the existing world-class, low-cost and high-volume manufacturing infrastructure, and allows Suncore to quickly respond to its customers' need in today's fast-changing solar energy market," says Suncore's general manager Dr Charlie Wang. "With our strong IP portfolio, solid financial status, and high-volume manufacturing capacity, Suncore is now ready to serve the worldwide renewable energy industry with state-of-the-art CPV products and technology."

Emcore staff engaged in product and business development for terrestrial CPV will be transferred to Suncore. Emcore executive VP Dr Charlie Wang will join Suncore, continuing to serve as its general manager on a full-time basis upon the closing of the transaction.

www.suncorepv.com

Soitec's CPV technology selected in French call for tenders for 'large solar power plant' projects

Soitec of Bernin, France says that its concentrator photovoltaic (CPV) technology is present in most of the eight projects in the sub-category 'concentrator solar plants with installed capacity of less than 12MW' after the selection of successful participants in the call for tenders to build and operate 'large solar power plants' (with individual capacity of over 250kWp), launched in September by France's Energy Regulatory Commission (CRE, Commission de régulation de l'énergie).

Recently selected by Delphine Bathot, French Minister of Ecology, Sustainable Development and Energy, the eight projects have over 54MW in total capacity, with CPV solutions accounting for at least 30% of each project's installed capacity.

"Their go-ahead depends of course on gaining all the requisite permits and their design may yet be tweaked by the various partners," notes Gaetan Borgers, executive VP of Soitec's Solar Energy Division, of the projects. "This choice reflects not only their confidence in our technology, but also in our manufacturing capabilities," he comments. "We possess a great deal of experience in large-scale manufacturing,

Soitec's CPV solar modules.

with automated lines and certified processes."

Soitec says that the solar energy conversion efficiency of its CPV modules is near to 30% — double that of conventional photovoltaic products.

"The announcement of the winners of this call for tenders illustrates the determination of our government to foster the emergence of a first-class solar energy industry," comments Soitec's chairman & CEO André-Jacques Auberton-Hervé. "Our company is originally from the Grenoble area of southeastern France, but thanks to its innovation and its expertise, it has established itself in global markets," he adds. "These projects will help to establish the ramp-up in the highest-performance technologies. For example, we are already working on development of a new, very high-performance cell."

Soitec's CPV technology uses triple-junction cells mounted on a glass plate. Fresnel lenses (manufactured using silicone on glass) concentrate sunlight 500 times before it reaches the photovoltaic cells. A metal frame holds two glass plates to form highly robust, durable and resilient modules. By combining several modules on biaxial trackers (based on a proprietary algorithm automatically optimizing their position based on the path of the sun), Soitec maximizes energy generation throughout the day.

Soitec says that its work on a new type of cell should ultimately enable it to achieve an energy yield of about 50%. In addition to its teams in France, Soitec also has 70MW in production capacity in Germany (with ISO 9001 and ISO 14001 certification). In the future, this manufacturing base will be boosted by Soitec's new plant in San Diego, CA, USA, which will ultimately add 200MW in capacity.

www.soitec.com

Tensoft's Fabless Semiconductor Management ERP and supply chain solution chosen by Solar Junction

Tensoft Inc of San Jose, CA, USA, an end-to-end ERP (enterprise resource planning) and supply chain solution provider for the technology industry, has signed a SaaS (software-as-a-service) agreement with San Jose-based Solar Junction to use Tensoft's Fabless Semiconductor Management (FSM) and Microsoft Dynamics as its core ERP and supplier collaboration solution.

Founded in 2007 as a developer of III-V multi-junction solar cells based on proprietary adjustable-spectrum lattice-matched (A-SLAM) materials for concentrated photovoltaics (CPV), Solar Junction sought a cloud solution to manage its rapidly expanding business. "Solar Junction evaluated various vendors during our system selection process," says Solar Junction's VP of finance Ivan Fujihara. "After an in-depth review, we selected Tensoft's semiconductor ERP solution as a backbone toward scaling our company's solar cell operations," he adds.

"We're pleased to work with Solar Junction to streamline their solar energy cell manufacturing process," says Tensoft's president & CEO Bob Scarborough. "A cloud-based implementation will ensure the optimal security, reliability, and scalability that Solar Junction requires to thrive in this burgeoning industry."

www.sj-solar.com
www.tensoft.com

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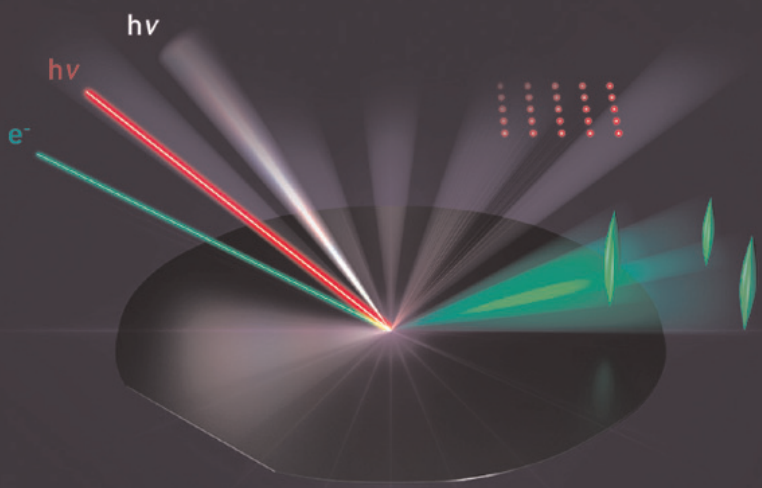

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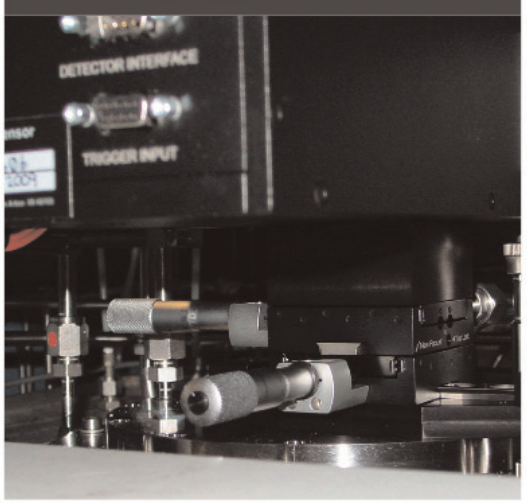

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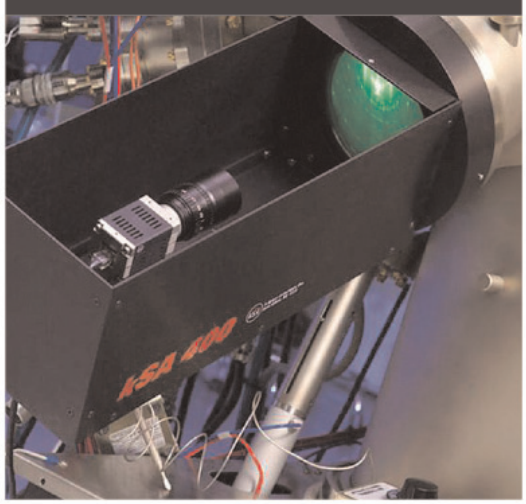

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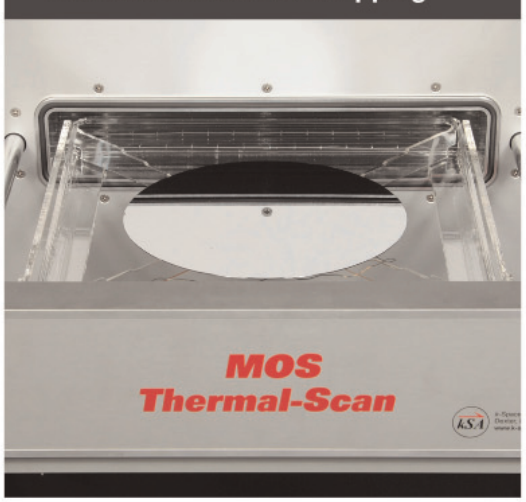


kSA Rate Rat Pro Thickness & Deposition Rate

kSA BandiT PV Process Tuning

First Solar sales almost double to $957m in Q2 as projects reach revenue recognition

Full-year forecast raised from $3.5–3.8bn to $3.6–3.9bn

For second-quarter 2012, 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 $957m, up 92% on $497m last quarter and 80% on $532.8m a year ago. Growth was due mainly to an increase in the number and size of projects under construction meeting revenue recognition criteria during the quarter, including Antelope Valley Solar Ranch 1 in California and Silver State North in Nevada.

"Despite market uncertainties, First Solar delivered strong performance in the quarter," comments CEO Jim Hughes. Compared with net income of $61.1m ($0.70 per fully diluted share) a year ago and a net loss of $449.4m ($5.20 per fully diluted share) last quarter, First Solar has returned to net income of $111m ($1.27 per fully diluted share).

However, this was impacted by pre-tax charges of $36m ($0.39 per fully diluted share) consisting of (i) $23.7m (reducing earnings per share by $0.25) related to $19m of expenses for the restructuring announced on 17 April plus $4.7m of costs associated with the repayment of debt for the German manufacturing center; and (ii) $12.5m (reducing earnings per share by $0.14) related to costs in excess of normal warranty expense associated with remediation of a manufacturing excursion between June 2008 and June 2009. Excluding these charges, non-GAAP net income was $144.9m ($1.65 per fully diluted share). During the quarter, cash and marketable securities fell from $750m to $744m.

Based on reductions in its ongoing cost structure related primarily to restructuring initiatives, First Solar is increasing its 2012 guidance for sales from $3.5–3.8bn to $3.6–3.9bn, and for earnings per fully diluted share from $4.00–4.50 to $4.20–4.70 (excluding restructuring and impairment charges, and costs in excess of normal warranty expense). This comes after in May raising guidance from $3.75–4.25.

"We are confident we have the right long-term strategy and the right platform to enable long-term growth and value creation," says Hughes. "By executing our strategic roadmaps and completing our restructuring program we can achieve our targets of 2.6–3.0GW of sales in sustainable markets, earning a return on invested capital of 13–17% by 2016," he believes.

First Solar appoints CEO James Hughes to board

First Solar has announced the election of CEO James Hughes to its board of directors.

After joining First Solar in March as chief commercial officer, Hughes was appointed CEO in May, succeeding founder & chairman Mike Ahearn, who had been serving as interim CEO since October 2011.

Hughes has nearly 20 years of experience in the global energy industry. Before joining First Solar, he was CEO of AEI, which owned and operated power distribution, conventional and renewable power generation, natural gas transportation and natural gas distribution businesses in 19 countries. Prior to that, he was president & chief operating officer for Prisma Energy.

Hughes also has a juris doctor from the University of Texas at Austin School of Law, a Certificate of Completion in international business law from Queen Mary's College, University of London, and a bachelor's degree in business administration from Southern Methodist University.

www.firstsolar.com

Thai operating subsidiary and Bangkok office established

Over 12MW of projects installed since entering Thai market in 2011

First Solar has established the operating subsidiary First Solar (Thailand) Ltd and opened an office in Bangkok.

The firm reckons that creating the local subsidiary will better enable it to execute its strategy to expand the market for utility-scale solar PV power plants in the local market, and to deliver value to Thai solar power producers.

"The long-term energy fundamentals in Thailand are very favorable for a solar power solution to meet their growing energy needs, and we will continue to invest here as part of our strategy to develop sustainable, utility-scale solar markets," says Won Park, senior manager, business development.

First Solar says that Thailand is expected to remain an important solar market in Southeast Asia due to its strong economic growth, significant energy demand and abundant solar resource. The firm entered the Thai PV market in 2011, and since then more than 12MW of solar projects have already been installed or are under construction using First Solar's modules.

www.firstsolar.com

State Governor celebrates groundbreaking on Maryland's largest PV project

Joined by local elected officials and representatives from FirstEnergy Solutions (a subsidiary of FirstEnergy Corp) and cadmium telluride (CdTe) photovoltaic module maker First Solar Inc of Tempe, AZ, USA, Maryland Governor Martin O'Malley broke ground on a new, 160 acre solar farm project on the grounds of the Maryland Correctional Institution (MCI) in Hagerstown, MD. Once built, the Maryland Solar project will produce 20MW — enough to power about 2700 Maryland homes, displacing about 23,000 metric tons of CO_2 annually (equivalent to taking 4400 cars off the road each year). The project will create 125 construction jobs, and at least three full time jobs will be created for the lifetime of the panels on the site.

The Maryland Department of General Services conducted a competitive leasing process for the land, and the solar project was awarded the lease for a term of 20 years. The project represents FirstEnergy's fulfillment of its renewable energy commitment pursuant to the negotiated settlement between it and the State as a condition of its merger with Allegheny Power. FirstEnergy Solutions has agreed to purchase the 20MW output for 20 years under a long-term purchase power agreement (providing the project with the source of guaranteed revenue necessary to obtain financing for its construction). Over the term of the lease, First Solar — which has a 100% stake in the project — will pay nearly $460,000 in rent to lease the land from the State.

"Over the last few years, we've helped put 2000 men and women to work in solar sector jobs, and we estimate that over the next six years we'll put another 10,000 Marylanders to work in the industry as we work towards our goal of increasing in-state renewable generation by 20%," says O'Malley.

Maryland's Renewable Energy Portfolio Standard (RPS) — enacted in May 2004 — was amended in 2007 to include a solar requirement of 2% by 2022 and resulted in the development of more than 1250MW of solar capacity. In 2008, the O'Malley-Brown Administration signed legislation that more than doubled the overall RPS to 20% and accelerated the compliance schedule. This year, legislation passed that accelerated the 2% solar target from 2022 to 2020. Maryland has seen great market growth in solar power since 2007, resulting in the State being named as a 'top 10' solar state by the Solar Energy Industries Association. Maryland now supports more than 2000 solar installation industry jobs.

We've helped put 2000 men and women to work in solar sector jobs. Over the next six years we'll put another 10,000 Marylanders to work in the industry as we work towards our goal of increasing in-state renewable generation by 20%

The project involves a unique public–private partnership with Hagerstown Community College (HCC) and the State Department of Public Safety and Correctional Systems (DPSCS). First Solar has agreed to incorporate elements of the construction and ongoing operation of the solar farm into HCC's growing alternative energy program, allowing students to learn firsthand about what it takes to construct and manage a commercial solar farm. First Solar has also agreed to allow pre-release inmates at MCI to participate in the solar farm's routine grounds keeping maintenance.

www.fes.com

First Solar to develop 139MW Campo Verde Solar Project

First Solar Inc of Tempe, AZ, USA says that it is developing the 139MWAC Campo Verde Solar Project, located near El Centro in Imperial County, CA, using its cadmium telluride (CdTe) thin-film photovoltaic modules.

Campo Verde is expected to start construction in third-quarter 2012 and be completed in 2013, creating about 250 construction jobs. San Diego Gas & Electric Company (SDG&E) will purchase the project's output under a 20-year power purchase agreement, which was approved on 24 May by the California Public Utilities Commission.

The project will generate enough electricity to power about 50,000 average California homes, displacing 80,000 metric tons of CO_2 per year (equivalent to taking 15,000 cars off the road).

"First Solar is very pleased to be working with SDG&E for the first time," says Brian Kunz, First Solar's VP of project development, North America.

The Campo Verde project is jointly owned by First Solar and US Solar Holdings LLC (which is a developer of solar-powered generation projects in the USA, with offices in Boise, Phoenix and San Diego).

However, First Solar has contractual rights to acquire a 100% ownership interest and the firm is in the process of completing its acquisition.

www.ussolarholdingsllc.com
www.firstsolar.com

IN BRIEF

AQT Solar unveils prototype 60W CZTS PV module

AQT Solar Inc of Sunnyvale, CA, USA, which makes copper indium gallium diselenide (CIGS) thin-film photovoltaic (PV) solar cells, says that, in conjunction with its module-making partners, it has developed a prototype copper zinc tin sulfide (CZTS) solar module capable of 60W power output.

The firm reached the prototype stage at what it reckons is an unprecedented pace by leveraging its unique, material-agnostic production platform, validating that its commercial platform can support a diverse range of materials required to satisfy the demand for low-cost, high-efficiency cells. AQT has had CZTS modules 'under-sun' testing since early this year.

AQT says that studies to-date demonstrate that, in addition to very low manufacturing costs, its CZTS solar cells have the potential to deliver a wide range of benefits to solar module manufacturers including:

- superior energy harvesting (compared to crystalline silicon);
- minimal mechanical yield losses during module assembly (due to superior durability of glass substrates);
- adaptable and scalable modules made using proven conventional materials and equipment; and
- availability in standard power sizes.

www.aqtsolar.com

AQT's prototype CZTS PV solar modules.

IBM sets efficiency record for thin-film PV using earth-abundant materials

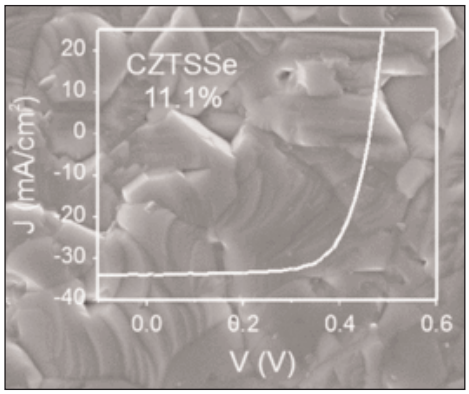
CZTS exceeds 11% conversion efficiency

In partnership with Tokyo-based Solar Frontier (the world's largest maker of copper indium selenium thin-film PV solar modules), Tokyo Ohka Kogyo (TOK) and DelSolar (a subsidiary of Taiwan-based Delta Electronics), the Materials Science team at IBM Research has developed an efficient and affordable photovoltaic cell made of abundant natural materials ('Beyond 11% Efficiency: Characteristics of State-of-the-Art $Cu_2ZnSn(S,Se)_4$ Solar Cells', Teodor K. Todorov et al, Advanced Energy Materials; DOI: 10.1002/aenm.201200348).

Energy from the sun reaching the earth's surface amounts to several thousand times the global consumption of electricity, IBM notes. Yet electricity from PV solar cells currently contributes significantly less than 1% of global production. Of all the existing PV technologies, none so far have combined being highly efficient, cheaply scalable, and made with abundantly available materials, the firm comments.

So far, tests of the new $Cu_2ZnSn(S,Se)_4$ thin-film devices (incorporating readily available copper, zinc and tin, i.e. CZTS) have achieved a record PV solar-to-electric power conversion efficiency of 11.1% (10% better than any previous reports) for this class of semiconductors. The devices can also be manufactured by using simple ink-based techniques such as printing or casting.

Currently, incumbent crystalline silicon solar panels (in applications ranging from home electricity to the International Space Station) are abundant and highly efficient. However, they have extremely high material purity requirements (>99.9999%). Also, the wafers are typically cut from large solid ingots and wired in series to form PV modules, making the technology expensive and difficult to scale up.



Current density versus voltage for CZTS PV cell.

Other thin-film chalcogenide materials used in PV cells, such as $Cu(In,Ga)(SSe)_2$ (CIGS) and CdTe, have been developed to a performance level close to that of silicon, with inherently more scalable processing. Also, they are directly deposited on large-area, low-cost substrates such as glass, metal or plastic foil. However, while CIGS and CdTe are easy to integrate into buildings and consumer products, their compounds contain rare and expensive elements that increase cost and limit their manufacturing levels to less than 100GW per year (global continuous electricity consumption is 15 Terawatts – 150 times greater than what CIGS can produce).

IBM reckons that its CZTS PV cells could yield up to 500GW/year– getting closer to the Terawatt levels of renewable electricity that the planet needs.

The firm says that the focus of the joint-development team remains to further increase device efficiency and transfer the technology to environmentally friendly, high-throughput industrial manufacturing. The hope is that, within several years, the new class of PV materials will begin to contribute to the wider availability of lower-cost solar electricity.

www.research.ibm.com

RIT & Raytheon co-develop HgCdTe-on-Si IR detectors

The US National Science Foundation has awarded Rochester Institute of Technology (RIT) $1.2m to develop, fabricate and test a new family of infrared detectors grown on silicon substrates by Raytheon Visions Systems (RVS) of Goleta, CA.

Cheaper, larger and better infrared detectors grown on silicon wafers could give more scientists access to IR astronomy and further spur the hunt for exoplanets and the study of the universe's acceleration. The same technology could also advance remote sensing and medical imaging.

"The astronomy community will have a ready supply of affordable detectors that could be deployed on a wider range of facilities," says Don Figer, director of the Center for Detectors at RIT and lead scientist on the project. "IR detectors are so expensive that there are only a few on the world's biggest telescopes — Keck, Gemini, the Very Large Telescope," he adds. "Those are the only facilities that can afford them, and then they can only afford a few. They have big telescopes with big focal planes and tiny detectors in the middle."

Building and using advanced astronomical instrumentation is one of the strategic goals of the Center for Detectors, Figer says.

Advancing IR detectors using silicon wafers will leverage the existing infrastructure built around the semiconductor industry and drive down the cost of building detectors, says RIT.

"The collaboration with RIT leverages over a decade of technological advancements Raytheon has made in manufacturing large-format MBE/Si focal planes," says Elizabeth Corrales, program manager at RVS. "IR detectors with lower-cost focal planes and improved performance will push the boundaries of infrared astronomy."

Cost constraints limit availability and scale of current detector technology, which use small, scarcely produced cadmium zinc telluride (CdZnTe) wafers.

"A typical state-of-the-art device has 2048 by 2048 pixels at a cost of around $350,000–500,000," Figer says. "Detectors on large telescopes can cost a significant fraction of the total instrument budget. Very large, affordable infrared arrays will be essential for making optimum use of the proposed 30m-class ground-based telescopes of the future," he adds.

"The key to making larger — up to 14,000 by 14,000 pixels — and less expensive IR detectors lies in using silicon wafer substrates, since large silicon wafers are common in the high-volume semiconductor industry and their coefficient of thermal expansion is well matched to that of the silicon readout circuits."

For the last 15 years, scientists have pursued the use of silicon substitutes in the quest for large IR detectors. But the crystal lattice mismatch between silicon and IR materials has thwarted advancement, since it causes defects that generate higher dark current and thus higher noise, reduced quantum efficiency and increased image persistence.

Atoms in a silicon crystal are spaced more closely together than those in infrared light-sensitive materials. When the IR material is grown on the silicon, defects are generated. Photo-generated charge that represents the signal can get stuck and lost, or pop out of the lattice and show up as a phantom signal. The difference in atomic spacing can create the false signal.

Raytheon has developed the prototype detector technology using a method of depositing light-sensitive material onto silicon — using MBE — while maintaining high vacuum throughout the many process steps.

"Raytheon has come up with an innovation to combine the silicon wafer with the mercury cadmium telluride [MCT, or HgCdTe] light-sensitive layer in a way that eliminates all these bad effects," Figer says. "Our proposal is to do a fabrication run of parts based on this new technology and then evaluate the technology in the laboratory and on a telescope."

RIT and Raytheon will design and fabricate arrays of 1024 by 1024 and 2048 by 2048 pixels and test them at the Center for Detectors.

"Not only are silicon wafers much more affordable, but they can be made in much larger sizes because the wafers are now big," Figer says. "Instead of being a 4" wafer, it can be 12", for instance. We can make a 14,000-by-14,000-pixel detector."

Noise can obscure signals coming from the faint objects in the universe. Figer's team will measure the detector performance using a system based on one he designed for the Space Telescope Science Institute to measure the performance of detectors to be flown on the James Webb Telescope.

Figer will also develop a new light-tight detector housing to keep the detector optically and thermally isolated from everything around it. The box-within-a-box design is cooled to 60K (–350ºF) to reduce the glow (blackbody radiation) emitted from warmer objects around the detector and to prevent additional noise.

The NSF funding to develop the technology will carry Figer and his team to the project's second phase and the design of a much bigger device of 4000 by 4000 pixels. However, an international consortium of organizations is needed to fund fabrication of such large detectors.

"I am going around the world talking to directors of observatories currently in existence and future observatories and asking them if they'd like to join a consortium of organizations, each of which contributes to, and benefits from, the development of the first run of 4K parts," he says. "This is the intermediate step before having a final product."

During the third and final phase of the program, Figer foresees RIT and Raytheon building an instrument for a large telescope. "One of the strategic goals for the Center for Detectors is to start a big astronomical instrumentation program at RIT," he says.

http://ridl.cfd.rit.edu
www.raytheon.com

Intermolecular collaborating with Saudi Arabia's KAUST

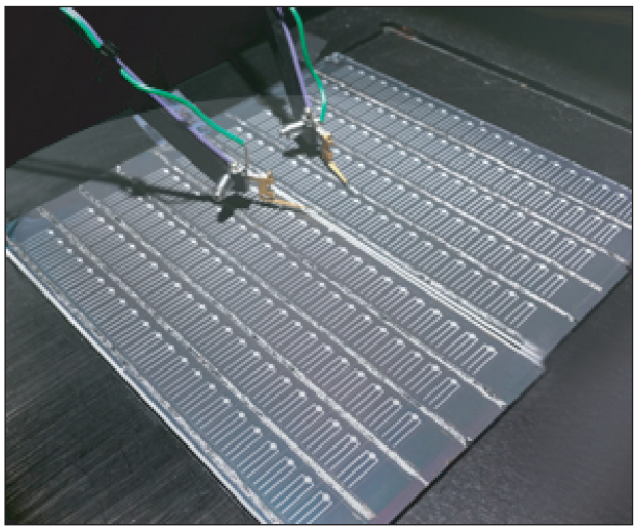
High Productivity Combinatorial platform to speed R&D on CIGS PV materials and process interdependencies

Intermolecular Inc of San Jose, CA, USA has announced an ongoing project with King Abdullah University of Science and Technology (KAUST) for the enhancement of copper indium gallium diselenide (CIGS) thin-film photovoltaic (PV) manufacturing technology.

The metrology capabilities of the Solar and Photovoltaics Engineering Research Center (SPERC) at KAUST in Thuwal, Kingdom of Saudi Arabia, are being used along with Intermolecular's High Productivity Combinatorial (HPC) platform in San Jose to rapidly learn about high-efficiency CIGS solar cell materials and process interdependencies.

Intermolecular says that its mission is to improve R&D efficiency in the semiconductor and clean-energy industries through collaborations that use its HPC platform, which allows R&D experimentation to be performed at speeds up to 100 times faster than traditional methods.

"Working with Intermolecular's team and HPC platform allows us to accelerate our mission of developing sustainable solar power," says professor Ghassan Jabbour, director of SPERC at KAUST.



"The Kingdom of Saudi Arabia is focusing enormous resources on developing renewable energy technologies as part of the strategy to transform its fossil fuel-based economy in the coming decades," he adds. "KAUST is at the forefront of this effort and sees CIGS technology as extremely promising in terms of its potential to deliver the lowest-cost solar electricity in the Kingdom."

The joint project is led by research scientist Dr Jessica Eid, a member of professor Jabbour's team, hosted at Intermolecular's facility in San Jose.

"We are fully committed to accelerating various PV technologies using our HPC platform," says Sandeep Nijhawan, Intermolecular's VP of its Clean Energy Group. "We recently reported progress on our patent-pending sulfur-free, two-step sputtered CIGS approach with fundamental manufacturing benefits at the IEEE PV Specialists Conference (IEEE-PVSC)," he adds. "The breakthrough result of 17.7% active-area CIGS efficiency at an open-circuit voltage of 692mV — which we developed internally in less than one year — reaffirms the broad applicability of our HPC platform to rapidly advance CIGS PV."

Intermolecular's mission is to drive our customers' success by transforming R&D and accelerating innovation in markets that derive competitive advantage from the interaction of materials science, processes, integration and device architecture.

www.intermolecular.com
http://sperc.kaust.edu.sa

MiaSolé reorganizes manufacturing and operations to reduce costs

MiaSolé of Santa Clara, CA, USA, which was founded in 2001 to make copper indium gallium diselenide (CIGS) thin-film photovoltaic panels, is to reorganize manufacturing and operations. The course of action will allow the firm to continue strategic discussions with potential partners.

In a move designed to reduce costs and focus the company on critical functions, MiaSolé will reorganize its workforce to retain employees in the technology, commercial and flexible product areas and to make reductions in manufacturing and operations.

The restructuring is intended to ensure continued CIGS technology development, execution on the firm's sales pipeline, and ongoing development of its flexible product, which the US Department of Energy's National Renewable Energy Laboratory (NREL) verified in May at a record 15.5% solar energy conversion efficiency.

"In the near term we need to conserve costs to enable a strategic partnership," says CEO John Carrington. "The company is looking forward to aligning with a partner and collectively executing on our technology roadmap, flexible product launch and additional capacity to fulfill our 1GW+ commercial pipeline," he adds. "I am confident, based on current discussions, we will finalize a partnership within the next 60–90 days."

www.MiaSole.com

South African CIGS spin-off PTIP orders €7m of equipment from partner Singulus

Singulus Technologies AG of Kahl am Main, Germany, which makes production equipment for the Optical Disc and Solar sectors, says that Photovoltaic Technology Intellectual Property (Pty) Ltd (PTIP), its long-term cooperation partner for the development of more efficient copper indium gallium diselenide (CIGS) thin-film solar modules, has extended its CIGS activities by ordering several of its systems (worth more than €7m) for vacuum coating, selenization and wet-chemical processes.

PTIP is a spin-off from South Africa's University of Johannesburg and already operates research machines for CIGS solar cell development in its newly established R&D facility in Techno Park close to Stellenbosch. Singulus has cooperated with scientists at the university for some years and had already delivered components in 2011. Various companies are currently using PTIP's R&D results and patents worldwide. The activities as well as results have already been presented by PTIP in April as part of the opening in Cape Town of the 'German-South Africa Year of Science', for which 'Climate Change' is one of the core themes.

PTIP intends to further expand the research facilities in Stellenbosch and to commission a development and laboratory line for CIGS modules in the original commercial size of 1200mm x 600mm. The development efforts are a focus of the South African government. The Industrial Development Corporation (IDC) recently supported the expansion of PTIP's operations in Techno Park, acquiring substantial shareholding in PTIP. Additional financial support was obtained from the Technology Innovation Agency (TIA), an initiative of the Department of Science and Technology.

"The support by the IDC and TIA confirms the goal of the South African government to support locally developed IP and to boost alternative and renewable energies, such as photovoltaic," says PTIP's CEO professor Vivian Alberts. "With this support PTIP is now in the position to invest in proven and well engineered equipment and process plants. We are now able to industrially and efficiently implement our developed process with the machines of our partner Singulus," he adds. "The goal is to set up a production line for CIGS thin-film modules in South Africa as soon as possible." The European Investment Bank has already announced €40m of support for the project.

"We are pleased to have already supplied four important process steps in a CIGS line, namely vacuum coating, selenization as well as two process steps in the wet-chemical area," says Singulus' CEO Dr Stefan Rinck. "PTIP's trust is based on the excellent R&D results from the start, which were achieved with our equipment," he adds. "We expect this to also translate to additional expansion stages."

www.singulus.de

Ascent selected to provide BIPV modules for pilot installation at new Foxconn plant

Ascent Solar Technologies Inc of Thornton, CO, USA, which manufactures thin-film photovoltaic modules based on copper indium gallium diselenide (CIGS) using flexible substrate materials, says that it has been selected to provide building-integrated photovoltaic (BIPV) solar modules in a pilot application at the new factory in Zhenzhou City, Henan Province, China of Foxconn Technology Group.

Foxconn is the world's largest manufacturer of electronic devices, and makes products including the iPad, iPhone, Kindle, Playstation and Xbox.

Ascent says that its modules' flexible and lightweight form factor allows them to be integrated seamlessly into the building structure in ways that traditional glass-back PV technology cannot. Integration of the modules will allow the factory to use cost-effective solar power to deliver what is claimed to be the highest power density available on thin-film plastic substrates.

"We plan to demonstrate the value of our technology and we hope to build a long-term relationship with Foxconn," comments Ascent Solar's president & CEO Victor Lee.

www.ascentsolar.com

Ascent has regained compliance with the Nasdaq Stock Market Listing Rules that require maintenance of a minimum $1 bid price.

On 17 August, the firm received notification from The Nasdaq Listing Qualifications department that it had regained compliance with the minimum bid price requirement set forth in Nasdaq Listing Rule 5450(a)(1) after maintaining a closing bid price equal to or in excess of $1 for a minimum of 10 consecutive trading days and that its noncompliance with that rule, as announced on 13 October 2011, had been rectified.

"We continue to work towards regaining the trust and confidence from our shareholders, employees and vendors," says president & CEO Victor Lee.

GSE expands BIPV module into Japan rooftop market

Global Solar Energy Inc (GSE) of Tucson, AZ, USA, which makes flexible copper indium gallium diselenide (CIGS) thin-film photovoltaic cells and modules, has announced an expansion into Japan's growing solar market, establishing local partnerships and offering a new design of its PowerFLEX BIPV (building-integrated photovoltaic) system that has been adapted specifically for use on rooftops in Japan.

Together with Japan-based partners CBC Co Ltd, Eco Holdings and OG Corp, Global Solar aims to enable Japanese businesses to adopt what is claimed to be the most powerful flexible solar roofing module on the market and to take advantage of the country's new feed-in tariff (FIT).

The Japanese government's progressive new FIT program went into effect on 1 July, requiring utilities to pay 42 yen per kilowatt-hour (about $0.52 per kilowatt-hour) for 20 years from solar plants generating 10kW of energy or more. As the country reduces its dependence on nuclear energy and opens the door for more renewable energy adoption through the new FIT, researchers estimate this could foster a solar market of $9.6bn and 3.2GW of capacity.

"With its recent FIT program and proven dedication to integrating more renewable energy into its utilities' portfolio mix, Japan will prove to be one of the most important markets for solar in the coming years," says chief sales officer Jean-Noel Poirier. "With our highly valued partners, Global Solar is well positioned to take advantage of the market growth and bring our powerful and cost-effective PowerFLEX BIPV solar solution to more rooftops around Japan," he reckons.

Global Solar claims that, with 12.6% aperture efficiency, its PowerFLEX BIPV module delivers the highest efficiency in the flexible module sector, with its large format and a high power density (300W) reduce installation and balance of system (BOS) costs. The PowerFLEX BIPV system's lightweight and flexible design suits commercial roofs where traditional glass solar modules are too heavy, the firm adds.

Typical Japanese buildings have compact roofs, making PowerFLEX BIPV a suitable fit as the module allows more power generation per square foot than any other BIPV solution, the firm claims. Also, by being applied directly to a roofing surface and requiring no mounting hardware or roof penetrations, the system maintains the integrity and aesthetics of a building structure.

"Recognizing the desire of many Japanese businesses to reap the benefits of the FIT program while also maintaining the aesthetics of their buildings, Global Solar offers an alternative to traditional heavy and rigid glass modules, as well as other flexible PV products," says Poirier.

Global Solar is already deploying its PowerFLEX systems in Japan, including a completed 400kW rooftop system on the Yokosuka Naval Base (a US military base), which was installed in partnership with Beachside Solar. Also, currently undergoing certification at the Japan Electrical Safety & Environment Technology Laboratories (JET) is a new 4m-long module (200Wp), a PowerFLEX BIPV system that Global Solar has specially designed for the Japanese market, complete with a back junction box allowing integration into various roofing systems. That system, and 2m and 6m modules (100Wp and 300Wp, respectively), are already UL and IEC certified.

Global Solar's German subsidiary applies for insolvency

Global Solar Energy says that — since it is consolidating operations and focusing on growth segments via its 40MWp factory in Tucson — its German executive team has applied for insolvency proceedings at subsidiary Global Solar Energy Deutschland GmbH (GSED).

GSED's operations focused exclusively on PowerFLEX products. Global Solar will continue to produce all product lines at its Tucson plant which, under current market conditions, has sufficient capacity to meet demand. It will no longer operate its 35MWp production facilities in Berlin, Germany.

"The EU renewables market is financially challenging due to high inventories, collapsing prices and significant reductions to European feed-in-tariffs," says CEO Dr Jeffrey Britt. "As a result of this difficult operating environment, a strategic decision has been made to plan and execute an EU capacity reduction and focus investment on the products and technology necessary to meet our customer's needs and fulfill our business plan," he adds. Global Solar will continue to honor all its warranty obligations and service European customers, but from its Tucson facilities.

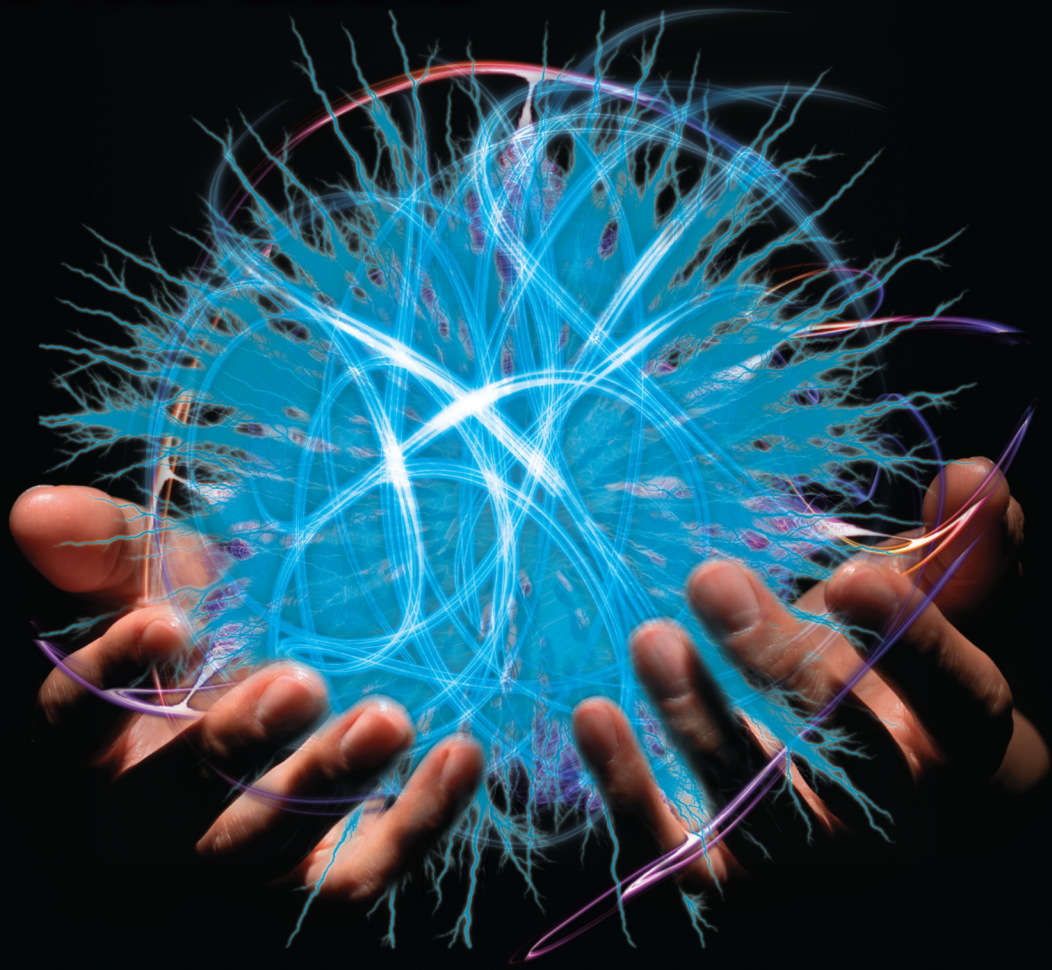
"While unfortunate, the Berlin facility shutdown provides an opportunity to address financial structure issues, appropriately scale production capabilities and align with growing markets in Asia, the Middle East and North America," continues Britt.

Global Solar sells its products into specific sectors such as weight-restricted roofs, integrated building products, military markets and emerging applications. It currently supplies interconnected solar cells for the DOW POWERHOUSE Solar Shingle roofing product line.

With these strategic changes put into effect, Global Solar will also continue with its efforts (announced on 7 June) to pursue new investor participation, being led by FTI Capital Advisors LLC.

www.globalsolar.com

Hold Your Ground



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Teflon and III-V double heterostructure transistors

Researchers at ETH Zurich show how interlayer dielectric can give performance close to that of air-bridges.

The Millimeter-Wave Electronics Group of the Swiss Federal Institute of Technology (ETH) Zurich has been exploring the use of Teflon amorphous fluoropolymer (AF) as an interlayer dielectric for III-V double heterostructure bipolar transistors (DHBT) [Ralf Flückiger et al, IEEE Electron Device Letters, published online 5 July 2012].

Teflon is attractive as an interlayer dielectric (ILD) due to its relatively low dielectric constant (1.9), giving low interconnect delays. Although some applications have been found, "to date, the use of Teflon AF ILDs in high-speed transistor technologies has never been reported," the researchers write.

Most work on III-V transistors uses benzocyclobutene (BCB) as the ILD of choice. BCB's dielectric constant at 2.7 is significantly higher than Teflon's. Teflon's dissipation factor is also 4x lower, and can be cured at lower temperatures than BCB's more than 250°C. High-temperature curing can degrade base contact performance.

The researchers used Teflon with indium phosphide/gallium arsenide antimonide (InP/GaAsSb) devices, but they believe that the approach is equally applicable to gallium indium arsenide HBTs and InP-based high-electron-mobility transistors (HEMTs).

The researchers compared their devices with air-bridge samples (i.e. with no ILD), which give the lowest dielectric constant of 1. However, air-bridge connections suffer from problems such as sagging, which raise difficulties for mass manufacturing robust, reliable devices.

The epitaxial layers for the ETH devices (Figure 1) were grown using metal-organic vapor phase epitaxy (MOVPE). Triple mesa structures were formed (Figure 2 inset). The Teflon interlayer dielectric was spin-coated in perfluorinated solution onto the device and then baked at temperatures that increased in three steps to 110°C (1 min), 165°C (15 min) and 180°C (30 min). The resulting cured 2.7μm layer was

5nm	n-$Ga_{0.25}In_{0.75}As$:Si	Emitter contact
10nm	GaInAs (Ga 49-25%)	Emitter contact
20nm	n-$Ga_{0.49}In_{0.51}As$:Si	Emitter contact
135nm	n-InP:Si	Emitter
15nm	n-GaInP:Si (Ga 20-0%, B-E)	Emitter
20nm	p-GaAsSb:C (As 54-65%, C-E)	Graded base
65nm	n-InP:S	Collector
60nm	InP	Collector
50nm	n-InP:S	Collector pedestal
20nm	n-$Ga_{0.4}In_{0.6}As$:Si	Etch-stop
300nm	n-InP:S	Buffer
	2-inch semi-insulating InP	Substrate

Figure 1. Epitaxial structure of InP/GaAsSb DHBTs.

etched back to 1.7μm, exposing emitter, base and collector contact posts for final interconnect metallization.

The researchers found that their technique provided sufficient planarization and enough dielectric material was left to reliably prevent short-circuiting between device terminals. The researchers believe that multiple layers and higher baking temperatures could improve the planarization, if necessary.

The team has also performed experiments where up to six layers of the Teflon were deposited, giving a stack thickness of 16.8μm. The researchers comment: "These findings suggest that monolithic microwave ICs (MMICs) with multiple metallization layers are feasible with this technology. Previous work by others has further established that Teflon AF films are fully compatible with submicrometer IC processing."

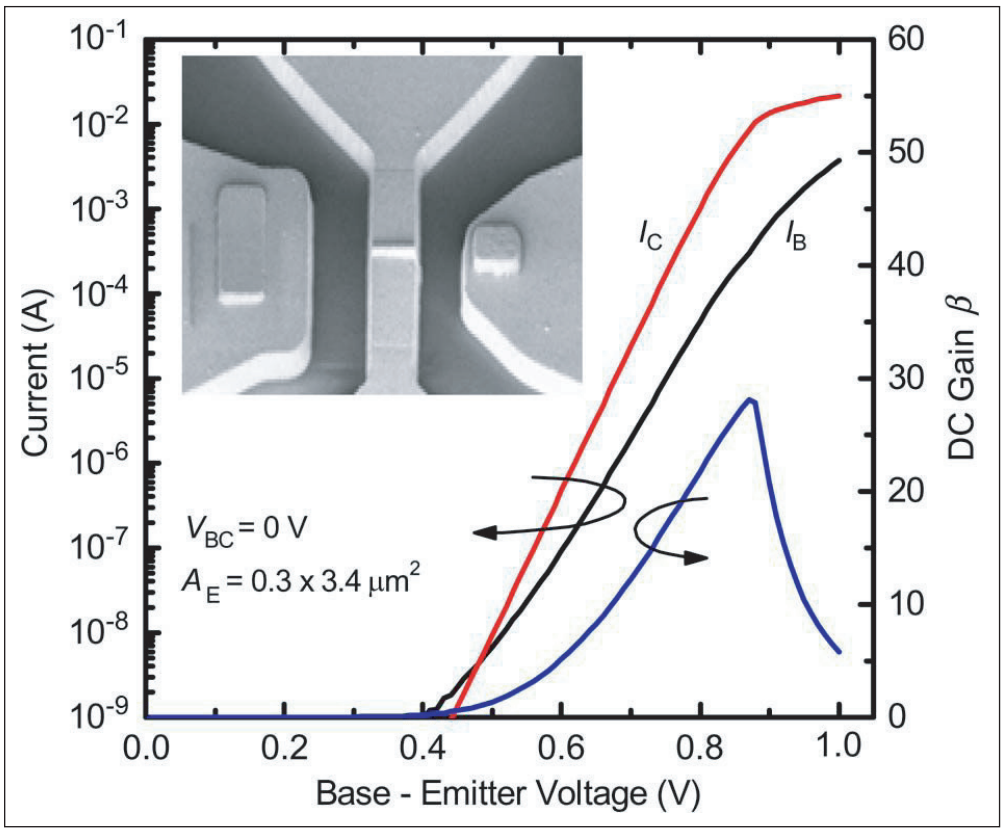

Figure 2. Gummel characteristics for a 0.3μm x 3.4μm DHBT measured with V_{BC} = 0V. The DC gain as a function of V_{BE} is also plotted. (Inset) SEM micrograph of a completed transistor with interconnects on Teflon.

The DC current gain of the resulting device was 28 at 0.87V base-emitter and 0V base–collector biases. The common emitter breakdown voltage at 1kA/cm^2 current density was 5.1V.

Extrapolated cut-off (f_T) and maximum oscillation (f_{MAX}) frequencies were 362GHz (366GHz by Gummel's method) and 450GHz, respectively, at 1.6V collector–emitter bias and with 8.9mA collector current when corrected for pad parasitics ('de-embedded'). The peaking of the two characteristics occurred simultaneously at the given bias condition.

A side-by-side comparison of slightly different epitaxial devices with Teflon planarization and with air-bridge interconnects showed about 3% reduction in frequency performance for Teflon (325GHz/330GHz f_T/f_{MAX}). The reduction of frequency performance was compensated by a 4% improvement in DC gain.

The researchers conclude: "We consider the present developments significant in terms of demonstrating a much needed low-temperature alternative to high-temperature BCB processes, with the added advantage of providing a high-quality interconnect dielectric medium for the realization of millimeter- and sub-millimeter-wave ICs." ■

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Copper wiring for nitride semiconductor HEMTs

Scientists in Taiwan show how GaN HEMTs using copper interconnects with comparable performance to gold promises lower costs.

Taiwan-based researchers have been working to reduce nitride semiconductor high-electron-mobility transistor (HEMT) costs by developing copper interconnect structures compatible with production processes on silicon substrates [Yueh-Chin Lin et al, Appl. Phys. Express, vol5, p066503, 2012]. The collaborators are at National Chiao-Tung University and National Chung-Cheng University.

Nitride HEMTs are being developed for power device applications due to the high breakdown voltages, high electron saturation velocities and high temperature operation that are possible. In conventional production processes, gold wiring is used as the major interconnection metal.

Unfortunately, gold is expensive, with gold prices fluctuating between $1500–1900/ounce in the past year; raw copper has varied between $3 and $4.50 per pound (19–28 cents/ounce). However, it is presumably more expensive to create the pure copper needed for semiconductor processing, and the densities are somewhat different, leading the Taiwan researchers to estimate that copper is 400 times cheaper than gold.

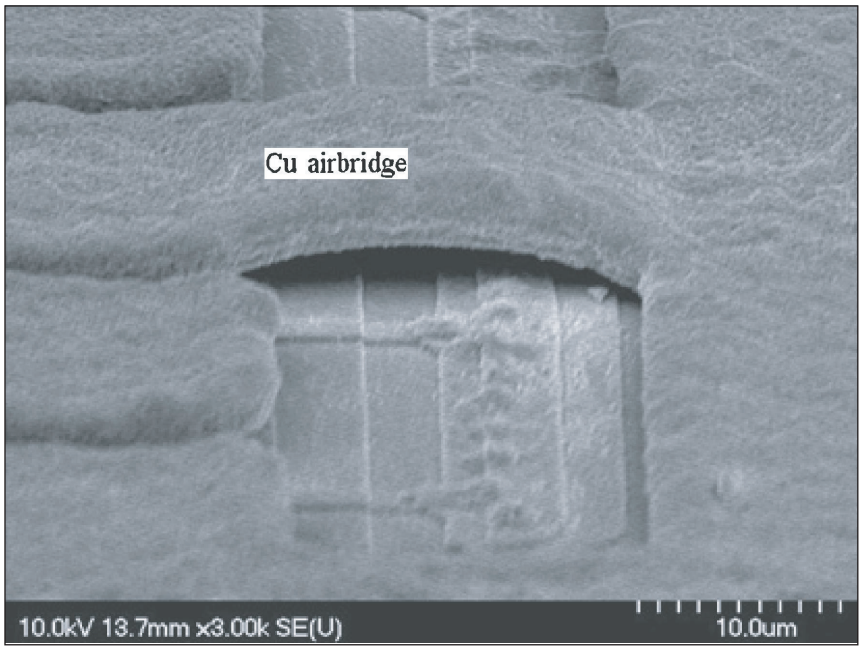

Figure 1. SEM image of the GaN HEMT with Cu airbridges by using a Ti/Pt/Ti/Cu multilayer diffusion barrier.

Further attractive properties of copper include lower resistivity (1.67μΩ-cm versus 2.2μΩ-cm) and higher thermal conductivity (4.01W/cm-K versus 3.18W/cm/K).

The drawback with copper is that it is not compatible with high-performance nitride semiconductor devices. A vital requirement, therefore, is finding a good barrier against diffusion of copper into the underlying nitride semiconductor device.

The epitaxial layers for the Taiwan devices were grown on silicon using metal-organic chemical vapor deposition (MOCVD) and consisted of AlN, AlGaN buffer, GaN channel, AlN spacer, AlGaN Schottky barrier and GaN cap. The ohmic source-drain contacts consisted of titanium/aluminum/nickel/gold annealed at 800°C for 60 seconds in nitrogen. Mesa isolation structuring was performed with a chlorine inductively coupled plasma etch.

The drawback with copper is that it is not compatible with high-performance nitride semiconductor devices. A vital requirement, therefore, is finding a good barrier against diffusion of copper into the underlying nitride semiconductor device

The gate region was defined using photolithography. The Schottky gate contact consisted of nickel/gold. Device passivation was provided by a silicon nitride film. Access to the contacts was achieved by etching through the passivation.

Seeds for the interconnects were sputtered with diffusion barrier layers of titanium/platinum/titanium followed by copper. Further copper was applied through electrolysis using a copper sulfate ($CuSO_4 \cdot 5H_2O$) electrolyte. The interconnect structures included air-bridges (Figure 1).

Auger electron spectroscopy (AES) showed that the diffusion barrier was effective with an anneal at 350°C for 30 minutes, but that a 400°C for the same

amount of time produced diffusion of the gold and copper towards each other, which would result in device deterioration.

Devices with 50μm x 4μm gates produced using copper interconnects, including air-bridges, showed comparable performance to HEMTs with gold-based structures (Figure 2). The maximum drain–source current for a non-annealed HEMT was 1020mA/mm, compared with 1010mA/mm for devices with gold-based interconnects. The threshold voltages were –4.1V and –4.2V for the copper and gold interconnected HEMTs, respectively. The respective peak extrinsic (uncorrected) transconductances at 10V drain bias were 184mS/mm and 187mS/mm.

After 350°C annealing for 30 minutes, the maximum drain current was 1012mA/mm, the threshold voltage was –4.3V, and the peak extrinsic transconductance was 181mS/mm. Stress at a drain bias of 28V showed only a small increase in current up to 24 hours stress time. The researchers comment that these results indicated that the material system was 'quite stable'. ■

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Author: Mike Cooke

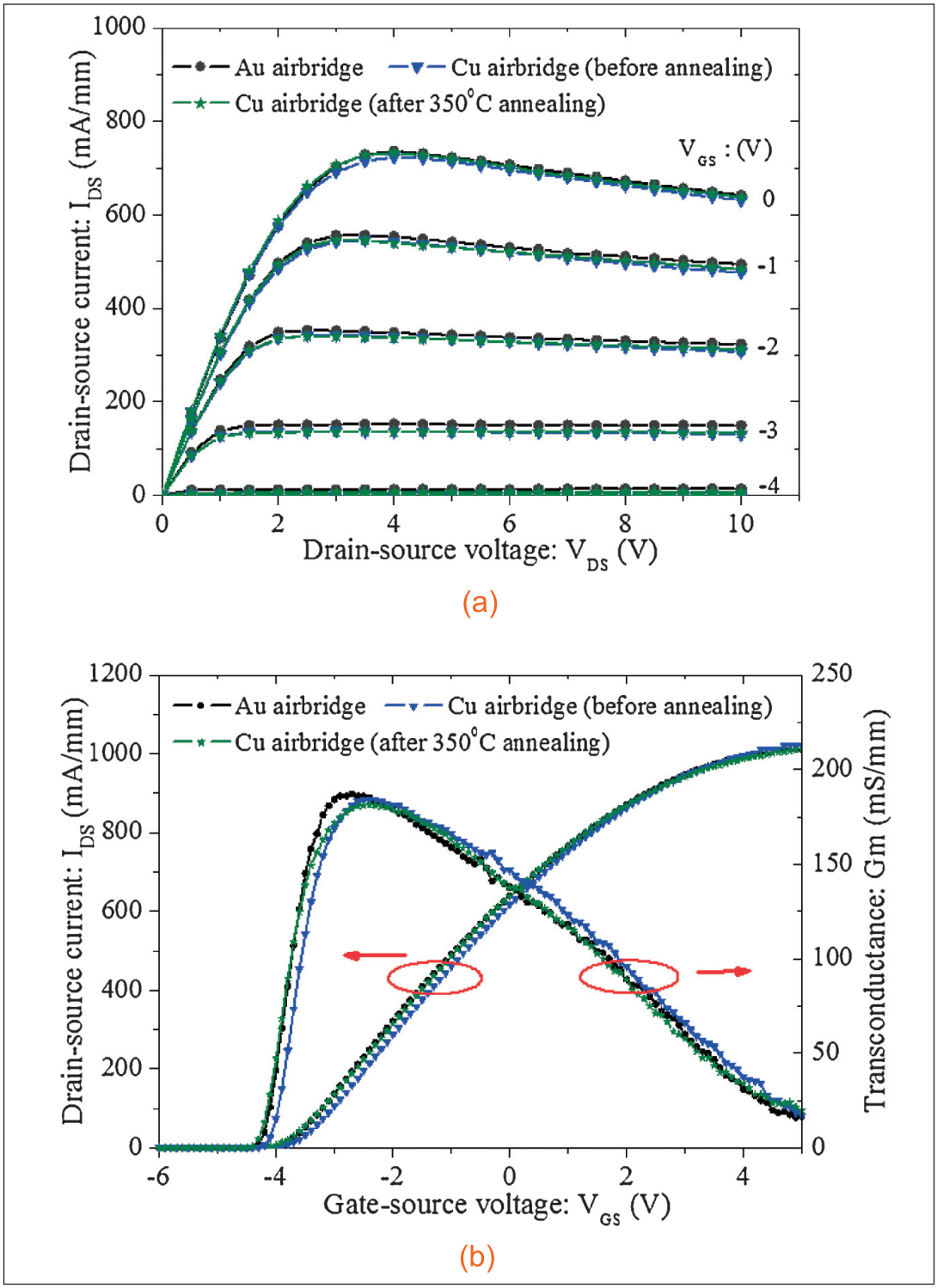

Figure 2. DC characteristics of the 50μm x 4μm-gate Cu-metallized GaN HEMT before and after annealing at 350°C for 30 minutes: (a) drain current vs voltage curves, and (b) extrinsic transconductance and IDS versus gate potential curves.

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Record 370GHz cut-off for InAlN barrier on GaN HEMT

Dielectric-free passivation, rectangular gates and re-grown contacts are shown to reduce the effects of parasitic resistance and capacitance.

University of Notre Dame (UND) and IQE RF LLC of Somerset, NJ, USA have achieved record cut-off frequencies of 370GHz for InAlN/AlN/GaN/SiC high-electron-mobility transistors (HEMTs) [Yuanzheng Yue et al, IEEE Electron Device Letters, published online 7 June 2012].

The use of indium aluminum nitride (InAlN) barrier layers rather than aluminum gallium nitride (AlGaN) allows lattice matching with GaN. In addition, a higher polarization discontinuity leads to higher charge density in the two-dimensional electron gas (2DEG) that forms in the GaN channel layer near the barrier/channel interface. The greater charge density allows for thinner barriers to be used, bringing the gate closer to the channel, improving electrostatic control.

In addition to use of the InAlN-based barrier layers, the UND/IQE team used dielectric-free passivation (DFP), rectangular gates and re-grown source–drain regions to improve performance through a reduction in the effects of parasitic passive resistance and capacitance.

The epitaxial structures were grown on silicon carbide using metal-organic chemical vapor deposition (MOCVD) — see Figure 1. The 1.6μm GaN buffer layer was iron-doped (Fe) to increase its resistivity, hence reducing the amount of current leakage through the buffer. A 200nm unintentionally doped GaN layer was followed by an AlN spacer and $In_{0.17}Ga_{0.83}N$ barrier that is lattice matched to GaN.

Silicon dioxide was used as a mask layer for etch and molecular beam epitaxy (MBE) of the source–drain regions. The separation between the 40nm-deep source–drain wells was 865nm. The source–drain material consisted of silicon-doped n-GaN, grown to a height of 80nm. Polycrystalline GaN was removed from the oxide with a buffer hydrofluoric acid lift-off process.

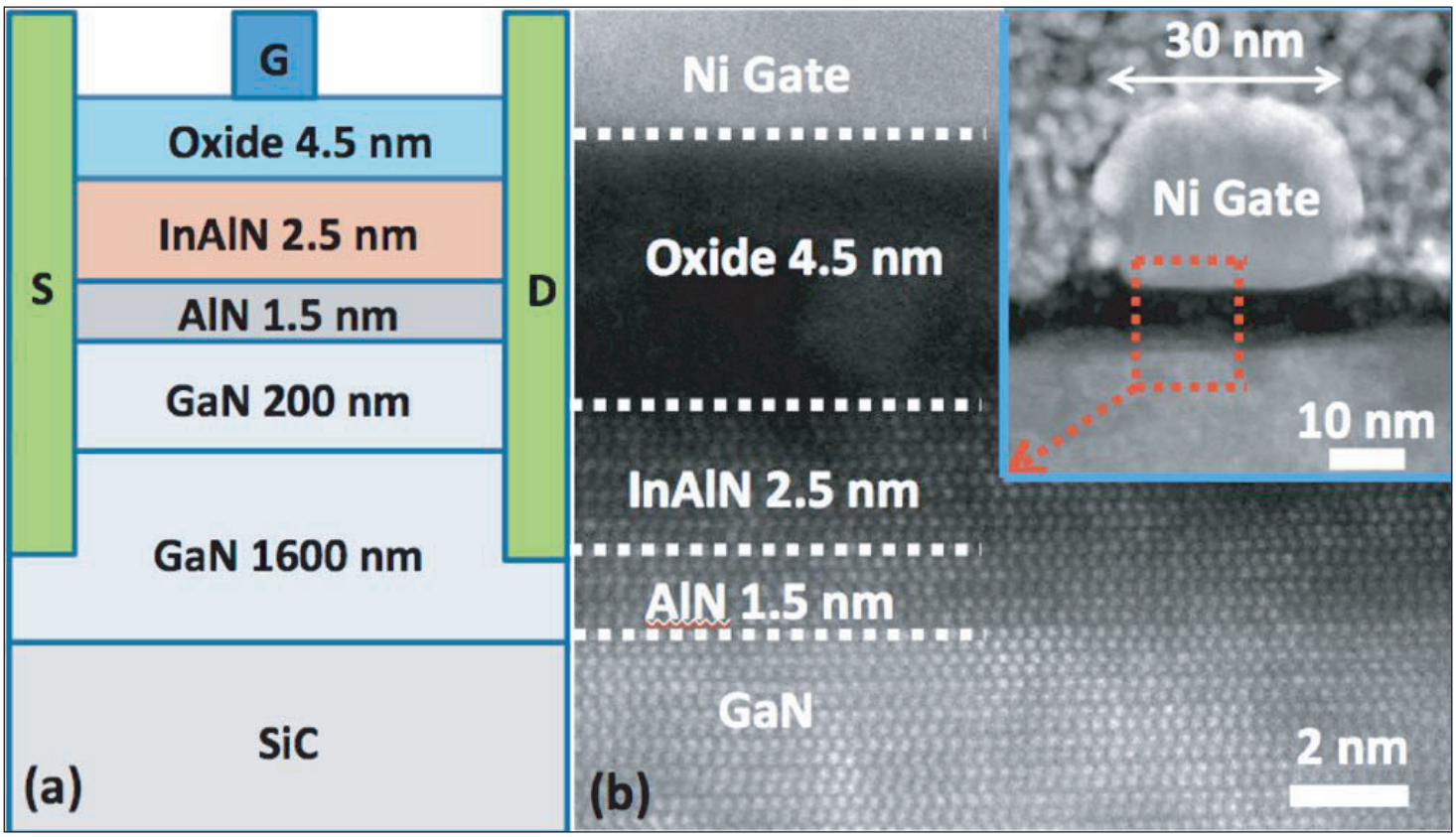

Figure 1. (a) Schematic of the InAlN/AlN/GaN HEMT cross section and (b) high-resolution TEM and (inset) scanning TEM images confirming HEMT layer structures and 30nm gate length after device fabrication.

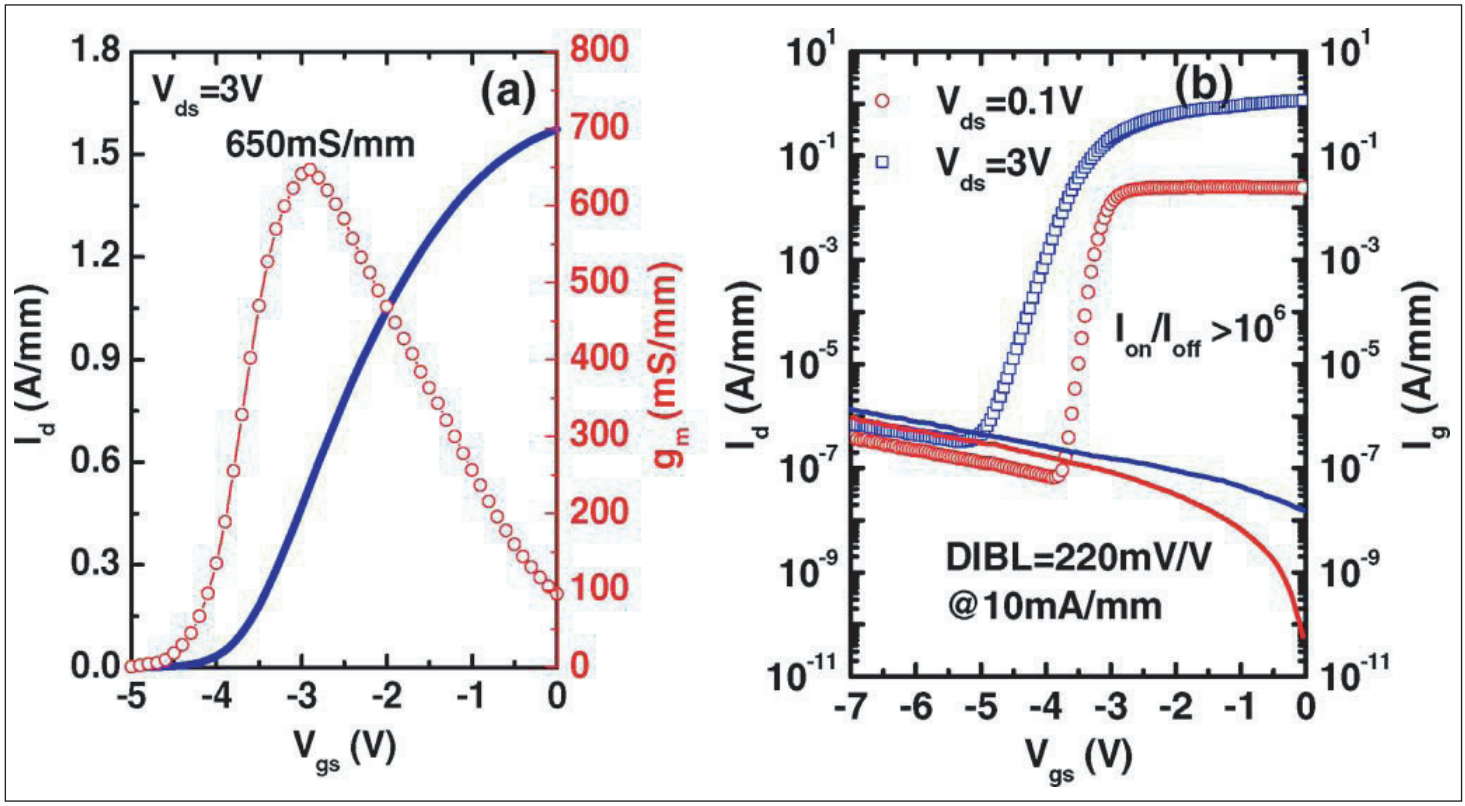

Figure 2. Transfer characteristics of InAlN/AlN/GaN HEMT at 3V and 0.1V drain biases: (a) linear scale and (b) semilog scale.

Ohmic source–drain contacts were made to non-alloyed titanium/aluminum layers. This was followed by mesa isolation using a chlorine plasma etch.

The dielectric-free passivation consisted of oxygen plasma treatment that oxidizes about 4.5nm of the original ~7.5nm InAlN barrier. Rectangular nickel gates were applied with a length of 30nm and a width of 2x25μm.

The maximum drain current of the resulting device was 1.5A/mm at zero gate potential and 5V drain. The on-resistance was 0.78Ω-mm between drain biases of 0 and 0.5V. The researchers find a difference 0.24Ω-mm, with the sum of the source and drain resistances (0.54Ω-mm) calculated on the basis of four-probe transmission line model (TLM) measurements. The origin of the difference is said to be unclear.

Pulsed measurements showed a slightly higher drain current at zero gate potential due to the suppression of self-heating. Nitride HEMTs often suffer 'current collapse' under such pulsed conditions. Although the device does not show current collapse, there is a 6% drain lag, "which merits further investigation".

The peak intrinsic transconductance was 650mS/mm at drain bias 3V and drain current 535mA/mm (Figure 2). The threshold was −3.5V. A high drain-induced barrier lowering (DIBL) of 220mV/V for 10mA/mm drain current is "indicative of significant short-channel effects" (SCEs).

On the plus side, the on–off ratio is more than six orders of magnitude (i.e. a factor of a million).

The researchers also attribute the good pinch-off to "low gate leakage resulting from the blanket DFP treatment". The three-terminal breakdown for 1mA/mm at −12V gate potential was 30V..

The frequency performance was measured between 250MHz and 110GHz, giving a current gain cut-off (f_T) of 370GHz after correcting for the effects of parasitics (de-embedding). The uncorrected f_T was 160GHz. The researchers comment: "To the best of our knowledge, an f_T of 370 is the highest reported in any GaN-based HEMT".

Unfortunately, the maximum oscillation (f_{MAX}) was low, at 30GHz (27GHz pre-de-embedded) "due to the high gate resistance induced by the rectangular gate".

Based on analysis of various delay effects, the researchers believe that 500GHz f_T should be possible with shorter gates. To improve the f_{MAX} value, more work is needed on reducing parasitic effects and improving the transconductance through better electrostatic control of the channel. One way to do the latter may be to use AlN/GaN/AlN quantum well structures.

The work was supported by grants from the US Defense Advanced Research Projects Agency (DARPA) and the US Air Force Office of Scientific Research. ■

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www.darpa.mil/Our_Work/MTO/Programs/Nitride_Electronic_NeXt-Generation_Technology_(NEXT).aspx

Author: Mike Cooke

Normally-off nitride transistors on silicon with record current and transconductance

Hong Kong researchers achieve maximum drain current of 860mA/mm and peak transconductance of 509mS/mm.

Hong Kong University of Science and Technology has achieved record maximum drain currents and peak transconductances for enhancement-mode (normally off) metal–oxide–(nitride) semiconductor heterojunction field-effect transistors (MOSHFETs) on silicon substrates [Tongde Huang et al, IEEE Electron Device Letters, published online 21 June 2012].

The researchers used aluminium nitride (AlN) barriers on gallium nitride (GaN) buffer layers, giving high values for carrier density in the two-dimensional electron gas (2DEG) channel due to the high spontaneous polarization field of the barrier. This reduces on-resistance.

The source and drain regions consisted of re-grown GaN that was heavily doped, reducing access resistance and thus also improving performance. Nitride semiconductor transistors often have source–drain contacts applied directly to the barrier layer, which creates high access resistance.

Researchers are seeking low-cost production of nitride semiconductor devices through growth on large-diameter silicon substrates. It is hoped such devices will be able to handle higher power densities, voltages and frequencies for radio-frequency transmission amplification and for power switching in voltage conversion equipment. A further requirement is for normally-off behavior, reducing power consumption and giving simpler circuits, which can be difficult to achieve in nitride transistors.

The nitride semiconductor heterostructure was grown on 2″ high-resistivity (HR, resistivity > 5000Ω-cm) silicon (111) using metal-organic chemical vapor deposition (MOCVD). The growth began with 40nm of AlN nucleation, eight periods of AlN/magnesium-doped GaN (Mg:GaN) (11nm/23nm) strain relaxation superlattice, two cycles of GaN/low-temperature AlN (600nm/20nm), and 125nm Mg:GaN. The structure was completed with a 875nm GaN buffer, a 1.5nm AlN barrier, and a 1nm GaN protective cap.

The mask for the re-growth step consisted of 84nm of silicon dioxide applied using plasma-enhanced chemical vapor deposition (PECVD). The mask was patterned using a dilute hydrofluoric wet etch. Chlorine-based plasma etch was used to etch out the source–drain regions to a depth of 120nm.

Silicon-doped GaN was re-grown in the source–drain regions using MOCVD at 1090°C. The doping was stepped with a more lightly doped region ($2.5x10^{19}Si/cm^3$) designed to provide a transition between the pure GaN of the buffer and the highly doped ($6x10^{19}Si/cm^3$) surface. The aim was to improve surface quality.

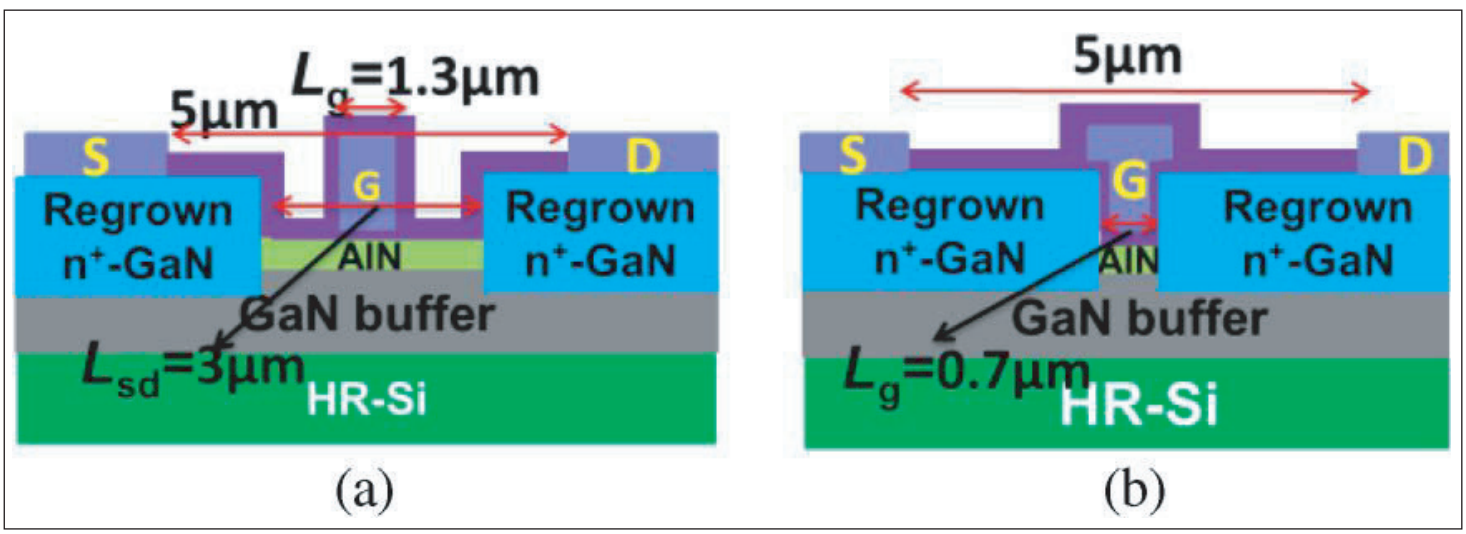

Figure 1. Device schematics of (a) MOS1 with gate length of 1.3µm and source–drain spacing of 3µm, and (b) MOS2 with gate length of 0.7µm.

After removal of the mask, the gate stack was applied, consisting of 6nm of aluminum oxide (Al_2O_3) dielectric and nickel/gold metal. The dielectric was applied using atomic layer deposition (ALD) at 300°C. A further 20nm of Al_2O_3 was applied as passivation after the gate metal. The samples were then subjected to annealing at 400°C for 10 minutes to enable gate sinking.

The metal contacts for the source–drain regions consisted of non-alloyed titanium/aluminum/nickel/gold. These were deposited after Al_2O_3 removal from the source–drain regions using hydrofluoric acid. The source–drain contacts were deposited last to avoid the thermal anneal.

Two MOSFET types were produced (Figure 1). MOS1 had a 1.3μm gate length and 3μm source–drain distance. For MOS2, the gate length and source–drain distance were the same at 0.7μm.

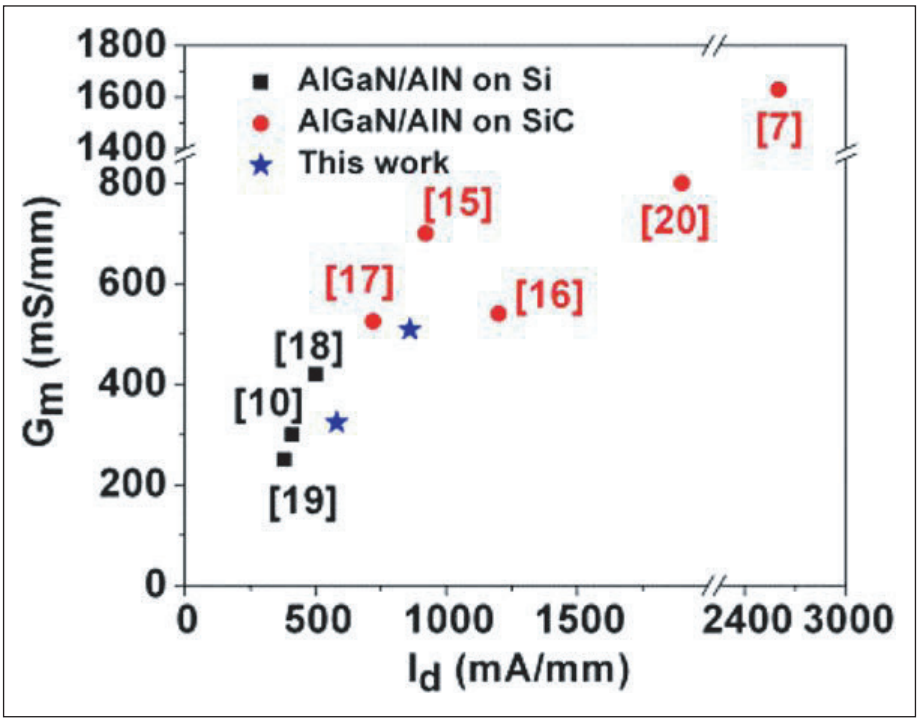

Figure 2. Comparison of peak transconductance as a function of maximum drain current value of GaN HEMTs on Si and GaN HEMTs on SiC (references available in paper).

The maximum drain current at gate potential +2V was 580mA/mm for MOS1 and 860mA/mm for MOS2. Pulsing the gate potential for 500μs showed current collapse for MOS2, but not significantly for MOS1. "The more severe current degradation in MOS2 is due to the higher electric field at the drain edge when compared with the case of MOS1," the researchers comment.

The peak transconductances for 4V drain bias were 324mS/mm and 509mS/mm for MOS1 and MOS2, respectively. The drain current and peak transconductance values are the highest for enhancement-mode (E-mode) MOSHFETs or HFETs on Si, according to the researchers' knowledge (Figure 2).

The researchers believe that reducing the gate length could improve the performance to be comparable with that of devices produced on much more expensive silicon carbide (SiC) substrates.

The threshold voltages are estimated to be +0.15V for MOS1 and +0.21V for MOS2. The respective on-resistance values (+2V gate) are 2.83Ω-mm and 1.63Ω-mm, respectively. The better transconductance of MOS2 can be explained as being due to its lower source access resistance. At 4V drain bias, the on–off ratio is about 10^6 between the gate potentials +2V and –0.5V for both transistor types. The gate leakage is smaller than 10^{-3}mA/mm.

The off-state (–0.5V gate) three-terminal breakdown in MOS1 occurs at 62V drain bias due to an increase in buffer leakage. Thus, an improvement in buffer could benefit the breakdown performance of MOS1.

The MOS2 breakdown occurs around 5.8V due to breakdown in the Al_2O_3 dielectric in the overlapping region between the gate and drain re-growth region. "The breakdown voltage of MOS2 could be increased by asymmetric re-growth technology with a large gate/drain spacing," the researchers believe. ■

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Author: Mike Cooke

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Hybrid ohmic-Schottky drain for higher breakdown in nitride HEMTs on silicon

Researchers in Taiwan achieve a 65% increase in breakdown voltage without significantly increased on-resistance.

Taiwan's National Tsing Hua University has used a hybrid ohmic-Schottky drain to reduce buffer leakage and improve breakdown performance in aluminium gallium nitride (AlGaN) semiconductor transistors produced on silicon substrates [Yi-Wei Lian et al, IEEE Electron Device Letters, published online 11 June 2012]. By combining ohmic and Schottky drain regions, the Tsing Hua researchers increased breakdown voltage by up to 65% with almost no degradation of on-resistance.

In the target application of high-power switching, buffer leakage causes significant power loss. Apart from the quality of the buffer growth process, the ohmic source-drain alloying process can also affect buffer leakage by introducing metal spikes into the nitride semiconductor. Such spikes focus electric field lines, inducing leakage currents and breakdown.

Recently, Schottky drain contacts have been proposed as a way to reduce buffer leakage. However, Schottky contacts have a non-linear current–voltage behavior, adding a turn-on voltage that increases on-resistance.

The Tsing Hua researchers tested the different drain electrode structures (Figure 1) using two epitaxial material samples. Sample A consisted of a 1μm GaN buffer/channel, followed by a 24nm $Al_{0.25}Ga_{0.75}N$ barrier. Sample B was more complex, with a 3.3μm GaN buffer, 1.5μm GaN channel, 20nm $Al_{0.25}Ga_{0.75}N$ barrier, and a 1nm GaN cap.

Although the researchers did not have exact knowledge of the growth process for the samples, they point out that buffer layers usually begin with AlN to prevent diffusion of Ga into the silicon substrate. Further AlN or AlGaN layers are often incorporated into the buffer to relax strain from the large lattice mismatch and block threading dislocations to improve material quality in the channel layer.

Hall-effect and electrical measurements on the samples indicate similar performance, with the mobility and carrier density of sample A being 1519cm^2/V-s and 8.6x10^{12}/cm^2, respectively. The corresponding figures for B were 1492cm^2/V-s and 9.7x10^{12}/cm^2. The sheet resistances for A and B were, respectively, 476Ω/square and 432Ω/square.

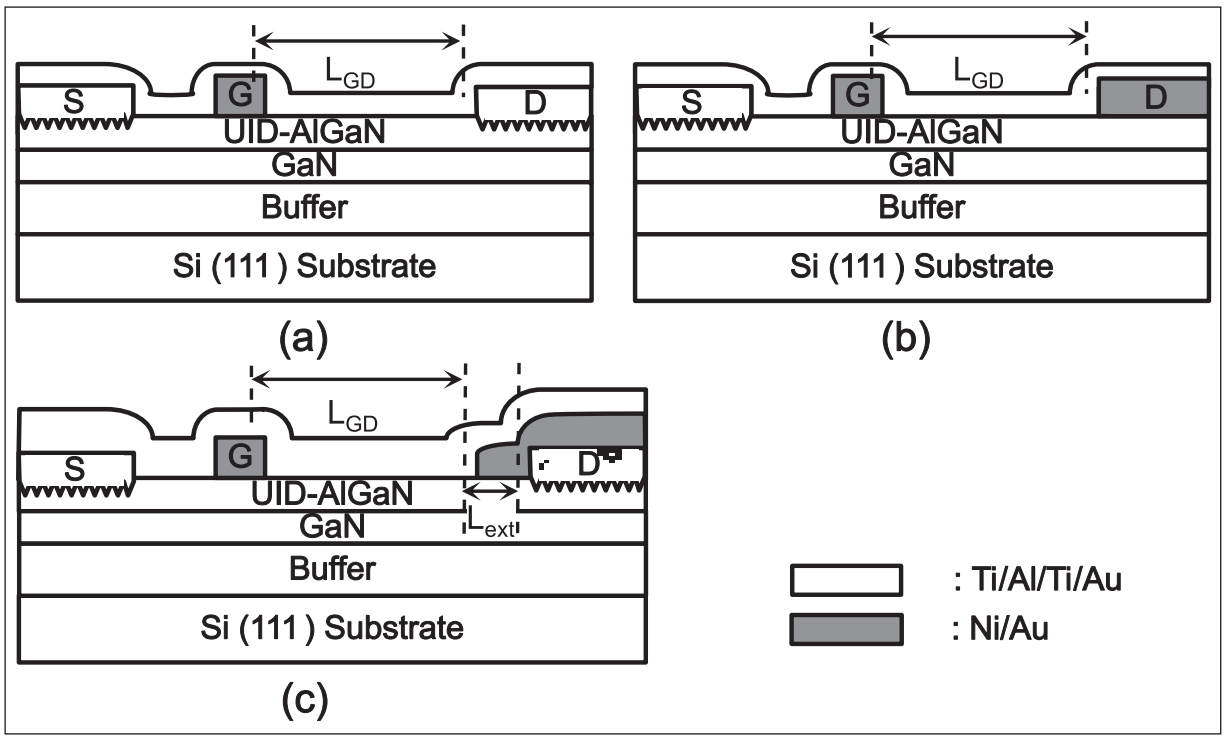

Figure 1. Cross sections of AlGaN/GaN HEMTs on silicon with different types of drain electrodes: (a) ohmic drain, (b) Schottky drain, and (c) hybrid drain.

Device processing began with isolation using a 300nm chlorine/argon inductively couple plasma (ICP) etch. The ohmic areas were patterned using photolithography and then treated with argon ICP to reduce contact resistance. The ohmic contact metals were titanium/aluminium/titanium/gold, applied using electron-beam evaporation and annealed at 800ºC in nitrogen for 30 seconds. The Schottky for the gate and drain (where appropriate) contact metals consisted of nickel/gold. The process was completed with multi-layer surface passivation with silicon nitride and silicon oxide applied with plasma-enhanced chemical vapor deposition (PECVD).

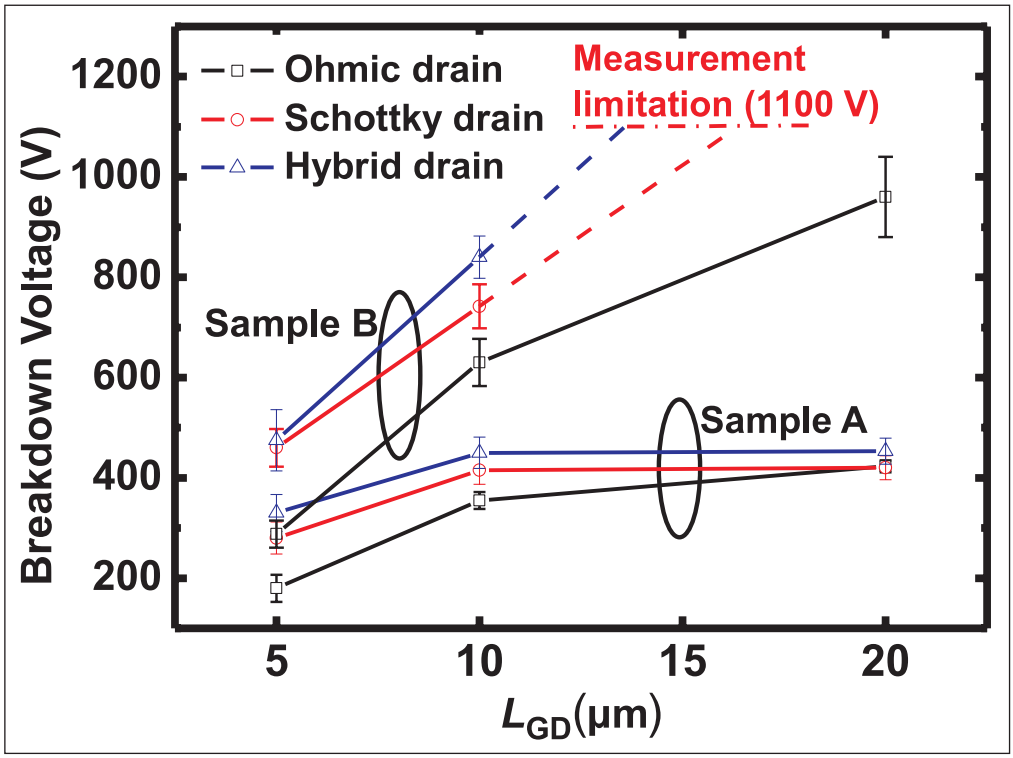

Figure 2. Breakdown voltage as a function of the gate-drain spacing with three different structures at −10V gate.

The different device types (Figure 1) were produced near to each other on the samples to ensure fair comparison. The hybrid device has a Schottky extension of 3μm towards the gate. However, the gate-drain separation is kept the same as the comparison devices to allow fair assessment of the breakdown voltage. The Schottky extension provided a field-plate shaped like the capital Greek letter 'gamma' (i.e. Γ). This avoids electric field concentrations that occur with the ohmic drain. Breakdown occurs at high electric field.

The drain contact is a square region with the gate and source electrodes as concentric square rings around the drain. The square layout is designed to "reduce the gate leakage current and mitigate the effects of traps originating from the dry etching damage at the sidewall of the mesa edge".

The devices had a fixed gate-source distance of 2μm and a gate width of 400μm (the length of the square line). The gate-drain distance was varied between 5μm and 20μm. The threshold voltage was negative, at −2.9V, giving normally-on 'depletion-mode' operation (i.e. current flows at zero gate potential).

Devices with ohmic, Schottky and mixed drain contacts showed similar saturation current levels at +1V gate potential. The pure Schottky contact required a turn-on voltage of about 1V, increasing on-resistance. By contrast, devices with mixed ohmic-Schottky drain showed no onset voltage. In figures, the on-resistances were 1.78mΩ-cm^2, 2.33mΩ-cm^2, and 1.80mΩ-cm^2 for ohmic, Schottky, and hybrid drains, respectively.

The hybrid devices also demonstrated the largest breakdown voltages (Figure 2) in three-terminal breakdown measurements (1mA/mm drain current in −10V gate, off-state). The researchers believe the improved performance of the hybrid drain is due to there being two electric field peaks — at the edges of the Schottky and ohmic regions — rather than one, as in the cases of the single-electrode-type devices. "This twin peak distribution can effectively alleviate and smooth out the electric field intensity around the drain side," the researchers comment.

Sample A devices with thinner buffer layer had lower breakdown voltages. The breakdown voltage also apparently saturates at 400–450V for large gate–drain distance, due it is thought to leakage through the buffer.

For sample B devices, the increase in breakdown voltage for a 5μm gate-drain distance over ohmic drains was 60% (170V) and 65% (187V) for Schottky and hybrid drains, respectively. At 10μm gate–drain, the increases were 18% (112V) and 33% (210V), respectively.

The Sample B devices with a 20μm gate–drain distance also had order-of-magnitude reductions in off-state (−10V gate) leakage current. "This can be attributed to the Schottky drain metal with a smooth contact interface, which can reduce the high electric field around the metal spikes and suppress the buffer leakage current," the researchers write. ■

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Author: Mike Cooke

Gold-free nitride MOS-HEMTs for CMOS compatibility

Singapore and Hong Kong scientists have achieved record breakdown voltage for nitride MOS-HEMTs made using a gold-free process.

Singapore and Hong Kong researchers have developed a gold-free CMOS-compatible process for nitride semiconductor metal–oxide–semiconductor high-electron-mobility transistors (MOS-HEMTs) [Xinke Liu et al, Appl. Phys. Express, vol5, p066501, 2012]. The participating institutions were National University of Singapore, Hong Kong University of Science and Technology, and Singapore's Nanyang Technological University.

Aluminium gallium nitride (AlGaN) alloys have a wide bandgap that makes them attractive for high-power/voltage operation, allowing the development of switches for boost converters, power factor correction (PFC) circuits, uninterruptable power supplies (UPS) etc. The development of AlGaN/GaN HEMTs on silicon promises the merging of nitride technology with mainstream CMOS circuitry, along with production cost reductions from the larger-diameter silicon wafers (150mm, 200mm) that are available.

However, to enable mixed nitride/silicon semiconductor technology, CMOS-compatible processes need to be developed. One issue is the general use of gold in nitride semiconductor transistor contacts. Gold reduces carrier lifetimes in silicon; although this may be desired in some applications such as infrared detection, it is to be avoided at all costs in CMOS circuits.

The epitaxial material for the Singapore/Hong Kong devices (Figure 1) was grown using metal-organic chemical vapor deposition (MOCVD) on 4-inch p-silicon (111) wafers. The 3.3μm buffer region consisted of multiple pairs of AlN and GaN layers. The device layers consisted of 1.5μm GaN followed by 25nm $Al_{0.25}Ga_{0.75}N$ barrier.

Mesas for device isolation were formed using chlorine plasma reactive ion etch (RIE), followed by native oxide removal and passivation in ammonium sulfate ($(NH_4)_2S$) solution. Aluminium oxide (Al_2O_3) gate dielectric was applied using atomic layer deposition (ALD), followed by a 450°C anneal in nitrogen for 60 seconds.

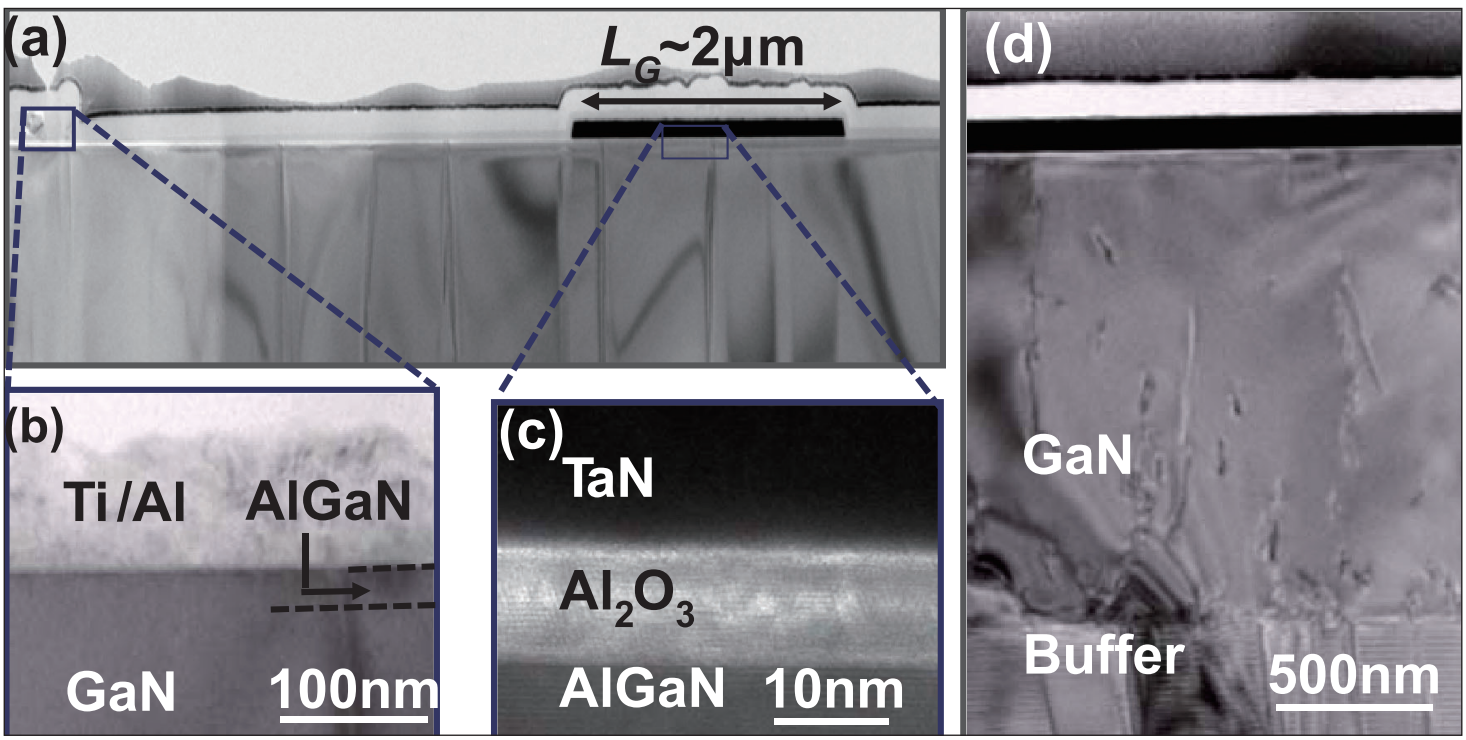

Figure 1. (a) Cross-sectional TEM image of fabricated gold-free AlGaN/GaN MOS-HEMT. (b) Zoomed-in image of a Ti/Al contact on AlGaN layer. (c) Zoomed-in image of a TaN/Al_2O_3/AlGaN stack. (d) Cross-sectional TEM image of TaN/Al_2O_3/AlGaN/GaN/buffer.

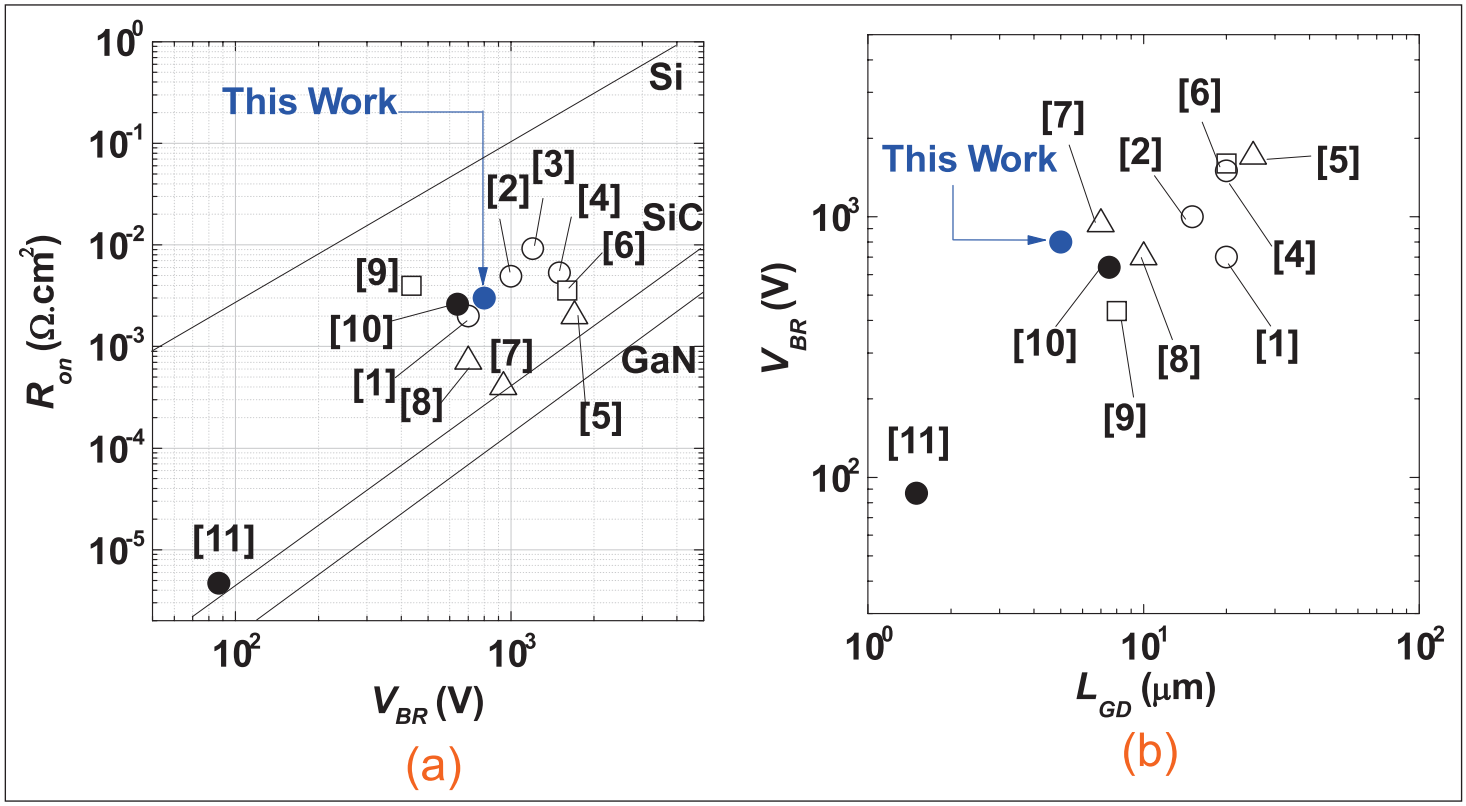

Figure 2. (a) Breakdown voltage VBR versus on-resistance Ron of fabricated AlGaN/GaN MOS-HEMTs, compared with those of state-of-the-art AlGaN/GaN MOS-HEMTs. (b) Breakdown voltage V_{BR} versus gate-to-drain spacing LGD of fabricated AlGaN/GaN MOS-HEMTs, compared with those of state-of-the-art AlGaN/GaN MOS-HEMTs. Open symbol: GaN MOS-HEMTs with gold. Solid symbol: GaN MOS-HEMTs without gold. Square: GaN-on-sapphire. Triangle: GaN-on-SiC. Circle: GaN-on-silicon.

The 2μm-long gate electrode consisted of sputtered tantalum nitride that was subsequently patterned and etched in chlorine plasma that was selective against the aluminium oxide gate dielectric as etch stop. The etch process was CMOS compatible.

The devices were then encapsulated in silicon dioxide. Contact openings were patterned and etched. Aluminium/titanium (71nm/30nm) stacks were used for source-drain metals, with ohmic contact created through alloying at 650°C for 30 seconds in nitrogen. The source–gate and drain–gate distance were both 5μm.

The researchers comment that the 800V breakdown is the highest for LGD below 10mm for AlGaN/GaN/Si MOS-HEMTs fabricated using a gold-free process...

A gold-free process enables the fabrication of GaN power devices in silicon foundries without the risk of contamination.

The devices could be generally useful for cost-competitive power switching circuits with a supply voltage in the range of several hundred volts

The threshold voltage of one resulting device was –6.3V, the negative value indicating normally-on (depletion-mode) behavior. The subthreshold swing was 90mV/dec and the peak transconductance was 41.6mS/mm with 5V drain bias.

On average, the subthreshold swing was 97.7mV/dec, the on–off current ratio was 106, and the gate leakage was 1.02×10^{-6}A/mm. Variations in performance were attributed to differences in interface trap density at the Al_2O_3–AlGaN interface and the thickness of the AlGaN barrier layer. The on-resistance was around 3mΩ-cm².

A vertical breakdown voltage of more than 800V was suggested by four-terminal off-state measurements with the gate bias at –12V and drain voltage kept to less than 1mA/mm. At 650V drain bias, the off-current was 3.8×10^{-7}A/mm. At 800V, the substrate current was around 10^{-7}A/mm.

The researchers comment that the 800V breakdown "is the highest for L_{GD} below 10μm for AlGaN/GaN/Si MOS-HEMTs fabricated using a gold-free process."

They conclude: "A gold-free process enables the fabrication of GaN power devices in silicon foundries without the risk of contamination. The devices could be generally useful for cost-competitive power switching circuits with a supply voltage in the range of several hundred volts." ■

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Author: Mike Cooke

First 40GHz 2.5W/mm output performance of GaN/Si HEMTs

IEMN demonstrates viable technology for cost-effective high-power millimeter-wave amplifiers fully compatible with silicon devices.

Institute for Electronics, Microelectronics and Nanotechnology (IEMN) in France has demonstrated high-power-density nitride high-electron-mobility transistors (HEMTs) on silicon (Si) at 40GHz "for the first time" [F. Medjdoub et al, IEEE Electron Device Letters, published online 14 June 2012]. Devices based on aluminium gallium nitride (AlGaN) layers on Si have previously demonstrated high power performance up to 26.5GHz.

The IEMN devices use AlN top barriers rather than the more usual AlGaN. The new HEMTs also incorporate an AlGaN back-barrier to reduce subthreshold drain leakage current and short-channel effects. The 40GHz performance brings Ka-band (26.5–40GHz) applications into range, such as satellite communications, high-resolution, close-range targeting radars for military aircraft, and remote vehicle speed measurement (speed traps).

The researchers comment: "These results show that an AlN/GaN/AlGaN heterostructure grown on silicon substrate is a viable technology for cost-effective high-power millimeter-wave amplifiers fully compatible with standard Si-based devices."

Nitride HEMTs on silicon have previously been proposed for lower-frequency power applications such as DC–DC converters, where one attraction is the lower cost from using large-diameter silicon substrates (up to 8-inch/200mm at present). If RF GaN-on-Si HEMTs could be combined with well-established Si-based technologies, new chips with higher functionalities and performance might become possible.

IEMN worked with AlN/GaN/AlGaN double-heterostructure epitaxial material supplied by EpiGaN nv of Hasselt, Belgium (which was spun off from nanoelectronics research center Imec of Leuven, Belgium in 2010). The material was grown using metal-organic chemical vapor deposition (MOCVD) on high-resistance 4-inch Si substrates.

A silicon nitride (SiN) cap was grown in-situ (i.e. in the MOCVD process chamber) at EpiGaN with the aim of providing early passivation and preventing strain relaxation of the structure. The strain increases the polarization contrast that is used to create the

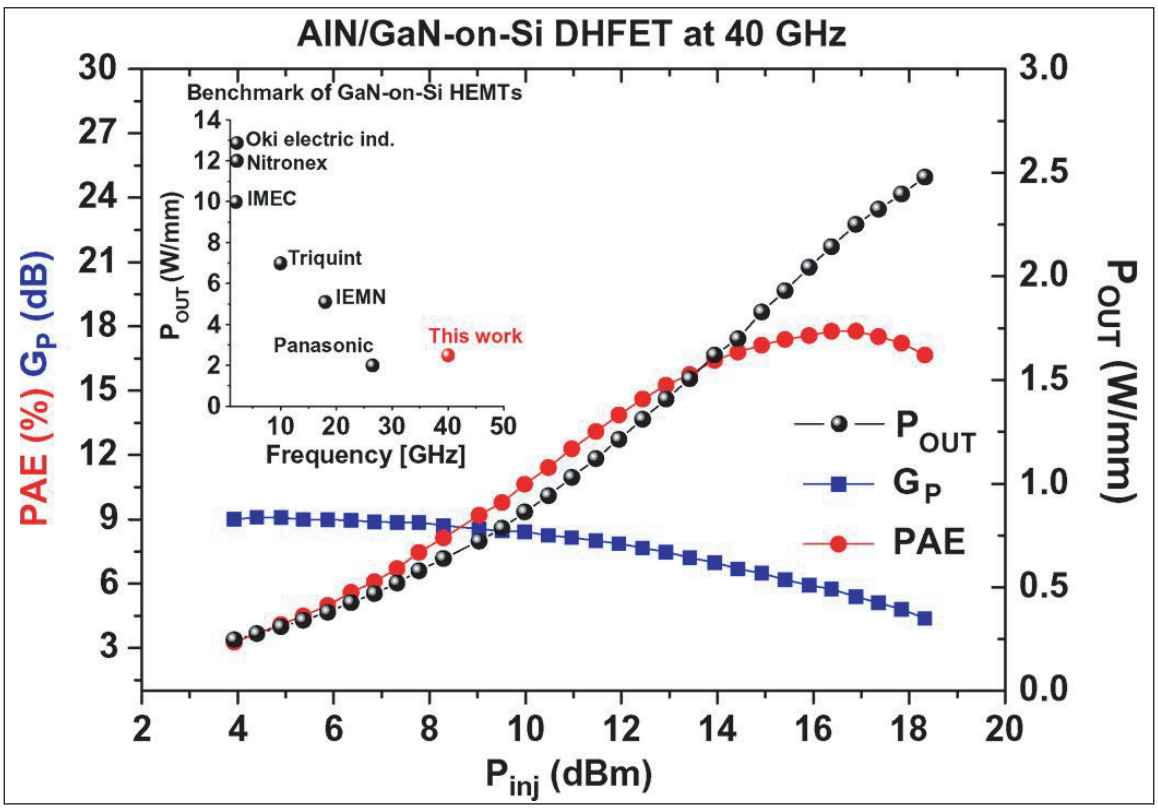

Figure 1. Transfer characteristics at 6V drain bias of IEMN HEMT. Inset: schematic cross-section of fabricated HEMT.

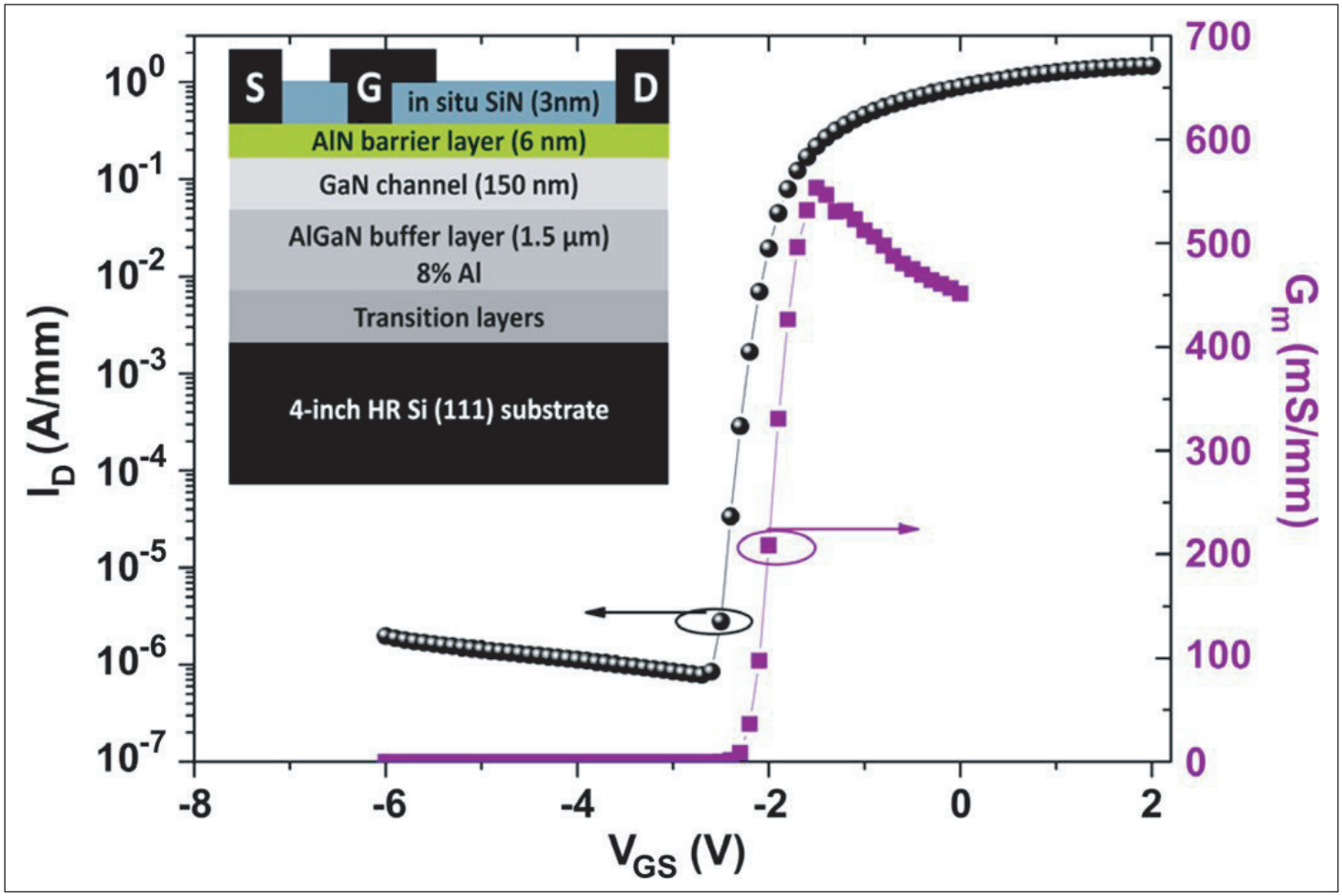

Figure 2. CW power sweep at 40GHz of AlN/GaN/AlGaN HEMT on highly resistive silicon substrate at drain bias of 15V and gate potential of −1.6V. Inset: RF power density benchmark of GaN-on-Si transistors.

two-dimensional electron gas (2DEG) channel that forms near the AlN/GaN interface. The resulting higher-density 2DEG allows thinner top barrier layers, which brings the gate closer to the channel, improving electrostatic control.

Hall measurements of the material gave a carrier concentration of 2.1×10^{13}/cm^2 and a carrier mobility of 1400cm^2/V-s. The resulting sheet resistance was 240Ω/square.

Source, drain and gate contacts were added (Figure 1) along with further SiN. The 0.1µm-long nickel-gold T-gate included a field-plate with 0.2µm extension toward the drain. The gate–source spacing was 0.3µm. Gate–drain spacing was 2µm. Device width was 50µm. A final passivation layer of 150nm of SiN was then applied.

The maximum drain current at +2V gate potential was 1.8A/mm, and the off-state leakage was less than 2µA/mm. Three-terminal breakdown defined by 1mA/mm leakage was more than 100V. The extrinsic transconductance peaked at 550mS/mm. Pulsed measurements showed almost no gate lag, but there was a slight drain lag.

Frequency performance was measured over the range up to 50GHz. The maximum oscillation frequency (f_{max}) was 200GHz; the current-gain cut-off (f_T) was 80GHz. Continuous wave (CW) output power at 40GHz was measured using an active load-pull large-signal network analyzer (LSNA).

The researchers comment: "An output power density of 2.5W/mm was reached at 40GHz when biased at 15V, which represents, to our knowledge, the first demonstration of high power density at 40GHz for a GaN-on-Si transistor (as shown in the inset in Fig. 2)."

The power-added efficiency (PAE) peaked at 18% and the linear gain was 9dB. The limiting factors for the PAE are given as self-heating and parasitic conduction at the buffer/silicon interface.

The researchers comment that performance at drain bias beyond 15V is limited by thermal effects. Their on-going work aims to optimize the Al content of the buffer to improve thermal dissipation, along with improving the buffer/Si interface quality to enhance large-signal gain at millimeter-wave frequencies. Thermal performance could also be enhanced by back-side processing through substrate thinning and application of a heat-sink. ■

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Author: Mike Cooke

Templates: the fast track to GaN-on-Si LEDs

By using templates, costly development can be avoided and the advantages of GaN-on-Si can be easily exploited with extremely short design-in cycles, says Erwin Ysewijn of AZZURRO Semiconductors.

The LED industry is facing ever increasing cost pressures. One approach to resolve this has been the move to larger wafer diameters. Furthermore, instead of typically using expensive sapphire, the use of inexpensive silicon as a substrate material for epitaxial growth of gallium nitride (GaN) has been advocated. The technical challenges of using silicon substrates — such as poor crystalline quality and wafer bow — have been difficult to overcome. Here we present a solution for LED manufacturers to migrate to the GaN-on-Si material system without the need for costly, lengthy and risky developments.

Templates

In general, templates allow the user to grow additional epitaxial layers on the existing epi-structure of the template. Being the biggest single cost factor of an LED epiwafer, a reduction in the required growth time is the primary goal of using templates. An extra benefit, sometimes overlooked, is that templates can offer the user advantageous technological features.

In this case, LED structures can be deposited on a high-quality buffer grown on a large-diameter and low-cost silicon substrate (Figure 1). The LED structures often incorporate IP-protected and proprietary layers such as multi-quantum-wells. This enables LED manufacturers to continue using their own epitaxial structures while at the same time being able to migrate to GaN-on-Si and hence utilizing the large associated cost savings of 60% and more.

To introduce templates successfully into LED production, the crystal quality must match that of epitaxial structures grown on sapphire substrates. Furthermore, GaN-on-Si templates must offer good homogeneities for good binning results.

The large mismatch between GaN and silicon in terms of their lattice constants and thermal expansion coefficients makes it difficult to achieve these preconditions. Thick GaN layers are needed to yield high crystal quality, and these are particularly challenging to achieve. Without excellent strain-management techniques, cracks and high wafer bow values limit the achievable GaN thickness and crystal quality. Strain management is also required to unlock the very significant homogeneity improvements that are possible by using GaN-on-Si. For the overgrowth of a wide range of different LED structures, the template also needs to offer large overgrowth thickness. With larger wafer diameter, the aforementioned challenges for GaN-on-Si increase. Finally, the resulting epiwafers need to offer large diameters of least 150mm and ideally 200mm, as well as very low bow values. These latter challenges are fundamental gating issues for epiwafers being processed in low-cost standard silicon lines.

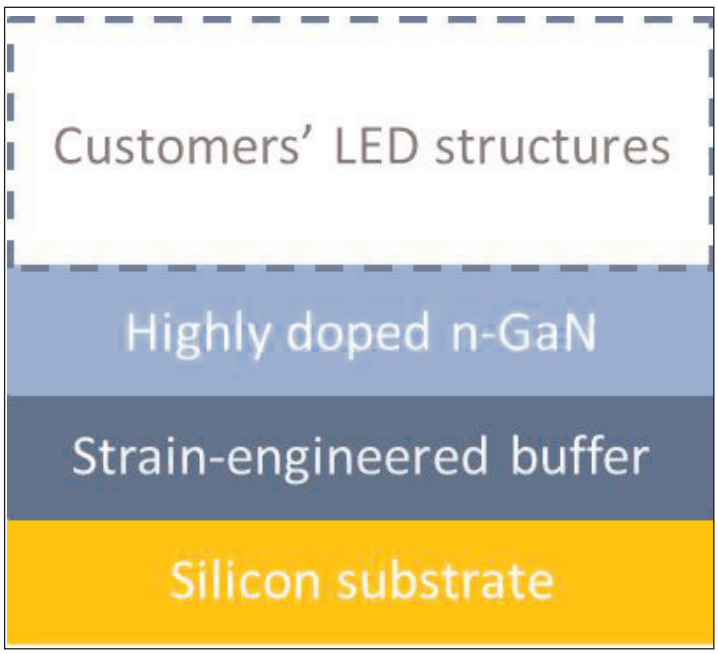

Figure 1: Template consisting of silicon substrate with high-quality strain-engineered buffer and highly doped n-GaN layer ready for overgrowth with LED structure.

In summary, GaN-on-Si templates offer huge saving potentials, but the technological challenges that need to be overcome require costly and lengthy development processes. Moreover, newcomers to the technology have to be aware of existing IP in the GaN-on-Si field.

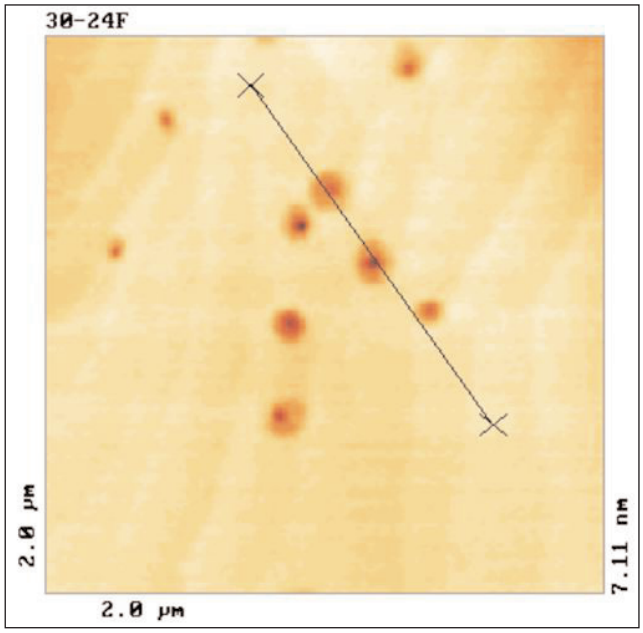

Figure 2: Crystal quality: low EPD of $2x10^8cm^{-2}$ and XRD result of 450 arcsec (for 102 plane).

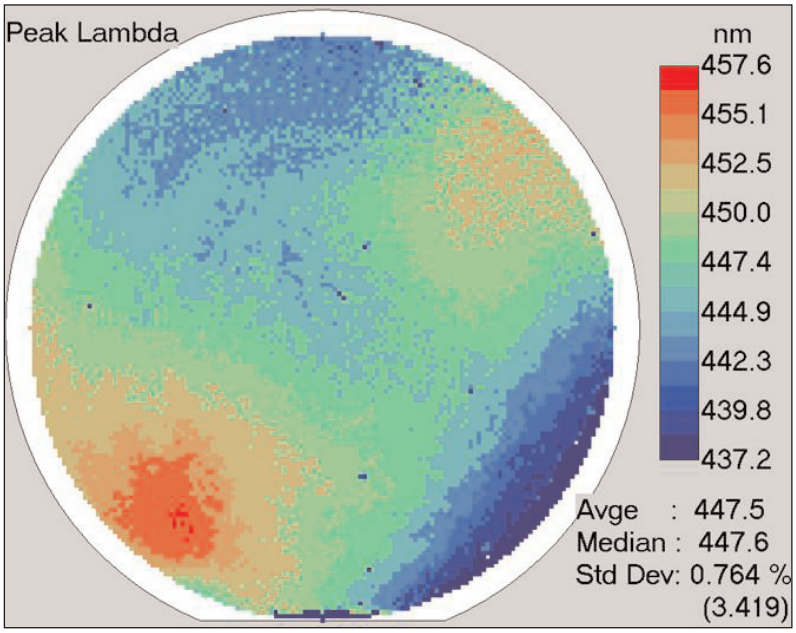

Figure 3: LED binning reduction made possible with strain-engineered 150mm GaN-on-Si templates.

Overcoming the challenges

Promising results with strain-engineered templates offer a road to migrating to GaN-on-Si and unlocking the savings potential of GaN-on-Si that can already be achieved today. Very good crystal quality has been achieved for highly n-doped ($5x10^{18}cm^{-3}$), 5.7µm-thick overgrown templates with x-ray diffraction (XRD) and etch-pit density (EPD) values in the range of those achieved on sapphire substrates (Figure 2). Also, excellent homogeneities have been demonstrated. These achievements on templates translate to an outstandingly narrow wavelength distribution for 150mm LED epiwafers, resulting in substantially reduced binning (see Figure 3).

To provide the epitaxial engineer overgrowing the templates with a wide range of LED structure designs, 3µm of highly doped ($5x10^{18}cm^{-3}$) GaN can be grown on top of the templates. All the above is achieved while the strain-engineering from the templates enables the resulting 150mm-diameter LED epiwafers to have a bow value of less than 20µm (Figure 4).

This allows the resulting LED epiwafers to gain from high-yield and low-cost processing in standard silicon lines.

Due to the high crystalline quality, the large overgrowth thickness and dedicated packages supporting the transfer of LED structure growth onto the GaN-on-Si templates, very short production phase-in times are facilitated.

Conclusions

Strain-engineering technology can enable high-quality GaN-on-Si templates. The templates discussed above enable the migration of LED production to the GaN-on-Si material system. LED manufacturers can transfer their own LED structures to the GaN-on-Si material system without the need for lengthy, risky and costly development of their own GaN-on-Si technology. The cost and homogeneity benefits from strain-engineered GaN-on-Si technology can be utilized quickly. ■

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Erwin Ysewijn is VP sales & marketing at AZZURRO Semiconductors AG of Dresden, Germany. The company pioneered GaN-on-Si and has a development package for customers to migrate quickly to templates, as well as offering epiwafers for LED and power semiconductor applications.
www.azzurro-semiconductors.com

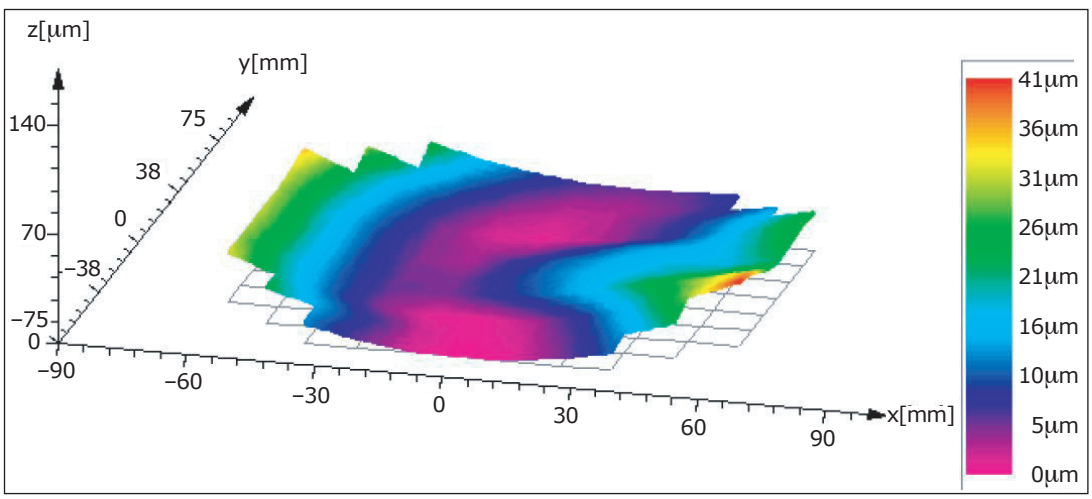

Figure 4: Strain-engineered low-bow wafer, ready for silicon processing lines.

Nitride LED transfer from silicon to copper boosts output by 122%

Improvements have been made due to growth substrate removal, strain relaxation, insertion of a mirror, elimination of electrode-shading, and AlN surface roughening.

Researchers in China have transferred nitride semiconductor light-emitting diodes (LEDs) grown on silicon (Si) to copper submounts, giving a 122% increase in light output at 350mA injection current [Tufu Chen et al, Appl. Phys. Lett., vol100, p241112, 2012]. The research was carried out at Sun Yat-sen University's State Key Laboratory of Optoelectronic Materials and Technologies.

Growth of nitride semiconductors on silicon is expected to lower costs due to access to larger-diameter wafer substrates, particular for power and high-frequency transistors. For LEDs, light absorption in the narrower-bandgap substrate material needs to be avoided, for example by interposing mirror layers.

Another technique is substrate removal, which can be achieved by transfer to a copper submount and thinning/etch. Copper is attractive for this application due to its good electrical and thermal conductivity.

Such techniques were proposed by Nagoya University in Japan in 2005, giving 49% more light than before substrate removal. In 2010, Hong Kong University of Science and Technology reported a 70% enhancement from the transfer of nitride LEDs to copper.

The Sun Yat-sen University researchers began by growing crack-free indium gallium nitride (InGaN) multi-quantum-well (MQW) layers on Si (111) substrates using metal-organic chemical vapor deposition (MOCVD).

A thin interlayer of GaN was grown at low pressure (70mbar) between high-temperature aluminium nitride (AlN) buffer and normal pressure (300mbar) GaN. The aim of the interlayer was to speed the transition between the 3D growth of the buffer and the 2D ('island') growth favored for thin high-quality layer LED structures. Low-temperature

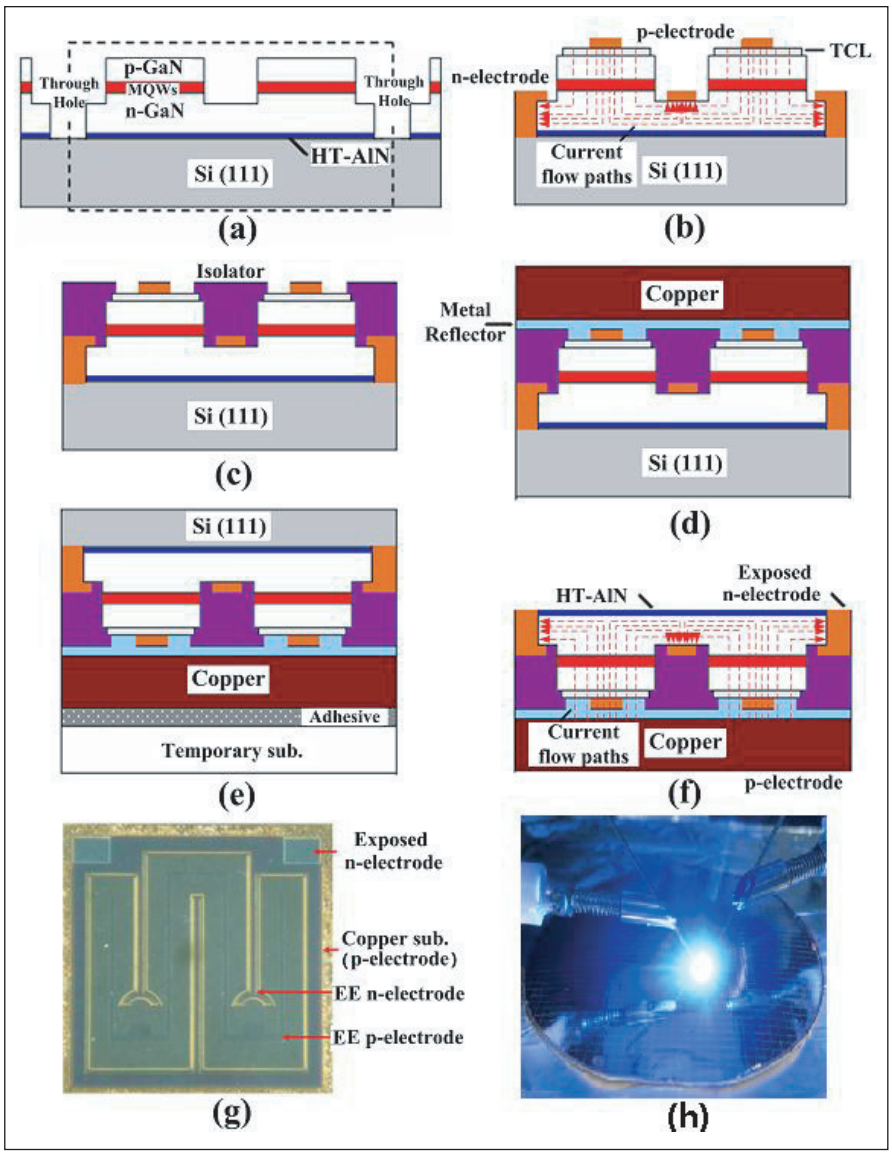

Figure 1. Fabrication process of LEDs on copper submount: (a) etch through-holes and mesa by ICP-RIE, (b) deposit TCL and p/n electrodes, (c) isolate n-electrode and p-electrode, (d) deposit metal reflector onto exposed TCL surface, and electroplate 100μm-thick copper, (e) bond wafer to temporary substrate using acrylate adhesive and thin silicon substrate, (f) remove Si substrate by wet-chemical etching and separate from temporary substrate. (g) Photograph of 1mm x 1mm LED on copper. (h) Light-emitting image of LEDs on 2" electroplated copper submount at 350mA current injection. Current flow paths of conventional LED on Si and LED on copper are shown in (b) and (f), respectively.

AlN interlayers were used to control stress in the preliminary epitaxial layers.

The further epitaxial structure consisted of 0.8μm undoped GaN, 0.75μm n-GaN (1050°C), 10-periods of 2nm-thick $In_{0.12}Ga_{0.88}N$ MQWs with 17nm-thick GaN barriers (880°C), and ending with a 0.15μm p-GaN cap (1050°C).

The epitaxial material was prepared for transfer to the copper submount by drilling through-holes to the silicon substrate using inductively coupled plasma reactive ion etching (Figure 1a). Mesas were then formed, also using ICP-RIE. This was followed by thermal annealing at 700°C in nitrogen for 25 minutes to activate the p-GaN and partially repair plasma damage.

Then nickel/gold (5nm/7nm) layers were applied and annealed at 550°C for 15 minutes in air to form a p-type nickel oxide transparent conducting layer (TCL). Layers of chromium/aluminum/palladium/gold (Cr/Al/Pd/Au) were then added and annealed as p- and n-electrodes (Figure 1b). In this process, the through-holes were also filled with metal.

The different polarity electrodes were isolated with an insulating material (Figure 1c) and a Cr/Al/Pd/Au metal reflector and 100μm copper submount were applied (Figure 1d). The main reflecting component was Al; the gold was used as a seed layer for copper electroplating.

The electroplating technique is unaffected by the concave wafer bowing that occurs with nitride semiconductor layers on silicon. Bowing makes alternative wafer bonding methods difficult to implement.

The structure was flipped onto a temporary substrate to allow thinning of the silicon substrate down to 100μm (Figure 1e), prior to complete removal using a wet chemical etch with hydrofluoric-nitric-acetic (HNA) acid (Figure 1f). The n-electrodes consist of the metal-filled through-holes and the process thus avoids further need to etch the HT-AlN layer at this stage.

The forward voltage at 350mA current was 3.75V, a 0.4V increase on that of a conventional LED produced from the same epitaxial material. The researchers suggest that the increased forward voltage may be due to a poor interface between the p-GaN and the metal reflector. The forward voltage could be reduced by process optimization of the interface contact, the researchers believe.

The wavelength peak of the light (~450nm, blue) emitted by the LED on copper was blue-shifted by 5nm (i.e. to shorter wavelengths) compared with the conventional device. The researchers attribute this to strain relaxation of the crystal structure in the LED on copper, which was also found in x-ray diffraction measurements.

Nitride semiconductor devices have strong polarization fields, some of which arise from strain in lattice-mismatched structures (piezoelectricity). These fields tend to shift energy levels, and emissions are hence shifted in the red/longer-wavelength direction. This is termed the quantum-confined Stark effect (QCSE). With lower strain, one expects less QCSE and higher internal quantum efficiency.

Another consequence of QCSE is shifts in peak emission wavelength as the applied field changes. With the LED on copper, there was no obvious wavelength shift as the injected current increased from 5mA to 300mA.

In terms of total emissions, the LED on copper showed a 122% increase over the conventional device at 350mA (Figure 2). The conventional device was produced as for the copper device up to Figure 1b. The improvement for the LED on copper was attributed to a number of factors: removal of the absorptive silicon substrate, elimination of electrode-shading losses, the rough AlN surface improving light extraction, and better thermal management with better heat conduction through copper than silicon.

At higher currents, the light output with the LED on copper begins to saturate. This is attributed to the poor contact between the nickel oxide TCL and metal reflector that is thought to impede heat dissipation.

The insets in Figure 2 suggest significant current crowding for the LED on copper due to the poor contact between the metal reflector and TCL. The bright areas correspond to the thick metal p-electrodes. In the conventional LED, light emitted from these regions is blocked by the electrode, so the current crowding is not observed. ■

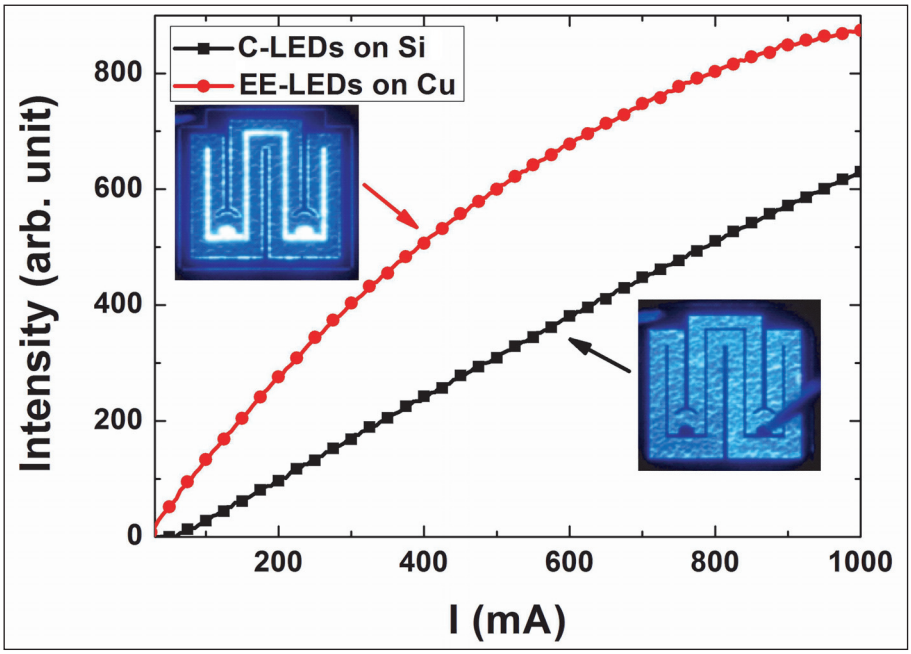

Figure 2. Light output versus current (L–I) of conventional LED on Si and LED on copper. Inset: light-emitting images of conventional LED on Si and LED on copper at 5mA current injection.

http://link.aip.org/link/doi/10.1063/1.4729414

Author: Mike Cooke

Boron nitride release transfer of nitride LEDs from sapphire to adhesive tape

By using a hexagonal boron nitride buffer layer to release nitride LEDs from sapphire, NTT has produced vertical LED prototype that are less than 0.1mm thick.

NTT Basic Research Laboratories in Japan has used hexagonal boron nitride (h-BN) layers to release nitride semiconductor light-emitting diodes (LEDs) from sapphire and transfer them to commercially available adhesive tape [Toshiki Makimoto et al, Appl. Phys. Express, vol5, p072102, 2012].

Commercial production of nitride LEDS tends to be performed on sapphire substrates, since the alternatives such as silicon carbide (SiC) and free-standing gallium nitride (GaN) are much more expensive. Some research has been directed to producing nitride LEDs on silicon (e.g. www.semiconductor-today.com/news_items/2012/JUNE/USKL_250612.html), but the substrate in that case strongly absorbs the emitted light.

Although LEDs on sapphire do not suffer the latter problem, they do experience strong self-heating effects that degrade performance. The self-heating occurs due to the low thermal conductivity of sapphire. Therefore, methods using laser lift-off or etch have been developed to remove the substrate. However, these methods can be time consuming (expensive) and/or can damage the performance of the LED.

Recently, NTT has reported the use of h-BN interlayers to allow simple mechanical release of devices from sapphire in seconds (www.semiconductor-today.com/news_items/2012/APRIL/NTT_160412.html). The h-BN is structured like multi-layer graphene/graphite with strong in-plane bonds and weak inter-plane bonds, allowing such release. The researchers have now named their process 'Mechanical Transfer using a Release layer' (MeTRe).

The researchers see potential applications of MeTRe as including transfer to flexible substrates, the integration of blue and green nitride LEDs with red phosphide-based LEDs, the combination of nitride with other photovoltaic solar cells produced in other mater-

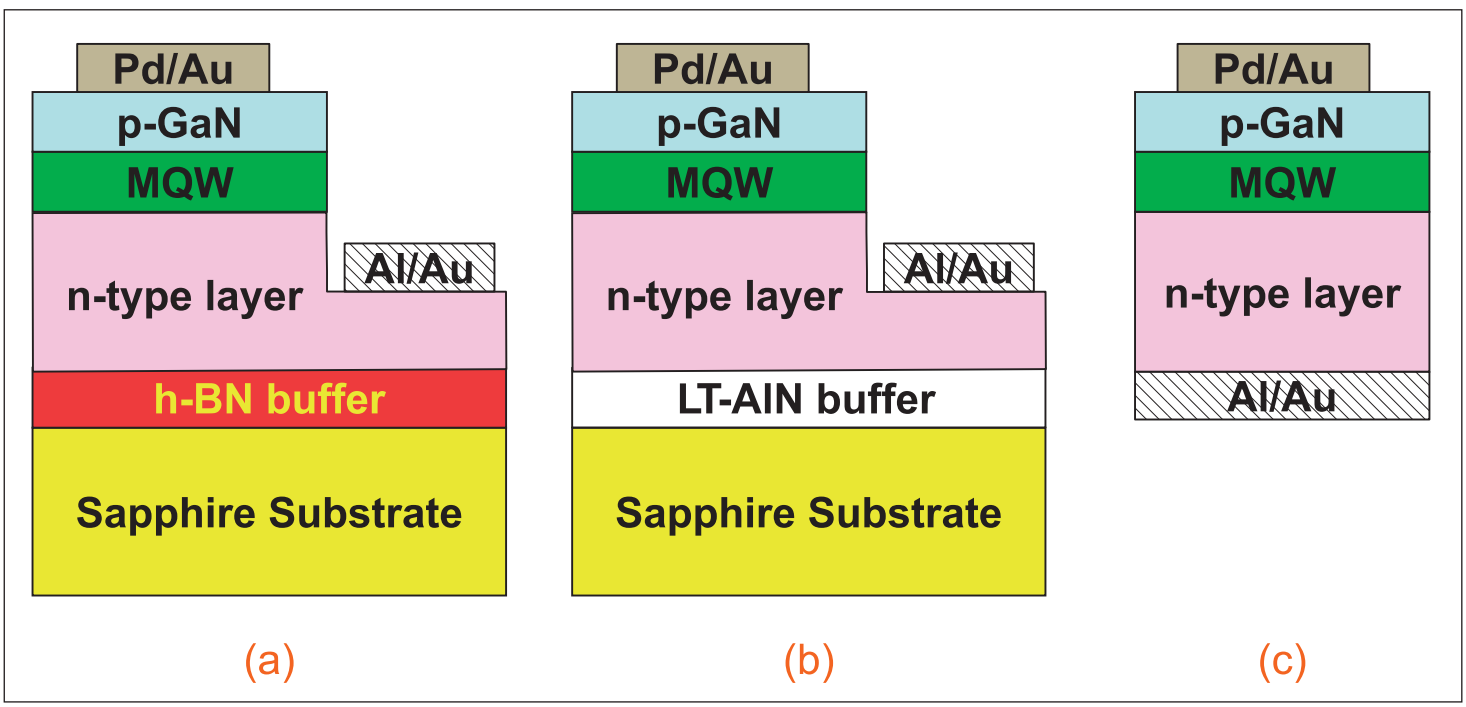

Figure 1. Schematic illustration of InGaN/GaN MQW LED structures: (a) lateral LED on h-BN, (b) lateral LED on LT-AlN, and (c) vertical LED.

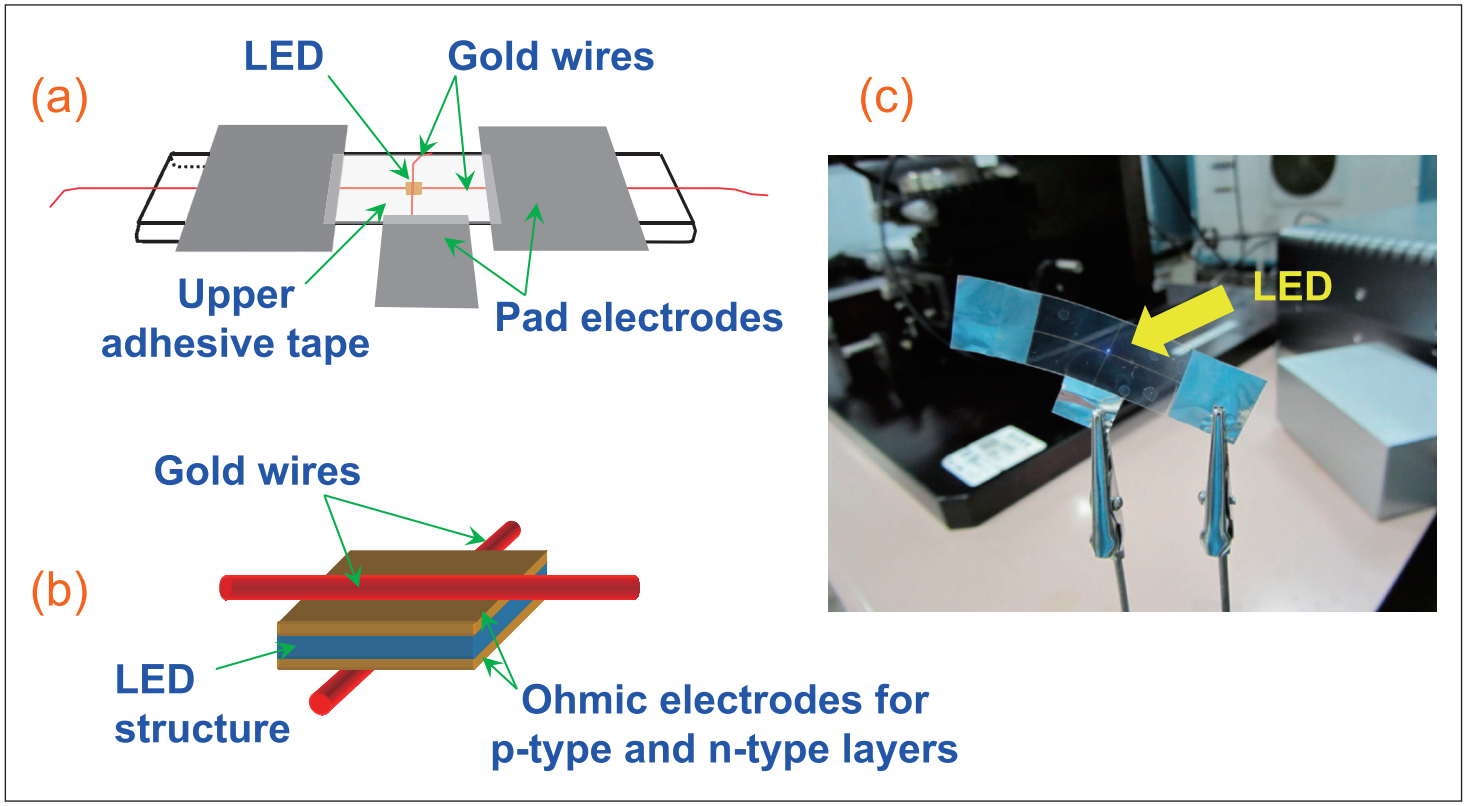

Figure 2. (a) Schematic illustration of a vertical LED sandwiched between two pieces of adhesive tape, (b) magnified schematic illustration of the LED, and (c) photograph of very thin (< 0.1mm) LED prototype emitting violet-blue electro-luminescence light at room temperature.

ial systems, and the integration of GaN-based devices with silicon complementary metal oxide semiconductor (CMOS).

The 3nm h-BN buffer was deposited on sapphire using metal-organic vapor phase epitaxy (MOVPE) of triethyl-boron and ammonia. Further layers consisted of a 300nm aluminium gallium nitride (AlGaN) buffer (16%-Al), a 3μm silicon-doped n-GaN, 10x InGaN/GaN multi-quantum well (15%-indium, 1.8nm/8.6nm), and 100nm of magnesium-doped p-GaN. A conventional structure with a low-temperature (LT) AlN buffer in place of the BN was also created for comparison.

Two LEDs were created in a fairly standard format with the p-electrodes and n-electrodes on the same side of the device, giving regions of lateral current flow (Figure 1a, b). A third device was also produced with vertical electrodes (Figure 1c). The vertical format is only possible with release from the electrically insulating sapphire growth substrate.

When tested at 20mA injection current, the conventional device emitted at a wavelength around 450nm and the BN devices around 460nm. The slight difference in violet-blue wavelength was probably due to different MOVPE growth conditions, according to the researchers. The lateral LED on BN had about three times the peak height of the conventional LED, although the researchers merely state that the performance is "comparable to or stronger than that of the lateral LED".

The vertical LED had a slightly reduced peak height compared with the lateral LED on BN, but it was still stronger than the conventional LED. In fact, the vertical LED spectrum consisted of a series of overlapping peaks around 14nm apart. These peaks were attributed to interference between directly emitted light and light reflected from the aluminium/gold n-electrode. The 14nm peak separation is consistent with the thickness and refractive index of the nitride semiconductor material making up the LED.

The underside surface is very smooth after being released from the sapphire growth substrate

The researchers comment: "The observation of the multiple peaks in the EL spectra means that the underside surface is very smooth after being released from the sapphire growth substrate."

The researchers also assembled the vertical LED into a structure consisting of a chip between crossed gold wires, and then this structure was sandwiched between two pieces of 46μm-thick commercial adhesive tape (Figure 2). The completed structure was less than 0.1mm thick.

The researchers conclude: "Our newly developed MeTRe method will open the way to releasing and transferring a wide range of GaN-based devices to large-area, flexible, and affordable substrates." ■

http://apex.jsap.jp/link?APEX/5/072102

Author: Mike Cooke

Transferring graphene to nitride optoelectronics

Researchers are keen to find practical applications for graphene. In the past year or so, scientists and engineers have been looking at the material's possible use in combination with nitride semiconductor optoelectronic devices such as LEDs and solar cells. Mike Cooke reports recent developments.

Graphene electrodes have recently been proposed as transparent conducting layers (TCLs) for spreading current uniformly across shorter-wavelength (blue-ultraviolet) nitride semiconductor light-emitting diodes (LEDs) and solar cells (SCs). In nitride light-emitting and absorbing devices, current spreading is essential in producing more efficient devices at high output power.

The hopes of those who are developing graphene as a TCL is to create current-spreading electrodes with high transparency, conductivity and flexibility at low cost for volume manufacturing. Other transparent conducting materials such as indium tin oxide (ITO) begin to cut off in the UV region. Also, indium is an expensive material. However, while graphene has better transparency characteristics, apart from being more experimental, its electrical conductivity tends to be lower because of the thinness of the layer.

200nm	p-GaN	Cladding/contact
	InGaN/GaN	Quantum wells/barriers
2µm	n-GaN	Cladding/contact
2µm	u-GaN	Buffer
	Sapphire	Substrate

Figure 1. Epitaxial structure of nitride semiconductor LED/SC material. The buffer and n-contact were grown at 1020ºC; the multi-quantum wells at 800ºC; and the p-contact at 980ºC.

Previous reports in Semiconductor Today have centered on the possibility of use as TCL for UV-LEDs (Mike Cooke, Semiconductor Today October/November 2011, p104), showing improved light output over devices with ITO TCL (www.semiconductor-today.com/news_items/2011/DEC/SEO_311211.html) and using a graphene/zinc oxide nanorod composite to increase light output and to improve current injection (www.semiconductor-today.com/news_items/2012/ FEB/HANYANG_290212.html).

Gold nanoparticle boost

Researchers in Korea have been studying how to improve graphene transparent conducting layers (TCLs) using gold nanoparticle (Au-NP) decoration [Minhyeok Choe et al, Appl. Phys. Lett., vol101, p031115, 2012]. The team was variously associated with Gwangju Institute of Science and Technology, Korea Basic Science Institute Jeonju Center, and Seoul National University.

The aim of applying the Au NPs was to control the graphene work function and conductivity performance. Work function matching is important in creating high injection currents in LEDs (and hence high output) and low series resistance in SCs (boosting conversion efficiency).

The graphene was formed in a chemical vapor deposition process on 300nm-thick polycrystalline nickel on silicon dioxide/silicon (SiO_2/Si). The methane source gas was delivered in a hydrogen/argon gas mix. The substrate temperature was 900ºC. The multi-layer graphene (MLG) layer was released from the nickel by a wet etch in iron chloride ($FeCl_3$) solution. The Au-NP decoration was achieved through immersion in gold chloride ($AuCl_3$) solution.

The graphene was transferred to nitride semiconductor LEDs and SC epitaxial structures (Figure1) grown using metal-organic chemical vapor deposition on sapphire. The n-contact regions were exposed by etching with inductively coupled plasma through the p-type gallium nitride (GaN) and indium gallium nitride (InGaN) multi-quantum well (MQW) layers. The MLG was transferred onto the p-GaN. The MLG over the n-contact regions was removed with photolithographic patterning and reactive-ion etch. The n-contact electrode consisted of chromium/gold. The MLG formed a transparent conducting electrode for the p-contact.

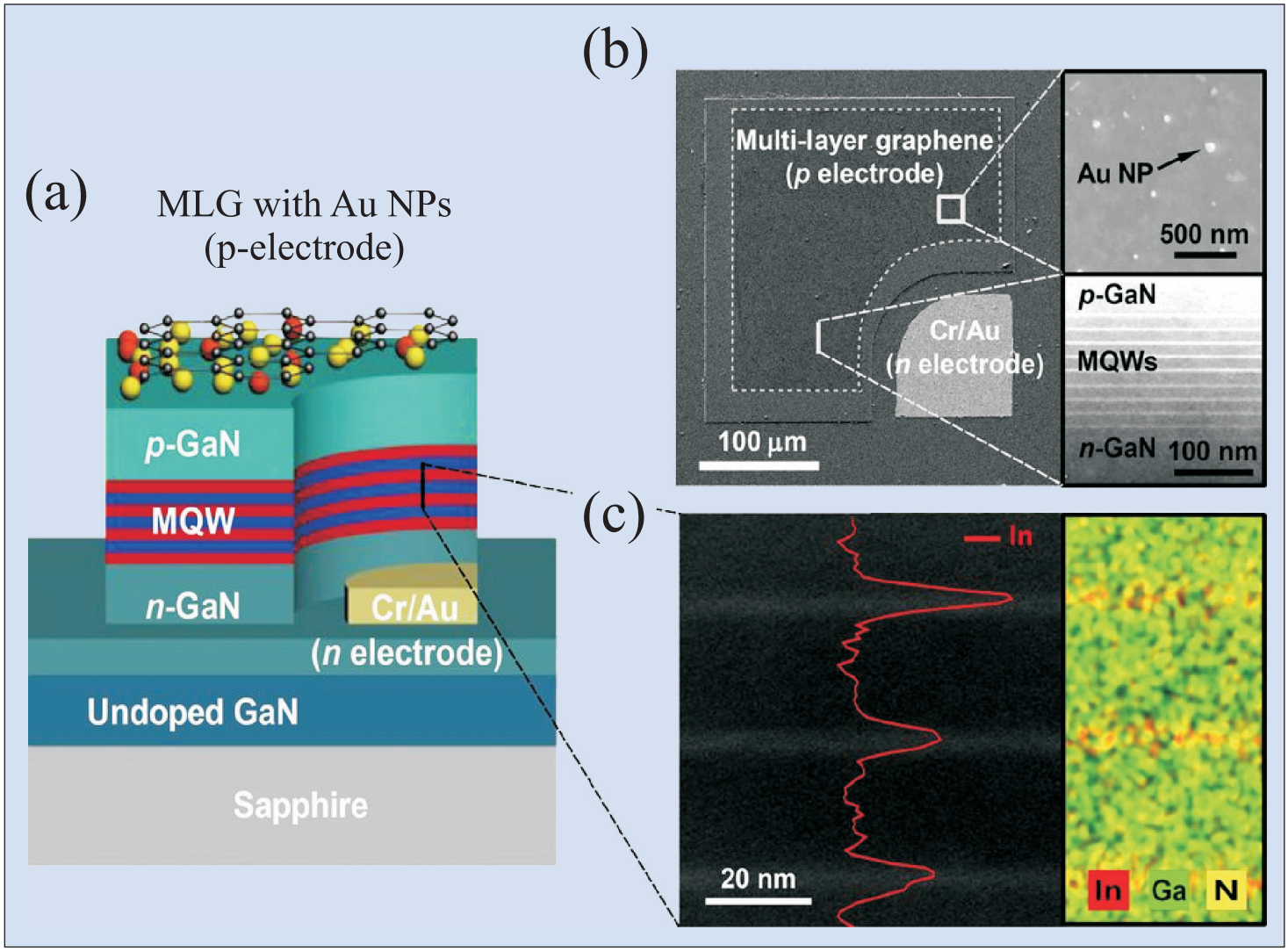

Figure 2. (a) Schematic illustration of MLG-electrode GaN-based LED device. (b) Plan-view SEM image of GaN-based LED device. Insets show SEM image of MLG with Au NPs (top) and TEM image of MQWs (bottom). (c) Magnified TEM image and energy-dispersive x-ray (EDX) mapping of the MQWs.

Various measurements (UV photoelectron and Raman spectroscopy) on MLGs with Au-NPs suggest a hole-doping effect and an increase in work function. One negative effect of adding Au-NPs is to reduce transmittance of near-UV 400nm wavelength light: the transmittance was 89% for MLG without Au-NPs, but 85% for MLG with Au-NPs deposited from a 5mMol/litre (5mM) $AuCl_3$ solution. Increasing the NP density with a 20mM solution further cut transmittance to 78%.

Hall measurements showed a reduction in sheet resistance and an increase in hole density from applying Au-NPs. The sheet resistance without Au-NPs was ~1000Ω/square, falling to ~200Ω/square and ~100Ω/square for the 5mM and 20mM Au-NP treatments, respectively. The respective hole densities were ~10^{13}/cm^3 (no Au-NPs), ~10^{14}/cm^3 (5mM), and ~2×10^{14}/cm^3 (20mM).

Further transmission electron microscope examination of samples gave the estimated thickness of the MLG as about nine layers with an interlayer distance of ~4Å.

When the MLG structures were applied as TCL to nitride semiconductor LEDs (Figure 2), the addition of Au-NPs reduced the forward voltage at 0.4mA to 3.94V (5mM) and 3.86V (20mM) from 4.73V for the TCL without Au-NPs. The reduced forward voltage with Au-NPs is attributed to the smaller work function difference between TCL and p-GaN allowing high current injection into the MQWs. However, the injection at present is not as good as that obtained with ITO TCLs.

Electroluminescence (EL) spectra (Figure 3) indicate that the peak wavelength did not shift noticeably with higher current. The best light output performance at 500μA was obtained from 5mM Au-NPs with 94% better performance than without NPs and 29% better performance than the TCL with 20mM Au-NP treatment. The worse light emission performance from the 20mM device is attributed to the reduction in transmittance.

The researchers comment: "By optimizing the concentration of the Au NPs for electrical conductivity and transparency, the current injection and light emission efficiency of the MLG-electrode GaN-based LEDs may be further enhanced."

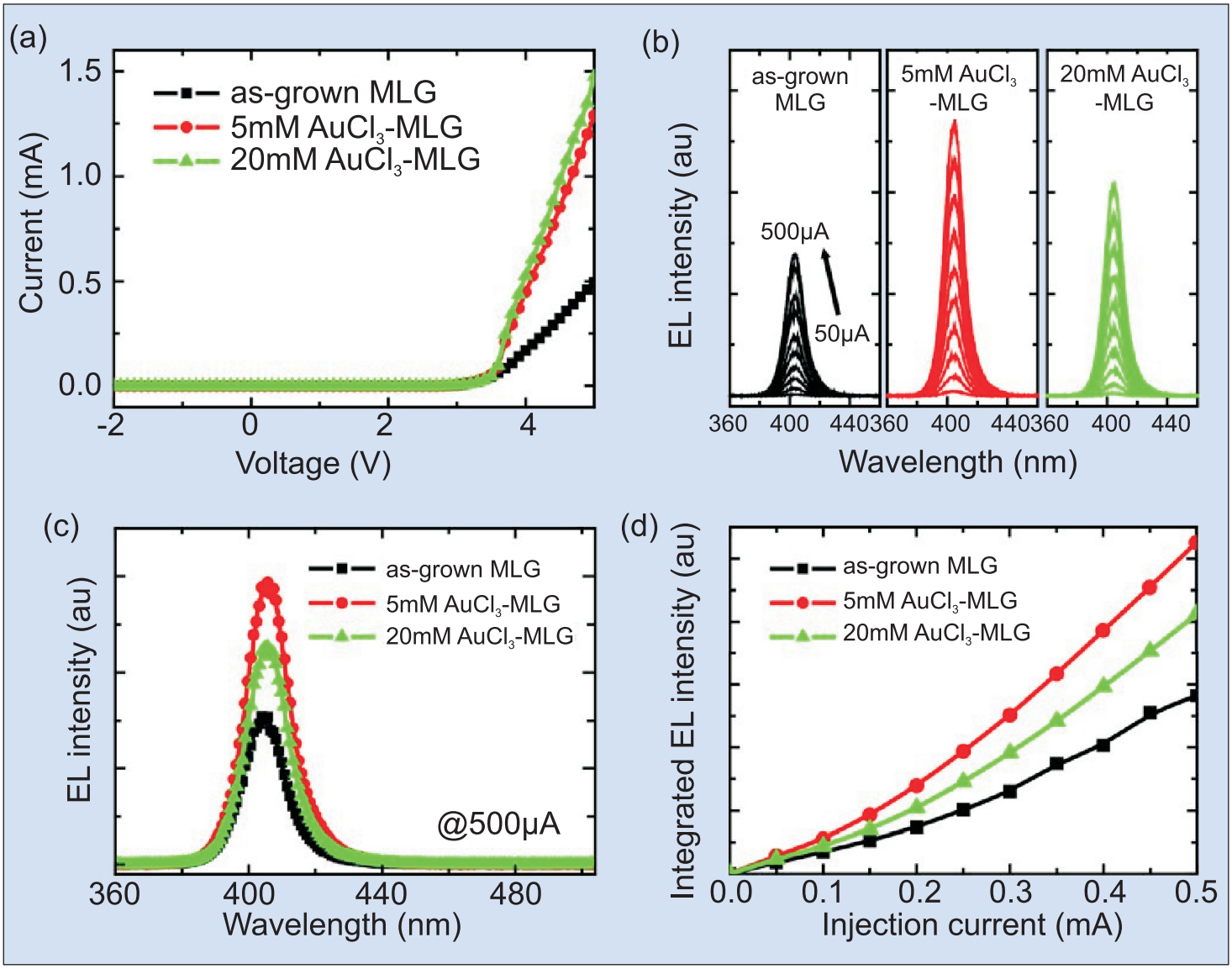

Figure 3. (a) Current–voltage (I-V) curves of GaN-based LEDs with as-grown MLG, 5mM $AuCl_3$-MLG, and 20mM $AuCl_3$-MLG. (b) EL intensity of the MLG-electrode GaN-based LEDs as a function of injection current. (c) EL intensity of MLG-electrode GaN-based LEDs measured at 500μA. (d) Integrated EL intensity of MLG-electrode GaN-based LEDs as a function of injection current.

For SCs (constructed in same way as the LEDs), the best performance was obtained from 20mM Au-NP MLG. For AM1.5G solar illumination, the short-circuit current was 0.67mA/cm^2, the open-circuit voltage 2.25V, and the fill factor 0.77, giving a power conversion efficiency of 1.2%.

The low level of power conversion is due to the peak response being around 400nm (UV), while the bulk of solar radiation is in the infrared-to-green regions (wavelengths longer than 500nm). However, such devices could be used as part of a multi-junction system to extract energy from short-wavelength sunlight. Further, it is hoped in future to create suitable high-quality InGaN quantum wells with narrower bandgaps that respond to longer wavelengths.

The power conversion for SCs that include MLG electrodes without Au-NPs was around 0.9% (short-circuit current 0.51mA/cm^2). The improved performance for 20mM Au-NPs is attributed to improved conductivity (boosting currents), better light absorption, and to a lower energy offset between the TCL and p-GaN (slightly increasing the open-circuit voltage).

Silicon nitride protection

Korea University, US Naval Research Laboratory and University of Florida have improved the reliability of graphene electrodes in ultraviolet light-emitting diodes (UV-LEDs) through application of 20nm silicon nitride (SiN) to avoid oxidation of the material at high temperature [Byung-Jae Kim et al, Appl. Phys. Lett., vol101, p031108, 2012].

The epitaxial material for the UV-LEDs (Figure 4) was grown on sapphire using metal-organic chemical vapor deposition. The few-layer graphene (FLG) was grown at 1000ºC on copper foil using methane as the carbon source for the graphene and hydrogen as the carrier. The graphene was covered with poly(methyl metha-

crylate) (PMMA) to allow etching away of the copper in sulfuric acid solution for 6 hours. The graphene was then transferred onto the epitaxial material before standard processing into mesa-type LEDs with metal electrodes.

When subjected to 10V bias for 30 seconds, these devices suffered serious degradation in performance both in terms of light emission and electrically (Figure 5). Before biasing, the LEDs showed bright emission from across the chip, but afterwards light came only from near the metal electrodes. The current–voltage curves also showed reduced current from the device stressing.

A pulsed bias condition (5% duty cycle) of 10V for 30 seconds was also applied to fresh devices to remove self-heating effects. Although the effect was not as severe, partial degradation of the performance was also seen.

The degradation was attributed to oxidation reducing the thickness of the FLG layer. It was estimated that, before the continuous bias, the FLG consisted of four layers, reducing to two layers after the electrical/thermal stress. The oxidation is thought to occur more readily at edges and defect sites. In the continuous bias test, the reduction in light emission proceeded from the outer edges of the graphene.

To avoid these effects, the researchers applied 20nm silicon nitride to the devices using a Unaxis plasma-enhanced chemical vapor deposition (PECVD) system. The aim was to protect the FLG from attack by oxygen. Silicon nitride has an intermediate refractive index of ~2.1, between the values for GaN (~2.5) and air (1). Also, SiN has high transmittance of UV light.

The SiN-passivated LEDs suffered much less degradation under 10V continuous bias (Figure 6). Further, the time for current to fall to half the initial value was 3–6 minutes.

200nm	GaN:Mg	p-cladding
8nm	AlGaN	Barrier
5nm	GaN	Single quantum well
8nm	AlGaN	Barrier
2µm	GaN:Si	n-cladding
25nm	AlN	
	Sapphire	Substrate

Figure 4. Epitaxial material for UV-LEDs. AlN deposited at 680ºC, 50Torr; other layers at 1025ºC,

The researchers comment: "Since this SiN_x-based passivation technique is compatible with current manufacturing process, it will be convenient and effective for improving the reliability of the graphene-based electronic/optoelectronic devices."

Vertical InGaN LEDs application

Researchers in China have applied graphene as transparent conducting layers (TCL) in vertical light-emitting diodes (VLEDs) made from indium gallium nitride (InGaN) semiconductors [Liancheng Wang et al, Appl. Phys. Lett., vol101, p061102, 2012]. The researchers were based in Beijing at Chinese Academy of Sciences'

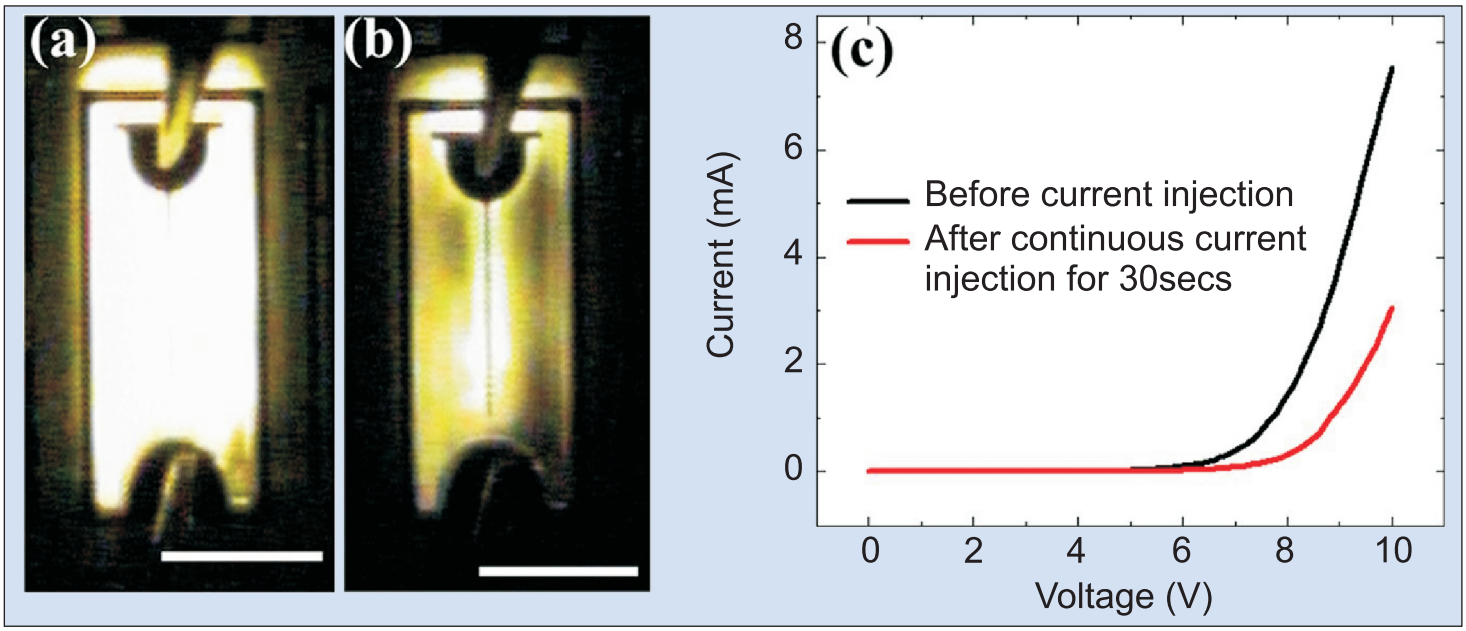

Figure 5. Microscopic electroluminescence images of UV-LED without SiN_x layer (a) before (b) after applying continuous current injection for 30s at forward bias of 10 V. (c) Current vs voltage (I–V) characteristics from UV-LED without SiN_x layer.

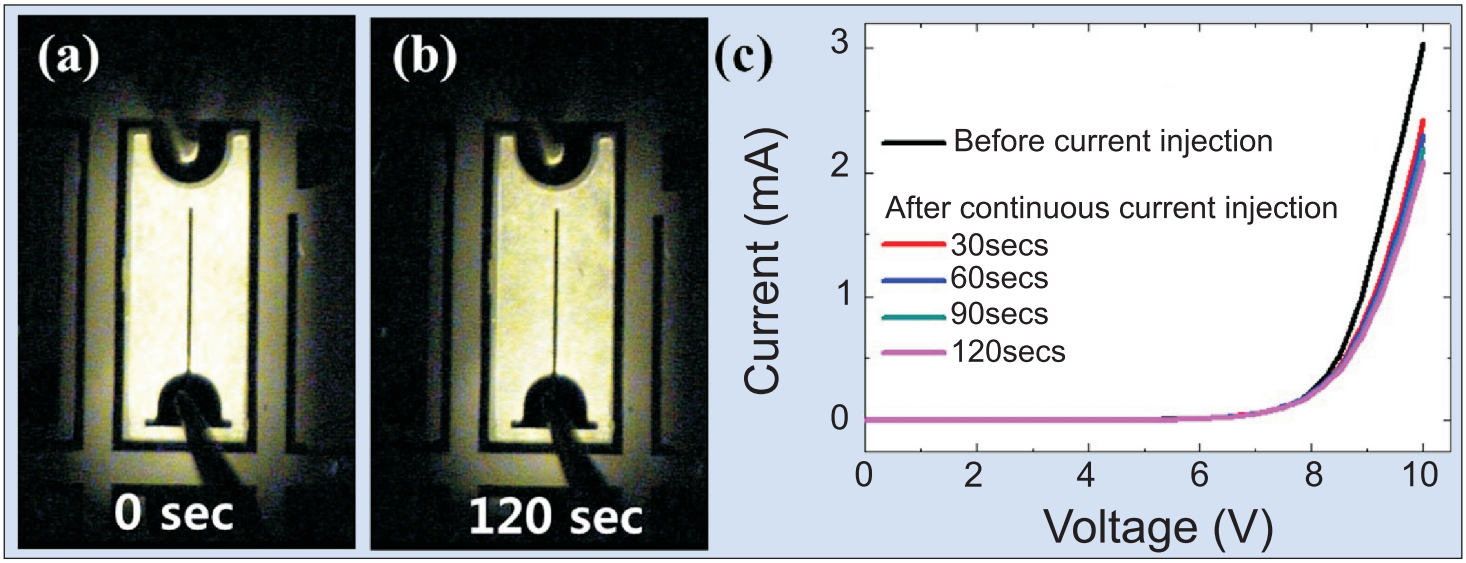

Figure 6. Microscopic electroluminescence images of UV-LED with SiN_x layer (a) before (b) after applying continuous current injection for 120s at forward bias of 10V. (c) I–V from UV-LED with SiN_x protective layer.

Institute of Semiconductors and Tsinghua University.

Although the use of graphene as TCL has begun to be explored recently, the application has generally been to more traditional lateral LEDs where the nitride epitaxial material remains attached to its sapphire growth substrate. In a lateral LED, the n- and p-type electrodes are on the same side of the device, away from the electrically insulating substrate. The current flow path is therefore partly lateral, as it flows through the LED to create light emission.

In the new research, the sapphire substrate was removed using a laser lift-off process to allow vertical current flow from n- and p-type electrodes on opposite sides of the LED chip. In theory, such an arrangement could allow much higher-performance devices, although there is some way to go to make such LEDs more competitive than their lateral counterparts.

One particular problem is the blocking of light output by the metal contacts used to deliver current to the devices. This could be improved by current-spreading layers to redistribute light output away from the contact region using TCLs.

In the new research, the epitaxial material was grown on sapphire using MOCVD (Figure 7). The u-GaN buffer was 2μm, the n-GaN contact was 5μm, and the p-GaN contact was 0.1μm. The multi-quantum-well active region consisted of 10 pairs of 3nm InGaN wells and 7nm GaN barriers.

After the epitaxial material was grown, a highly reflective metal was deposited on the p-GaN contact layer, followed by electro-deposited copper. The copper eventually became the substrate of the complete VLED. The original sapphire growth substrate was then removed using a laser lift-off process.

The graphene was grown on copper foil in a chemical vapor deposition process.

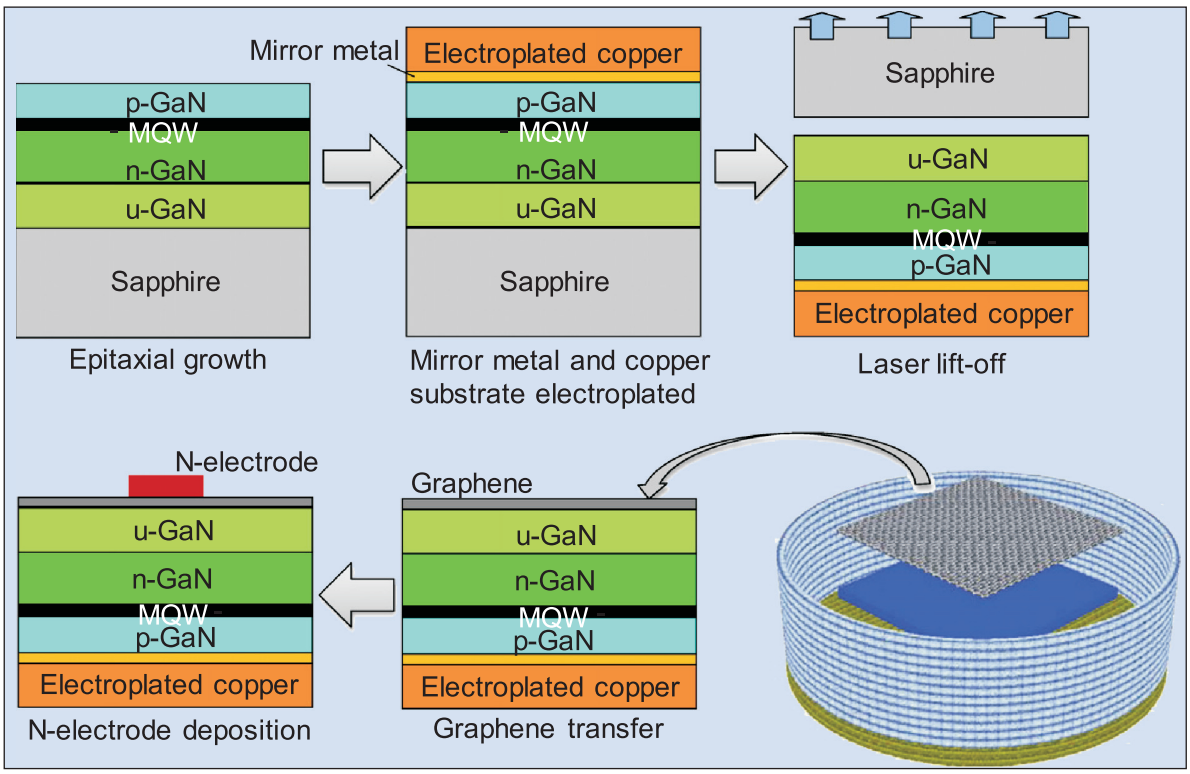

Figure 7. Schematic diagram of G-VLED fabrication process.

The foil was removed using iron chloride solution and the graphene was transferred to the flipped GaN layer of the VLED. After drying, the chromium/platinum/gold n-electrode was applied. The VLED chips were isolated and packaged before testing.

The researchers estimate that the resulting graphene consisted of 6 or 7 monolayers. The transmittance of the film was between 85% and 97% in the 400–800nm wavelength range. This compares with ITO with a transmittance in the same range of around 80%.

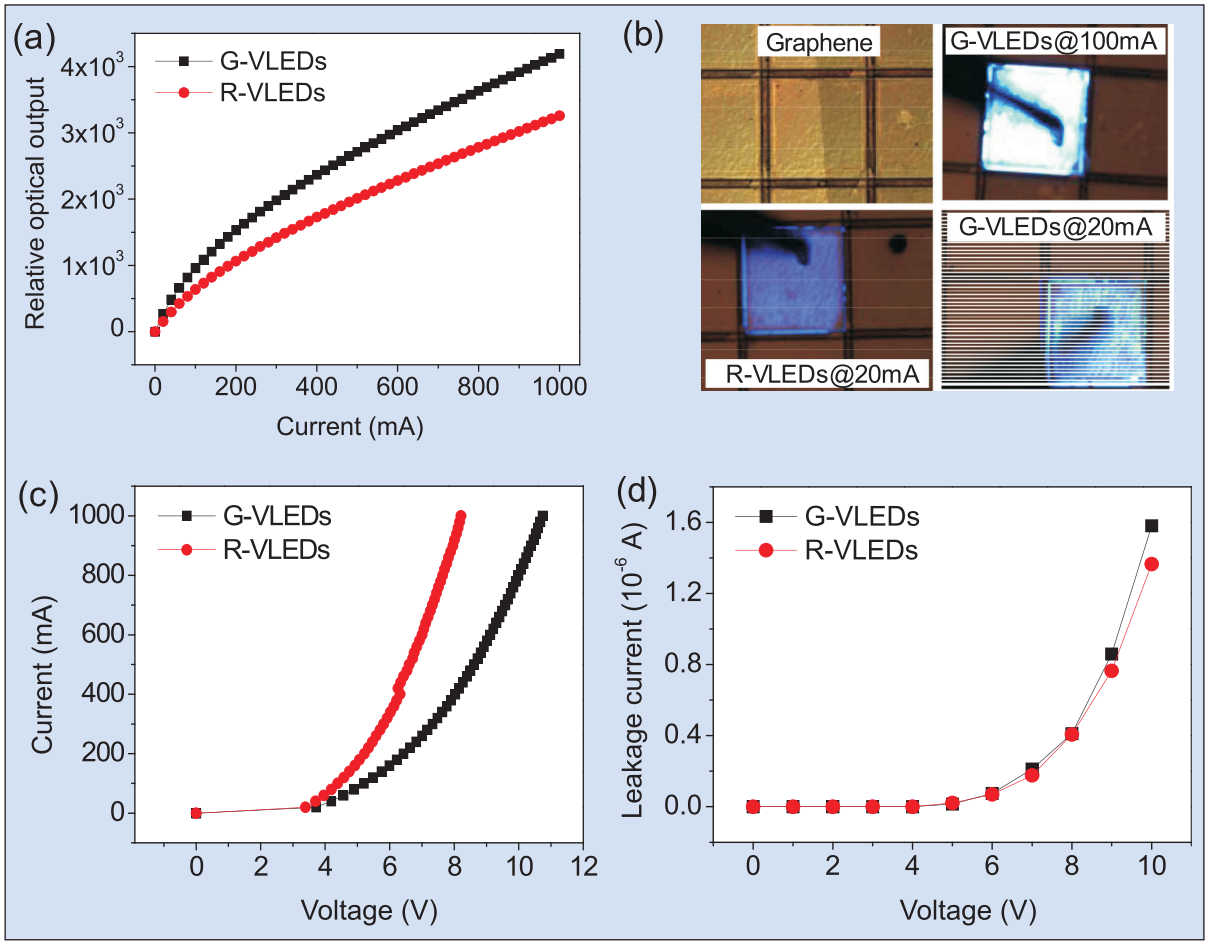

Figure 8. (a) Light output intensity vs current curve for G-VLEDs and R-VLEDs. (b) Emission graph of GVLEDs at different injection currents. (c) I–V characteristics of G- and R-VLEDs before annealing. (d) Reverse I–V curves of G- and R-VLEDs before annealing.

The result of using graphene (G-VLED) rather than ITO (R-VLED) is a 25% increase in light output (Figure 8). The researchers comment: "The light output improvement of G-VLEDs can be attributed to the higher conductivity of graphene than that of u-GaN. In addition, due to the injection current spreading characteristics of graphene, G-VLEDs have relatively uniform current distribution, preventing the current accumulating below the n-electrode."

At present, the drawback of graphene is a higher forward voltage than the ITO TCL devices (9.35V at 1000mA, compared with 8.21V). Higher forward voltage indicated higher series resistance and hence power efficiency losses. The source of the problem is that graphene has a higher contact resistance with u-GaN than ITO.

The forward voltage became higher with annealing. From their measurements, the researchers conclude: "Inter-diffusion of metal atoms and Ga atoms during annealing lead to the partially sandwiched graphene structure, which has been demonstrated to be helpful to improve the performance and reliability of G-VLEDs. It is suggested that more attention need to be paid to the inter-diffusion of metal atoms between metal pads and GaN, especially when graphene films are extensively used in LEDs as transparent electrodes."

Some improvement in light output was found with annealing due to higher resistance under the n-electrode spreading and increasing the current density away from the n-electrode that blocks light output.

A final interesting development is research from Taiwan suggesting a two-fold increase in internal quantum efficiency of nitride MQWs with a graphene surface layer [Huei-Min Huang, Appl. Phys. Lett., vol101, p061905, 2012]. The internal quantum efficiency was measured in a series of photoluminescence experiments at varying temperature.

The researchers from National Chiao Tung University and National Cheng Kung University suggest the effect may be due to a high density of free carriers between the MQW structure and the graphene layer providing a screening of the large polarization electric fields that occur in standard nitride semiconductor heterostructures. These polarization electric fields tend to hold the electrons and holes apart, reducing the amount of recombination into light/photons — often referred to as the quantum-confined Stark effect (QCSE). ■

Mike Cooke is a freelance technology journalist who has worked in semiconductor and advanced technology sectors since 1997.

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Fax: +33 169 33 02 92
www.ums-gaas.com

19 Facility equipment

MEI, LLC
3474 18th Avenue SE,
Albany, OR 97322-7014,
USA
Tel: +1 541 917 3626
Fax: +1 541 917 3623
www.marlerenterprises.net

20 Facility consumables

W.L. Gore & Associates
401 Airport Rd,
Elkton, MD 21921-4236,
USA
Tel: +1 410 392 4440
Fax: +1 410 506 8749
www.gore.com

21 Computer hardware & software

Ansoft Corp
4 Station Square, Suite 200,
Pittsburgh, PA 15219,
USA
Tel: +1 412 261 3200
Fax: +1 412 471 9427
www.ansoft.com

Crosslight Software Inc
121-3989 Henning Dr.,
Burnaby, BC, V5C 6P8,
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Tel: +1 604 320 1704
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10404 Patterson Ave., Suite 108,
Richmond, VA 23238,
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Tel: +1 804 740 8314
Fax: +1 804 740 3814
www.semitech.us

22 Used equipment

Class One Equipment Inc
5302 Snapfinger Woods Drive,
Decatur, GA 30035,
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Tel: +1 770 808 8708
Fax: +1 770 808 8308
www.ClassOneEquipment.com

Brumley South Inc
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Fax: +1 704 664 9246
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Fax: +44 (0)20 7405 9772
www.henrybutcher.com

M+W Zander Holding AG
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Stuttgart,
Germany
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Fax: +49 711 8804 1950
www.mw-zander.com

24 Consulting

Fishbone Consulting SARL
8 Rue de la Grange aux Moines,
78460 Choisel,
France
Tel: + 33 (0)1 30 47 29 03
E-mail: jean-luc.ledys@neuf.fr

25 Resources

SEMI Global Headquarters
3081 Zanker Road,
San Jose, CA 95134, USA
Tel: +1 408 943 6900
Fax: +1 408 428 9600
www.semi.org

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45 rue Sainte Geneviève,
69006 Lyon,
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event calendar

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6–9 September 2012
14th China International Optoelectronic Exposition (CIOE 2012)
Shenzhen Convention & Exhibition Center, Shenzhen, China
E-mail: cioe@cioe.cn
www.cioe.cn

10–14 September 2012
42nd European Solid-State Device Research Conference (ESSDERC-2012)
and
38th European Solid-State Circuits Conference (ESSCIRC-2012)
Bordeaux, France
E-mail: cor.claeys@imec.be
www.esscirc.org

11–12 September 2012
Deutscher MBE-Workshop 2012
Leibniz Universität Hannover, Germany
E-mail: DMBE2012@mbe.uni-hannover.de
www.dmbe2012.uni-hannover.de

11–13 September 2012
IEEE Photonics Society's 2012 Avionics, Fiber-Optics & Photonics Conference (AVFOP 2012)
Courtyard by Marriott, Cocoa Beach, FL, USA
E-mail: c.c.scott@ieee.org
www.avfop-ieee.org

16–20 September 2012
ECOC 2012 (European Conference on Optical Communications)
RAI Convention Centre, Amsterdam, The Netherlands
E-mail: ecoc@medicongress.com
www.ecocexhibition.com

17–18 September 2012
CPV China 2012 & 4th International CPV Workshop
Parkyard Hotel, Jiaxin, near Shanghai, China
E-mail: cpvworkshop@concentratoroptics.com
www.concentrating-pv.org

18–20 September 2012
Strategies in Light Europe
M.O.C. Event Centre, Munich, Germany
E-mail: jamesh@pennwell.com
www.sileurope.com

23–27 September 2012
IEEE Photonics Conference 2012 (IPC-2012), formerly the IEEE LEOS Annual Meeting)
Hyatt Regency San Francisco Airport, CA, USA
E-mail: m.hendrickx@ieee.org
www.ipc-ieee.org

23–28 September 2012
17th International Conference on Molecular Beam Epitaxy (MBE2012)
Nara Prefectural New Public Hall, Japan

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E-mail: secretary@mbe2012.jp
http://mbe2012.jp

23–28 September 2012
37th International Conference on Infrared, Millimeter, and Terahertz Waves (IRMMW-THz 2012)
University of Wollongong, Australia
E-mail: daniel@rice.edu
www.irmmw-thz.org

24–26 September 2012
2012 International Semiconductor Conference Dresden-Grenoble (ISCDG)
MINATEC Campus, Grenoble, France
E-mail: iscdg2012@insight-outside.fr
http://iscdg2012.insight-outside.fr

24–27 September 2012
SPIE Remote Sensing 2012 and SPIE Security & Defence 2012
Edinburgh, Scotland, UK
E-mail: customerservice@spie.org
http://spie.org/security-defence-europe.xml
http://spie.org/remote-sensing-europe.xml

24–28 September 2012
27th European Photovoltaic Solar Energy Conference and Exhibition (EU PVSEC 2012)
Frankfurt, Germany
E-mail: pv.conference@wip-munich.de
www.photovoltaic-conference.com

25–27 September 2012
LED Japan/Strategies in Light
Pacifico Yokohama, Yokohama, Japan
E-mail: jamesh@pennwell.com
www.sil-ledjapan.com

30 September – 5 October 2012
37th International Conference on Infrared, Millimeter, and Terahertz Waves (IRMMW-THz 2012)
Wollongong, Australia
www.irmmw-thz.org

7–10 October 2012
International Semiconductor Laser Conference (ISLC)
San Diego Mission Valley Marriott, CA, USA
E-mail: m.hendrickx@ieee.org
www.photonicsconferences.org

7–12 October 2012
222nd Electrochemical Society (ECS) Meeting
Hawaii Convention Center, Honolulu, Hawaii, USA
E-mail: meetings@electrochem.org
www.electrochem.org/meetings/biannual/fut_mtgs.htm

9–11 October 2012
SEMICON Europa 2012
Messe Dresden, Germany
E-mail: eweller@semi.org
www.semiconeuropa.org

14–17 October 2012
IEEE Compound Semiconductor Integrated Circuit Symposium (CSICS 2012)
Hyatt Regency Hotel, La Jolla, CA, USA
E-mail: customer.service@ieee.org
www.csics.org

14–17 October 2012
29th North American Conference on Molecular Beam Epitaxy (NAMBE 2012)
Evergreen Marriott, Stone Mountain Park, Georgia, USA
E-mail: della@avs.org
www2.avs.org/conferences/nambe/2012

14–19 October 2012
International Conference on Nitride Semiconductors (IWN2012)
Sapporo, Japan
E-mail: secretary @ iwn2012.jp
http://iwn2012.jp

28–31 October 2012
7th International Workshop on Modeling in Crystal Growth (IWMCG-7)
Grand Hotel Taipei, Taiwan
E-mail: kennykang@tl.ntu.edu.tw
http://iwmcg7.ntu.edu.tw

29 October – 2 November 2012
15th European Microwave Week (EuMW2012)
Amsterdam, The Netherlands
www.eumweek.com

1–2 November 2012
LEDforum Taipei 2012
Taipei, Taiwan
E-mail: christseng@trendforce.com
www.trendforce.com/event

5–7 November 2012
9th China International Exhibition and Forum on Solid State Lighting (China SSL 2012)
Guangzhou, China
E-mail: Chinassl.forum@gmail.com
www.exhibition.sslchina.org/eng

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