

# semiconductor TODAY

COMPOUNDS & ADVANCED SILICON

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A microscopic view of nitride μLED displays, showing a grid of small, circular structures on a substrate. The structures are arranged in a regular pattern and appear to be made of a material with a distinct texture. The background is a light blue color.

**Nitride  $\mu$ LED displays  
driven at video rates**

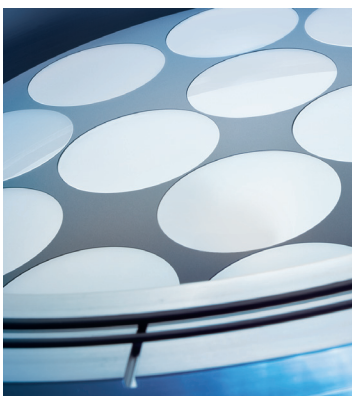
A photograph of several circular GaN-on-Si LEDs. The LEDs are arranged in a grid pattern and have a distinct, iridescent appearance. The background is a light blue color.

**GaN-on-Si LEDs nearing  
sapphire-based efficiency**

**Veeco exits CIGS PVs • Kyma launches  $n^+$  bulk GaN substrates  
Cree acquires Ruud • Translucent launches vGaN templates**

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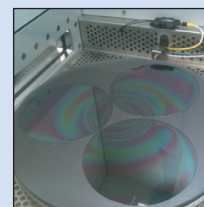
**p26** SemiSouth's new SJE120R063A and SJE120R100A high-linearity, low-distortion SiC JFETs for high-end audio.



**p60** Osram Opto's new ChipLED SFH 4053 infrared emitter for use in low-profile multi-touch displays.



**p77** CEO Rob Gillette and vice mayor Scott Somers unveil a marker commemorating construction progress for First Solar's new factory in Mesa.



**Cover:** MOCVD growth on 8-inch wafers at Bridgelux, which has raised its previous industry record for luminous efficiency for GaN-on-Si LEDs to 160lm/W at 4350K (cool-white) and 125lm/W at 2940K (warm-white), comparable to state-of-the-art commercial sapphire-based LEDs, it is claimed. **p52**

# Lighting on the horizon

This issue we report second-quarter 2011 financial results for GaAs RFIC makers (pages 12–19) as well as optical communications component makers (pages 64–72), LED makers (page 54) and equipment & materials suppliers (pages 34–36 and 45–47, respectively).

The boom in smart-phones (forecast to take a 28% share of the handset market in 2011 — see page 10) is driving demand for increasing GaAs RFIC content per phone. However, suppliers' fortunes are varied, depending on the diversity of their product portfolio and client base. For example, compared with Q1, Skyworks grew a greater-than-expected 6% due to taking market share via diverse markets, while TriQuint grew a less-than-expected 2% due to shifting focus from 2G to 3G, and RFMD made an earlier-than-expected return to growth (despite the declining sales for its largest customer Nokia, due to diversifying). Meanwhile, Anadigics fell 18%, mainly due to sales shifting from its largest customer (North America-based Blackberry-maker RIM) to Korean and Chinese firms Samsung and ZTE, which have grown their handset market share (page 11).

Korea and China, as well as Taiwan, are also driving the LED market. China's LED market is forecast to grow 23% in 2011, while its GaN epiwafer production capacity is expected to quadruple over 2010–2012 (page 8). Correspondingly, the two main suppliers of MOCVD growth systems, both launched larger-capacity systems this year. Also, in June Aixtron opened a subsidiary (and announced a training center) in China, and Veeco has just opened a Taiwan Technology Center (to be reported next issue) as part of an Asia-wide expansion plan.

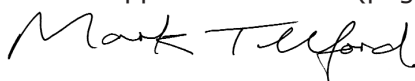
However, while sales of MOCVD reactors have boomed over the last year or so, Veeco and Aixtron both showed a slowdown in Q2. Veeco attributes this to the timing of revenue being impacted by the longer order-to-revenue cycle times associated with business coming from China (due to "customer facility readiness and credit tightening"). Aixtron likewise blames "later-than-scheduled LED production facility completions by Chinese customers (causing shipment delays) and temporary regional customer financing delays".

Correspondingly, analyst firm IMS Research has lowered its forecast for GaN LED market growth in 2011 to just 4% based on the "rapid reduction in first-half 2011 average selling price (ASP) due to a rising surplus, slower growth in the LCD and LED panel markets, and the lighting market not yet being cost competitive" (see page 9). With oversupply worsening and credit in China tighter than expected, it has lowered its 2011 GaN MOCVD system forecast by 24% to 833 reactors. However, this is still up 4% on 2010. Also, the 2011 delays, along with 13 new entrants in China that are taking tools, should yield a still-healthy market of 569 tools in 2012, down 36% but higher than previously expected.

Yet, despite the backlighting slowdown and falling ASPs, US LED maker Cree has returned to quarterly growth, driven by lighting products (prompting its acquisition of Ruud Lighting) — see page 54. The long-awaited 'lighting revolution' may also be accelerated by the likes of Bridgelux, which is claiming luminous efficiencies for silicon-based white LEDs now comparable with those based on sapphire substrates (page 52).

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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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## Optoelectronics market to reach \$22.5bn in 2011 LED sector to grow at 18% annually, from \$8.4bn to \$23.3bn in 2016

Optoelectronics still comprises the fastest-growing individual semiconductor product segment and, as a result, is being entering many new end-markets, comments market research firm Databeans Inc in its report '2011 Optoelectronics'. In particular, the mounting need for energy efficiency across the entire semiconductor industry has led to new developments and applications for LEDs, image sensors, and other optoelectronics.

Databeans expects that optoelectronics will remain the fifth largest semiconductor market by global sales (behind memory, logic, analog and microprocessors) with \$22.5bn in projected 2011

revenue. Sales and unit shipments are expected to take off, starting in 2011 as demand grows for LEDs and organic LEDs (OLEDs) in new products ranging from new TV displays to general lighting applications. Over the forecasted period (2011–2016), optoelectronics will experience the industry's highest average sales growth of 14% annually, at which time it will account for 8% of the total semiconductor industry.

LEDs (including OLEDs, high-brightness white LEDs, and others) will remain the largest and fastest-growing individual product within the optoelectronics market, with global sales reaching \$8.4bn, reck-

ons Databeans. Over the next five years, sales of LEDs will continue to grow at an average rate of 18% annually, more than doubling to \$23.3bn by 2016. Market leaders in 2011 generally include dedicated LED suppliers such as BetaLED, Cree, Lighting Science Group, and Philips.

The other major product in the optoelectronics segment, image sensors, will reach \$7.4bn in 2011, reckons Databeans. This growth is due primarily to CMOS sensor technology, which lends itself to the development of low-cost, high-volume camera phones, the firm adds.

[www.databeans.net](http://www.databeans.net)

## Asia driving near-term adoption of LED lighting Chinese government aims for 5–6 players that can compete globally

"While we continue to see steady and positive proliferation of LED lighting products, key price points could trigger real commercial demand, and Korea, Japan and China have the solutions," says The Information Network in its report 'Niche Markets and Strategies for Small/Mid-size Semiconductor Equipment Companies'.

The rapid increase in the market for LEDs used in applications such as notebook backlights and automobile headlights is spurring heavy capital investments by LED makers, says the market research firm. LEDs are hence creating a niche market for conventional suppliers of semiconductor processing tools and a lucrative market for suppliers of metal-organic chemical vapor deposition (MOCVD) reactors.

High-brightness LED (HB-LED) unit shipments will rise from less than 100 billion in 2010 to nearly 135 billion in 2011, forecasts The

Information Network. In particular, shipments of backlight-unit (BLU) LEDs will rise from 20 billion in 2010 to 30 billion in 2011.

In July the South Korean government launched a new LED lighting adoption program as part of its national energy-saving program, which targets 100% adoption of LED lighting in the Korean public sector and 60% penetration in all lighting applications nationwide by 2020. The government will fund \$185m in 2012 and 2013 to support energy-efficiency rebates.

**HB-LED unit shipments will rise from less than 100bn in 2010 to nearly 135bn in 2011. In particular, shipments of backlight-unit LEDs will rise from 20bn in 2010 to 30bn in 2011**

South Korea's Samsung and LG are marketing domestically a broad range of LED lighting products coupled with highly competitive pricing strategies. Samsung already has a 60W-equivalent LED light bulb priced at less than \$20.

In Japan, the sales volume of LED light bulbs has already reached an adoption rate of more than 40% and is expected to exceed 50% in second-half 2011.

In China, the central Government's objective is to end up with five to six major Chinese players that can compete globally, including three to five flagship companies. Not only will China become a powerhouse in low-cost manufacturing by 2015, it will also be the largest consumer of LEDs, reckons The Information Network. Currently, there are 50 large indoor and outdoor lighting projects either ready or in place, notes the firm.

[www.theinformationnet.com](http://www.theinformationnet.com)

## Cumulative CPV installations expected to grow from 23MW in 2010 to 12.5GW by 2020

Out of a global CPV cumulative installed capacity of currently 23MW, in 2010 Spain dominated the CPV market with about 16MW (70% of the global CPV installed base), according to a report 'Concentrated Photovoltaic (CPV) — Global Installation Size, Cost Analysis, Efficiencies and Competitive Analysis to 2020' available from [companiesandmarkets.com](http://companiesandmarkets.com).

Most parts of Spain experience high DNI (direct normal irradiation), which attracts CPV installers for investments in Spain. However, the technology is still developing, so most CPV projects are in the pilot or prototype stage. Guasor Foton's Navarre power plant and Murcia power plant are the largest existing CPV plants, with installed capacities of 7.8MW and 2MW, respectively.

Spain is followed by the USA, with a cumulative installed capacity of about 4.5MW (20%). Greece and Australia have also attracted CPV system installers due to a high DNI concentration (accounting for about 5% and 3% of global CPV cumulative installed capacity, respectively).

In the USA, emerging companies are SolFocus, Amonix, Emcore and Skyline Solar. European firms such as Concentrix and Abengoa Solar as well as Taiwan's ArimaEco are also making progress in the CPV market, says [companiesandmarkets.com](http://companiesandmarkets.com).

Companies that have successfully operated CPV prototype systems in pilot locations are progressing towards multi-megawatt CPV projects, notes the market research firm. With an increased understanding of CPV in terms of technology and investment, most of the players have plans for large-scale CPV projects, it adds.

The CPV market is forecasted to grow dramatically over the next three years. Firms such as SolFocus, Amonix and ArimaEco are planning to expand their pro-

duction capacities in order to meet the upcoming demand. Countries such as Italy, China, Australia, India and South Korea are proving to be important emerging markets in the CPV industry. In particular, Italy's CPV FIT (feed-in tariff) program and China's low-cost produc-

tion and high DNI in its western region are attracting CPV investors in these countries.

The report concludes forecasts that, in total, global cumulative installations are forecasted to reach 12.5GW by 2020.

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## China's LED industry to grow 23% to \$5.8bn in 2011 Street lighting to grow from \$1.5bn this year to \$1.8bn in 2012

Buoyed by government support and increased penetration into new applications, China's LED market will jump to \$5.8bn in 2011, up a robust 23% from \$4.7bn in 2010, according to the IHS iSuppli China Electronics Supply Chain Service from information and analysis provider IHS.

The LED market in the world's most populous country is forecast to reach \$6.9bn next year on its way to \$11.1bn by 2015, equivalent to a five-year compound annual growth rate (CAGR) of 17.7%.

"Driven by markets including backlights for liquid-crystal display (LCD) TVs and street lighting, LEDs have become a hot item for manufacturing in China and also an attractive investment segment in the country," says Vincent Gu, senior analyst for China electronics research at IHS. "Moreover, official government commitments to the industry appear to be paying off dividends."

Exceedingly broad, the Chinese LED market covers a range of applications including LED displays, traffic signals, automotive use, LCD backlighting, handset key pads,

digital still camera flashlights, decorative lighting, street lighting and general illumination.

Street lighting will be the biggest segment, reaching \$1.5bn this year and reaching \$1.8bn in 2012, it is forecasted. The LCD backlighting market is also headed for strong growth on the basis of the rapid adoption of LEDs for large-sized LCD TVs and laptops, generating \$1.8bn in 2015, up from \$713m in 2011.

A new demand driver for LEDs in the medium to the long term will be the general lighting market.

Given the global trend to reduce carbon emissions, China demand in the general lighting segment will be strong for LEDs, which offer low-power consumption and are environmentally safe. LED shipments for general lighting will make up 15.5% of the total LED market this year, IHS data shows.

Despite the current popularity of LEDs in China, the domestic LED industry is still in its infancy compared to its counterpart in thriving LED-focused countries such as the USA and Taiwan.

Some reasons why China trails in the field include lagging technological capabilities currently available in the country as well as a paucity of adequately experienced management teams and R&D engineers to lead the way, says IHS. Furthermore, the lack of Chinese intellectual property in core and upstream segments — such as in LED wafers — is a serious concern.

Still, China's LED players enjoy ample funding from local and government sources, which should help domestic entities to capture the large Chinese end-demand for LEDs in the future. To date, local governments in China have subsidized at least 70% of the purchase price for metal-organic chemical vapor deposition (MOCVD) equipment employed in LED manufacturing — equivalent to \$1.5m for each machine. Furthermore, tax and utility payment benefits are offered to encourage investments in the domestic LED industry, which is proving to be an additional advantage for local players.

[www.ihs.com](http://www.ihs.com)

## China GaN epi production to grow 300% in 2 years

Amid explosive growth in equipment spending from LED fabs globally (jumping last year from \$606m in 2009 to \$1.78bn in 2010), GaN epitaxial wafer production capacity in China in particular will grow by more than 300% in just 2 years (2010–2012), reaching 1,282,000 wafers per month (2" equivalents), according to the 'China LED Fab Industry Report' from global industry association Semiconductor Equipment and Materials International (SEMI).

Noting that the global LED industry could grow from \$10bn in 2010 to over \$100bn by 2020, the report summarizes China's rapidly growing LED industry, including capital and equipment spending, fab capacity, and sales rankings of Chinese LED makers. Also included are subsidies

for China fab projects, along with new LED fab projects, names of China's sapphire wafer suppliers, and profiles of China's top LED makers.

China has developed government support infrastructure for LED manufacturing and consumption, aided by subsidy programs from local governments. The country is the world's leading consumer of solid-state lighting and the leading producer of LCD TVs (the main driver for HB-LED consumption), notes the report. LED production investments have hence escalated rapidly, with new LED fab projects blossoming in the past two years. China now accounts for almost 50% of overall equipment spending.

The report therefore covers LED wafer and sapphire substrate

manufacturing projects, government incentive programs, MOCVD tool forecasts, and emerging China-based manufacturing.

In particular, MOCVD tool installations are growing from a cumulative total of 323 reactors in 2010 to more than 1000 reactors by the end 2012. In addition, to catch up with the production expansion as well as the non-Chinese supplier bases, 10 new sapphire substrate projects are beginning in China.

The report is prepared by SEMI China-based market analysts and is based on the SEMI Opto/LED Fab Watch and Forecast service (which monitors LED capital spending at more than 160 fabs worldwide) as well as other sources.

[www.semi.org](http://www.semi.org)



# IMS lowers 2011 GaN MOCVD forecast by 24% to 833 reactors and upgrades 2012 forecast

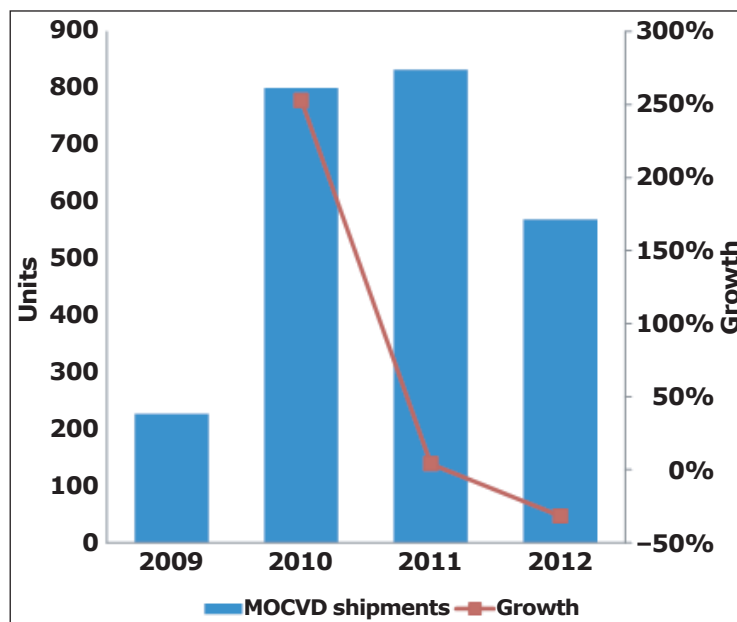
## New LED entrants and 2011 delays boost 2012 outlook

The latest chapters on metal-organic chemical vapor deposition (MOCVD) in IMS Research's 300-page 'Quarterly LED Supply and Demand Report' reveal significant shifts in MOCVD adoption for LED manufacturing.

In June, the previous quarter's report lowered the growth forecast for annual gallium nitride (GaN) LED revenue to just 4% (to \$8.7bn). This was based on the rapid reduction in first-half 2011 average selling price (ASP) due to a rising surplus, slower growth in the LCD and LED panel market, and the lighting market not yet being cost competitive. With growth slowing, margins shrinking, the oversupply worsening and credit in China tighter than expected, LED makers have pushed out a significant number of MOCVD reactor installations in 2011, resulting in a surprisingly large downgrade in MOCVD shipments.

IMS Research has hence lowered its 2011 GaN MOCVD forecast by 24% to 833 reactors. However, this still represents 4% growth over 2010. The lower capacity growth should slow down LED oversupply and stabilize pricing, which will benefit near-term LED manufacturer profitability and eventually lead to more tool sales, says IMS, resulting in an upgrade to the 2012 outlook.

The 2011 delays, along with 13 new entrants in China that are taking tools, should result in a healthy GaN MOCVD market of 569 tools in 2012, down 36% on 2011 but higher than previously expected. Tool shipments are forecasted quarterly and identified by customer and wafer size. These new entrants are a key reason for the growth, with these firms accounting for 110 tools in 2012. Due to the smaller surplus, the lower price reductions should boost the 2012 GaN LED market to \$10bn, up 15%



**GaN MOCVD shipments, results and forecast (2009–2012).**

on 2011 (with packaged LEDs for lighting up 35% to \$2.3bn).

China is expected to continue to dominate the market for GaN MOCVD tools, but shrink to 61% in Q4/2012 as Taiwan and Korea rebound. Taiwan's Epistar is expected to be the top MOCVD customer in 2012, followed by China's San'an Optoelectronics, GCL Opto, Taiwan-based SemiLEDs and Taiwan's Genesis Photonics. The report also identifies two Chinese manufacturers of MOCVD tools that are expected to win business from second-half 2011.

The most recent report also quantifies Q2/2011 GaN MOCVD shipment results. Highlights include:

- Shipments were down year-on-year for the first time since at least 2008, falling 14% if Veeco's MaxBright reactors were excluded (as Veeco has not yet recognized revenues for this new tool according with GAAP). Including MaxBright reactor shipments, installations were still down 2%.
- Excluding MaxBright shipments, China continued to dominate the market, accounting for 70% of

installations, with Korea and Taiwan at 11% each.

● Lextar was the top customer in Q2/2010, and nine of the top 10 customers had operations in China.

● Aixtron remained top in GaN MOCVD shipments, gaining 4 points of market share to 57% (excluding MaxBright),

with Veeco losing 3 points to 41%. However, including MaxBright reactors, Aixtron's advantage slips to 49% versus 48% for Veeco (the closest it has ever been between the two competitors).

● By region (excluding MaxBright), Veeco led in China, USA and Europe, while Aixtron led in Korea and Taiwan. Veeco's K465i remained the industry's most popular tool, but Aixtron's CRIUS II and G5 each gained share and rose to the number 2 and 3 positions, respectively.

● The share of shipments that were for 4" wafers rose more than 50%, while the 6" share more than doubled as companies move to larger wafer sizes to boost their output and lower costs.

IMS Research says that its latest 'Quarterly GaN LED Supply and Demand Report' also forecasts LED demand by application through 2016, panel and LED panel shipments by supplier, number of LEDs/panel by supplier by size, LED and MOCVD supply/demand through 2016, sapphire supply and demand and sapphire pricing.

[www.ledmarketresearch.com](http://www.ledmarketresearch.com)

## Smart-phone sales of 420m in 2011 to take 28% of market

Sales of smart-phones will exceed 420 million devices in 2011, accounting for nearly 28% of the entire global handset market, according to market analyst firm IMS Research. With the introduction of more affordable 'entry-level' smart-phones, IMS predicts that annual sales will surpass 1 billion devices by the end of 2016, accounting for half of all mobile handsets sold.

"But, despite the higher margins for smart-phones, and the seemingly insatiable consumer appetite for converged devices, it is clear that not all OEMs are equally positioned to capitalize on this market trend," says Josh Builtta, analyst in IMS' Mobile Technologies Group. "For instance, LG, despite being the third largest OEM in the world, has offered a fairly limited smart-phone portfolio in recent years, a factor that resulted in the company reaching less than a 3% share of the total smart-phone market in 2010," he adds. At the same time, Nokia saw its share of the smart-phone market decline so dramati-

cally that in early 2011 it dropped the Symbian platform in favor of Microsoft's Windows Phone OS. In Q2/2011, Nokia reported that its smart-phone sales were down 34% year-on-year to 16.7 million.

Clearly, one of the key dynamics of the mobile handset competitive environment in recent years has been the inability of many traditional market leaders to recognize and adjust to the growing smart-phone tier," says Builtta. "The reasons for these failures vary and include everything from poorly designed and manufactured devices, unsatisfactory user interfaces, and portfolios that don't offer products with a differentiating feature," he adds. "These lapses have created opportunities for newer entrants to the market, which they have aggressively pursued."

In recent years, no company has flourished in this environment as much as Apple. In Q2/2011, Apple reported record sales of more than 20 million iPhones, indicating that it can be expected to remain an influential presence in the market

despite the increased competition.

However, Apple is not alone in its success. Of the traditional handset makers, Samsung has demonstrated the best results in recent years. Capitalizing on its diverse portfolio — which includes devices using the firm's own bada operating system along with Android and Windows Mobile — as well as its highly popular Galaxy series, Samsung's share of the smart-phone market increased from about 3% in Q1/2010 to more than 13% in Q1/2011. At the same time, smaller, dedicated smartphone vendors such as HTC have seen their position rise dramatically, says IMS.

"These companies are well positioned to benefit from the projected growth of the smart-phone market in the future," reckons Builtta.

"Though the other OEMs are stepping up their efforts in the space, companies such as Apple, HTC and Samsung have a considerable amount of momentum. Catching them will not be an easy task."

<http://imsresearch.com>

## Wireless infrastructure GaAs devices \$320m in 2015 New architectures to drive 8% annual growth

With mobile data consumption continuing to skyrocket, operators are refining their wireless infrastructure network architecture to support the increasing data demand. Also, developments like MIMO (multiple input/multiple output) antennas, heterogeneous networks, remote radio heads and small cells will increase the number of base-station sectors, but reduce the transmit power required from each sector, according to the Strategy Analytics GaAs and Compound Semiconductor Technologies Service (GaAs) Forecast and Outlook 'Wireless Infrastructure RF Power Device Demand: 2011 – 2015'. Both trends should lead to a consistent growth rate for gallium arsenide devices, boosting the wireless infrastructure GaAs

device market from about \$205m in 2011 to \$320m in 2015.

The report forecasts that base-station sector shipments will rise to slightly over 9.2 million in 2015, with more than half for lower-power, smaller cells. The report also details the history and latest trends for antennas, power amplifiers, low-noise amplifiers, transceivers and front-end components.

"Mobile data consumption is rapidly pushing the wireless infrastructure market to an inflection point," comments Eric Higham, director of the Strategy Analytics GaAs and Compound Semiconductor Technologies Service. "Operators are implementing networks that rely on smaller, lower-power cell footprints to ensure that consumers continue

to embrace data applications. This architecture expands opportunities for GaAs components," he adds.

"4G technologies, like LTE, are forcing the network evolution to larger numbers of lower-power infrastructure sectors, which will increase the opportunity for GaAs amplifiers," says Asif Anwar, director in the Strategy Analytics Strategic Technologies Practice.

The report segments the wireless infrastructure amplifier market by function (power, driver, low noise) and technology. It also forecasts the number of base-station sectors by geography, frequency and output power, and addresses trends in subscriber growth, antenna technologies and power amplifier designs.

[www.strategyanalytics.com](http://www.strategyanalytics.com)

## Handset shipments up 13% annually to 361 million in Q2 Nokia's market share down to just 24.5% as Apple takes 4th place

Despite multiple debt crises and economic volatility worldwide, global handset shipments grew 13% year-on-year to 361 million units in second-quarter 2011, according to a report from market research firm Strategy Analytics' Wireless Device Strategies (WDS) service.

"Apple was a star performer during the quarter, as it shipped a record 20.3 million units [up from just 8.4 million a year ago] and closed the global market share gap with [third-place] LG to its lowest ever level of just over one point," says senior analyst Alex Spektor. Apple's market share consequently more than doubled, from 2.6% to 5.6%.

"LG's 3G smartphone volumes are expanding fast, but the Korean vendor is struggling to grow in the 2G feature phone and basic phone sub-categories," Spektor adds. LG's unit shipments fell year-on-year from 30.6 million to 24.8 million, cutting its market share from 9.6% to just 6.9%.

Leading handset maker Nokia's

Handset vendor shipments (millions) and market share.		
Shipments	Q2/10	Q2/11
Nokia	111.1	88.5
Samsung	63.8	74.0
LG	30.6	24.8
Apple	8.4	20.3
ZTE	10.5	18.0
Others	95.6	135.5
<b>Total</b>	<b>320.0</b>	<b>361.1</b>
<b>Growth</b>	<b>14.5%</b>	<b>12.8%</b>
Share	Q2/10	Q2/11
Nokia	34.7%	24.5%
Samsung	19.9%	20.5%
LG	9.6%	6.9%
Apple	2.6%	5.6%
ZTE	3.3%	5.0%
Others	29.9%	37.5%

global market share dropped sharply from 34.7% in Q2/2010 to 24.5% in Q2/2011 (its lowest level since 1999), as its shipments fell from 111.1 million to 88.5 million units. "Samsung is now just 4 points behind and breathing down

Nokia's neck," says Neil Mawston, director at Strategy Analytics. "An unexciting touchphone portfolio, inventory correction, wavering demand for the Symbian platform, and limited presence in the huge US market continued to weigh on Nokia's near-term performance," he adds.

Samsung's shipments rose from 63.8 million to 74 million handsets worldwide in Q2/2011, raising its market share from 19.9% to 20.5%. Its smartphone volumes soared but its global feature phone and basic phone market share fell slightly, due to intense competition from Chinese brands such as TCL-Alcatel and ZTE.

ZTE maintained an upward growth trend during the quarter. Keen pricing of low-end 2G models and aggressive promoting of mid-range 3G models enabled the Chinese vendor to capture 5% global handset market share (up from 3.3% a year ago), as shipments rose from just 10.5 million to 18 million units, notes Strategy Analytics.

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## Apple becomes number one smartphone vendor in Q2/11 Nokia's market share falls year-on-year from 38% to 15%

Global smartphone shipments grew 76% year-on-year to a record 110 million units in second-quarter 2011, according to a report from market research firm Strategy Analytics' Wireless Smartphone Strategies (WSS) service. Both Apple and Samsung overtook long-time volume leader Nokia for the top two spots in the rankings.

"We had previously reported on Apple becoming the largest smartphone vendor in terms of revenue and profits. Now, just four years after the release of the original iPhone, Apple has become the world's largest smartphone vendor by volume," says

Strategy Analytics' senior analyst Alex Spektor. The firm's shipments have risen from just 8.4 million to 20.3 million units, boosting its market share from 13.5% to 18.5%. "Apple's growth remained strong as it expanded distribution worldwide, particularly in China and Asia," he adds.

Samsung's shipments grew a huge 520% year-on-year, from 3.1 million to 19.2 million units, raising its market share from 5% to 17.5%. "Samsung's Galaxy portfolio has proven popular, especially the high-tier S2 Android model," says Neil Mawston, director at Strategy Analytics.

"Having become the first ever vendor to ship 100 million smartphones in a single year during 2010, long-time leader Nokia has slipped two places in our rankings in Q2/2011," notes Strategy Analytics director Tom Kang. Its quarterly unit shipments fell year-on-year from 23.8 million to 16.7 million in Q2/2011. "The vendor's 15.2% global smartphone market share is less than half of what it was just one year earlier [38.1%], as the industry awaits Nokia's pending transition to Windows Phone 7," he adds.

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# Anadigics' revenue falls 18% in Q2 to \$35.6m

## Shift in customer mix from RIM to Korea and China shortens lead times and visibility

For second-quarter 2011, GaAs-based broadband wireless and wireline communications component maker Anadigics Inc of Warren, NJ, USA has reported net sales of \$35.6m, down 18.1% on Q1's \$43.5m and down 31.1% on \$51.7m a year ago.

In particular, the firm's largest customer, North America-based Blackberry maker Research In Motion (RIM), fell by \$9m from Q1's \$16.6m (down from 38% of total revenue to just 22%). In contrast, other top customers in Q2 (Samsung, ZTE, Cisco, Huawei, and LG) yielded growth.

"The sequential drop in net sales for the second quarter primarily reflects a decrease in shipments to one of our large North American customers [RIM], which was partially offset by the resurgence in shipments of our line amplifier products," notes president & CEO Ron Michels.

Wireless revenue fell by 29% from Q1's \$36.2m to \$25.7m (from 83% of total revenue to 72%), mostly due to RIM. However, this was partially offset by broadband revenue rising by 36% from Q1's \$7.3m to \$9.9m (from 17% of total revenue to 28%).

Of broadband revenue of \$9.9m, set-top boxes fell slightly from Q1's \$2.4m to \$2.2m and WiFi (WLAN) fell from \$1.7m to \$1.2m. However, WiMAX almost doubled from \$900,000 to \$1.5m and cable infrastructure more than doubled from \$2.3m to \$4.8m.

Gross margin has fallen from Q1's 29.4% to 20%, factoring in fab utilization falling to the low 50% range. Operating expenses were a less-than-expected \$16.6m.

"Achieving a competitive cost structure and aligning our expenses to the current revenue level [while keeping R&D intact] are extremely important, and we've made significant progress in this regard during the quarter," notes Michels.

Excluding a \$1m restructuring charge for a workforce reduction in May (which should save about \$4m annually), non-GAAP net loss was \$9.4m, compared with just \$5m in Q1 and a profit of \$1.1m a year ago.

Capital expenditure was \$800,000 and depreciation was \$4.7m. Nevertheless, during the quarter, cash, cash equivalents and short- and long-term marketable securities fell slightly from \$104m to \$103.4m, due to better-than-expected cash collection from customers.

"Looking forward, I am encouraged by the progress being made on new design opportunities with our other wireless customers, particularly in Korea and China," says Michels.

"We've received the top PA supplier rating from Samsung for our power amplifiers, based on our delivery, quality, technology, and responsiveness," he adds. "We have three times the number of parts qualified with Samsung compared to a year ago... a leading indicator of future engagements," he adds. "We have secured a very high-profile design win on the Sam-

**Anadigics is continuing to increase its served available market for CATV line amplifiers by incorporating gallium nitride technology into its surface-mount line amplifier portfolio, and is expanding into a hybrid form factor. "We have already sampled these products and we've sampled them with more than 20 customers," says Michels. "We expect to announce design wins later this year"**

sung Droid Charge, one of the top selling Verizon 4G smartphones. We have secured another high-profile design win for the LG Revolution, and our relationship continues to be strong with LG," continues Michels. "We remained dominant on all the tablets and smartphones at ZTE. At Huawei, we recently received an award ranking us their number one PA supplier."

While RIM is still ramping down as expected, Anadigics continues to work closely with them on new platforms for 2012, notes Michels, adding that the firm has a 90% share on the 3G Blackberry Playbook.

"Additionally, we remain on track with our initiatives to expand revenue opportunities over the longer term with our new products for the wireless 3G/4G/LTE and broadband markets," says Michels. Anadigics has created a reference design team dedicated to the largest reference design partner, in order to further business opportunities with Qualcomm. "As a result, we have expanded our engagement on their future reference designs. These efforts have already generated reference design wins for us, both on the LTE Fusion and the Gobi 3000 platforms. Most of our customers will be designing with the Fusion chipset, which is expected to ramp in 2012," says Michels.

"We are now pursuing design opportunities beyond our traditional wireless and broadband customer base to expand our marketing share," he adds.

"We have refocused our energies on more balanced and targeted product portfolios that expand our SAM [served addressable market] in wireless from \$1bn in 2011 to roughly \$2bn, beginning in second-half 2012," says Michels.

In particular, in broadband, Anadigics is continuing to increase its served available market for CATV line amplifiers by incorporat-

ing gallium nitride (GaN) technology into its surface-mount line amplifier portfolio, and is expanding into a hybrid form factor. "We have already sampled these products and we've sampled them with more than 20 customers," says Michels. "We expect to announce design wins later this year."

In wireless infrastructure, Anadigics is also expanding its SAM through higher-power-efficiency products, taking it beyond the small-cell femtocell markets, by using gallium arsenide and gallium nitride technologies. This has the potential to increase SAM by nearly \$70m annually, the firm reckons. "We are close to finalizing a definitive agreement with a Tier 1 OEM for these products," says Michels.

The shift in wireless customer mix, particularly to Korea and China, has led to order lead times coming down from 6–8 weeks (typical of having one dominant customer) to just 2–4 weeks. "Additionally, there is greater use

by customers of hub arrangements [mostly in China]. That consigned inventory is making it even more difficult to accurately forecast revenues," says Michels. "In light of these factors, although we continue to target our revenue plans on the basis of the second quarter being the revenue trough, we have decided to suspend our quarterly financial guidance," he adds.

"We felt it prudent to focus our time and attention on providing the continued qualitative information required by investors and analysts, thus being dedicated to the long-

**We are making sure that some portion of what we are shipping in high-volume production next year will be done at WIN, regardless of the fact that we still have 50% of utilization here that we want to fill**

term business interest than on short-term expectations," says chief operating officer & chief financial officer Thomas Shields. "This comes especially in light of our inability to accurately forecast revenue resulting from the shift in customer order lead times and the movement by key customers to hub arrangements," he adds.

"Our corporate capacity strategy remains intact, with dual production sourcing coming from within our New Jersey fab and through our foundry partnership with WIN Semiconductors in Taiwan," continues Shields. "We are making sure that some portion of what we are shipping in high-volume production next year will be done at WIN, regardless of the fact that we still have 50% of utilization here that we want to fill. But we absolutely will not get caught with not having enough capacity," he adds. Utilization at Anadigics' New Jersey fab is expected to rise throughout Q3.

[www.anadigics.com](http://www.anadigics.com)

## Anadigics ships HELP4 LTE PA for 'Revolution by LG' smartphone

RF and mixed-signal semiconductor maker Anadigics Inc of Warren, NJ, USA is shipping production volumes of its ALT6713 fourth-generation High-Efficiency-at-Low-Power (HELP4) LTE power amplifiers (PAs) to LG Electronics.

Optimized for LTE applications, the ALT6713 is powering the Revolution by LG VS910 smartphone for Verizon Wireless. The feature-packed handset includes a large 4.3" capacitive touch screen, 1GHz Snapdragon processor, 5.0 megapixel rear-facing camera, 720p video capability, Android 2.2 operating system, and 4G LTE connectivity. The ALT6713 PA is also used to power LG's VL600 USB LTE modem.

"The selection of Anadigics' power amplifiers for the Revolution by LG demonstrates the strength of the relationship forged between Anadigics and LG Electronics," says Michael Canonico, Anadigics' senior VP of worldwide sales. "We under-



**Anadigics' LT6713 power amplifier.**

stand the challenges facing handset manufacturers today as the demand for power-hungry multimedia and high-speed data features continues to threaten battery-life," he adds. "Anadigics has responded to these challenges

by delivering the industry's most efficient LTE power amplifier," he claims. "We look forward to working with LG Electronics on the design of future platforms."

Anadigics says that its HELP4 4G power amplifiers use its exclusive InGaP-Plus technology to achieve optimal efficiency across low-range and mid-range output power levels. The ALT6713 helps improve battery life by combining high power-added efficiency (35% PAE @ +27.5dBm operating in the 777–798MHz Bands 13 and 14) with what is claimed to be the industry's lowest quiescent current (3mA), reducing average power amplifier current consumption by 30% compared with previous-generation devices.

A high level of integration in a 3mm by 3mm by 1mm footprint also incorporates internal voltage regulation and integrated 'daisy chainable' directional RF coupler.

[www.anadigics.com](http://www.anadigics.com)

# RFMD returns to sequential revenue growth

## Double-digit growth in core business offsets transceiver tail-off

For its fiscal first-quarter 2012 (to 2 July 2011), RF Micro Devices Inc of Greensboro, NC, USA has reported revenue of \$214.2m, down 21.8% on \$273.8m a year ago but up 0.4% on last quarter's \$213.3m in contrast to the expected 5% drop.

This return to sequential growth (after a 23.5% drop last quarter) was due mainly to a steep decline in sales of legacy POLARIS transceiver products to RFMD's largest customer Nokia (to just 15% of total revenue), offset by another quarter of double-digit sequential growth in core business (up 8–12%, outpacing addressable markets).

"June quarterly results demonstrate how RFMD has been transformed into a highly diversified growth-oriented supplier of RF components," says president & CEO Bob Bruggeworth. "We launched several industry-leading new products, and this fueled a sharp improvement in our customer and product mix — yielding our most diverse quarter by customer concentration."

In particular, in RFMD's Cellular Products Group (CPG), sales of 3G/4G products for smartphones and tablets grew over 50% sequentially as the firm gained market share.

The Multi-Market Products Group (MPG) saw double-digit sequential revenue growth across its diversified market. New product and technology cycles, including its PowerSmart converged power amplifiers (PAs), high-performance switches, Phenom high-efficiency single-mode PAs, and gallium nitride, all contributed to better-than-consistent revenue performance.

Revenue for the PowerSmart power platform surpassed \$10m in support of multiple flagship smartphones and tablets. Also during the quarter, RFMD started production shipments of its ultra-high-efficiency 3G/4G PAs in support of multiple customers, secured an additional high-performance 3G/4G switch design win on a Qualcomm refer-

ence design, ramped volume shipments of new GaN-based products to leading military radar and CATV customers, was awarded two DARPA contracts for advanced thermally managed GaN RF power technology (valued at about \$3m through fiscal 2013), and secured major design wins across multiple growth markets, including 3G/4G smartphones, emerging market handsets, wireless infrastructure, Smart Energy/Advanced Metering Infrastructure (AMI), high-performance WiFi, and point-to-point radio for cellular backhaul.

On a non-GAAP basis, gross margin was 38.5%, down on 39.2% a year ago but up from 37.5% last quarter, despite the flattish revenue and historically low fab utilization rates. "We are in the early stages of this favorable mix shift that PowerSmart, switch-based products, Phenom and new MPG products are forecasted to provide a greater percentage of our total revenue going forward," says chief financial officer Dean Priddy. "Regarding fab utilization, our internal focus is on capital efficiency," he adds. "In some cases, we're simply designing smaller die. In other cases, such as PowerSmart and our switch-based products, we're changing the game and relying more on outsourced silicon technology. We refer to this business model as a fab-right strategy."

Net income was \$21.3m, down slightly from \$21.7m last quarter and less than half the \$44.3m a year ago. Nevertheless, RFMD generated about \$19.1m in cash flow from operations, retired \$22m principal amount of convertible debt, and repurchased about 945,000 shares of common stock at an average price of \$5.93. Capital expenditures were \$19.9m, with depreciation of \$14.6m and intangible amortization of \$4.6m. Cash, cash equivalents and short-term investments have hence fallen from \$291.6m to \$255.6m.

"With transceiver revenue now at immaterial levels, RFMD is positioned to achieve continued sequential revenue growth, enabling broad improvement in our financial performance, including margin expansion," says Priddy.

"Increasing demand for mobility, energy conservation, and 'always-on' broadband data continues to favor RFMD's core strengths and expanding product and technology portfolio," says Bruggeworth. "We plan to capitalize on these global secular growth drivers to outperform our addressable markets," he adds. "We see further customer diversification in the September quarter, supported by share gains in smartphones, tablets, smart energy management solutions, point-to-point radio chipsets for cellular backhaul, and other growth markets."

For its fiscal second-quarter 2012 (to end September), RFMD expects revenue to rise about 6% sequentially (mainly due to further diversifying its customer base, through market share gains in 3G/4G smartphone and tablet products, and Nokia falling below 15% of total revenue and maybe being overtaken by Samsung). RFMD also expects gross margin to rise to 39%. Operating expenses should be roughly flat to up \$1m sequentially.

"We believe utilization rates have bottomed and expect this metric to improve this year and into next year," says Priddy. "Improving factory utilization, combined with exciting new product cycles, gives us confidence to project an optimistic long-term outlook regarding margin expansion," he adds. RFMD expects to further diversify its revenue base in the December quarter. "New product cycles we are ramping today will extend multiple years and reinforce our position as a highly diversified growth-oriented supplier of RF components and compound semiconductor technologies."

[www.rfmd.com](http://www.rfmd.com)

## RFMD adds FD25 low-noise and FET1H switching GaAs pHEMT processes to foundry portfolio

RF Micro Devices Inc of Greensboro, NC, USA says that its Foundry Services business unit has expanded its portfolio of process technologies to include two additional GaAs process technologies — RFMD's FD25 low-noise pHEMT process and its FET1H switching pHEMT process (available immediately to foundry customers).

The firm says that its 0.25µm FD25 pHEMT process technology delivers low noise, medium power and high linearity for applications including low-noise front ends and transmitter MMICs. RFMD's 0.6µm FET1H pHEMT process technology delivers low-noise and high-linearity switching of RF signals for applications including wireless front ends, transmit/receive modules and phased arrays.

The two new process technologies complement RFMD's existing 0.3µm FD30 pHEMT process technology, which was made available to foundry customers in 2010 and is optimized for applications including X-band phased-array power amplifiers and 8–16GHz wideband military EW (electronic warfare) jammers.

RFMD says that the rapid growth in the wireless communications, aerospace & defense, and radar/radar jammer markets continues worldwide, driven by end applications requiring the higher levels of integration enabled by leading semiconductor technologies. This increases the need for foundries to develop and offer technologies with flexible high-performance capabilities, it adds. The firm's low-noise

FD25 and high-linearity switch FET1H technologies, along with its existing FD30 0.3µm power process technology, offer the ability to design and manufacture devices for a wide range of application needs.

"Our FD25 0.25µm and FET1H 0.6µm processes further expand on our goal to provide the wireless industry a technically advanced semiconductor foundry service offering," says Bob Van Buskirk, president of RFMD's Multi-Market Products Group (MPG). "We are pleased to expand and grow our foundry services business beyond our current GaN and GaAs offerings to assist our customers in meeting their individual market and product needs."

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## RFMD celebrates 20 year anniversary by ringing the NASDAQ opening bell

RF Micro Devices rang the NASDAQ stock market opening bell today, celebrating the firm's twenty year anniversary.

Bob Bruggeworth, president and CEO of RFMD, said, "It is a pleasure to commemorate RFMD's twentieth anniversary and celebrate RFMD's twenty years of RF product and technology leadership by ringing the NASDAQ opening bell. RFMD is a recognized pioneer and innovator in the semiconductor industry, and our sharp focus on product and technology leadership is equally as evident today — with the continued ramp of multiple industry-leading, new products — as it was with the commercialization of the world's first GaAs HBT PA."

Founded by William Pratt (the firm's original CEO), Jerry D. Neal (the first marketing executive), and Powell Seymour (the original VP of operations), RFMD was incorporated on 27 February 1991. A pioneer in the commercialization of RF

components using gallium arsenide (GaAs), in the 1990s RFMD was a primary contributor to the rapid growth in the cellular handset market, and in 2000 it was identified by Fortune magazine as the second-fastest growing company in the USA. In 2004, RFMD became the first semiconductor firm to ship 1 billion cellular power amplifiers (PAs), and currently routinely ships more than 3 million RF components per day.

RFMD was the first firm to introduce integrated power control for cellular power amplifiers, or PAs, (PowerStar); the first to introduce integrated power management for PAs (PowerSmart); the first to exceed 50% peak efficiency in 3G/4G PAs; the first to commercialize high-performance silicon CMOS for cellular switches; and the first to introduce gallium nitride (GaN) for CATV amplifier applications, says the firm.

[www.rfmd.com](http://www.rfmd.com)

### IN BRIEF

#### RFMD shareholders approve proposals at annual meeting

RFMD says that, at its 2011 Annual Meeting of Shareholders, all agenda items were approved by the shareholders.

Proposals approved included:

1. election of eight directors to serve a one-year term;
2. the company's executive compensation (approved on an advisory, non-binding basis);
3. a frequency of every one year for holding the non-binding, advisory vote on executive compensation (approved on an advisory, non-binding basis);
4. reapproval of RFMD's Cash Bonus Plan, pursuant to the provisions of Section 162(m) of the Internal Revenue Code of 1986, as amended; and
5. appointment of Ernst & Young as RFMD's independent registered public accounting firm for the fiscal year ending 31 March 2012.

# TriQuint's Q2 and Q3 revenue hit by product focus

## Strong growth to resume in Q4 as design wins ramp

For first-half 2011, RF front-end product and foundry services provider TriQuint Semiconductor Inc of Hillsboro, OR, USA has reported revenue of \$453.1m, up 17% on first-half 2010's \$388.3m.

However, second-quarter 2011 revenue was \$228.8m (up just 10% on \$207.5m a year ago and a less-than-expected 2% on Q1's \$224.3m, and below the forecast \$230-240m).

Defense & Aerospace revenue for first-half 2011 was down 17% year-on-year. But, although down 11% on \$26m a year ago, Q2 rebounded by 31% from Q1's \$17.6m to \$23m (rising from 8% to 10% of total revenue).

Networks revenue for first-half 2011 was down 3% year-on-year. Although down 3.4% on \$47.5m a year ago, Q2's \$45.8m was up slightly from Q1's \$45.6m (remaining at 20% of total revenue).

"Headwinds include macro-economic weakness, including the tsunami, largely impacting our networking business [specifically point-to-point radio, as some Japanese customers slowed their order rates], and a steeper decline in our 2G business than I originally expected," says president & CEO Ralph Quinsey.

Mobile Devices revenue for first-half 2011 was up 29% year-on-year. Due to supply constraints last year for GaAs devices and bulk acoustic wave (BAW) filters, TriQuint chose to shift capacity and focus from 2G products to 3G and LTE, resulting in a year-on-year decline in revenue of 68% for GSM and 46% for legacy CDMA (with a step-down in Q1 for GSM, and in Q2 for legacy CDMA). Revenue growth of 66% for wide-band CDMA products (driven by the smartphone and data-card markets) has more than offset the decline. However, the transition has muted growth for Q2 and Q3/2011.

Q2 Mobile Devices revenue was \$159.9m, up 19% on \$134m a year

ago but down on Q1's \$161.1m (falling from 72% to 70% of total revenue). Of Mobile Devices revenue, 2G has fallen from 19% a year ago through 11% in Q1 to just 4% in Q2, while 3G/4G has risen from 61% through 68% to 73%, and Connectivity has risen from 20% through 21% to 23%.

On a non-GAAP basis, gross margin was a slightly better-than-expected 41.4%, down from 42.3% a year ago but up from 40% in Q1.

Operating expenses rose by \$2.4m from Q1's \$63.2m (28.2% of revenue) to \$65.6m (28.7% of revenue), due mainly to growth in litigation expenses from \$5.4m to \$7.5m (related to anti-trust and IP claims against Avago Technologies over BAW filters).

Although down from \$33.1m a year ago, net income was \$28.9m, up 11% on Q1's \$26.1m. However, core earnings (excluding legal expenses) were up 15%, benefiting from the improved gross margin.

A rise in capital expenditure from Q1's \$51.8m to \$60.7m was only partially offset by \$31.6m of cash flow from operations (tripling from \$10.8m in Q1) plus about \$8m of cash from stock option exercises. During the quarter, cash, cash equivalents and investments fell from \$198.8m to \$180.9m.

For Q3/2011, TriQuint expects flat revenue of \$225-235m, with gross margin of 40-42%. Operating expenses should fall to \$64-65m, including litigation expense falling to about \$5m as the discovery phase of the process is completed.

"We are growing our market share where it counts, but I am disappointed our revenue growth appears to have stalled in Q2 and Q3," says Quinsey. "When our factories filled up last year to support 34% growth in 2010, we made decisions to focus in key areas. Some products did not see the success we had planned for, particularly Android-based tablets and WLAN demand

for Symbian phones. In the long run, I am sure those decisions and the way we handle them will pay off, starting in Q4," he adds.

"Currently, we are not as diversified in Mobile Devices as I would prefer, but we have not been idle. We have created a new capacity footprint and a product roadmap that has broad customer interest. We are leading the industry of mobile devices with the inherent advantages of co-designing the filter MMPA [multi-mode power amplifier] for efficient PA-Duplexer integration," Quinsey claims. TriQuint is currently sampling the MMPA, targeting design wins at key customers in China and Taiwan. "The bulk of the industry volume has been and will continue to migrate towards PA-Duplexers. PA-Duplexers offer a clear advantage in layout flexibility and solution size," he believes.

"Innovative technologies such as copper bump to flip and wafer-level packaging for duplexers are allowing us to cut the RF footprint for smartphones in half. Our best-in-class optical drivers are in high demand to support increased traffic for broadband data and video on demand. We have solid product roadmaps for share gain in cable and base-station RF," he continues. "We have established a new capacity footprint that will allow us to leverage growth over the next several years, and we continue to benefit from our relationships in Defense & Aerospace," Quinsey adds.

"During 2011, we have sharpened our focus and invested in innovation to ensure we support our customers for the long-term growth opportunities ahead," Quinsey says. "Based on the current design wins and customer forecasts, I expect to return to strong revenue growth in Q4," he adds. "Our greatest challenge is managing our growth opportunities in this strong RF market."

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# Skyworks quarterly revenue up 27% year-on-year to \$356.1m, beating guidance

## SiGe acquisition to boost September-quarter revenue to \$400m

For its fiscal third-quarter 2011 Skyworks Solutions Inc of Woburn, MA, USA, which makes linear products, power amplifiers, front-end modules and radio solutions for handset and infrastructure equipment, has reported revenue of \$356.1m (with linear high-performance analog representing just over 25% of revenue, and handsets just under 75%).

However, excluding a contribution of \$6.5m from the acquisition of fabless RF front-end IC supplier SiGe Semiconductor (which closed on 10 June), revenue would have been \$349.5m. This is still up on guidance of \$345m, and up 27% organically on \$275.4m a year ago and up 6% on \$325.4m last quarter, despite what is described as a "challenging quarter for some of our market and OEM customers" by president & CEO David Aldrich.

"Our momentum is being driven by content growth and share gains within leading smart phones, tablets, gaming platforms, home automation systems and network infrastructure, coupled with diversification into new vertical markets," says Aldrich. "Further, the advent of LTE, machine-to-machine and cloud computing applications is translating into stronger design-win activity as more and more electronic platforms are becoming wirelessly enabled to share data, voice and video," he adds.

On a non-GAAP basis, gross margin has risen further, from 43.3% a year ago and 43.9% last quarter to 44.9%. Operating expenses have risen from \$55.6m a year ago and \$57.9m last quarter to \$62.5m, mainly due to an increase in R&D spending.

Despite this, strong operating leverage has led to operating income rising from \$63.5m a year ago (23.1% operating margin) and \$84.9m last quarter (26.1% margin)

to \$97.6m (27.4% operating margin). Net income was \$93m, up on \$78.7m last quarter and \$58.7m a year ago.

During the quarter, Skyworks generated \$86m in cash flow from operations. Capital expenditure was \$20m, down from \$32m last quarter as the firm has begun to moderate back towards steady-state levels after completing most capacity investments in its facilities in Mexicali and Newbury Park. After accounting for about \$210m for the SiGe acquisition and \$19m as part of an ongoing stock repurchase program, as well as \$15m in depreciation, the firm's cash balance fell from \$504m to about \$310m during the quarter.

"Skyworks exceeded all key metrics last quarter, and we see a steep growth trajectory heading into the second half of calendar 2011," says Aldrich. "Given our differentiated product portfolio, extensive customer engagements, technology roadmaps and scale, Skyworks is uniquely positioned to capitalize on this rapidly approaching connectivity revolution and, in turn, to sustainably outpace industry growth," he reckons.

During fiscal third-quarter 2011, Skyworks enabled wireless connectivity at all three market-leading gaming console OEMs; ramped high-power filters for military and homeland security markets; captured wireless networking design wins in support of home monitoring

**Based on strong bookings and order visibility, the stage is set for Skyworks to again outperform our addressable markets throughout the back half of 2011 and into 2012**

and security deployments; was awarded a major electronic toll collection system contract with a portfolio of analog control ICs; secured high-power, transmit/receive switches, high-frequency modulators and wide-band digital attenuator sockets in support of the TD-LTE China market; launched ultra-low-power low-noise amplifiers (LNAs) for diverse markets including set-top boxes, Bluetooth headsets, hearing aids, meter readers and 2.4GHz wireless networks; unveiled the first stand-alone, high-dynamic-range power detectors for 3G and LTE smart-phones and datacards.

For its fiscal fourth-quarter 2011 (to end-September), Skyworks expects record revenue of \$400m (including \$20–25m from SiGe, but up organically 7% quarter to quarter).

"We expect to continue to grow in December, both in an organic and a consolidated basis," says Aldrich. "This highlights the real power of our diversification strategy," he adds. During the quarter (in late May), Skyworks also announced a definitive agreement to acquire power management firm Advanced Analogic Technologies Inc (AnalogicTech) of Santa Clara, CA, an analog semiconductor firm focused on enabling energy-efficient devices for the application-specific power management needs of feature-rich consumer electronic devices as well as devices in a range of computing, industrial, medical and communications applications.

"Based on strong bookings and order visibility, the stage is set for Skyworks to again outperform our addressable markets throughout the back half of 2011 and into 2012," confirms Donald W. Palette, VP & chief financial officer. "We are well positioned to expand margins and deliver operating leverage."

[www.skyworksinc.com](http://www.skyworksinc.com)

## Kopin's first-half III-V revenue up 10% year-on-year Margin continues to grow, despite increased R&D spending

For second-quarter 2011, Kopin Corp of Taunton, MA, USA has reported revenue of \$31.4m, up 4% on \$30.2m a year ago but down 10% from last quarter's record \$34.9m.

Revenue from Displays (used in mobile applications including smartphones and tablet PCs, military thermal weapons sights and wearable computers) was \$15.4m, up 7.7% on \$14.3m a year ago but down 11% from \$17.3m last quarter. Revenue from III-V heterojunction bipolar transistor (HBT) epiwafers was \$16m, up slightly from \$15.9m a year ago but down 9% on \$17.6m last quarter.

"Our second-quarter operating results reflect a continuation of the strategy we set forth at the beginning of the year — balancing short-term financial performance with a focus on long-term growth," says president & CEO Dr. John C.C. Fan.

Gross margin (as a proportion of product revenue) has risen further, from 25% a year ago and 33.3% last quarter to 35%.

Operating expenses were \$31m, up only slightly on \$30.9m a year ago and cut from \$32.8m last quarter. However, of this, R&D expenses were \$7.1m (23% of revenue), up from \$6.4m (18.3% of revenue) last quarter and \$4.9m (16% of revenue) a year ago, reflecting Kopin's investments in its Golden-i technology, III-V smartphone products and capacity expansion, military display products, and inclusion of Forth Dimension Display's expenses.

Including a net gain of \$0.4m from the sale of investments and a net loss of \$0.3m from foreign currency fluctuations, net income was \$0.8m, down on \$2.1m last quarter and \$1.9m a year ago. However, the latter included gains of \$1.9m from the sale of investments and \$0.7m related to foreign currency fluctuations. During the quarter, cash and marketable securities rose slightly from \$99.1m to \$99.3m.

"We are in the enviable position of having strong growth projections for our III-V products, the opportunity to add a new military display product category — night-vision systems — to our current portfolio of thermal weapon sight products, and the development of a potentially game-changing, hands-free wireless industrial computing product in Golden-i," says Fan. "Because of the current strong growth of smart phones, the requirement for those competing for an award of the Enhanced Night Vision program in 2012 to provide qualification units in 2011, and our drive to be a leader in voice-activated cloud computing, these opportunities have required significant investments this year," he adds.

"Yet, with all of our development efforts, through the first half of fiscal 2011 we have maintained strong operating results," Fan notes.

"Overall our revenues are up 19%, with our III-V revenues up 10% over the same period last year as we head into what historically has been our strongest part of the year,"

he adds. "Although the current federal budget situation has impacted the timing of display product sales, we expect another year of strong military revenues, as evidenced by our recently announced \$23.2m in follow-on orders for the TWS Bridge (TWS-IIB) program," Fan says.

"Our income from operations is \$2.6m for the first half of 2011 compared with a loss of \$0.8m through the same period last year, we have generated \$3.5m in cash flow from operating activities and repurchased \$1.9m of our common stock."

"Our III-V technology is helping to drive the rapid adoption of advanced 3G and 4G technologies across the major smartphone and tablet platforms," Fan continues.

"These advanced new devices not only require more III-V transistors, but structures that are more technologically complex and challenging to produce. As these phones continue to become more complex, Kopin is benefitting with higher and higher dollar content per handset."

With first-half 2011 revenue of \$66m and the third and fourth quarters traditionally Kopin's strongest, the firm is on course to achieve its full-year revenue guidance of \$130-140m (up 8-16% on 2010).

"Robust smartphone demand should continue to fuel our III-V business, just as the TWS-IIB and a number of military R&D programs are expected to generate momentum for our display unit," Fan concludes.

[www.kopin.com](http://www.kopin.com)

## Skyworks supports ZTE with multiple front-end solutions

Skyworks is supporting ZTE's ramp of next-generation tablets and laptops with EDGE and WCDMA/LTE front-end modules, powering data cards and USB modems.

With the wins, Skyworks is broadening its relationship with ZTE, which already uses several of its TD-SCDMA and CDMA solutions for handsets

and will soon use its antenna switch modules in several forthcoming smart-phone platforms. According to market research firms IDC and Strategy Analytics, ZTE was ranked as the fifth-largest global handset maker in second-quarter 2011, growing both its unit shipments and market share.

ZTE is positioned to capture a disproportionate share of the smartphone segment in emerging markets such as China, India and Latin America, says Bradley C. Byk, Skyworks' senior VP of worldwide sales. "These markets are predicted to deliver the greatest number of wireless customers in the coming years."

## IN BRIEF

## GaAs broadband push-pull amplifier for CATV

M/A-COM Technology Solutions has launched a GaAs push-pull CATV amplifier that features 20.5dB gain and broadband linear performance. Packaged in a 4mm x 4mm QFN 20-lead plastic package and operating from an 8V supply, the MAAM-009455 can be used as an inter-stage or output amplifier.

"With the introduction of the MAAM-009455, we continue to expand our portfolio of high-performance amplifiers for CATV infrastructure applications," says product manager Graham Board. "The MAAM-009455 utilizes M/A-COM Tech's established 0.5µm MESFET process to deliver a highly linear, 75Ω push-pull amplifier with 20.5dB of small-signal gain," he adds.

The device targets next-generation CATV HFC, FTTH, HDTV, and EdgeQAM infrastructure applications, where high gain and low distortion are a requirement. The MAAM-009455 is a highly linear amplifier, with low noise figure and power dissipation. This differential amplifier uses M/A-COM Tech baluns, input and output, in order to ensure what is claimed to be best-in-class second-order performance. It also features external feedback, allowing for gain tuning.

The MAAM-009455 exhibits gain flatness of 0.5dB (typical) over the 50-1000MHz operating band. Input return loss has been optimized to achieve better than 20dB across the band. Very low distortion characteristics provide composite second order (CSO) and composite triple beat (CTB) performance of -70dBc. The amplifier exceeds DOCSIS 3.0 DRFI specifications, making it suitable as an output stage solution for EdgeQAM head-end infrastructure.

## Front-end ICs launched for mid- and high-band MoCA applications

M/A-COM Technology Solutions has launched the XZ1003-QT and XZ1004-QT fully integrated, monolithic front-end integrated circuits (FEICs) for Multi Media over Coax Alliance (MoCA) mid-band and high-band RF applications. Both devices are fully compatible with Entropic Communications c.Link MoCA RF transceivers.

Packaged in an industry-standard 3mm, 16-lead QFN package, the ICs operate from a single 3.3V supply. They include a high-linearity transmit amplifier, SPDT switch, power detector, digital attenuators bias and digital control circuitry. The integrated bias circuit stabilizes transmit amplifier performance over temperature and process variation with an optional bias adjustment.

M/A-COM Tech says that existing front-end solutions require a 5V amplifier in the transmit path, which drives the need for an expensive voltage regulator. The XZ1003-QT and XZ1004-QT

eliminate the need for a regulator while still meeting all MoCA 1.0 & 1.1 specifications.

Key applications are MoCA-enabled customer premises equipment (CPE) such as home gateways, routers, Ethernet-to-coax bridges, network

**The XZ1003-QT and XZ1004-QT eliminate the need for a regulator**

attached storage, and set-top-boxes. The new devices are also qualified

for MoCA infrastructure applications, such as drop amplifiers, and optical network terminals.

"M/A-COM Tech's FEICs simplify MoCA RF implementation," says product manager Graham Board. "Integrating key RF functions along with bias and control logic into a single 3mm QFN reduces real-estate requirements, speeds up development cycles, and reduces system costs," he adds.

## M/A-COM Tech appoints senior director Asia Pacific sales

M/A-COM Technology Solutions Inc of Lowell, MA, USA (which makes semiconductors, components, and subassemblies for RF, microwave and millimeter-wave applications) has appointed Vincent Pelliccia as senior director of Asia Pacific sales, reporting to VP of sales Jack Kennedy and tasked with helping to penetrate the Asia Pacific market.

Pelliccia was most recently director of sales operations & business development, in which he helped to implement an SAP Customer Relationship Management solution, while concurrently playing a lead role in simplifying the firm's order management system.

Prior to that, Pelliccia was VP of sales at fabless RF, microwave and millimeter-wave IC firm Mimix



**Vince Pelliccia.**

Broadband Inc of Houston, TX, USA (acquired by M/A-COM Tech in May 2010). Previously, he worked at M/A-COM Inc for 11 years as a product group manager.

Pelliccia has 25 years of experience in the industry, with a strong background in engineering, finance and sales. He also has B.S. and M.S. degrees in Electrical Engineering from the University of South Florida. "His industry experience and strong leadership will greatly benefit the company," believes Kennedy.

[www.macomtech.com](http://www.macomtech.com)

## M/A-COM Tech launches digital phase shifters for communications, electronic warfare and radar

M/A-COM Technology Solutions Inc of Lowell, MA, USA (which makes semiconductors, components, and subassemblies for RF, microwave and millimeter-wave applications) has launched a set of digital phase shifters for communications, electronic warfare (EW), and radar applications that are said to facilitate easy implementation in communication antennas, phased array radars, weather radars, and EW receivers.

The firm says that the GaAs pHEMT 4-bit and 6-bit digital phase shifters meet the performance requirements of communica-

**The GaAs pHEMT 4-bit and 6-bit digital phase shifters meet the performance requirements of communications and radar system manufacturers**

tions and radar system manufacturers, optimizing for fast switching speed, low phase error, and serial or parallel control capability.

"M/A-COM Tech's new 1.4–2.4GHz digital phase shifters maintain low

phase error and low attenuation variation over the 360° range," says product manager Kevin Harrington. "The built-in CMOS driver allows for serial or parallel control and low DC power consumption," Harrington adds.

The MAPS-010143 is a 4-bit digital phase shifter housed in a 4mm 24-lead PQFN package. It provides 360° phase-shift range with a step size of 22.5°. Insertion loss is 3.2dB, with a low ±0.5dB attenuation variation and ±2.0° phase accuracy over the 1.4–2.4GHz frequency range.

The MAPS-010163 is a 6-bit digital phase shifter housed in a 4mm 24-lead PQFN package. It provides 360° phase-shift range with a step size of 5.625°. Insertion loss is 5.0dB, with a low ±0.8dB attenuation variation and ±4.0° phase accuracy over the 1.4–2.4GHz frequency range.

Each digital phase shifter can be controlled with a single +5.0V serial or parallel control line.

Production quantities and samples of MAPS-010143 and MAPS-010163 are available from stock.

## M/A-COM Tech launches 8-way splitter for CATV

M/A-COM Technology Solutions has launched an 8-way active splitter for CATV applications.

The MAAM-010237 belongs to a larger family of broadband active splitters and targets multi-tuner set-top boxes, home gateways and other broadband, Internet-based customer premises equipment (CPE) applications. Featuring a default-on loop-through path, it allows access to the cable signal even when the CPE box is powered down.

Fabricated using M/A-COM Tech's E/D pHEMT process, which opti-

mizes default loop-through operation, low noise and low distortion, the MAAM-010237 is designed for operation at 50–1100GHz, and is packaged in an RoHS-compliant leadless 4mm PQFN package.

"The MAAM-010237 8-way active splitter with default-on loop-through path reduces the front-end design complexity, component count, and real-estate requirements in today's 'green' multi-tuner gateways," says product manager Graham Board.

[www.macomtech.com](http://www.macomtech.com)

### IN BRIEF

#### 400–2700MHz analog control VGA delivering high gain for cellular infrastructure

M/A-COM Technology Solutions Inc of Lowell, MA, USA has launched a new analog control variable gain amplifier (VGA) for cellular infrastructure applications. The MAAM-009320 is designed to lower bill of materials cost and complexity for OEM design engineers that are designing next-generation 3G/4G/LTE base-stations.

New base-station designs have multi-band capabilities but numerous space constraints, says M/A-COM Tech. The MAAM-009320 delivers higher levels of integration and space savings by performing three circuit functions in a single 4mm PQFN package. The MAAM-009320 has a wide frequency range complemented by high gain (25.5dB) and what is claimed to be excellent input and output return loss. Noise figure is 3.0dB, attenuation range is 26.5dB, OIP3 is 42.0dBm.

Packaged in a RoHS-compliant 4mm, 24-lead PQFN package, the VGA is designed for operation from 400–2700MHz. External matching components are used to set the center frequency and achieve return loss performance while analog control is accomplished through a single control pin of 0 to +3V.

"With excellent IP3 for only 231mA of current, the MAAM-009320 is a great choice for applications requiring gain with a wide attenuation range while maintaining linearity," says product manager Jack Redus. "The MAAM-009320 balances linearity and noise figure for optimal performance in cellular base-station applications."

[www.macomtech.com](http://www.macomtech.com)

## AWR announces Microwave Office model library for Mitsubishi's nonlinear GaAs & GaN RF devices

AWR Corp of El Segundo, CA, USA, a supplier of electronic design automation (EDA) software for designing RF and high-frequency components and systems, has announced the availability of a Microwave Office model library for Mitsubishi Electric's nonlinear gallium arsenide (GaAs) and gallium nitride (GaN) RF devices.

The model library includes high-power and low-noise high-electron-mobility transistor (HEMT) devices, which are commonly used in base-station and DBS receivers and other radio communications equipment, given their high-power, high-efficiency, broadband and low-noise advantages. AWR says that the new model library helps designers better explore design alternatives while meeting demanding performance specs with a cost-effective solution.

"The good collaboration between AWR's engineers and our own resulted in a robust and reliable model library," says Takao Ishida, manager of Wireless Communication Device Application Engineering Section at Mitsubishi Electric High Frequency & Optical Device Works. "This now means that AWR's customers have timely access to our nonlinear RF models," he adds.

Customers and potential customer of AWR software were able to learn about the new model library at the AWR Asia Design Forum (ADF 2011) in Tokyo, Japan on 22 July.

AWR's Microwave Office library for Mitsubishi Electric's nonlinear RF models is free for use within Microwave Office software (release 2010 and later) for active, licensed AWR customers.

[www.awrcorp.com](http://www.awrcorp.com)  
[www.mitsubishielectric.com/semiconductors/network](http://www.mitsubishielectric.com/semiconductors/network)

## Agilent and UCD announce Millimeter Wave Research Center

Measurement equipment maker Agilent Technologies Inc of Santa Clara, CA, USA and the University of California, Davis (UCD) are to establish the Davis Millimeter Wave Research Center (DMRC) as an industry-university cooperative research program focusing on advancing technology in millimeter-wave and terahertz (THz) systems for radar, imaging systems, sensors, wireless communications and integrated passive devices in electro-magnetic metamaterials and antennae.

The DMRC is vertically integrated, with research involving devices, integrated circuits, packaging, metamaterials and defected ground integrated passives, imaging systems, THz vacuum electronics, THz micro-machined devices, nonlinear modeling, nanomaterials and wireless implantable devices.

These devices and systems are found in commercial products such as medical imaging systems, security scanners, gigabit wireless communications devices and sensors,

as well as defense applications such as radar and active denial systems.

The first aim of the new center is to establish a core test facility with measurement capabilities that include Agilent nonlinear vector network and spectrum analysis test equipment up to 325GHz. These facilities will support gigabit wireless communications at 60GHz and 80GHz as well as the imaging, radar and active denial systems to 325GHz.

"In launching the DMRC, our goal is to become a premier millimeter-wave research center nationally and internationally," says UC Davis' chancellor Linda P.B. Katehi. "With this new facility, UC Davis will be able to expand the research, and recruit outstanding graduate students and faculty," she adds.

"Millimeter-wave implementation has broad industry impact, and our many first-to-market test solutions are ideal tools for revealing the information critical to their work," claims Gregg Peters, VP of Agilent's Component Test Division.

[www.agilent.com](http://www.agilent.com)

## Hittite continues growth in Q2 Profit rebounds, despite drop in margin

For second-quarter 2011, Hittite Microwave Corp of Chelmsford, MA, USA (which designs and supplies analog and mixed-signal RF, microwave and millimeter-wave ICs, modules and subsystems as well as instrumentation) has reported revenue of \$68.5m, up 1.9% on \$67.2m last quarter and 13.6% on \$60.3m a year ago.

Of total revenue, 45.7% came from the USA (\$31.3m, up from \$30m last quarter) and 54.3% came from outside the USA (\$37.2m, level on last quarter).

However, gross margin has fallen further, from 74.8% a year ago and 73.0% last quarter to 72.7%. Nevertheless, operating income has

risen, from \$29.7m (49.2% of revenue) a year ago and \$31.2m (46.4% of revenue) last quarter to \$32m (46.8% of revenue), rebounding from a slight drop from Q4/2010 to Q1/2011.

Likewise, net income is up by 8.8% from \$19.2m (\$0.64 per diluted share) a year ago and by 3.3% from \$20.2m (\$0.66 per diluted share) last quarter to \$20.8m (\$0.68 per diluted share). During the quarter, total cash and cash equivalents rose by \$13.9m, from \$311.7m to \$325.6m.

For third-quarter 2011, Hittite expects revenue of \$68-70m, with net income of \$20-20.8m (\$0.65-0.68 per diluted share).

## SEMATECH showcases technologies and manufacturing methods at SEMICON West

At SEMICON West 2011 in San Francisco (11–15 July), through a wide range of lectures and workshop sessions, global semiconductor manufacturers' research consortium SEMATECH of Albany, NY, USA and International SEMATECH Manufacturing Initiative (ISMI) presented a variety of technology solutions and manufacturing methods.

SEMATECH and ISMI reported their latest advances in new materials and device structures and lithography, with a special focus on addressing key opportunities and challenges in 3D interconnect technology. "Both SEMATECH and ISMI recognize that the industry needs innovative and practical solutions for continued scaling of semiconductor technologies that can easily be incorporated into real-world manufacturing environments," says SEMATECH's president & CEO Dan Armbrust.

Several SEMATECH experts spoke on the SEMICON West TechXPOT Stage, in the North and South Halls of the Moscone Center, including:

- Raj Jammy, VP of Emerging Technologies, on 'Heterogeneous Integration of High Mobility Ge/III-V Channels on Si' (12 July at 11am);
- David Gilmer, project engineer of Advanced Memory Technologies, on 'Metal-Oxide based RRAM Materials and Development' (12 July at 11:30am);
- Stefan Wurm, associate director of Lithography, on 'EUV Mask Infrastructure (EMI) Partnership' (13 July at 11:05am);
- Sitaram Arkalgud, director of Interconnect, will co-moderate the panel session '3D in the Deep Sub-micron Era' (13 July at 1:50pm); and
- Chris Hobbs, CMOS scaling program manager of Front End Process, on 'Non-Planar CMOS Device Challenges and Opportunities' (14 July at the NCCAVS Advanced Process and Integration in Semiconductor Technologies session).

Additionally, SEMATECH and ISMI experts will host and present at various public workshops, at the Marriott Marquis, during SEMICON West:

- Equipment suppliers will identify opportunities and bridge understandings on enabling 3D technology in the wafer handling process space at the workshop 'Enabling 3D: Temporary Bonding Workshop' (11 July at 1pm);
- Equipment suppliers and end users will meet to address topics such as SEMI S23 reporting and goals, applying high-temperature process cooling water on process tools, and idle mode interface for process equipment subsystems at the 'ISMI Equipment Energy Workshop' (12 July at 8am);
- Equipment suppliers will share their plans on how new and existing wafer metrology technologies can be used, modified, or enhanced to measure and improve 3D interconnect processes at SEMATECH's '3D Metrology Workshop' (13 July at 12:00pm);
- Co-sponsored by SEMI and ISMI, the 'EDA Workshop' will focus on the equipment data acquisition (EDA) interface requirements and implementation for the 0710 standards freeze level, with participants able to discuss with industry experts how the changes for the new freeze level can be implemented and evaluated (13 July at 1pm);
- A day-long preview of this year's International Technology Roadmap for Semiconductors will be offered at the Summer 'ITRS Public Conference' (13 July);
- Hosted by SEMATECH, in collaboration with Fraunhofer IZFP, the fifth workshop on 'Stress Management for 3D ICs using Through Silicon Vias' will discuss product-level reliability, including product qualification, product-level test requirements, and failure analysis (14 July at 9am).

[www.sematech.org](http://www.sematech.org)

### IN BRIEF

## MagnaChip ramps Peregrine's STeP5 RF switches to mass production

MagnaChip Semiconductor Corp of Seoul, South Korea (a designer and manufacturer of analog and mixed-signal semiconductor products for high-volume consumer applications) has announced its ramp to mass production of RF switch products using the latest-generation STeP5 UltraCMOS SOS (silicon-on-sapphire) technology of Peregrine Semiconductor Corp, a fabless provider of high-performance radio-frequency integrated circuits (RFICs).

UltraCMOS technology uses a sapphire substrate, enabling high levels of monolithic integration which results in smaller die, higher yields and fewer external components compared with compound semiconductor processes such as gallium arsenide, Peregrine claims.

Peregrine and MagnaChip have been engaged in the transfer of the patented UltraCMOS technology since mid-2007 and have implemented Peregrine's STeP3 and STeP4 process generations at MagnaChip's 0.35µm manufacturing facility in Cheongju, South Korea. MagnaChip has now completed the final qualification phase in the transfer of STeP5 process generation and has ramped to high-volume production.

"The continued introduction of these robust and unique RFIC solutions is a direct result of the combined expertise — MagnaChip's manufacturing services and Peregrine's technology and design engineering — and of the long-term strategic roadmap we have outlined," comments TJ Lee, senior VP & general manager of MagnaChip's corporate and SMS engineering.

[www.psemi.com](http://www.psemi.com)

## IN BRIEF

## Amalfi appoints VP of worldwide sales

Amalfi Semiconductor says that Derek Best has joined it as VP of worldwide sales. He has more than 30 years of international sales and marketing experience in the semiconductor industry as well as experience in the high-volume mobile handset market (the primary target market for Amalfi's CMOS power amplifier technology).

"Derek is a widely respected executive with a history of guiding leading semiconductor businesses through periods of growth," says CEO Mark Foley. "His expertise will be invaluable as we aim to take Amalfi to the next level by strengthening and expanding our customer relationships," he adds.

From 1997 to 2010, Best was a senior VP at Silicon Storage Technology Inc (SST, a designer and high-volume manufacturer of NOR flash, NAND flash controllers, solid-state drives, micro-controllers and wireless power amplifier technology), responsible for building and running their sales & marketing organization worldwide. While at SST, he gained sales & marketing knowledge of the Asian markets, adding to his experience of the North American and European markets.

Prior to joining SST, Best held executive positions at Micromodule Systems, Hitachi and Texas Instruments, as well as being the co-founder of Mosaic Semiconductor.

"Amalfi has developed a highly differentiated, high-performance CMOS power amplifier technology that is attaining strong acceptance within the mobile market," comments Best. "I look forward to using my worldwide sales experience to rapidly grow Amalfi's customer base and revenue across the mobile phone market."

## Amalfi launches second-generation AdaptiveRF CMOS PA architecture

Amalfi Semiconductor of Los Gatos, CA, USA, a fabless firm developing highly integrated CMOS RF and mixed-signal integrated circuits (ICs), has announced the launch and immediate availability of what it claims to be the world's most economical and high-performance CMOS-based transmit modules for front-end GSM/GPRS cellular handsets.

Leveraging the inherent scalability of bulk CMOS processes, the firm's proprietary AdaptiveRF architecture can incorporate highly integrated derivative functions including switches and complex filters, allowing a significant ongoing reduction in front-end costs, size and power consumption, it is claimed.

"Mobile phone manufacturers are under extreme price pressure, and yet need to maintain high performance and long talk-time," says CEO Mark Foley. "Amalfi's CMOS architecture offers the most aggressive integration and price-down roadmap while delivering the highest power efficiency and overall performance, in turn enabling our customers to offer lower-cost handset solutions with superior performance and extended talk-time," he claims.

The family of dual- and quad-band GSM/GPRS transmit modules uses a standard CMOS process and proprietary architecture that outperform competing technology in performance, integration and cost, it is claimed. The modules are targeted primarily at the high-growth entry-level and ultra-low-cost (ULC) product segments in the emerging BRIC (Brazil, Russia, India and China) markets.

Mobile phone power amplifiers typically use between one-third and 3.5W of power during cellular transmission (30-70% of the electrical current used by the phone when the user is talking). The lower current consumption resulting from the CMOS-based transmit

module enables the cell phone to support longer talk-time compared with existing solutions, Amalfi says. Mobile phone makers can then use smaller, less expensive batteries, reducing the overall size and bill of materials (BOM).

The transmit modules' architecture integrates the power amplifier, controller, transmit and receive switch, filtering and all matching components into a 28mm<sup>2</sup> package, providing the smallest, most highly integrated transmit module in mass production, it is claimed. The small size reduces PCB space and cost and provides a more flexible design layout, enabling users to build smaller phones or phones with additional features.

Amalfi's second-generation, CMOS-based transmit modules achieve better power-added efficiency (PAE) in the typical operation ranges relative to leading GaAs power amplifiers, it is claimed. The architecture allows the transmit module to achieve high efficiency over a broad output power range. In operation, where output power is dynamic and subject to non-ideal loads, these improvements result in a talk time increase of up to 40%, it is reckoned.

The modules are also capable of withstanding a best-in-class 2kV electro-static discharge (ESD, human body model) on all pins, including RF pins. This makes the device less susceptible to ESD damage during manufacturing, resulting in better yields and overall lower cost. The devices are also capable of withstanding 8kV ESD on the antenna port, further lowering BOM as no additional ESD protection is required on the phone to meet industry standards.

The entire family of transmit modules is fully qualified for mass production and available with standard leadtimes.

[www.amalfi.com](http://www.amalfi.com)



## TowerJazz completes qualification of 0.13 $\mu$ m SiGe process transferred from US fab to Israel fab

Specialty foundry TowerJazz says that its 0.13 $\mu$ m silicon germanium (SiGe) technology (SBL13) has been successfully transferred from the fabrication plant of its US subsidiary Jazz Semiconductor in Newport Beach, CA, USA to its Tower Semiconductor Ltd fab in Migdal Haemek (MH), Israel.

The firm has completed the internal qualification of a heavily analog 0.13 $\mu$ m SiGe flow, adding a copper (Cu) backend in MH. "This helps extend our leadership in SiGe technology and provides a unique multi-fab SiGe sourcing capability for our customers," says Dr Marco Racanelli, senior VP & general manager, RF and High Performance Analog Business Group, TowerJazz. "Providing a 0.13 $\mu$ m SiGe process with a Cu backend is important for

applications that require high levels of integration," he adds.

The technology is targeted at the wireless RF and digital TV tuner markets (worth >\$1bn combined), where higher performance, lower cost and higher digital integration are required. TowerJazz says that it has won SBL13 customers that are now taking advantage of the Cu back-end offered in the Israeli facility, and it expects volume to ramp in Israel in first-half 2012.

TowerJazz says that its SBL13 process is suited to WLAN transceivers, cell-phone transceivers, and TV tuners. By combining SiGe bipolar performance with a mature 130nm CMOS copper backend, it enables high-performance RF with more integrated digital logic. It also allows the design of complex base-

band and demodulator functions at less than a half the die size of a 0.18 $\mu$ m process, it is reckoned. A 100GHz SiGe bipolar device enables integration of low-noise and low-power RF, and a high-voltage SiGe device enables the integration of power amplifiers and drivers.

The SBL13 process includes three NPN transistors with an threshold frequency ( $f_T$ ) of 40GHz, 74GHz and 100GHz, respectively, as well as high-density passive elements such as high-density MIM capacitors and 3 $\mu$ m-thick copper inductors. TowerJazz says that 130nm CMOS with copper metallization achieves digital logic densities of up to 200K gates/mm<sup>2</sup>, resulting in higher performance and more highly integrated RF products.

[www.towerjazz.com](http://www.towerjazz.com)

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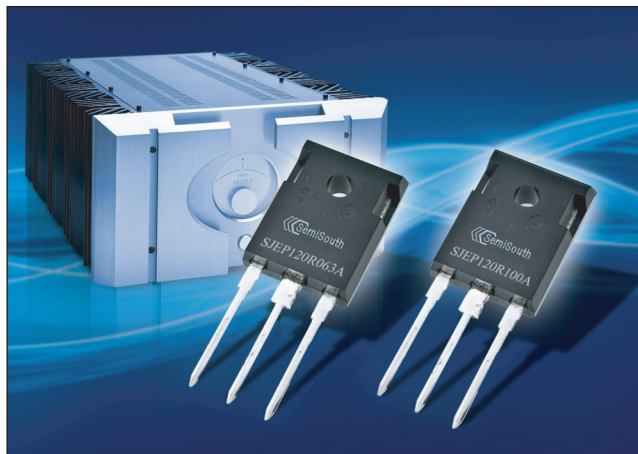
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## SemiSouth launches high-linearity, low-distortion SiC JFETs for high-end audio

SemiSouth Laboratories Inc of Starkville, MS, USA, which designs and manufactures silicon carbide (SiC) power devices and electronics for high-power, high-efficiency, harsh-environment power management and conversion applications, has launched a new family of low-cost SiC junction field-effect transistors (JFETs) with what is claimed to be very good linearity targeted at high-end audio applications.

Compatible with standard gate driver ICs, the SJEP120R100A and SJEP120R063A feature a positive temperature coefficient for ease of paralleling; extremely fast switching with no 'tail' current at up to a maximum operating temperature of 150°C, and a low  $R_{DS(on)max}$  of 0.100Ω and 0.063Ω, respectively. Devices are available in TO-247 packages; the 100mΩ part is also available in die form for integration into modules.

"Over the last 40 years I have greatly appreciated the qualities of



**SemiSouth's SJEP120R063A and SJEP120R100A.**

low-power JFETs in audio circuits, and experimenting with the few examples of 'unobtainable' power JFETs has convinced me of their great potential," comments Nelson Pass, founder of audio amplifier manufacturer Nelson Pass Inc. "With the new SiC power JFETs from SemiSouth, this potential has been realized in reliable linear power amplifiers. In push-pull topologies, they exhibit a 50-70%

improvement in distortion, and in single-ended circuits the improvement has been nearly ten-fold," he adds. "Currently, we profitably produce a small high-end audio amplifier using the SJEP120R100A devices, and are engaged in developing other higher-power amplifiers using this and the SJDP120R085 depletion-mode devices."

"These parts are especially suitable for high-end audio amplifier designs which demand the best linearity performance and lowest distortion," notes Dieter Liesabeths, SemiSouth's director of sales. "Compared to conventional SiC JFET for power applications, the prices for these audio parts has been reduced by about 15% in order to meet the demand of customers," he adds.

## Premier Farnell signs worldwide stocking distribution deal

Multi-channel electronics distributor Premier Farnell plc has announced a worldwide stocking distribution agreement with SemiSouth Laboratories Inc of Starkville, MS, USA, which designs and manufactures silicon carbide (SiC) diodes and transistor technology for high-power, high-efficiency, harsh-environment power management and conversion applications.

SemiSouth's SiC diodes and junction field-effect transistors (JFETs) will be made available via Premier Farnell's operating brands Farnell (in Europe), Newark (in the USA, Canada and Mexico) and element14 (in Asia Pacific), and will be stocked at all of its warehouses worldwide. Further product information documents are also

made available via the element14 online community, and the new agreement will also be supported via the element14 knode, Premier Farnell's online design platform that is exclusively focused on the needs of electronic design engineers.

"This is our first major catalogue outlet and we are excited about the new project opportunities it will drive," says SemiSouth's director of sales Dieter Liesabeths.

Through Premier Farnell's global distribution network and element14, SemiSouth's products can be ordered in bulk and

are available for next-day delivery. Local language websites and regional offices ensure that Premier Farnell's customers receive sales and technical support on all its product lines.

"Our vast customer base will benefit from the leading performance of the SemiSouth products," comments David Shen, group senior VP & global head of technical marketing of Premier Farnell. "These diodes and JFETs are a perfect fit for applications such as solar inverters, hybrid electric vehicles, industrial motors, computing and defence, and we will be able to introduce them to design engineers working in these applications," he adds.

[www.premierfarnell.com](http://www.premierfarnell.com)  
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**These diodes and JFETs are a perfect fit for applications such as solar inverters**



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## EPC adds 100 milli-Ohm power transistor to 2nd-generation 200V E-mode GaN FET range

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

The EPC2012 FET is a 1.6mm<sup>2</sup> 200V<sub>DS</sub> device with a maximum on-resistance  $R_{DS(ON)}$  of 100m $\Omega$  with 5V applied to the gate. The firm says that the latest EPC2012 eGaN FET provides significant performance advantages over the first-generation EPC1012 device. It has an increased pulsed current rating of 15A (up from 12A), is fully enhanced at a lower gate voltage, and has superior dv/dt immunity due to an improved ratio of  $Q_{GD}/Q_{GS}$ .

Compared with a state-of-the-art silicon power MOSFET with similar on-resistance, the EPC2012 is much smaller and has many times superior switching performance,

says EPC. Applications that benefit from eGaN FET performance include high-speed DC-DC power supplies, point-of-load converters, class D audio amplifiers, hard-switched and high frequency circuits.

"This new generation of eGaN

products are the industry's first gallium nitride FETs to be offered as lead-free and RoHS-compliant," notes co-founder & CEO Alex Lidow.

In 100-piece quantities, the EPC2012 is priced at \$2.10 and is available through Digi-Key Corp. An application note is available.

### Development board for fast development of power conversion circuits and systems

EPC has introduced the EPC9004 development board, which the firm says will make it easier for users to get started designing with EPC's 200V eGaN FET in applications such as solar micro-inverters, class D audio amplifiers, power over Ethernet (PoE), and synchronous rectification.

The EPC9004 is a 200V maximum input voltage, 2A maximum output current, half bridge with on-board gate drives, featuring the EPC2012 200V eGaN FET. The board's purpose is to simplify the evaluation process of the EPC2012 eGaN FET by including all the criti-

cal components on a single board that can be easily connected into an existing converter.

Measuring 2" x 1.5", the EPC9004 development board contains not only two EPC2012 GaN FETs in a half-bridge configuration with gate drivers, but also an on-board gate drive supply and bypass capacitors. There are also various probe points to facilitate simple waveform measurement and efficiency calculation.

EPC9004 development boards are priced at \$95 each. A 'Quick Start Guide' is included for reference and ease of use.

## EPC launches 2nd-generation 40V, 16 milli-Ohm E-mode GaN FET power transistor

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

The EPC2014 FET is a 1.87mm<sup>2</sup>, 40V<sub>DS</sub>, 10A device with a maximum on-resistance  $R_{DS(ON)}$  of 16m $\Omega$  with 5V applied to the gate. The firm says that the latest eGaN FET provides significant performance advantages over the first-generation

EPC1014 device. It has an increased maximum junction temperature rating of 150°C and is fully enhanced at a lower gate voltage.

Compared with a state-of-the-art silicon power MOSFET with similar on-resistance, the EPC2014 is much smaller and has many

**Compared with a state-of-the-art silicon power MOSFET with similar on-resistance, the EPC2014 is much smaller and has many times better switching performance**

times better switching performance, says EPC. Applications that benefit from eGaN FET performance include high-speed DC-DC power supplies, point-of-load converters, class D audio amplifiers, hard-switched and high-frequency circuits.

"This new-generation enhancement-mode gallium nitride FET is offered as lead-free, halogen-free and RoHS-compliant," notes co-founder & CEO Alex Lidow.

In 100-piece quantities, the EPC2014 is priced at \$1.12 and is available through Digi-Key Corp.

[www.epc-co.com](http://www.epc-co.com)  
<http://digikey.com>

## Amkor makes available first QFN package design kit for Agilent's ADS software

Contract semiconductor assembly & test service provider Amkor Technology Inc of Chandler, AZ, USA has announced the availability of its quad flat no-lead (QFN) package design kit for Agilent Technologies' Advanced Design System electronic design automation software (ADS 2009 Update 1 and ADS 2011.01), claimed to be the first available package design kit for ADS.

Based on Amkor's MicroLeadFrame (MLF) packages, the kit enables mutual Amkor and Agilent customers to improve their RFIC/MMIC design quality and time-to-market, says Amkor. It allows designers to quickly explore various design specifications with accurate package information and implement optimized RFIC/MMIC designs, providing a greater range of choices

and more flexibility when designing QFN packages, the firm adds.

"Our customers demand ever-increasing design effectiveness and efficiency to achieve their business objectives with today's sophisticated QFN packages," says ChoonHeung Lee, Amkor Technology Korea's corporate VP & chief technology officer.

"Agilent is the RF and microwave CAD leader and many of our customers already use ADS for circuit design and characterization," he adds.

"Customers are looking for easy ways to accurately characterize vendor-supplied packages, both

alone and with ICs and laminates mounted," says Todd Cutler, planning & marketing senior manager with Agilent's EEs of EDA organization. "Amkor is one of the world's leading outsourced assembly & test services providers, and we are extremely pleased with this package design kit," he adds.

"This collaboration between Amkor and Agilent delivers significant benefits for our mutual customers, and illustrates our aligned focus on meeting customer needs."

The Amkor package design kit contains models for 3x3, 4x4, 5x5, and 6x6 MLF QFNs. All die are scalable, and their material properties can easily be modified. The kit also includes scalable models for bond pad arrays and board via arrays.

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## 5N Plus reports record quarterly revenue, earnings, EBITDA, funds from operations, and backlog MCP acquisition drives revenue up six-fold year-on-year

5N Plus Inc of Montreal, Quebec, Canada has reported financial results (in Canadian dollars) for its fiscal fourth-quarter and full-year 2011 (to end May) in which revenue, earnings, EBITDA, funds from operations, and backlog all reached record levels.

Results for the quarter and fiscal year include the operating results of MCP Group SA of Tilly, Belgium — a producer and distributor of bismuth and bismuth chemicals as well as other specialty metals (including gallium, indium, selenium and tellurium) — since that firm's acquisition on 11 April.

Founded in 2000, 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. The firm owns materials subsidiaries including: 5N PV GmbH (Eisenhuttenstadt, Germany), Firebird Technologies Inc (Trail, BC, Canada), 5N Plus Corp (DeForest, WI, USA) and Sylarus Technologies LLC (St George, UT, USA). However, 5N Plus now operates and reports operating performance under two business segments, namely Electronic Materials and Eco-Friendly Materials.

Revenue for fiscal fourth-quarter was \$119.8m, up about six-fold on \$20.6m last quarter and \$19.7m a year ago. Revenue for the fiscal year was \$178.8m, up 153% on \$70.8m a year ago.

Net earnings from continuing operations for the quarter were \$10m, up on just \$3.7m last quarter and \$4.4m a year ago. For fiscal 2011, net earnings were \$21.6m, up on \$15.1m a year ago.

Earnings before interest, taxes, depreciation and amortization (EBITDA) for the quarter were \$19.2m, up more than three-fold on \$6m last quarter and \$6.2m a year ago. Full-year EBITDA was \$36.8m, up on fiscal 2010's \$22.9m.

Funds from operations (cash generated from operating activities before changes in non-cash working capital) rose to \$13.1m in fiscal Q4 and \$29.6m in fiscal 2011, compared with just \$5.7m and \$20.4m, respectively, a year ago.

The backlog of orders expected to translate into sales over the next 12 months was \$253.8m at the end of May, up from the previous record of \$71.2m last quarter and \$52.7m a year earlier.

5N Plus' board of directors has agreed to change the firm's financial year-end from 31 May to 31 December, aligning the year-ends of both 5N Plus and MCP and simplifying internal processes with all subsidiaries and business units. The first quarter ending 30 September will include four months of 5N Plus'

results, and the annual period ending 31 December will include seven months of results.

"With the acquisition of MCP, we have literally transformed our company into a specialty metals and chemicals powerhouse with a strong focus on clean technology markets," says president & CEO Jacques L'Ecuyer. "We now have a much broader product portfolio and a well diversified customer base supported by operations worldwide and a strong commercial network, providing an expanded organic growth platform," he adds.

"With revenues increasing by more than 500% in the quarter and earnings more than doubling following the acquisition of MCP, it is easy to lose sight of some of the other accomplishments that were made during the year. These include the renewal and extension of our contract with First Solar until the end of 2015, the set-up of an integrated germanium production capacity following construction and commissioning of a new facility in Trail, our investments in Sylarus, and the development of a solar module recycling facility in Wisconsin, all of which have enabled us to further strengthen our business," L'Ecuyer comments. "We also received several awards during the year related to the clean-tech technology sector, recognizing our efforts in both recycling and sustainable development," he notes.

[www.5nplus.com](http://www.5nplus.com)

### 5N Plus closes new CDN\$250m credit facility

5N Plus has closed a new \$250m senior secured multi-currency revolving credit facility to replace its existing \$50m two-year senior secured revolving facility with National Bank of Canada. The funds will be used to refinance existing indebtedness and for

other corporate purposes, including capital expenditures and growth opportunities.

The credit facility has a four-year term and bears interest at either prime rate, US base rate, LIBOR or EURO LIBOR plus a margin based on 5N Plus' senior consolidated debt

to EBITDA ratio. 5N Plus also has a US\$35m credit facility in Asia.

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

## AZZURRO opens Asia regional office

AZZURRO Semiconductors AG of Magdeburg, Germany has strengthened its Asian customer support reach by establishing a regional office in Taipei, Taiwan.

AZZURRO makes GaN epiwafers based on large-area silicon substrates. The epiwafers are used in the power semiconductor industry to build higher-performance transistors and diodes, and in the LED industry they can enable the production of inexpensive high-brightness LEDs. The firm says that its technology provides high-quality, crack-free GaN layers on 150mm (and soon 200mm) standard silicon wafers with very low bow values, enabling the use of standard semiconductor production facilities. It reckons that the GaN-on-Si technology, previously not available on large-scale wafers, can trigger a new wave of highly efficient and cost-optimized components for the LED and power semiconductor sectors.

Increasing customer design-in and ramp-up activity has driven a swift decision to open a regional support office (the first outside Germany).

"As customer support in the design-in phase is pivotal to make the customers' products a business success, close contact is absolutely necessary," says Erwin Ysewijn, VP sales & marketing. "With the chosen location in Taipei, Taiwan, the Chinese, Japanese and Korean markets can also be reached very quickly within 2 hours flight time," he notes.

"The aim to enable its customers a fast and smooth product introduction to quickly reap the rewards of AZZURRO's GaN-on-Si technology was the key driver. This enables us to better understand and resolve customer challenges in a timely fashion and offer professional solutions, in local language, local time zones and with an experienced management team on the ground."

[www.azzurro-semiconductors.com](http://www.azzurro-semiconductors.com)

## Neo Material acquires 80% stake in Gallium Compounds

Neo Material Technologies Inc of Toronto, Canada (which produces neodymium-iron-boron magnetic powders, rare earths and zirconium-based engineered materials, as well as other rare metals and compounds via its Magnequench and Performance Materials divisions) has acquired an 80% stake in Gallium Compounds LLC of Quapaw, OK, USA.

As a supplier of specialty value-added gallium products, Gallium Compounds' primary business is the manufacturing of gallium tri-chloride for applications including the production of LEDs. Neo Material plans to expand gallium tri-chloride production business into South Korea.

Design and construction is underway for a new manufacturing facility in the Hyeongok Industrial Zone, in the heartland of South Korea's booming LED industry, with plans to replicate Gallium Com-

pounds' proven technology for the production of gallium tri-chloride. Commercial production is expected to start by third-quarter 2012.

The purchase price for Gallium Compounds was US\$6.5m, subject to working capital adjustments, plus a potential earn-out payment which is dependent on the performance of the Gallium Compounds' business from the date of closing to the end of 2014.

"Acquisition of Gallium Compounds and the expansion into South Korea significantly strengthens our position in value-added gallium products and is an important step in our overall rare metals strategy," says executive VP & chief operating officer Geoff Bedford. "We look forward to working with our colleagues at Gallium Compounds to expand the business globally."

[www.neomaterials.com](http://www.neomaterials.com)

### IN BRIEF

#### IQE appoints head of sales & marketing for Asia Pacific

Epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK has appointed Norio Hayafuji as head of sales & marketing for the Asia Pacific region.

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

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

"We confidently expect China, Taiwan, Korea and Japan to become major global powers in emerging technologies over the next decade," says CEO & president Dr Drew Nelson. "We already have a considerable presence in the Far East, with a solid customer base and state-of-the-art manufacturing facility. The appointment of an acknowledged industry expert with extensive knowledge and experience of our industry in the region will help ensure that IQE is well positioned

to exploit this growth potential."

IQE's wireless portfolio includes III-V PHEMT, HBT, and BiFET epiwafers grown by MBE and MOCVD at IQE's manufacturing sites in the US, UK, and Singapore.

[www.iqep.com](http://www.iqep.com)

## SEMI-GAS offering bulk specialty gas source systems with flow rates of 1000slpm

SEMI-GAS Systems of Malvern, PA, USA, a division of Applied Energy Systems Inc that manufactures ultra-high-purity gas source and distribution systems, says that it is offering bulk gas source systems to safely deliver hazardous specialty process gases (including  $\text{NH}_3$ ,  $\text{HCl}$ ,  $\text{SiH}_4$ ,  $\text{N}_2\text{O}$ , and  $\text{H}_2$ ) from large vessels at high flow rates (from 100 slpm up to 1000slpm).

SEMI-GAS' bulk specialty gas source systems consolidate many gas cabinets into a single system for high-volume semiconductor production, as well as for high-gas-volume-consuming processes, as found in LED and solar cell production applications. With consideration to the local climate, the source systems can be installed both indoors or outdoors.

Source vessel heating is incorporated into the system to facilitate the liquid-to-gas phase change and to

sustain the high gas flow rates. Additional heating elements within the process gas lines, prior to pressure regulation, also control the enthalpy and undesirable phase changes.

SEMI-GAS says **The standard source system enclosures are 86" tall, 40" wide and 23" deep** that bulk specialty gas source systems help to increase operator safety by minimizing the frequency that the operator must change the empty gas cylinders. Safe operation is also ensured through several levels of system redundancy designed into the source system to continue critical gas supply and system operation at all times, avoiding costly downtime.

Each SEMI-GAS bulk source system includes a PLC controller designed

to monitor analog and digital process sensors, perform purging and cylinder switchover automatically, and continuously monitor system conditions for alarms (including flow, pressure, exhaust and fire). The source system will shut down automatically in the event of an alarm trip. All of these elements can be monitored and controlled via the color touch-screen operator interface.

The standard source system enclosures are 86" tall, 40" wide and 23" deep, and constructed of welded 11 gauge steel. Each features a self-closing and self-latching door and window with 1/4" thick safety glass and polycarbonate face shield for increased operator protection. The fire sprinkler that is included is UL-approved.

[www.semi-gas.com](http://www.semi-gas.com)

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## AXT Q2 revenue rebounds by 22% sequentially to \$30m Revenue boosted by record third-party raw material sales

For second-quarter 2011, AXT Inc of Fremont, CA, USA, which makes gallium arsenide, indium phosphide and germanium substrate and raw materials, has reported revenue of \$30m, up 29.6% on \$23.2m a year ago and up 22% on \$24.6m last quarter (which had been down 8.6% on the prior quarter).

Total gallium arsenide (GaAs) substrate revenue was \$18m, up 13% on \$15.9m last quarter and 11% on \$16.2m a year ago. Indium phosphide (InP) substrate revenue was \$1.6m, up 23% on \$1.3m last quarter and 45% on \$1.1m a year ago. Germanium (Ge) substrate revenue was \$2.7m, down 10% on \$3m last quarter but up 69% on \$1.6m a year ago. Raw materials sales were \$7.7m, up 75% on \$4.4m last quarter and 83% on \$4.2m a year ago.

"Revenues exceeded our expectations, driven by double-digit growth in our substrate business and

record revenues from third-party raw material sales," says CEO Morris Young. "We are experiencing healthy demand across all of our product categories and are pleased to see our competitive positioning continue to strengthen," he adds.

Gross margin has grown from 36.8% a year ago and 43.4% last quarter to 46.7%. Compared with \$3.6m a year ago, operating expenses have risen from \$4.2m last quarter to \$4.4m. Nevertheless, income from operations has risen further, from \$5m a year ago and \$6.5m last quarter to \$9.5m. Net income was \$7.1m, up from \$4.2m last quarter and \$5.5m a year ago.

"Our strong business model and solid operational execution are resulting in healthy growth to our bottom line," notes Young. "The trends fueling our growth are substantial, and we are well positioned to benefit with the capacity, raw

material access and attractive cost-structure that are unique in our industry," he believes.

For Q3/2011, AXT expects revenue to rise to \$30.5–31.5m.

● AXT has filed a registration statement with the US Securities and Exchange Commission (SEC) to offer and sell (from time to time, in one or more offerings) up to \$60m of common stock, preferred stock, debt securities, warrants to purchase any of these securities, depository shares, units or any combination of such securities.

The timing of any offering will be at AXT's discretion and will depend on many factors, including the prevailing market conditions.

AXT intends to use the net proceeds of any sale of securities for general corporate purposes, which may include capital expenditures in connection with its planned expansion of manufacturing facilities in China.

[www.axt.com](http://www.axt.com)

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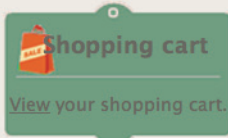
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## Veeco's Q2 yields record orders as MaxBright comprises 40% of MOCVD orders

### CIGS exited due to timeframe and cost to commercialization

For second-quarter 2011, epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA has reported revenue of \$264.8m, up 4% on Q1's \$254.7m and up 20% on \$221.4m a year ago for continuing operations (excluding the Metrology business, sold to Bruker Corp of Billerica, MA, USA on 7 October).

In particular, Data Storage revenue was \$45.7m (the highest quarterly level in five years), up 15% on Q1's \$40m and 28% on \$35.7m a year ago. LED & Solar revenue was \$219.1m (up 2% on Q1's \$214.7m and 18% on \$185.6m a year ago). This included metal-organic chemical vapor deposition (MOCVD) revenue of \$206m, up slightly on Q1's \$204m and up 18% on \$175m a year ago.

Veeco met its quarterly guidance of \$255–285m. However, the timing of revenue continues to be impacted by the longer order-to-revenue cycle times associated with the high percentage of MOCVD business currently coming from China, due mainly to customer facility readiness and credit tightening.

Non-GAAP net income was \$57.6m (\$1.34 per share), up from \$56.6m (\$1.33 per share) last quarter and \$40.7m (\$0.94 per share) a year ago.

Order bookings were a record \$311m, up slightly from \$310.5m a year ago but up 35% on Q1's \$230.9m (boosting order backlog from \$530m to \$558.2m). In particular, Data Storage orders were \$37.5m, down 25% on \$50m a year ago but up 15% on Q1's \$32.6m. LED & Solar orders were a record \$273.3m (up 38% on Q1's \$198.3m and 5% on \$260.4m a year ago). Of this, molecular beam epitaxy (MBE) bookings were a strong \$24m. MOCVD orders were \$250m, down slightly on \$251m a year ago but up 34% on Q1's \$186m. While

China was again the main region for new systems purchases, Korea showed signs of improvement, including a multi-system MaxBright MOCVD order from an "important LED industry leader".

"We have seen spectacular customer reaction to our new MaxBright MOCVD system [launched in February] — in the second quarter we booked over \$100m of MaxBright systems — 40% of our total MOCVD bookings," says CEO John R. Peeler. "Customers are clearly recognizing that MaxBright is simply the best tool on the market to drive down LED manufacturing costs," he believes.

#### **CIGS business discontinued**

"Veeco has decided to exit the CIGS Solar Systems business for various reasons, including the improved performance of mainstream solar technologies and the lower-than-expected end-market acceptance for CIGS technology to date," says Peeler. "While CIGS remains an important thin-film solar technology, we have determined that the timeframe and cost to successful commercialization are not acceptable to Veeco," he adds.

"Veeco intends to transfer our R&D facility, pilot line, technology and key personnel in Clifton Park, New York to the College of Nanoscale Science and Engineering (CNSE) in order to support their planned CNSE/SEMATECH Photovoltaic Manufacturing Consortium (PVMC)," Peeler continues. "PVMC is much-needed to drive CIGS industry roadmaps, collaboration, market acceptance and commercialization," he believes.

Veeco's second-quarter GAAP results were negatively impacted by about \$51m in asset impairment and restructuring charges related to the CIGS Solar Systems business. In addition, about \$20m in CIGS deposition systems has been removed from Veeco's backlog.

Effective third-quarter 2011, Veeco will treat its CIGS Solar Systems business, which operated at a loss, as a discontinued operation. "The closure of our CIGS Systems business is expected to have an immediate and positive impact to Veeco's profitability," says Peeler. "Veeco will continue to sell CIGS deposition components and remains the top supplier of MOCVD and MBE tools to the concentrator photovoltaic (CPV) market," he adds.

#### **Veeco repurchases shares, eliminates convertible debt, and invests in technology**

During Q2/2011, under its board-authorized share buy-back program, Veeco purchased \$7.8m in stock at an average price of \$46.91 per share. It also completed the redemption of its outstanding convertible subordinated notes for \$98.1m aggregate principal amount and completed the purchase of a privately held company that supplies certain critical components to its MOCVD business for \$28.3m. "In addition to paying off our convertible debt and making a small technology purchase, Veeco recently utilized cash to buy-back our shares, reflecting our continued confidence in the long-term outlook for the company," comments Peeler.

Subsequently, as of 26 July, Veeco had purchased an additional \$71.9m of stock during July, at an average price of \$42.21 per share. Since the \$200m buy-back program was authorized last August, Veeco has repurchased a total of 3 million shares for \$117.8m.

#### **Q3/2011 guidance**

"Quoting activity in MOCVD remains robust and we are experiencing extremely positive customer reaction to MaxBright," Peeler says. "MOCVD order patterns will continue to fluctuate from quarter to quarter, depending upon the timing of customer deposits," he adds. "In the short term, orders will likely be

► impacted by several headwinds that have been widely reported, including weak near-term LED industry end-market demand and global macro-economic concerns. We therefore currently forecast that Veeco's third-quarter 2011 bookings will be lower than our record second quarter."

For third-quarter 2011, Veeco expects revenue of \$235–285m, and non-GAAP net income of \$41.3–57.7m (\$1–1.40 per share). "We expect to have a great 2011 and are on track to deliver on our guidance of over \$1bn in revenue and over \$5.25 in non-GAAP earnings per share," notes Peeler. "We are confident that the company can perform well during any short-term fluctuations in business thanks to our variable cost model and strong cash position." Despite spending \$134.2m on repurchasing shares, eliminating convertible debt, and investing in technology, Veeco's cash and short-term investments at the end of the quarter still totaled \$632.7m.

"While short-term business conditions are uncertain, there is a fantastic growth opportunity ahead of us as LED lighting market adoption is expected to increase in 2012 and 2013," comments Peeler. "We believe lighting market penetration will accelerate due to a variety of factors including ban the bulb legislation in Europe and the US, Japan's move to stimulate LED adoption, significant investment by Korean and Taiwanese leaders who have already introduced lighting products in the sub-\$15 range, China's emergence as a major LED industry player, and rapidly declining LED prices... In fact, we estimate that over 50% of our first-half 2011 MOCVD shipments were for lighting, up from 28% in 2010," he adds. "While accurately predicting industry investment cycles is difficult, our forecast of an MOCVD market opportunity of 5000 reactors from 2011 to 2015 appears conservative, given the industry's growth potential."

[www.veeco.com](http://www.veeco.com)

## Riber triples first-half revenue

For second-quarter 2011, Riber S.A. of Bezons, France, which manufactures molecular beam epitaxy (MBE) systems as well as evaporation sources and effusion cells, has reported revenue of €7.2m, compared with €5.7m in Q1/2011 and just €1.5m in Q2/2010. This took first-half 2011 revenue to €13m, tripling (up 198%) from just €4.4m in first-half 2010.

In particular, first-half 2011 revenue from systems was €3.4m, more than tripling from €1.1m a year ago. Three research systems with high unit values were delivered, compared with just two in first-half 2010.

Sales of services and accessories are stable, contributing revenue of €2.6m, roughly level with €2.7m a year ago.

Business in first-half 2011 was distinguished by sales of evaporation sources and cells of €7m, up more than 13-fold from about €0.5m in first-half 2010 due to delivery of the first significant orders for the rapidly growing organic LED (OLED) and copper indium gallium diselenide (CIGS) thin-film photovoltaic panel markets.

The order book at the end of June was €18m, up 6.4% on €16.9m a year ago. This includes systems orders worth €15.1m (up 12.4% on

€13.4m a year ago), comprising six research systems and four production systems (with three to be delivered after 2011).

Orders for cells and sources were €1.2m, level on a year ago. However, in addition, a major order was sealed at the beginning of July for OLED production equipment (cells).

Orders for services and accessories were €1.7m, down 'temporarily' by 26.8% on €2.3m a year ago, although this does not call into question the business outlook for the year, says Riber.

Riber says that the results are in line with its strategic business model, which is based on the following profitable growth drivers:

- continuing to strengthen its market leadership in MBE systems;
- capitalizing on the installed base and growing sales of epitaxy equipment, spare parts and accessories, as well as corresponding services;
- rolling out a diversification policy, including launching a range of high-value-added equipment (cells and sources) for high-growth applications (thin-film solar panels, OLED lighting and flat-panel displays, etc).

For full-year 2011, Riber is targeting revenue growth of €27–29m, up 35% on 2010, paving the way for strong growth in operating income.

[www.riber.com](http://www.riber.com)

## Riber sells Compact 21 MBE system to US solar module maker

Riber has sold a Compact 21 MBE system to a US-based photovoltaic solar module maker, for use in developing new thin-film structures for solar cells. The system is expected to be delivered in 2012.

Riber says that the Compact 21 offers high modularity and flexibility, making it possible to satisfy the most demanding specifications for the controlled development of semiconductor-based nanostructures.

The firm says that the new order further strengthens its presence in the USA, as well as the credibility

of its offering in several fields associated with renewable energies.

It also says that the order confirms the relevance of its business model and strategy, which is focused on:

- capitalizing on the installed base and growing sales of epitaxy equipment, spare parts and accessories, as well as the corresponding services;
- rolling out a diversification policy, involving launching a range of high-value-added equipment and services for high-growth application fields (thin-layer solar cells, organic LED lighting and displays etc).

## Aixtron's revenue dips in Q2 after China customer delays

For first-half 2011, deposition equipment maker Aixtron SE of Herzogenrath, Germany has reported revenue of €381m (up 10% on first-half 2010's €346.3m). Of this, 92% came from equipment sales and 8% from spare parts and services. "We used to assume that spare parts and services would contribute about 10% to total revenues, but this has changed slightly in the context of surging demand for our systems in the last two years," notes chief financial officer Wolfgang Brems.

However, second-quarter revenue was €175.6m, down 8% on \$191.8m a year ago and 15% on Q1's €205.4m. With over 90% of revenue generated in US dollars, Q2 was impaired by the dollar weakening against the euro by 6%, as well as by a shift in regional product mix and selling prices influenced by larger order volumes. Additional causes of the decline were later-than-scheduled LED production facility completions by Chinese customer (causing shipment delays) and temporary regional customer financing delays.

Gross margin fell from 53% in first-half 2010 to 48% in first-half 2011. In particular, quarterly gross margin has fallen from 55% a year ago and 51% in Q1 to 44% in Q2 (due to the quarterly sequential revenue drop, set against a stable sequential cost base).

EBIT (earnings before interest and taxes) operating profit was €129.2m in first-half 2011, up 21% on €106.9m a year ago. However, quarterly EBIT fell from €74.9m in Q1 to €54.3m in Q2, due mainly to gross margin effects, partly compensated by the improved operating cost base and positive hedging effects. EBIT margin has fallen from 36% last quarter to 31%.

Net income was €90.4m in first-half 2011, up 22% on €74.1m a year ago. However, quarterly net income fell from €52.3m in Q1 to €38.2m in Q2, due partly to the lower gross margin.

Reduced profitability is partly due to Aixtron's increased business in

China (which grew eight-fold in 2010 and should be the firm's biggest-revenue region in 2011). "A greater percentage of our Chinese customers have a preference for our CRIUS Showerhead systems, which carry a lower ticket price than our Planetary Reactor systems," says president & CEO Paul Hyland. "Moreover, the shift away from single orders towards large multiple orders, especially from China, means that customers are able to negotiate lower average selling price," he adds. "China is a very competitive market and we fully intend to compete for all of that business."

During the quarter, cash and cash equivalents fell, due to the \$60.7m cash dividend payout after May's annual general meeting (AGM).

Despite some short-term market volatility, Hyland remains confident about prospects for the rest of the year. "Despite some unfriendly currency and mix effects in Q2, we have had an excellent quarter: we have seen sequentially higher order intake, a very positive customer response to a new product launch [the CRIUS II-L, the largest-capacity MOCVD reactor available, at 69 x 2" wafers], and some increasingly encouraging signals from a rapidly emerging LED lighting market." The percentage of orders received for latest-generation products rose again from 65% in Q1 to 70% in Q2, indicating strong customer adoption.

During first-half 2011, equipment order intake was €432.5m, up 26% on first-half 2010's €343.9m. Orders continued to be received at an historically high level, fueled mainly by HB-LED backlighting and lighting applications, the latter becoming more prominent in the second quarter. Equipment order intake for Q2 was €222.2m, up 6% on Q1's €210.3m and up 27% on €175.4m a year ago. "Order activity is flattening out, which is not surprising given the business environment and the base effect caused by an extremely strong 2010," says Hyland. In line with the trend seen

in recent quarters, China was the strongest regional driver.

During Q2, order backlog rose from €321.1m to a record €373.5m (of which more than two-thirds is for China). Of this, about €50m is due for delivery in 2012. Hence, the remaining €323.5m of order backlog shippable in second-half 2011, added to first-half 2011's revenue of €381m, should amount to revenue of €705m for full-year 2011. Assuming spares and services revenue of another €30m in second-half 2011 (in line with the first-half 2011 run rate). Aixtron hence requires a further €65–165m of order intake that can be delivered and recorded as revenue this year in order to achieve the firm's full-year 2011 revenue guidance of €800–900m.

"Although the 'choppy waters' we predicted in Q2 are likely to continue in Q3, we believe that they are transitional effects of a growing market and consequently will pass through in the course of this year," says Hyland. "We remain very positive that there will be little or no substantial gap between the end of backlighting demand and the development of LED lighting," he adds.

"The risk to the conversion timing of our existing backlog will remain if customers do not finish their fabs on time, or don't get their funds in place on time or can't find the necessary engineers," says Hyland.

"With a far greater percentage of outstanding system orders being dominated by a smaller number of customers, any consequential delays would delay revenue recognition... We don't predict that that will be the case, or we would have revisited our year-end guidance," he adds.

"Albeit challenging, we remain optimistic of achieving our original targets set for the full year," states Hyland. Despite the short-term volatility in the market, Aixtron has reconfirmed its 2011 guidance of revenue of €800–900m and EBIT operating margin of about 35%.

[www.aixtron.com](http://www.aixtron.com)

## Aixtron delivers its first CRIUS II-L system to Taiwan's Epistar

Deposition equipment maker Aixtron SE of Herzogenrath, Germany has announced the first delivery of its first CRIUS II-L metal-organic chemical vapor deposition (MOCVD) system (launched in early July) to Taiwan's biggest LED chipmaker, Epistar Corp. Aixtron says that the CRIUS II-L offers the largest MOCVD reactor capacity of 69x2" or 16x4" wafers, and reflects the next evolution of the proven CRIUS II system (launched in 2010).

One of Aixtron's local service teams will install the new reactor at Epistar. Earlier this year, two CRIUS II systems in 55x2"-wafer configuration dedicated to the mass production of ultra-high-brightness (UHB) blue LED materials were installed in the same facility.

"The transfer of our process recipes from the CRIUS and CRIUS II to the latest CRIUS II-L will be flawless," expects Epistar's president Dr Ming Jiunn Jou. "It will be easy to achieve the desired uniformity promptly," he believes.

Epistar is focused on developing and manufacturing UHB-LED products. Through the application of its proprietary MOCVD epitaxy technology, Epistar has commercialized the full spectrum range of LEDs with the characteristics of compact size, low power consumption and long operation life. After qualification of Aixtron's next-generation AIX G5 HT system in 2010, Epistar placed a repeat order for multiple G5 systems this April.

[www.epistar.com.tw](http://www.epistar.com.tw)

## Korea's Pusan National University buys Black Magic PECVD system

Korea's Pusan National University (PNU) has procured an Aixtron 4" Black Magic plasma-enhanced chemical vapor deposition (PECVD) system for the production of carbon nanotubes (CNTs) and graphene for renewable energy devices. The turnkey system was installed and commissioned by the local Aixtron service and support team.

Professor Kwang-Ho Kim and assistant professor Hyung Woo Lee from the National Core Research Center (NCRC) at PNU are working on a government-supported project for hybrid materials based on CNTs and graphene.

"Our research is focussed on developing novel hybrid structures containing CNT and graphene which utilize the unique physical and electronic properties of these materials," Kim says. "We apply these in various electronic devices such as solar cells and sensors," he adds. "Our study needed equipment with a wide process range in

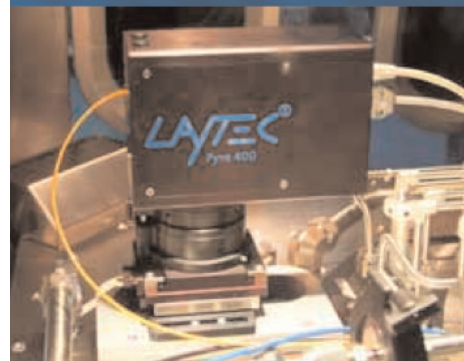
CVD and PECVD in order to reproducibly synthesize all different CNT and graphene structures which we are interested in; these stringent process requirements are met with Aixtron's Black Magic system," Kim comments. "The system indeed produces high-quality films reliably with ease and flexible control."

Established in 2006, the National Core Research Center for Hybrid Materials Solution at PNU comprises 90 researchers and is a leading center in Korea for industrial materials research. Lee, who worked in Massachusetts Institute of Technology (MIT) in the USA as a postdoctoral associate, joined PNU as an assistant professor in 2010 and is in charge of the Advanced Carbon-based Energy Systems (ACES) lab. His research interests lie in organic solar cells, biosensors, dye-sensitized solar cells, supercapacitors, and ultra-fast rechargeable batteries based on CNT/graphene nanostructures.

[www.pnu.edu](http://www.pnu.edu)

## Real GaN surface temperature

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## SPTS completes management buyout from SPP

European private equity backer Bridgepoint and the management of etch, deposition and thermal processing equipment maker SPP Process Technology Systems Ltd (SPTS) of Newport, Wales, UK have completed the acquisition of the latter from former parent firm Sumitomo Precision Products Co Ltd (SPP). The deal (which was announced on 27 June) closed with an enterprise value of nearly \$200m. SPP will continue to have an association with SPTS through a minority equity stake in the firm, and will cooperate with SPTS to jointly serve the Japanese market.

SPTS was formed by SPP in October 2009 to merge predecessor firm Surface Technology Systems plc (STS) together with assets acquired from Aviza Technology Inc, including Newport-based single-wafer process equipment subsidiary Aviza Technology Ltd (ATL) and Aviza's Scotts Valley-based Thermal Products business (which provides spare parts, upgrades, and new or remanufactured sys-

tems to existing customers of Watkins Johnson, SVG, and Aviza furnaces and APCVD systems). Also, last December saw completion of the transfer of ownership from SPP to SPTS of Primaxx Inc of Allentown, PA, USA, which provides residue-free micro-electro-mechanical systems (MEMS) dry etch release equipment.

After the acquisition from SPP, there will be no change in management, product strategy, customer focus or mission at SPTS, except for a minor change in name in deference to the former parent company.

Now renamed SPTS Technologies, the firm designs and manufactures capital equipment for producing electronic and micro-devices for high-growth end-markets including micro-electro-mechanical systems (MEMS), power management, advanced packaging, high-speed RF components, and high-brightness light-emitting diodes (LEDs). With more than 500 staff in manufacturing, sales and service opera-

tions across 19 countries, SPTS serves micro-device manufacturers from its main manufacturing facilities in Newport, Wales, UK and in San Jose, CA, USA. In 2010 it generated sales of \$217m and earnings before interest, taxes, depreciation and amortization (EBITDA) of \$58m.

The firm says that the all-equity, debt-free transaction sets a positive example for private-equity-funded management buy-outs of equipment companies, with Bridgepoint known for taking a long-term view on its investment portfolio.

"Bridgepoint's financial backing and merger & acquisition (M&A) experience will be great assets in our growth strategy for the company," says SPTS' president & CEO Dr William Johnson. "Bridgepoint provides a solid foundation as we expand our operational infrastructure and we will continue our focus on best-of-breed customer satisfaction," agrees executive VP & chief operating officer Kevin Crofton.

[www.spp-pts.com](http://www.spp-pts.com)

## Stanford Nanofabrication Facility buys additional Plasma-Therm etching systems

Stanford University is extending its research capabilities in nanotechnology and photonics by purchasing three dry etching systems from plasma process equipment maker Plasma-Therm of St. Petersburg, FL, USA. The new systems complement a previous facility upgrade when two Plasma-Therm deposition systems were ordered in February 2010.

The latest systems, all configured as inductively coupled plasma (ICP) etchers, will add to Stanford's Nanofabrication Facility (SNF) infrastructure, which has a 10,000ft<sup>2</sup> class 100 cleanroom providing researchers with access to nanofabrication equipment and expertise. SNF is one of the 14 universities that make up the

US National Science Foundation's National Nanotechnology Infrastructure Network (NNIN), which provides nanofabrication resources to researchers across the USA in both industry and academia.

The new equipment will focus on high-performance etching of silicon, metals and dielectrics, and are based on Plasma-Therm's leading product, the VERSALINE. Plasma-Therm claims that its fast process technology suite for deep silicon etching (DSE) and the strength of

**The new equipment will focus on high-performance etching of silicon, metals and dielectrics**

its service organization were among the differentiating factors. The combination of etching and deposition tools will fulfill many of the processing needs for more than 600 registered SNF users.

"This new set of equipment provides SNF with both upgraded and new capabilities that will stimulate researchers' imaginations and play a role in scientific discovery," says Dr David Lishan, principal scientist & director of technical marketing. "For example, our VERSALINE DSE system delivers precise control needed for intricate SOI [silicon-on-insulator] structures and exceptionally smooth feature sidewalls while maintaining the benefits of wide process windows," he adds.

[www.plasmatherm.com](http://www.plasmatherm.com)



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## IN BRIEF

## Oxford Instruments Plasma Technology adds to executive team

UK-based Oxford Instruments Plasma Technology (OIPT) says that it has responded to demand for its etch, deposition and growth equipment by investing in key business areas and expanding its workforce by over 30% in the last year. As part of this expansion, the firm has now appointed Steve Chittock as operations director (Supply Chain and Manufacturing) and Neil Perry as finance director.

A Chartered Engineer, Chittock has 20 years operations experience in market leading, multi-national engineering companies operating in aerospace, defence and automotive markets. Previous employers include Morgan Crucible, SKF & Bostrom.

Perry brings a wealth of experience, gained in a number of industries, including telecommunications, aerospace and automotive. Previous employers include Wireless International and Matra Marconi Space (incorporating BAe Space Systems) in commercial, interim and finance director roles.

"These two appointments give us considerable strength to meet the needs of our customers and to develop the competencies and resources that support our future growth", said Andy Matthews, managing director of Oxford Instruments Plasma Technology. "In order to remain competitive and produce world leading products, it is imperative that we bring the skills and experience into the Company that meet the needs of the 21st century, and I believe that these two new appointments will help to achieve this."

[www.oxford-instruments.com](http://www.oxford-instruments.com)

## OIPT receives 3rd Queen's Award

The Lord Lieutenant of Somerset, Lady Elizabeth Gass, has visited North Somerset-based Oxford Instruments Plasma Technology (OIPT) to present its Queen's Award for Enterprise. This is the third time that the firm has been honoured in the Queen's Awards.

The UK-based manufacturer of etch, deposition and growth equipment for the semiconductor industry received the award for International Trade for more than doubling overseas earnings over six years of sustained growth, and exporting more than 90% of production. The firm says that this performance was based on its comprehensive product range, addressing a broad spread of markets combined with an aggressive strategy of developing new markets, primarily in Asia.

The Lord Lieutenant toured Oxford Instruments' manufacturing plant, research laboratories and offices in Yatton, North Somerset, accompa-



**Lady Gass, Lord Lieutenant of Somerset, presents the Queen's Award to OIPT managing director Andy Matthews.**

nied by John Cullum (High Sherriff of Somerset) and Graham Turner (chief executive of North Somerset Council).

"We were able to demonstrate our technology, and show the extensive improvements and growth in both facilities and workforce that have taken place recently," says OIPT's managing director Andy Matthews.

[www.oxford-instruments.com](http://www.oxford-instruments.com)

## Nanoscale Plasma Processing workshop

OIPT is continuing its series of workshops with a one-day 'Nanoscale Plasma Processing' event at the French research center CEA-LETI in Grenoble, France on 18 October. The workshop will be particularly relevant to those working in industry and academia with an interest in R&D advances, plus future trends in the fabrication and application of micro- and nano-structures and devices.

The workshop will consist of presentations, discussions and a networking lunch, focussing on the latest innovations in MEMS Etch developments, Ion Beam Etch and Deposition, Atomic Layer Deposition (ALD), Silicon and III-V Etch for nanowire applications.

Invited guest speakers from key research institutes will discuss their research, including professor Daniel Alquier (director, LMP in Tours, France); a speaker from

IEMN (Lille, France); and Dr Alex Robinson (University of Birmingham, UK). In addition, experts in their field from Oxford Instruments will speak on the latest process and application developments in a number of plasma processing areas.

"We've been hosting these successful seminars worldwide for several years, most recently at IOS-CAS (Institute of Semiconductors, Chinese Academy of Sciences), Lawrence Berkeley National Laboratory, USA, and the University of Southampton, UK, attracting many scientists to each event," comments Mike Smyth, EMEA business manager, OIPT. "We've chosen Grenoble as our next venue as it is a hub for innovation in France," he adds.

There is no charge for the workshop, but advance booking is essential.



## Industrial–academic collaborations demonstrated at Southampton University

UK-based Oxford Instruments says that industry and academia came together at the University of Southampton recently to demonstrate the success of an industrial collaboration that is creating the nanotechnology needed for smaller, low-power devices.

With talks by university researchers in nanotechnology and industrialists from Oxford Instruments Plasma Technology (OIPT), the workshop 'Knowledge Creation Partnership – From Funding to Results' described how the two organizations have partnered during a two-year collaboration to develop nanotechnology tools. Combining the university's knowledge and research with Oxford Instruments' tools has already produced results, and these were presented by the university's professor Peter Ashburn, Oxford Instruments' chief technology officer Dr Mike Cooke, and their colleagues.

"We recognize the importance of partnerships between the commercial and the academic sectors in today's highly competitive, fast-moving and demanding global markets, and at Oxford Instruments we see businesses forming the bridge between science and the consumer," comments

OIPT's business development director Frazer Anderson. "Through collaborations with some of the world's leading scientists and institutions, companies like ours turn smart science into commercially successful products," he adds.

"Our university and Oxford Instruments have worked together to

develop a range of processes for the company's tools which will be used to make nanoscale transistors," says Ashburn, of the university's Nano Research Group within the School of Electronics and Computer Science (ECS). "These new plasma-based technologies provide etching and deposition functions on nanoscale materials and are being used in the Southampton Nanofabrication Centre, one of Europe's leading multi-disciplinary state-of-the-art cleanroom complexes."

OIPT is also involved in collaborations at the Molecular Foundry, Lawrence Berkeley National Laboratory (LBNL) in the USA, and with Taiwan's Industrial Technology Research Institute (ITRI), each focussing on key areas of scientific R&D, ultimately leading to the development of tools for use in wider markets of research and production.






[www.oxford-instruments.com](http://www.oxford-instruments.com)

**These new plasma-based technologies provide etching and deposition functions on nano-scale materials**

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## EVG breaks ground on expansion and seeks 100 new staff

EV Group (EVG), a supplier of wafer bonding and lithography equipment for the MEMS (micro-electro-mechanical system), nanotechnology and semiconductor markets, says that earlier this month it broke ground on an expansion of its manufacturing capacity at its headquarters in St Florian, Austria. The firm says that the expansion is the latest example of its steady growth since its foundation more than 30 years ago.

In addition, EVG has seen a 40% increase in order intake in fiscal 2011 compared with fiscal 2010, and it is currently aiming to recruit about 100 additional employees. "This strong growth validates the need for this manufacturing floor expansion," says Dr Werner Thallner,

executive operations and financial director.

The new building, directly adjacent to the existing manufacturing facility, will more than double production floor space and is due to be completed by the end of this year.

In parallel, EVG continues to invest in additional capacity for its machining center and new manufacturing technologies, as well as planning to further modernize the existing manufacturing facility. One upgrade includes the installation of several filter fan units, bringing a virtually particle-free environment to EVG's entire equipment production. In addition, the entire manufacturing area will be fully air-conditioned and additional hydraulic ramps and a large overhead crane will be

installed to provide a better working environment for staff.

Customers will also have access to a new area dedicated for visitors, which houses two glass domes that provide a complete view into the manufacturing area and a sophisticated entry control system. Additional test rooms will facilitate customer-specific process development and customization, including a smooth source inspection process even at times of increased orders.

To support future growth, EVG aims to recruit about 100 new staff, mainly in manufacturing and technical service and support. The firm's newly launched recruitment campaign is geared to attract educated professionals with a passion for technology.

[www.evgroup.com/en/careers](http://www.evgroup.com/en/careers)

### IN BRIEF

#### ESI expands suite of LED manufacturing systems and applications

At the SEMICON West 2011 trade show in San Francisco (12-14 July), Electro Scientific Industries Inc (ESI) of Portland, OR, USA showcased its expanded suite of LED manufacturing systems and applications.

The firm claims that its new products deliver the industry's highest-light-output LED wafer scribing; the most advanced LED packaging solution; and the highest-throughput, highest-accuracy packaged LED test.

"In working closely with our LED customers, ESI has developed revolutionary systems that are directly aligned with their production roadmaps targeting the next generation of devices for high-brightness solid-state lighting applications," claims president & CEO Nick Konidaris.

[www.esi.com](http://www.esi.com)

#### ESI unveils LED wafer scribing system for high-volume HB-LED manufacturing

At the SEMICON West exhibition, Electro Scientific Industries Inc (ESI) Inc of Portland, OR, USA, which provides laser-based manufacturing solutions for the microtechnology industry, unveiled the AccuScribe 2600 LED wafer scribing system.

ESI says that it developed the AccuScribe 2600 on the basis of customer requirements for high-brightness light-emitting diode (HB-LED) manufacturing, including patterned sapphire substrate (PSS), distributed Bragg reflector (DBR), metal mirror (MM) and other advanced light extraction technologies.

"ESI pioneered the laser scribing of LED wafers with our patented technology for LED sapphire substrates," claims Jonathan Sabol, general manager of ESI's LED uEngineering Division. "Industry-wide expansion of high-brightness LEDs is driving rapid changes in LED architecture and manufac-

turing processes to continuously increase lumens/watt," he adds. "The AccuScribe 2600 is specifically designed to match our customers' most demanding technology roadmaps while achieving industry-best yield, performance and cost."

ESI says that multiple customers have recently confirmed that the AccuScribe 2600 delivers the industry's highest-brightness scribing for a wide range of HB-LED technologies, including PSS and DBR metal mirror. Increased light output results in increased revenue and profitability for LED makers, comments ESI.

This, coupled with achieving the highest yield, lowest cost, least environmental impact, and complete elimination of employee work hazards related to chemical etching, will allow Accuscribe 2600 users to lead in the most profitable segment of the HB-LED market, the firm reckons.

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## IN BRIEF

## Sono-Tek exhibiting photoresist and thin-film solar coating system

At Semicon West/Intersolar 2011 in San Francisco (12–14 July), Sono-Tek Corp of Milton NY, USA displayed its ExactaCoat Tabletop Coating System along with working demonstrations of its patented precision ultrasonic spray nozzles.

The ExactaCoat Tabletop Coating System is a fully enclosed programmable XYZ motion system designed for depositing uniform thin-film coatings for electronics and solar applications, including photoresist deposition and various thin-film solar cell coatings.

Particularly suitable for deep well topography coatings, the ExactaCoat is a full coating solution for R&D and low-volume production applications such as depositing photoresist onto wafers and micro-electro-mechanical systems (MEMS). The system is also suited to applying buffer layers such as cadmium sulfide (CdS) and active layers such as copper indium gallium diselenide (CIGS) and cadmium telluride (CdTe) onto thin-film solar cells, phosphoric doping for inline diffusion, organic solar cell coatings, and fluxing of solder bus lines.

The ExactaCoat can be tailored with a number of customizable options including nozzle tilt, dual nozzle, camera, laser pointer, low oxygen atmosphere, and rod coating attachment. It can also be configured with any of Sono-Tek's precision ultrasonic atomizing nozzles to produce highly uniform targeted thin-film coatings with very little overspray and non-clogging repeatable performance, with savings in spray materials, maintenance and clean-up costs, it is claimed.

[www.sono-tek.com](http://www.sono-tek.com)

## Bruker launches Dimension Edge PSS AFM for HB-LED production

Bruker Corp (a provider of scientific instruments and solutions for molecular and materials research as well as for industrial and applied analysis) has launched the Dimension Edge PSS atomic force microscope, a production-environment AFM specifically tailored for patterned sapphire substrate (PSS) metrology in high-brightness light-emitting diode (HB-LED) manufacturing.

Bruker says that the Dimension Edge PSS is an easy-to-operate AFM that delivers resolution far beyond traditional optical techniques while at the same time providing precise 3D profile information to control the most advanced PSS processes. The system performs automated measurement, data collection, data analysis and report generation on 2–6-inch wafers for production metrology applications, and offers a multitude of AFM capabilities essential for LED R&D, the firm adds. The Dimension Edge PSS comes with Bruker's exclusive AutoMET software package, which improves manufacturing productivity by fully automating AFM data collection and analysis report generation to provide a PASS/FAIL output for technician operation.

"Driven by ever increasing performance and cost demands, HB-LED manufacturers are looking to PSS technology to deliver critical process improvements, and the Dimension Edge PSS is instrumental in controlling these advanced processes," says Mark R. Munch PhD, president of the Bruker Nano Surfaces Division. "The Dimension Edge PSS provides rapid process feedback with its speed of measurement and unmatched precision and resolution," he claims.

"The Dimension Edge PSS brings reliable AFM metrology into industrial applications, enabling the highest-resolution measurements, and providing simple pass or fail



**Bruker's Dimension Edge PSS AFM with AutoMET software and nine-wafer chuck.**

measurement criteria for operator ease of use," says David V. Rossi, VP & general manager of Bruker's AFM Business.

The Dimension Edge PSS system uses the strengths of the Dimension Edge AFM along with proprietary software to provide a turnkey production metrology solution for patterned sapphire substrate manufactures. These features combine

to allow for technician-level operation and a system suited to production environments. Bruker's automation software package is designed specifically to

meet the production needs of HB-LED makers. The software can easily be configured to measure between one to nine wafers at multiple points per wafer, including automated data analysis and reporting, providing measurement details to the engineer and a PASS/FAIL indicator to the operator.

[www.bruker-axs.com](http://www.bruker-axs.com)

**HB-LED manufacturers are looking to PSS technology to deliver critical process improvements**

## Rubicon's Q2 revenue driven by 62% growth for 6" sapphire ...but Q3's 2-4" sales to be hit by weakness in LED backlighting

For second-quarter 2011, 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 \$43m, up 13% on Q1's \$38m and 173% on just \$15.8m a year ago. In particular, sales of 6" wafers were \$13.9m, up 62% sequentially and 216% year-on-year.

"We delivered strong financial and operational results driven by increased demand for our 6" polished wafer product," says president & CEO Raja Parvez. "Our capacity expansion and increased efficiencies at our new factories helped meet the strong customer demand and drove growth in revenue and operating income," he adds.

"We made solid progress in adding large-diameter polishing capacity and increased our output of large-diameter crystal from our new crystal growth facility," says Parvez. "These actions, coupled with on-going efficiency improvements,

have led to further wafer and core cost savings."

Gross margin was 63%, level with last quarter and up from 46% a year ago. After more than doubling from 25% a year ago to 53% last quarter, operating margin has grown further to 54%. However, although up from \$3.9m a year ago, net income has fallen from \$19.1m last quarter to \$9.9m.

"As larger-diameter substrates offer chip manufacturers the potential to realize significant savings through both the increased usable area of the wafer and the efficiencies gained in the manufacturing processes, we are forecasting continued strong demand for our 6" polished wafers in the third quarter as our customers continue to ramp their 6" production capacity," says Parvez.

"Prolonged weakness in the LED backlighting market is now having an impact on demand for 2" through 4" diameter cores," Parvez continues. "We have limited visibility at the moment for new core sales and,

given our polishing customers have ample core inventory at the moment, current pricing for 2" through 4" diameter cores is down as much as 60% sequentially," he adds. "While we believe this situation will improve by the end of the quarter, it will have an impact on our third quarter results."

For Q3/2011, Rubicon expects revenue to fall to \$28-34m. But despite the decline in 2-4" core pricing, due to a favorable product mix and low cost structure the firm expects gross margin of 40-45%.

● Rubicon's board of directors has authorized a program to repurchase up to \$25m of common stock in the open market over a period of 2 years, at times and prices considered appropriate (depending on market conditions and other corporate considerations). "The stock repurchase program is a reflection of the company's strong financial position and ongoing commitment to increasing shareholder value," states Parvez.

## Rubicon completes upgrade to large-diameter furnaces

Rubicon has completed a company-wide installation of enhancements to its proprietary crystal growth furnaces, bringing all furnaces up to Rubicon Furnace Version ES2-XLG3.0. This is the latest version of its proprietary furnace design for producing large-diameter sapphire and provides greater automation and yield consistency.

The firm says that, over time, its Design for High Volume Manufacturing (DHVM) approach has led to improvements that have created an equipment platform for high-volume sapphire crystal growth. Version ES2-XLG3.0 is now operating in Rubicon's US growth facilities in Batavia and Bensenville, IL.

"Sapphire crystal growth is extremely complex," says president & CEO Raja Parvez. "Variables such as stable power, growth pro-

files, cooling profiles and feedback control mechanisms must be optimally managed to maximize the yield of quality sapphire crystal. This is even more vital when producing sapphire for the expanding large-diameter wafer market," he adds. "With hundreds of years of combined experience and innovations such as those embedded in the Rubicon Furnace Version ES2-XLG3.0, Rubicon's design and equipment engineers and material scientists have achieved industry leading yields and performance."

With the Batavia crystal growth facility qualified with over a dozen customers and the Malaysia polishing facility now also qualified, Rubicon has shipped more than 100,000 6" sapphire wafers.

Market research firm iSuppli expects the LED market to double

to nearly \$14.3bn by 2013, driven by penetration of LEDs into general illumination (including light bulbs). LEDs are a popular option for backlighting screens from HDTVs, traffic lights and large displays, and in a range of consumer devices including tablets, notebooks, laptops, mobile phones, navigation devices, digital music players, digital photo frames, digital cameras and keypads. LED use in general lighting is also rising significantly, particularly in applications like street lighting, industrial lighting and architectural lighting.

The transition to larger-diameter wafers in LED production has started, says Rubicon. Several key LED chip makers have announced plans to migrate to and/or test large-diameter wafers in 2011/2012.

[www.rubicon-es2.com](http://www.rubicon-es2.com)

## Thermal Technology adds sapphire crystal grower assembly facility, tripling capacity

Thermal Technology LLC of Santa Rosa, CA, USA, which designs and manufactures crystal growth systems and high-temperature vacuum and controlled-atmosphere furnaces for the processing of metals, ceramics, glass and quartz, has recently added a new production facility, tripling its manufacturing space. The new location is dedicated to Model K1 sapphire crystal grower production and is adjacent the firm's sales and manufacturing site.

"Market response to the K1 grower is strong. Potential customers see our machines in full production elsewhere and are convinced of our technology," says president & CEO Matt Mede. "Utilizing the modified-Kyropoulos method, our growers remain the most productive tool in the market, with large crystal size and a short growth cycle," he claims. "We also have the most growers in successful production,

compared to our competitors."

Thermal Technology says that it is shipping multiple sapphire growers weekly. The new high-volume production facility enables the firm to meet rising demand for the Model K1.

"The new manufacturing facility significantly increases our production capacity and improves the overall flow of our production processes," says production manager Jim Coffey. "The expansion was fueled by continued growth in



**Thermal Technology's new production facility for Model K1 sapphire crystal grower assembly.**

our Model K1 sales," he adds. [www.thermaltechnology.com](http://www.thermaltechnology.com)

## ARC Energy signs two contracts worth \$96.9m 30,000ft<sup>2</sup> expansion to triple manufacturing capacity

Advanced RenewableEnergy Company LLC (ARC Energy) of Nashua, NH, USA, which was founded in 2007 to provide c-axis sapphire crystal growth technologies and turnkey processing solutions for the LED solid-state lighting and other clean-energy markets, has signed \$96.9m in additional new contracts with two leading Asian manufacturers.

ARC Energy will provide each customer with LED sapphire manufacturing equipment and technology, including highly automated c-axis Controlled Heat Extraction System (CHES) furnaces, and additional turnkey solutions and services.

ARC Energy is also expanding its manufacturing facility by 30,000ft<sup>2</sup>. Scheduled for completion in fourth-quarter 2011, the expansion will triple the firm's manufacturing

capacity, enabling it to become one of the world's largest sapphire furnace suppliers for LED manufacturing, it is reckoned.

"Many manufacturers are now installing and operating ARC Energy's technology for mass production of large-diameter sapphire," says senior VP Hap Hewes. "These new contracts and our

**c-axis wafers are the optimum orientation for LED applications and, compared with conventional a-axis technologies, c-axis growth leads to higher material utilization and lower overall costs**

planned capacity expansion highlight the advantages of our unique c-axis sapphire platform and ARC Energy's associated turnkey solutions," he adds.

ARC Energy says that c-axis wafers are the optimum orientation for LED applications and, compared with conventional a-axis technologies, c-axis growth leads to higher material utilization and lower overall costs. The firm's offerings include CHES furnaces (highly automated 'c-axis' growth furnaces for producing sapphire boules); turnkey solutions such as material handling, inspection, core fabrication and material recycling; and services such as setup and installation followed by localized training and support by field service and account management teams.

[www.arc-energy.com](http://www.arc-energy.com)

## GT Solar's quarterly revenue rises 71% year-on-year Name changed to GT Advanced Technologies

For its fiscal first-quarter 2012 (ended 2 July 2011), GT Solar International Inc of Merrimack, NH, USA (a provider of polysilicon production technology as well as sapphire and silicon crystalline growth systems and materials for the solar, LED and other specialty markets) has reported revenue of \$231.1m (98% from Asia). This is down 15% on \$271.6m last quarter but up 71% on \$135.2m a year ago. Revenue by business segment was \$23.9m in polysilicon (down from \$79.2m last quarter), \$198.6m in photovoltaics (up from \$186m), and \$8.6m in sapphire, all of which was sapphire materials revenue (down from \$15.3m).

"Our efforts to diversify the company's revenue base position us to weather cyclicity that we may encounter in the PV, polysilicon and LED industries," believes president & CEO Tom Gutierrez. In particular, during the quarter, GT Solar shipped its first advanced sapphire furnace (ASF), for which volume shipments are expected to start in fiscal Q2/2012.

Gross margin has risen from 34% a year ago and 43% last quarter to a record 49.1%. Meanwhile, operating margin has increased from 20% a year ago and 30.5% last quarter to 34%, despite operating expenses almost doubling from \$18.8m a year ago and \$34.1m last quarter to \$34.7m (including R&D spending rising from \$3.7m through \$8m to \$11.3m). Net income has grown from \$16.5m a year ago and \$51.9m last quarter to \$52.1m.

During the quarter, cash and cash equivalents rose from \$362.7m to a record \$473.4m, while capital expenditure was \$9.5m (down from \$16.1m last quarter) and debt was cut by \$24.7m from \$120.3m to \$95.6m.

Net new orders totaled a record \$1.3bn (\$464.7m in polysilicon,

\$95.2m in PV, \$776.8m in sapphire). As of 2 July, quarter-end backlog was a record \$2.3bn (almost doubling from \$1.19bn last quarter). This included \$978.2m in polysilicon, \$369.6m in PV, and \$952.5m in sapphire. Included in the backlog was \$395.7m of deferred revenue.

"Our strong balance sheet and cash generation capabilities enable us to evaluate additional strategic opportunities to strengthen the company's long-term growth prospects," comments Gutierrez.

"Bolstered by our \$2.3bn backlog position, we are confident in our ability to achieve our fiscal-year 2012 guidance and also believe that we have built a solid foundation for continued growth in fiscal-year 2013 and beyond," he adds.

After raising its original fiscal 2012 revenue guidance from \$850m–1bn in late May, GT Solar has reiterated its latest fiscal 2012 guidance for revenue of \$1–1.1bn (up 17% on fiscal 2011's \$899m). However, the firm has now also raised its guidance for gross margin from 42–44% to 43–45%, and for operating expenditure from \$115–125m to \$130–140m. Expected capital expenditure remains \$25–30m.

● Effective 8 August (with the market opening on NASDAQ), GT Solar International Inc is changing its name, ticker, CUSIP number and website address to GT Advanced Technologies Inc, GTAT (NASDAQ), 36191U 106 and [www.gtat.com](http://www.gtat.com) respectively as it establishes a new global brand to reflect its broader range of markets and technologies since its July 2010 acquisition of Crystal Systems Inc of Salem, MA, USA (a crystalline growth technology firm manufacturing large-area sapphire substrates for the LED, defense, medical and aerospace industries).

[www.gtsolar.com](http://www.gtsolar.com)

## ARC countersues GT for anticompetitive conduct

Advanced RenewableEnergy Company LLC (ARC Energy) of Nashua, NH, USA (which was founded in 2007 to provide c-axis sapphire growth technologies and turnkey processing solutions for the LED industry) has filed an Answer and Counterclaim in Hillsborough County, New Hampshire Superior Court against GT Solar International Inc of Merrimack, NH, USA (a provider of polysilicon production technology as well as sapphire and silicon crystalline growth systems) and various of its subsidiaries.

In its filing, ARC denies that any of its products or technologies make use of any proprietary GT Solar technology, and has countersued GT for anticompetitive conduct. The counterclaim asserts that GT has made knowingly false and defamatory statements about ARC's business and products for the unlawful purpose of inhibiting sales of ARC's sapphire crystal growth system into the fast-growing LED market.

ARC also states that GT Solar's allegations are baseless and that its proprietary c-axis CHES sapphire technology is different from other sapphire growth technologies, including GT's. ARC says that its technology for growing sapphire crystals on the c-axis affords several advantages over a-axis technologies. It claims that c-axis wafers are the optimum orientation for LED applications, and that c-axis growth leads to greater material utilization and lower overall costs compared with conventional technologies.

"We must defend our right to continue to develop and deliver new and innovative technologies that have very real potential to help solve important energy problems," states ARC's secretary & general counsel Daniel Lyman. "We must also defend the rights of our customers to choose the technologies and products best suited to give them an advantage in the market."

[www.arc-energy.com](http://www.arc-energy.com)

## Translucent launches vGaN wafer templates for epitaxial growth of GaN devices

Translucent Inc of Palo Alto, CA, USA (a subsidiary of Australian-listed company Silex Systems Ltd), which provides rare-earth-oxide (REO) engineered silicon substrates for low-cost epitaxy, has announced the commercial availability of its vGaN family of silicon-based wafer templates. The firm says that vGaN ('virtual gallium nitride') products provide a low-cost, high-quality epitaxial surface for the growth of GaN devices such as LEDs or FETs.

The vGaN product line is claimed to be the world's first commercial REO-based family of III-N semiconductors with scalable GaN-on-Si wafers. Use of crystalline REO layers provides stress relief and wafer flatness through customized lattice engineering, leading to a high-quality growth surface, says Translucent. Also, the wide bandgap of the REO layer is expected to lead to much higher breakdown-voltage characteristics for FETs grown on vGaN.

The firm says that vGaN provides a semiconductor growth surface that has the physical properties of GaN, but uses a silicon substrate upon which is grown an epilayer of REO material that accommodates a top epilayer of Group III nitrides such as GaN. The vGaN substrate enables, for the first time it is claimed, industry-standard MOCVD growth processes with the low-cost structures and economies of scale currently enjoyed by the silicon industry.

"We are bringing a decade of Translucent REO epitaxial experience to bear on the challenge of enabling GaN growth to scale cost-effectively well beyond current limitations," notes general manager Michael Lebby. "Our vGaN platform is an 'on-silicon' technology, allowing us to harness mature silicon-substrate technologies and their low costs, and we expect this to have an extremely beneficial impact in driv-

ing down costs for GaN-based LEDs and FETs," he adds.

GaN is typically grown on sapphire substrates, which are significantly more expensive at large diameters, especially 200mm and larger. Additionally, a major challenge facing device manufacturers is the handling of large, heavy and expensive sapphire wafers. Such handling may require the purchase of special handling equipment for the fabrication plants. Conversely, the widely used infrastructure of fabrication plants that are ready to run silicon wafers up to 200mm already exists, making large-diameter silicon a suitable choice to bring economies of scale into the lighting (LED) and power electronics (FET) industries, says Translucent.

The vGaN wafers are already available at 100mm diameters, with 150 and 200mm to be available during the next year.

[www.translucentinc.com](http://www.translucentinc.com)

### GaN-on-Si templates with embedded DBR mirrors target LEDs

Translucent has developed a proprietary GaN-on-Si wafer template with embedded distributed Bragg reflector (DBR) mirrors for application to low-cost LED growth.

The structure and growth process were presented at July's International Conference on Nitride Semiconductors (ICNS-9) in Glasgow, Scotland, UK in the post-deadline paper 'Integrated High Reflectivity Silicon Substrates for GaN LEDs'.

Translucent reported technical details of developing a 100mm-diameter wafer that exhibits high reflectivity using a lattice-matched REO material grown onto a silicon substrate. The structure is capped by a GaN layer that can support further nitride epitaxy for the growth of LED structures. The lattice engineering offered by the REO material system, which is grown epitaxially on silicon (111)

substrates, can be used to mitigate strain that arises during growth of GaN. REO materials further enable highly reflective mirrors embedded in engineered silicon substrates. The new technology is being offered to prospective customers who are ready to grow LEDs on large-diameter wafers.

Translucent says its silicon solution mitigates the need to remove the substrate and the use of handle wafers during subsequent processing. As the LED industry migrates to larger wafer sizes, a one-step epitaxial solution is expected to provide the best path to cost-effective scaling, the firm adds.

Using the new embedded silicon solution ('Mirrored Si'), LEDs can now be grown directly on top of the GaN-on-Si template that includes an embedded DBR mirror, directly lattice matched to the silicon sub-

strate. On top of this DBR mirror is a layer of proprietary rare earth oxide, which allows GaN to cap the template and does not require subsequent removal of the substrate.

The device-ready GaN template can be supplied to LED makers as-is for LED growth. Calculations are made that show that mirror reflectivity can exceed 98% at the LED-emitted wavelength range of 450nm in ultra-thin layers of lattice-matched REO material.

The material was grown using MBE reactors at Translucent. The quality of the growth achieved to date leads to high-quality crystalline interfaces that are scalable to large-diameter silicon wafers, the firm claims.

Translucent is currently scaling its embedded silicon mirror technology for commercial rollout with 150mm and 200mm wafers.



## Kyma launches n<sup>+</sup> bulk GaN substrate

Kyma Technologies Inc of Raleigh, NC, USA, which provides crystalline gallium nitride (GaN) and aluminum nitride (AlN) materials and related products and services, has launched its n<sup>+</sup> c-plane bulk GaN substrate product line.

The n<sup>+</sup> GaN substrates will have a bulk resistivity specification of <math><0.02\Omega\text{-cm}</math>, which is two orders of magnitude lower in resistivity than Kyma's previously offered n-type GaN. The firm has also produced n<sup>+</sup> bulk GaN wafers with measured carrier concentrations of up to

Kyma's n-type GaN product is still being offered and, for distinction, is being relabeled as n<sup>-</sup> GaN. Kyma says that, while its n<sup>-</sup> GaN remains an excellent starting material for a variety of materials and device studies, its n<sup>+</sup> GaN offers benefits for vertical devices as well as reduced contact resistance for all devices.

Key advantages for vertical power devices include ultra-low on-resistance as well as decreased parasitic resistance. Advantages for LEDs include low vertical resistance and mitigation of current-crowding effects.

"We are pleased to respond to our customers' requests for more conductive substrates," says characterization and device engineer Dr Jacob Leach. "The high electron concentrations in this new product line directly support higher performance and reliability for a number of device applications of great commercial interest," he adds.

"We are happy to offer these new substrates in form factors of 10mm x 10mm squares and 18mm x 18mm squares," says technical sales engineer Tamara Stephenson. "Additionally, the development of commercially available 2" diameter and larger n<sup>+</sup> bulk GaN substrates is underway."

[www.kymatech.com](http://www.kymatech.com)

## Kyma promotes and hires staff

Kyma Technologies has announced three recent staffing promotions and a key new hire.

Heather Splawn has been promoted to chief operating officer. She joined Kyma in 2010 as director of business development and was later promoted to VP of operations. Splawn received a PhD in Electrical Engineering from Duke University in 2009.

Kevin Udway has been promoted to director of engineering. He joined Kyma in 2007 as wafering engineer and was later promoted to engineering team leader. Udway has previous industry experience in the growth, characterization, and fabrication of crystalline AlN grown by physical vapor transport (PVT). He received a B.S. in Physics from Siena College.

Jacob Leach has been promoted to director of production. He joined Kyma in 2010 as characterization

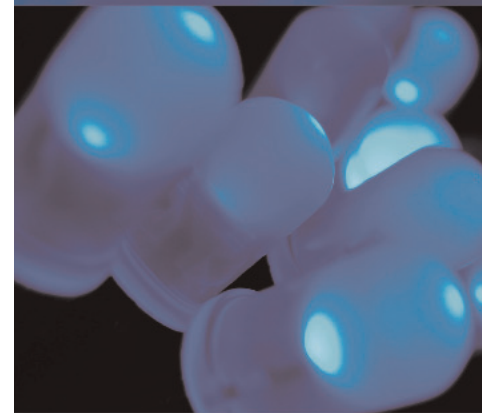
and device engineer after receiving a PhD in Electrical Engineering from Virginia Commonwealth University earlier in the year.

Also, Karen Nield recently joined Kyma as director of finance. She has a track record in corporate finance, having formerly served in several executive finance roles, including most recently as VP finance at ParagonDx LLC, a spin-off of Gentriss Corp (which is moving its operations to another state). Nield received a B.S. in Accounting from UNC Charlotte and a B.S. in Marketing from UNC Chapel Hill.

"Heather, Kevin, and Jacob have demonstrated great leadership and a clear dedication to building customer satisfaction and shareholder value," comments president & CEO Keith Evans. "Karen brings key experience and energy into a role that is critical for our next stage of growth," he adds.

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## IN BRIEF

## SETi nominated for South Carolina Manufacturer of the Year Award

Deep ultraviolet (UV) LED maker Sensor Electronic Technology Inc (SETi) of Columbia, SC, USA has been recognized by the South Carolina Chamber of Commerce as one of 12 outstanding manufacturers to be put forward for the South Carolina Manufacturer of the Year Award.

SETi has pioneered the development and manufacturing of semiconductor materials using aluminum gallium arsenide (AlGaIn) and supplies UV LEDs using these materials.

UV LEDs can be used in applications from sensing and detection of harmful gases and airborne diseases to disinfection of water, surfaces and air in markets including medical, industrial, military and consumer.

Over the past few years, SETi's UV LED products have been transferred from research to production and the firm now operates production procedures certified to ISO9001 standards. Despite the economic climate, SETi's business has more than doubled in the last two years and the company is now planning a large expansion to further ramp its UV LED production capacity.

[www.s-et.com](http://www.s-et.com)

**Over the past few years, SETi's UV LED products have been transferred from research to production. SETi's business has more than doubled in the last two years and the company is now planning a large expansion**

## Lumex adds 355, 365 and 377nm UV LEDs to QuasarBrite family

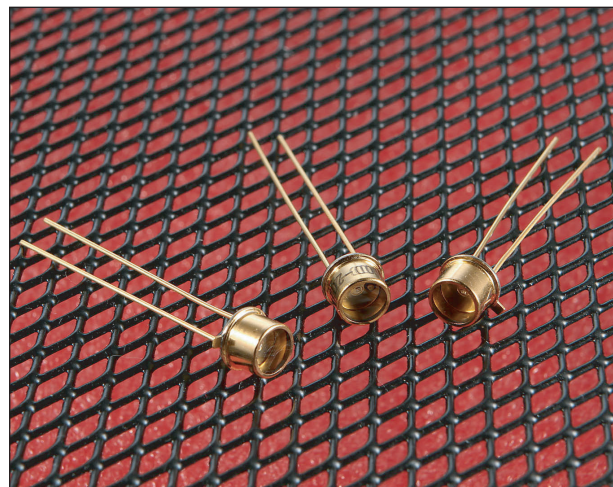
Lumex of Palatine, IL, USA has announced the global expansion of its QuasarBrite UV family of LEDs to include three new standard wavelengths as well as the availability of custom UV LED arrays. The firm claims that QuasarBrite UV LEDs provide up to 10 times longer life-span, up to 50% cost savings, up to 70% energy consumption savings, and superior light performance compared with alternative technologies.

The RoHS-compliant QuasarBrite UV LEDs are now available in standard 355nm, 365nm and 377nm wavelengths in a through-hole format. They are suited to a wide range of applications including:

- security (counterfeit detection for currency, passports and other travel documents);
- forensic (applications related to forensic analysis of bodily fluids);
- photo catalyst (for air and water purifier applications in homes, offices and automobiles).

"Previously, widespread use of UV LED technology, especially in the shorter UV wavelengths, was hindered because the materials used in the epoxy LED lens degraded the lifespan of UV LEDs to less than 5000 hours," says product technology manager Kay Fernandez. "Recent technological developments have allowed the epoxy lenses to be replaced by a robust TO-46 package with a glass lens, making it possible for QuasarBrite UVs to last 10 times longer — with life spans of over than 50,000 hours," she adds.

Lumex says that QuasarBrite UV LEDs also provide several benefits compared to alternative technologies like CCFLs (cold-cathode fluorescent lamps), including a uniform beam pattern. To match this per-



Lumex's QuasarBrite UV LEDs.

formance, CCFLs would require a secondary lens, resulting in additional cost and space investment. Additionally, QuasarBrite UV LEDs do not use the hazardous material mercury that is found in CCFL technology. They are also more durable in their design, reducing maintenance costs. Finally, the UV LEDs have up to 70% lower energy consumption than CCFLs. Combined, these factors allow QuasarBrite UV LEDs to provide cost savings of up to a 50% compared with CCFLs, the firm claims.

"Because of significant cost and performance benefits UV LEDs provide over alternative technologies such as CCFLs, there is a dramatic growth in demand for UV LED technology," says Fernandez. "Lumex now offers a total of six standard UV wavelengths (355, 365, 377, 385, 405 and 415nm) as well as an almost limitless number of custom options to meet the needs of this growing market."

The new 355, 365 and 377nm QuasarBrite UV LEDs feature a 80° viewing angle and operating temperature range of -40°C to +100°C. Standard and custom production lead times are 18–20 weeks. Pricing is \$20–28 per unit in production quantities, dependent on size and quantity ordered.

[www.lumex.com](http://www.lumex.com)

## Aquionics and Dot Metrics sign JDA to co-develop UV-LED disinfection products

Aquionics Inc of Erlanger, KY, USA (a Halma Company that develops and manufactures UV technology for non-chemical disinfection and microbiological control) has signed a joint development agreement with LED specialist company Dot Metrics Technologies Inc of Charlotte, NC, USA to develop a new line of UV-LED disinfection products.

The agreement formalizes several months of working together to bring new disinfection systems to the market.

As a small firm associated with the University of North Carolina at Charlotte, Dot Metrics focuses on UV LED systems development for the disinfection of water, air and surfaces. For several years, Dot Metrics has been testing and discovering new applications for UV LEDs.

UV treatment of fluids is replacing traditional chemical treatment in many applications, but it still has a number of drawbacks. However, UV LEDs overcome almost all the problems associated with standard, mercury-based UV disinfection, says Aquionics.

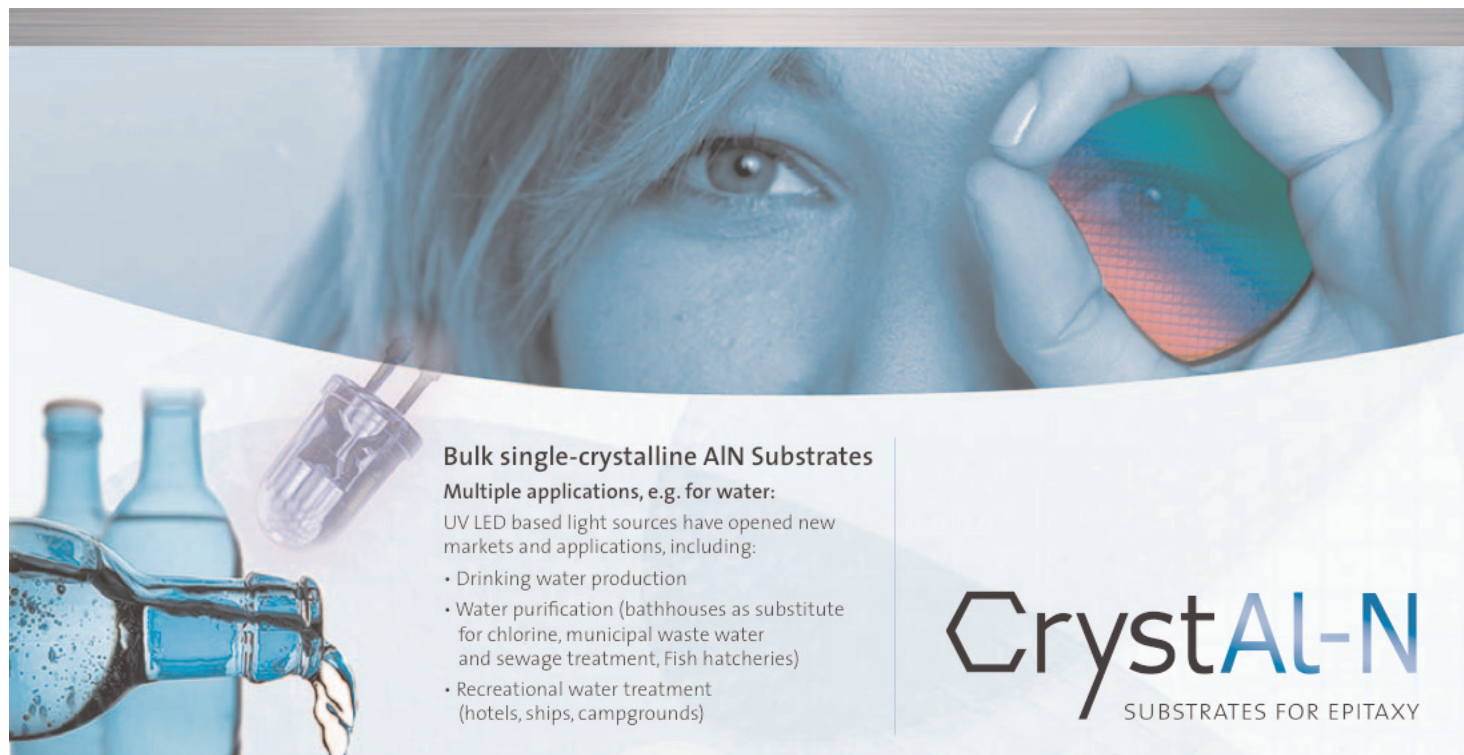
"Dot Metrics brings innovative UV LED expertise and Aquionics contributes its experience and resources to rapidly com-

**The development of UV LED chips has progressed significantly in the last few years to allow commercial adoption. Dot Metrics brings added value in packaging the chips and configuring them in a usable system**

mercialize the technology and provide access to key markets," says Dot Metrics' president & CEO Rosanna Stokes. "In addition, access to technology from Aquionics' sister companies within the water and photonics industries provides a strong basis for a long-term relationship," she adds. "The combined results of our efforts will provide a novel, small-footprint, non-mercury-based UV disinfection system in the market," Stokes continues.

"The development of UV LED chips has progressed significantly in the last few years to allow commercial adoption," comments Aquionics' president Oliver Lawal. "Dot Metrics brings added value in packaging the chips and configuring them in a usable system," he adds.

[www.aquionics.com](http://www.aquionics.com)  
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# Bridgelux raises GaN-on-Si LED efficiency record

## 160lm/W cool-white, 125lm/W warm-white rivals LEDs on sapphire

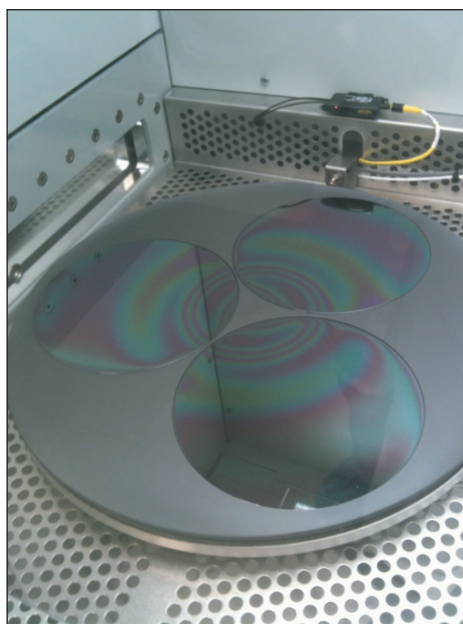
LED chip and lighting array maker Bridgelux Inc of Livermore, CA, USA (which claims to be the only vertically integrated maker of LED solid-state light sources specifically for the lighting industry) says that it has raised its previous industry record for luminous efficiency (lumen per Watt) for gallium nitride on silicon (GaN-on-Si) LEDs.

In March, Bridgelux demonstrated GaN-on-Si-based LED technology exhibiting luminous efficacy of 135lm/W at a correlated color temperature (CCT) of 4730K (using a single 1.5mm-diameter power LED operated at 350mA), representing what was claimed to be the industry's first commercial-grade performance for a silicon-based LED. The LEDs had very low operating voltages, requiring just 2.9V at 350mA and <3.25V at 1A.

Bridgelux says that it has now demonstrated performance levels comparable to state-of-the-art commercial sapphire-based LEDs. Cool-white LEDs showed efficiencies as high as 160lm/W at a CCT of 4350K. Warm-white LEDs constructed from the GaN-on-Si chips delivered 125lm/W at a CCT of 2940K and a color rendering index (CRI) of 80.

Encapsulated 1.5mm blue LEDs emit 591mW with wall-plug efficiencies as high as 59% at 350mA, exceeding any published values it is claimed. The LEDs have very low forward voltages, 2.85V at 350mA, suiting use at high current densities. At a drive current of 1A the LEDs emitted 1.52W of blue power at a forward voltage of 3.21V, resulting in a wall-plug efficiency of 47%. Wavelength uniformity of sigma 6.8nm has been demonstrated for 8-inch LED wafers with a median wavelength of 455nm.

Conventional LEDs are made using sapphire or silicon carbide (SiC) substrates as the starting material. Both are more expensive than silicon, so production costs



**GaN MOCVD growth at Bridgelux.**

have inhibited the widespread adoption of LED lighting in homes and commercial buildings, says Bridgelux. But growing GaN on larger, low-cost silicon wafers that are compatible with high-volume semiconductor manufacturing can deliver a 75% improvement in cost over existing approaches, says the firm. Bridgelux reckons that its technology process has the potential to significantly drive down the cost of manufacturing LEDs and make them competitive with conventional white lighting technology.

One problem is that the thermal expansion coefficient of GaN is considerably larger than that of silicon. This mismatch can cause the epitaxial films to crack, or the wafers to bow, either during epitaxial growth or at room temperature. However, Bridgelux says that its proprietary buffer layer process

produces crack-free wafers that are virtually flat at room temperature. Using its proprietary buffer layer technology, Bridgelux has demonstrated growth of crack-free GaN layers on 8-inch silicon wafers, without bowing at room temperature, improving the performance and manufacturability of GaN LEDs on silicon substrate.

"These achievements are a direct result of our investment in building a world-class team of Bridgelux materials scientists and chip design engineers with a strong focus on driving industry-leading epitaxial process technology," says chief technology officer Dr Steve Lester. "We will continue to aggressively develop our GaN-on-Si processes in order to drive the migration of LED commercial production from sapphire to silicon substrates," he adds. "Our first commercially available GaN-on-Si products remain on schedule for delivery to the market within the next two years."

"This new technological breakthrough is a direct result of Bridgelux's continued investment in R&D combined with a singular focus on the needs of the solid-state lighting market," says CEO Bill Watkins. "This key innovation is a game-changer for the industry, delivering dramatic reductions in the up-front capital investment required for solid-state lighting and thereby significantly increasing the rate of market adoption," he adds.

Bridgelux, which maintains an asset-light operating model, aims to leverage its R&D and intellectual property position in LED epitaxy to pursue partnerships with existing semiconductor manufacturers. Using existing semiconductor fabs via partnerships with established semiconductor manufacturers has the potential to favorably impact production costs, margins and returns on invested capital, the firm reckons.

[www.bridgelux.com](http://www.bridgelux.com)

# Bridgelux raises \$60m in equity financing round led by Craton

## Funding to speed GaN-on-Si development for LED lighting

Bridgelux Inc of Livermore, CA, USA has raised \$60m in a Series E financing round led by Los Angeles-based Craton Equity Partners (Southern California's largest clean-tech private equity fund) and joined by existing financial and strategic investors including VantagePoint Capital Partners, DCM, El Dorado Ventures, Novus Energy Partners, Invus Group, VTS, Harris & Harris Group, and Passport Capital. Previously, in late January, Bridgelux announced raising \$20.74m of the \$60m round.

Bridgelux has now raised total venture capital of about \$180m, including \$2.5m in angel funding in 2002, \$8.55m in May 2005, \$23m in August 2007, and \$80m in Series D financing, including \$30m (plus a \$10m line of credit from investors) in a first tranche in April 2008 — used to develop new products (some of which were rolled out in 2009) — and an extra \$50m in January 2010.

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

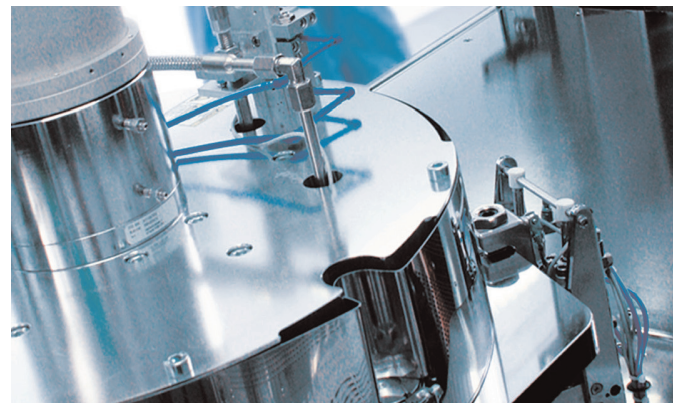
Bridgelux says that it will use the new funding to extend its position in the solid-state lighting market by accelerating R&D in key areas of strategic focus, including GaN-on-silicon development and LED chip-on-board architecture.

"At Craton we continually strive to support standout sector leaders, like Bridgelux, that are positioned to address today's global clean energy challenges through the application of new technologies to massive markets," says Craton managing partner Kevin Wall. Craton Equity Partners' principal David Asarnow will join the Bridgelux board as an observer.

"Craton Equity Partners is a top growth-stage investor in clean tech, and we welcome their support as we work to expand the market for solid-state solutions for general lighting — which we expect to triple this year to over \$3bn," says Bridgelux's CEO Bill Watkins. "This additional capital will accelerate our breakthrough development efforts in producing commercial-grade LEDs on silicon and in creating new packaging solutions for our LED chips," he adds. "We think our proprietary innovation in both of these areas is critical to driving market adoption."

[www.cratonep.com](http://www.cratonep.com)

[www.bridgelux.com](http://www.bridgelux.com)



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# Cree's quarterly revenue up 11%, driven by LED lighting

## Lower CapEx focused on new products until fab utilization recovers

For fiscal 2011 (ended 26 June), Cree Inc of Durham, NC, USA (which makes LED chips, lamps and lighting fixtures as well as GaN and SiC power-switching and RF/wireless microelectronic devices and SiC substrates) has reported record revenue of \$987.6m, up 14% on fiscal 2010's \$867.3m.

Although down 8% on \$264.6m a year ago, fiscal fourth-quarter revenue of \$243m is up 11% on \$219.2m last quarter, and at the high end of the targeted range of \$225–245m.

Growth was driven mainly by strong growth in sales of LED lighting products to commercial and retail customers, and solid growth in XLamp LED component sales (driven by a rebound in demand across applications from direct customers and through distribution), offsetting slightly lower sales for LED chips and power & RF devices.

"We continue to build momentum in growing our LED lighting business and delivered a range of revolutionary new market-leading products, including our CR6 downlight, high-output-power lamps and CR series troffers [offering shorter payback, better light quality and better efficacy than comparable fluorescents]," says chairman & CEO Charles Swoboda about fiscal 2011. "Our success over the last year has reinforced the value of having a lighting systems product line to complement our components business and give us the ability to drive the market and LED lighting adoption," he adds.

"We grew the LED component business year-over-year despite a very tough business cycle by continuing to enable the market with innovative application-optimized new product platforms, including our XM, ML-E, MT-G, CXA arrays and LMR modules," says Swoboda.

"We made progress in growing the Power & RF product line, and we released the first silicon carbide power MOSFET," he notes.

On a non-GAAP basis, fiscal Q4 gross margin has fallen further, from 49.9% and 42.4% last quarter to 38.8%. This is due to lower factory utilization (while slowing LED production to reduce inventory) and the very competitive LED pricing environment, offset partially by yield improvements and cost reductions.

Operating expenses were cut from \$71.7m last quarter to \$61.4m. Although almost halved from \$60.1m a year ago, net income for fiscal Q4 of \$30.6m is up slightly on \$30.1m last quarter. This took full-year net income to \$186.8m, up 4% on \$179.2m in fiscal 2010.

For fiscal 2011, operating cash flow was \$251.4m (up slightly from \$250.6m for fiscal 2010). After capital expenditure of \$204m (up from \$168m in fiscal 2010), free cash flow was just \$14.3m (down from \$81.9m in fiscal 2010).

However, for fiscal Q4/2010 in particular, operating cash flow was \$65.4m (up from \$41.2m last quarter). After capital expenditure of \$47.9m (down from \$62.8m last quarter) and depreciation and amortization of \$30.2m, free cash flow was \$16.6m (an improvement on -\$21.7m last quarter). During the quarter, cash, cash equivalents and investments rose by \$12.7m to \$1,085.8m. Cree continues to be debt-free.

"As we look ahead to Q1, demand has improved from earlier in the calendar year [with backlog slightly ahead on this point last quarter], but we are still operating in a short-lead-time environment with limited visibility," says Swoboda. For fiscal first-quarter 2012 (ending 25 September 2011), Cree expects revenue to rise to \$245–255m, driven by double-digit growth in LED lighting and mid-single-digit growth in LED components. However, LED chip sales will be flat to down, and Power & RF sales will be slightly down due to lower demand from solar inverter-related customers.

On a non-GAAP basis, gross margin should be steady at 38–39%, factoring in the competitive pricing environment and higher inventory costs from Q4, offset partially by higher factory utilization and cost-reduction programs.

Operating expenses are targeted to rise by about \$2m, mainly in R&D expenses in order to further support new LED chip development, the 150mm LED chip product qualification, new LED component platforms, and continued investment in LED lighting products. In particular, the 150mm wafer development program is on schedule: the first chip-level products have been qualified, and the initial production ramp has started in fiscal Q1. Net income should be \$27.5–31m.

"Our long-term goal for gross margins continues to be in the mid-40s, but over the short- to mid-term our goal is to get back into the low 40s," says chief financial officer John Kurtzweil. "To hit the short-term goal, we target an improvement later in our fiscal year for new product introductions, higher factory utilization rates, and cost reductions from programs such as the transition to 150mm wafers," he adds.

For fiscal 2012, Cree aims to authorize capital spending of \$160m. This is down on fiscal 2011's \$204m, but current capital spending is focused primarily on new-product-related areas, as the current factory utilization can provide sufficient first capacity in the near term.

"The investments we're making in the near term are really going to be technology oriented," notes Swoboda. "As the utilizations come up, that's when we would start to spend more of the money on capacity... very little of our short-term CapEx is for capacity, just because the utilization rates give us a plenty of buffer in the near term," he adds. "We will continue to invest, but it will be at a lower rate until we see the demand in the utilization rates pickup."

[www.cree.com](http://www.cree.com)

# Cree acquires Ruud Lighting

## BetaLED product line supplements LED lighting & component range

Cree has acquired LED outdoor lighting firm Ruud Lighting Inc for an estimated net cost of about \$525m.

Cree reckons that combining two highly complementary LED firms will help it to drive adoption of energy-efficient LED lighting. The shared focus on LED-based systems has led to thousands of LED lighting installations over the past several years.

The acquisition focuses on indoor and outdoor LED lighting, aiming to expand the market for both Cree's LED systems and components. Other synergies include increased access to the lighting market through expanded sales channels, and operating leverage from increased economies of scale. Cree says that, through a broader presence in the lighting systems mar-

ket, it gains additional expertise to develop next-generation lighting-class LED components.

Ruud will continue to be based in Racine, WI, USA and will operate as a subsidiary of Cree's lighting business. Also, Alan Ruud has joined the Cree board. Ruud, through its BetaLED product line, was one of the first traditional lighting firms to transform most of its business to LED-based systems.

Cree has acquired all of Ruud's outstanding stock for an estimated net cost of \$525m, consisting of \$372m in cash, \$211m in stock (6,074,833 Cree shares at \$34.74 each), and \$85m to retire outstanding debt. The acquisition was structured for tax purposes as a deemed asset purchase, so the cost to Cree will be offset by \$143m of

expected future tax benefits related to the acquisition.

Ruud's financial and operating results will be consolidated for the balance of Cree's fiscal first-quarter 2012, for which Cree is revising its targets. These include about 40% of a full quarter's results from Ruud. Cree now targets revenue of \$265–275m.

Non-GAAP gross margin should be at the low end of the previously targeted 38–39%. Operating expenses are now targeted to rise to \$69m.

Non-GAAP net income should be at the low end of the previously targeted \$27.5–31m. Cree targets the transaction to be accretive to non-GAAP earnings for the balance of fiscal 2012.

[www.ruudlighting.com](http://www.ruudlighting.com)

## Mouser and Cree sign global distribution agreement

Mouser Electronics Inc of Mansfield, TX, USA, a design engineering resource and global distributor for semiconductors and electronic components, has signed a global distribution agreement with Cree.

The agreement enables lighting designers worldwide to quickly find, compare, select and order Cree's latest products, including its line of lighting-class XLamp LEDs, high-brightness LEDs, LED modules and power products. Cree LED components and solutions are used in applications including general lighting, electronic signs and signals. Cree also manufactures SiC-based diodes for power control and management, providing increased efficiency in applications from solar inverters to industrial motor drivers to wireless technologies.

Cree gains access to Mouser's design engineering marketing programs and to its fulfillment operations. The distributor offers 17 customer support locations across

multiple continents with 42 country websites. Mouser says that its Product Knowledge Centers and application guidance tools will give lighting designers easy access to view Cree's product technical specifications and data sheets.

"For design engineers and manufacturers, this means faster access to Cree's LED lighting solutions and SiC power products on a global basis," says Mouser's VP of advanced technology Russell Rasor.

"With the distribution might of Mouser behind our products, our customers will not only have worldwide access to our products, but will also have the search and comparison resources available through Mouser's award-winning online catalogs and websites," comments Mark Desportes, Cree's VP of global channels. "The service and support Mouser offers as an authorized worldwide distributor is invaluable to us and to our customers."

Mouser says that the agreement reinforces its commitment to sup-

port new solid-state lighting designs by offering a comprehensive lineup of Cree LED components. In support of Cree's products, Mouser will provide engineers with optical and mechanical products along with IC-based LED drivers from key suppliers such as Texas Instruments, On Semiconductor, STMicroelectronics and Maxim Integrated Products, strategically positioning it to deliver lighting technology components for new design projects.

Mouser Electronics' website is updated daily and searches more than 8 million products to locate over 2 million orderable part numbers from more than 450 manufacturers available for easy online purchase. Mouser.com also houses an interactive catalog, data sheets, supplier-specific reference designs, application notes, technical design information, and engineering tools.

[www.mouser.com](http://www.mouser.com)  
[www.cree.com](http://www.cree.com)

## Cree's 1300lm, 152lm/W prototype exceeds DOE's '21st Century Lamp' L Prize requirements

LED chip, lamp and lighting fixture maker Cree Inc of Durham, NC, USA has unveiled a concept LED light bulb from its lighting R&D team that delivers more than 1300 lumens at a luminous efficacy of 152 lumens per watt (LPW) using Cree TrueWhite Technology. The prototype LED light bulb exceeds the performance goals set by the US Department of Energy (DOE) for the 21st Century Lamp, which is the third category in its L Prize competition.

"Not long ago, fixture efficacy of 100+ lumens per watt was impossible, but Cree is shipping fixtures at 110LPW today," says Cree co-founder Neal Hunter. "We calculate that, if fully deployed, LED lighting at 150LPW could bring a 16.5% reduction in the nation's electric-energy consumption, returning it to 1987 levels," he adds.

LED lighting at this level of performance is only made possible by advancements across all elements of the LED lighting system – lighting-class LEDs, optical elements, drivers and power supplies, says Cree. Optimizing each element was critical in achieving the performance reached by the prototype LED lamp, the firm says. As an efficiency comparison, a traditional 75W incandescent light bulb produces 1100 lumens at only 14.6 lumens per watt.

Third-party testing by independent lab OnSpeX confirmed that Cree's lamp delivered more than 1330 lumens and consumes only 8.7W. The lamp uses Cree TrueWhite Technology to deliver a color rendering index (CRI) of 91 at a warm-white correlated color temperature (CCT) of 2800K. Cree says that the project benefits

from technology developed under DOE-funded contracts, which are part of the firm's ongoing collaboration with DOE to advance the adoption of energy-saving solid-state lighting.

The Energy Independence and Security Act of 2007 directed the DOE to establish the Bright Tomorrow L Prize competition. The 21st Century Lamp competition is the third category in the legislation, joining competitions to create replacements for some of the most widely used and most inefficient lighting technologies on the market today: 60W incandescent lamps and PAR-38 halogen lamps. The preliminary specifications for the 21st Century Lamp include: output of >1200 lumens, luminous efficacy of >150 lumens per Watt, >90 CRI and CCT of 2800–3000K.

[www.cree.com](http://www.cree.com)

## Cree launches XLamp XT-E Royal Blue LED and patent licensing program for remote phosphor applications

Cree has announced the commercial availability of a XLamp XT-E Royal Blue LED optimized for use in remote-phosphor lighting and other applications with similar requirements.

The firm claims that the new XLamp XT-E LED delivers the industry's tightest wavelength bins combined with category-leading brightness to simplify remote-phosphor designs and lower system costs.

Cree has also announced a remote-phosphor-component patent licensing program providing access to its remote-phosphor patents. The program is designed to drive the LED lighting revolution by enabling lighting-fixture firms to develop and introduce their own LED system products using LEDs such as the XLamp XT-E Royal Blue. With a license under the new program, lighting OEMs can gain

access to fundamental Cree patents required to manufacture and use the combination of a remote-phosphor optical element with blue LEDs in LED lighting applications.

"Customers using remote-phosphor designs for their lighting products need both high output and consistent color," says Mike Watson, Cree senior director of marketing, LED components.

"The new Cree XLamp XT-E Royal Blue LED outperforms the competition in both elements, enabling

**Lighting OEMs can gain access to fundamental Cree patents required to manufacture and use the combination of a remote-phosphor optical element with blue LEDs**

our customers to design high-performance and low-cost systems," he claims.

Built using Cree's proven Direct Attach LED technology that is claimed to deliver higher flux, lower forward voltage and lower thermal resistance than other technologies, the XLamp XT-E Royal Blue LED delivers output of up to 525mW at a drive current of 350mA and at 85°C. The new LED is also available in 2.5nm wavelength bins to allow users to achieve the desired color consistency.

XT-E Royal Blue LEDs are available now with standard lead times.

Companies interested in obtaining a license under Cree's patents for the manufacture and use of remote phosphor components should e-mail [licensing@cree.com](mailto:licensing@cree.com) or call +1 919-313-5300.

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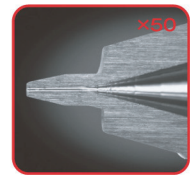
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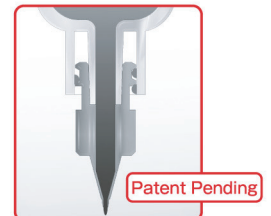
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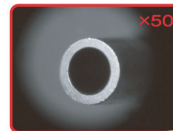
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- Maximize dispensing yield
- Alleviate bubbling



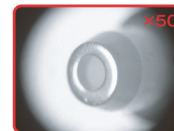
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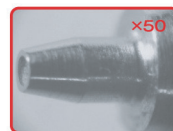
Stainless Steel Nozzle Tip



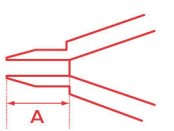
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## LUXEON Rebel LEDs power L Prize-winning retrofit bulb

Philips Lighting North America has won the 60W replacement bulb category of the US Department of Energy's Bright Tomorrow Lighting Prize (L Prize) competition, which challenges the lighting industry to develop high-performance, energy-saving replacements for conventional light bulbs. Replacing every 60W incandescent bulb in the US with the 10W L Prize winner would save about 35 terawatt-hours of electricity (\$3.9bn) a year and avoid 20 million metric tons of carbon emissions, it is reckoned.

Established in 2008, the L Prize competition targets the 60W bulb since it is widely used by consumers and represents about 50% of the domestic incandescent bulb market.

The DOE's requirements for the L Prize include:

- Efficacy of more than 90lm/W (which exceeds the efficiency of all incandescent and most compact fluorescent sources today, which range from 10 to 60lm/W).
- Energy consumption of <10W

(compared to a 60W incandescent).  
 ● Output of more than 900 lumens (equivalent to a 60W incandescent light bulb).

● A lifetime of more than 25,000 hours (25 times greater than a typical incandescent bulb).

● A color rendering index (CRI) of greater than 90 (high light quality).

● A color temperature of 2700–3000K ('warm' white light, comparable to that of incandescent sources).

"The L Prize challenges the best and brightest minds in the US lighting industry to make the technological leaps forward that can greatly reduce the money we spend to light our homes and businesses each year," said Energy Secretary Steven Chu. "Not only does the L Prize challenge innovative companies like Philips to make LED technology even more energy efficient, it also spurs the lighting industry to make LEDs affordable for American families."

Submitted in 2009, the Philips LED bulb completed 18 months of field, lab and product testing to meet the

rigorous requirements of the L Prize competition.

Philips Lumileds (a subsidiary of Philips) of San Jose, CA, USA says that its LUXEON Rebel LEDs are at the heart of the winning L Prize bulb, as well as dozens of different retrofit bulbs sold around the world.

"Our success with the L Prize is tangible proof of superior performance under real-world operating conditions", said Steve Barlow, senior VP of sales & marketing. "LUXEON has quickly become the LED of choice when quality, efficiency, reliability, and performance, are essential to our customers' retrofit bulb requirements".

Lumileds' Illumination Grade LEDs offer a wide range of options that address quality of light, efficiency, light output specifications, and cost concerns, says the firm. Each bulb format, from the small candelabra bulbs to larger PAR lamps, can be easily and directly addressed with the portfolio.

[www.usa.lighting.philips.com](http://www.usa.lighting.philips.com)

## Lumileds' LUXEON Rebel LEDs win Electron D'Or 2011 award

Philips Lumileds' LUXEON Rebel LEDs have been honored in Paris, France with the Electron D'Or award from ElectroniqueS magazine.

Selected by the editors and evaluated by a jury of experts from the world of business and research, 13 innovative products in different categories were recognized for excellence by this year's Electron D'Or awards. LUXEON Rebel was noted for meeting the stringent requirements of the lighting industry.

Over the last year, Lumileds' LUXEON Rebel portfolio has continued to expand to meet the needs of the lighting community, with new combinations of correlated color temperature (CCT) and color rendering (CRI) for white LEDs as well as a broader color portfolio.

[www.electroniques.biz](http://www.electroniques.biz)



2011 Electron d'Or award.

## Deep red added to LUXEON Rebel LEDs

With demand for colored LEDs rising, Lumileds is boosting performance and adding new colors to its LUXEON Rebel color LED portfolio.

'Deep Red' outputs 720mW (at 700mA) at 650–670nm. This wavelength range is essential for horticultural applications and is required by some governments around the world for applications like road and railway signaling. Other applications include entertainment.

"We are committed to the continuous improvement of our color portfolio and have delivered substantial light output increases," says Steve Barlow, senior VP of sales & marketing. The drive to improve energy efficiency and deliver better lighting solutions is as strong today for colored applications as it is for white-light applications, the firm adds.

[www.luxeon.com](http://www.luxeon.com)



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## IN BRIEF

## DOE announces Round 8 funding opportunities for solid-state lighting

The US Department of Energy (DOE) has announced two solid-state lighting (SSL) funding opportunities seeking applications for projects to advance research, development, and market adoption of SSL technology.

The funding is directed toward two existing DOE SSL R program areas for Core Technology Research and Product Development.

The Department of Energy is soliciting solid-state lighting projects in the following categories:

- Core technology projects focus on applied research for technology development, with particular emphasis on meeting efficiency, performance, and cost targets. Selected projects will fill technology gaps or provide enabling knowledge or data.

- Product development projects focus on using the knowledge gained from basic or applied research to develop or improve commercially viable materials, devices, or systems. Selected projects will develop targeted market applications with fully defined price, efficacy, and other performance parameters necessary for success of the proposed product.

Potential applicants should note that the response time for both opportunities has been lengthened and applications are due 3 November. In addition, under the Core Technology opportunity, the cost share requirement is waived for projects in which the prime recipient is a federal research center or national laboratory.

<https://eere-exchange.energy.gov>

## IR LED for low-profile small- and medium-size touch-screen displays

Osram Opto Semiconductors GmbH of Regensburg, Germany says that its new ChipLED SFH 4053 infrared emitter (IRED) combines tiny dimensions with high efficiency, suiting the demands for low-profile and powerful IR components in all-in-one computer, tablet PC and laptop displays.

The IRED is also small enough to be integrated into smart-phones.

Optical touch screens are available in a wide variety of designs, but they share a common principle in that the touch of a finger will either cast a shadow or reflect light. In basic versions, an array of infrared emitters (IREDs) and detectors create a grid of vertical and horizontal beams. The components are housed in a low-profile frame, known as the bezel, measuring a 0.5–1mm in depth around the screen. "To make this frame even shallower requires particularly small IREDs and detectors," says product marketing manager Bianka Schnabel. "This is especially important for mobile devices such as tablet PCs and laptops because of the positive effect on the design aspect." The ChipLED SFH 4053 measures just 0.5mm x 1mm, so it takes up very little space. Combined with a height of 0.45mm in industry standard 0402 (length/width), it is one of the smallest IREDs on the market, the firm claims.

In addition to their small size, the high light output of the components plays a key role, particularly for camera-based touch screens, Osram Opto adds. Such a display setup requires considerably fewer IR emitters than the traditional version, but the emitters must have a very high output because they flood the display with infrared light



**The ChipLED can be used in multi-touch displays installed in everything from tablet PCs to all-in-one PCs, even smart-phones. Icons can not only be selected and moved, they can also be zoomed.**

from two corners. Next to the IR emitters are camera chips that detect a change in the signal when a pen or finger touches the display.

Due to Osram's thin-film chip technology, the SFH 4053 provides high output from a very small package for this application, rated at 35mW from an operating current of 70mA. In pulse mode, it can achieve as much as 260mW from 700mA. "This ChipLED provides enough light to make it easy and cost effective to expand camera-based touch-screen systems to larger diagonal sizes," Schnabel notes.

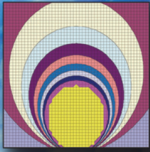
The ChipLED SFH 4053 is part of a broad range of components being used in an increasing number of touch-screen applications — from narrow-angle emitters for light grids to low-profile components for optimum coupling into light guides. Osram Opto's ChipLEDs are available in 0603 sizes with lens types from  $\pm 40^\circ$  to  $\pm 10^\circ$  and with different chip technologies, including thin film and nanostack.

The wavelength of the ChipLED suits the requirements of these applications. At 850nm, light from the IRED is barely discernible to the human eye, but receiver components are highly sensitive to it.

[www.osram-os.com](http://www.osram-os.com)

**FerroTec**

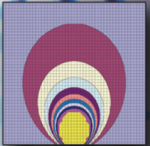
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**Ti**

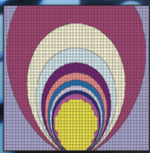
Titanium



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*Temescal*

## Avago launches Fast Ethernet transceiver for 50m (NA0.5) or 70m (NA0.3) links in harsh environments

Avago Technologies has launched a Fast Ethernet transceiver for providing reliable data transmission over plastic optical fiber (POF) link lengths up to 50m (NA0.5) or 70m (NA0.3). The AFBR-5972Z provides the ability to implement fast communication up to 100Mbps, and is suitable for networking in harsh environments such as factory automation or power generation and distribution applications. Featuring a compact design using an Avago Versatile Link duplex connector, the transceiver reduces board footprint.

An extension of the proven Versatile Link connector series, the AFBR-5972Z eliminates the electromagnetic interference, crosstalk, and electrical ground problems that are common with copper wire solutions, while also providing easier, more flexible installation, says Avago. The transceiver's new AFBR-4526Z duplex connector is similar in size to electrical RJ-45



**Avago's AFBR-5972Z Fast Ethernet transceiver.**

sockets and is compatible with existing simplex Versatile Link connectors.

In addition to the smaller size, the transceiver is more cost-efficient than comparable PROFINET industrial Ethernet standard connector solutions, the firm claims. Offering robust operation in the  $-40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$  extended industrial temperature range, the device

is suitable for industrial applications and supports various Ethernet Fieldbus protocols and is compatible with quasi-industry-standard IEEE 802.3 100BASE-FX.

The AFBR-5972Z's transmitter is based on a high-power, 650nm LED with an integrated driver that operates at 3.3V. The transmitter receives a LVPECL/LVDS electrical input and converts it into a modulated current, driving the LED. The LVPECL digital interface enables a direct connection to Ethernet PHY ICs. The high-bandwidth receiver contains a PIN photodiode, which is packaged in an optical subassembly that couples the optical power efficiently from POF fiber to the receiving PIN photodiode.

The AFBR-5972Z is priced at \$24.18 each in 100-piece quantities. Avago provides a reference design for its implementation, as well as an application note.

[www.avagotech.com](http://www.avagotech.com)

## Avago announces production availability of first 16 Gigabit Fibre Channel transceiver for storage-area networking

Avago Technologies has announced production availability of a 16 Gigabit Fibre Channel transceiver with industry-standard signaling rates up to 14.025GBd. The new AFBR-57F5PZ SFP+ transceivers support high-speed serial links over multimode optical fiber with double the data throughput of existing 8 Gigabit Fibre Channel modules. The modules address 16 Gigabit Fibre Channel switches, routers, host bus adapters, RAID controllers, tape drives and video switching, as well as inter-switch and inter-chassis aggregated links.

The AFBR-57F5PZ SFP+ transceiver reduces the number of ports required for inter-switch connectivity by a factor of two compared to existing 8 Gigabit Fibre Channel



**Avago's AFBR-57F5PZ SFP+ 16 Gigabit Fibre Channel transceiver.**

solutions and operates at essentially the same power level. The SFP+ module's transmitter and receiver can operate at different data rates, as is often required during Fibre Channel speed negotiation. The module maintains compatibility with legacy 8 Gigabit and 4 Gigabit Fibre Channel devices,

simplifying design migration.

"Avago has worked closely with our top customers to develop solutions with the bandwidth and port-density they require," says Victor Krutul, director of marketing for Avago's Fiber Optics Products Division.

The AFBR-57F5PZ transceiver incorporates Avago's 850nm vertical-cavity surface-emitting laser (VCSEL) technology and PIN detector technology. This combination ensures that the multi-rate SFP+ module is compliant with FC-PI-5 and 16G/8G/4G Fibre Channel specifications. The module will respond to both rate select pin and control bit inputs, which simplifies Fibre Channel host auto-negotiation algorithms, layout and software.

## Advanced Photonix's quarterly revenue grows 3.8%, but 15–20% annual growth still expected

For fiscal first-quarter 2012 (to 1 July 2011), 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 terahertz instrumentation) has reported revenue of \$8.1m, up 3.8% on \$7.8m last quarter and up 30% on \$6.3m a year ago.

Operating expenses have risen further, from \$3.2m a year ago and \$3.7m last quarter to \$3.8m. Gross margin has fallen further, from 47% a year ago and 44% last quarter to 42%. On a non-GAAP basis, compared with a net profit of \$97,000 a year ago and \$221,000 last quarter, fiscal Q1 saw a net loss of \$96,000. During the quarter, cash reserves fell from \$5.2m to \$3.9m.

"As we stated in our year-end conference call, this year would start slow and build throughout the

year," notes chairman & CEO Richard Kurtz. "If we annualize the first-quarter revenue of \$8.1m, that would give us \$32.4m for fiscal 2012, or a projected growth rate of 13% over last year," he adds.

"Our second quarter is also strong and we are continuing to see an increase in demand for our HSOR products," Kurtz reports. "While this will be offset by a slowing of our Optosolutions product platform, we expect to meet our target annual growth plan of 15–20%," he assures.

"Our focus today is on the drop in gross margin that we experienced this quarter," Kurtz notes. "We are looking at all aspects of our cost of goods, including scrap and rework within our HSOR and labor and overhead in our Optosolutions product line. We are optimistic about meeting our growth goals and driving our gross margins to our goal of 50%."

### IN BRIEF

#### Advanced Photonix hires CFO

Advanced Photonix Inc has hired Jeffrey Anderson as chief financial officer, effective 29 August.

"Jeff has over 30 years of business experience, starting in public accounting and moving into a number of high technology companies with annual revenues ranging from \$50m to over \$3bn," says president & CEO Richard (Rick) Kurtz. "He has guided companies through merger and acquisitions and he has completed over ten financings involving bond and equity raises. He has run accounting organizations with as few as five employees and as many as 140 in over 14 different countries," he adds.

Anderson also has a BA, MBA, CPA and CM. "This unique combination of skills will be important in managing the growth of API," believes Kurtz.

[www.advancedphotonix.com](http://www.advancedphotonix.com)

## Opnext revenue hit by 40G DQPSK and 100G CFP module production constraints

For its fiscal first-quarter 2012 (to end-June 2011), optical module and component maker Opnext Inc of Fremont, NJ, USA has reported revenue of \$93.1m, up 18% on \$78.9m a year ago but down 2% on \$95.3m last quarter.

Revenue for industrial & commercial products has risen 25% from \$6.7m a year ago and 2% from \$8.2m last quarter to \$8.4m.

Revenue from 10Gbps and below products of \$50.6m is down 9% from \$55.9m a year ago but up 4% from \$48.9m last quarter.

Revenue from 40Gbps and above products of \$34.1m has more than doubled from \$16.3m a year ago, but fallen 11% from \$38.2m last quarter due to lower 40G subsystem sales and 40G DQPSK and 100G

CFP module production constraints.

On a non-GAAP basis, gross margin has risen from 20.9% a year ago and 21.3% last quarter to 23.5%, including a 100 basis point benefit from lower idle capacity and damaged inventory charges resulting from March's earthquake in Japan, partially offset by a 30 basis point impact from foreign currency exchange rate fluctuations.

R&D expense has fallen from \$15.8m a year ago and \$15.2m last quarter to \$13.1m, due mainly to the timing of material and outsourcing costs associated with new-product introductions.

Net loss has been cut from \$12.1m a year ago and \$8.7m last quarter to just \$4.6m. Compared with -\$2.2m last quarter and -\$6.1m a

year ago, adjusted EBITDA was \$1.9m. "We delivered on our break-even adjusted EBITDA objective and we improved our working capital management," says chairman & CEO Harry Bosco.

Cash used in operations has been cut from \$19.7m a year ago and \$2.1m last quarter to \$1.7 (with net cash used in the last 12 months being less than \$6m). However, net gain on sale of technology assets was just \$2.1m (compared with \$21.4m last quarter). During the quarter, cash and cash equivalents hence fell from \$100.3m to \$97.2m.

For fiscal Q2/2012 (ending in September 2011), Opnext expects revenue of \$89–95m, as near-term demand remains soft, says Bosco.

[www.opnext.com](http://www.opnext.com)

## GigOptix product revenue rises 8% in Q2 to record \$7.6m Consolidation of Endwave in new San Jose HQ to yield cost savings

For second-quarter 2011, GigOptix Inc of San Jose, CA, USA, which designs modulator and laser drivers and transimpedance amplifier (TIA) ICs based on III-V materials as well as polymer electro-optic modulators, has reported total revenue of \$7.6m (up 21% on \$6.3m a year ago but down slightly on \$7.7m last quarter).

However, this represents GigOptix's seventh consecutive quarter of growth in terms of product revenue, up 38% on \$5.5m a year ago (excluding \$755,000 of government contract revenue) and up 8% on Q1's \$7.1m (excluding \$610,000 of government contract revenue) — exceeding guidance of just 5%.

"GigOptix continued to gain strong momentum throughout the second quarter," says chairman & CEO Dr Avi Katz. "We continued to experience solid customer interest for our 40G and 100G optical networking products," he adds.

"From a product development perspective, we continued to make significant advancements in the commercialization of our TFPS [Thin Film Polymer on Silicon] Mach-Zehnder modulators [MZMs]," says Katz. "A number of our tier 1 customers have validated the performance of our first-generation 40G TFPS modulator, and we have recently begun production shipments," he adds. "Additionally, we released and began sampling our second-generation more advanced 40G modulator, the LX8220, to

continue to bring customers the lowest-power, smallest-footprint and lowest-cost modulator available in the market," he claims.

"We are also making significant progress with our 100G modulator offering and expect to release engineering samples for our customers' planned evaluation programs before the end of the year," says Katz.

"In addition, interest in our 40G and 100G drivers and amplifiers continues to grow with Tier 1 telecom customers," he adds. "I am satisfied with the progress we have made and the key design wins and production opportunities we have secured for both our 40G and 100G products."

Although down on 58% a year ago, non-GAAP gross margin has rebounded slightly from 51% in Q1 to 52%. Total operating expenses were \$6.4m, up from \$4.7m a year ago but cut from \$7.2m last quarter.

Nevertheless, net loss has risen from \$0.4m a year ago and \$0.4m in Q1 to \$0.8m. Adjusted EBITDA (cash flow, net of changes in working capital and capital expenditures) was a loss of \$0.3m, compared to income of \$45,000 in Q1 and \$0.4m a year ago.

During the quarter, cash and investments rose from \$4.1m to \$18.3m, due mainly to the addition of the net cash balance acquired from Endwave. On 17 June GigOptix closed the acquisition of Endwave Corp of San Jose, CA (which

designs and makes high-frequency RF solutions and semiconductor products, particularly point-to-point radio communication systems).

During the quarter, the firm substantially completed the integration of Endwave's operational, global sales, US engineering and IC design teams at GigOptix's new corporate headquarters in San Jose. "GigOptix has taken actions that we believe will result in significant cost savings for the consolidated company since the closing of the acquisition," says Katz.

"We are further enhancing our position as the leading one-stop supplier of component solutions that enable high-speed information streaming, and we will be bringing to market more advanced bundled integrated solutions based on our unique component portfolio," says Katz.

For third-quarter 2011, GigOptix expects sequential revenue growth, including product revenue rising 8%. "We remain committed to driving increased quarter-over-quarter product revenue by further commercializing our innovative, industry-leading high-speed 40G and 100G solutions for next-generation end-to-end communications networks and capitalizing on our high-performance MMIC solutions, which enable next-generation wireless systems," states chief financial officer Curt Sacks.

[www.GigOptix.com](http://www.GigOptix.com)

### GigOptix shares begin trading on OTCQX

Since 16 August, GigOptix' primary trading venue for its common stock has been upgraded from the OTCQB platform to the quality-controlled OTCQX US Premier trading platform, indicating that it meets the highest financial standards among OTC-traded companies.

"Since its inception four years ago, GigOptix has advanced from

a start-up to an industry leader by successfully executing on our business plan and growth strategies, says chairman & CEO Dr Avi Katz. "We have consistently increased quarterly product revenue, while strictly managing expenses," he adds.

"GigOptix's transition to the OTCQX is the next step toward further increasing investor awareness

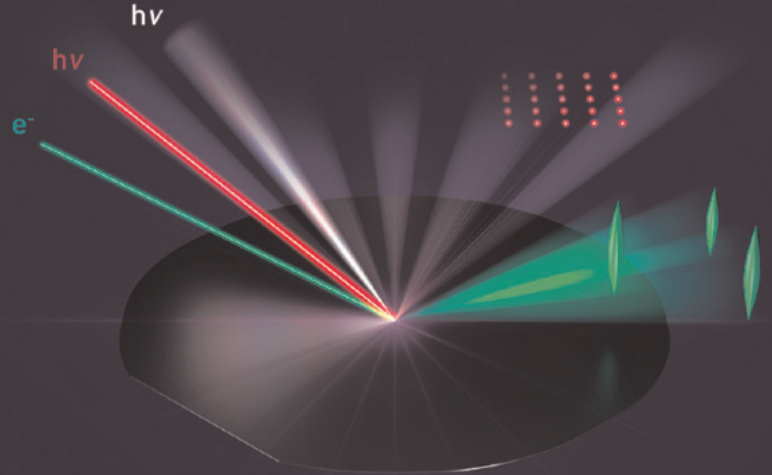
through the platform's increased trading transparency and more prominent access through US broker-dealers," Katz says. "We have reached a level of recognition that will enhance value for our shareholders as we continue to pursue our ultimate goal of listing on a national exchange."

[www.otcqx.com](http://www.otcqx.com)





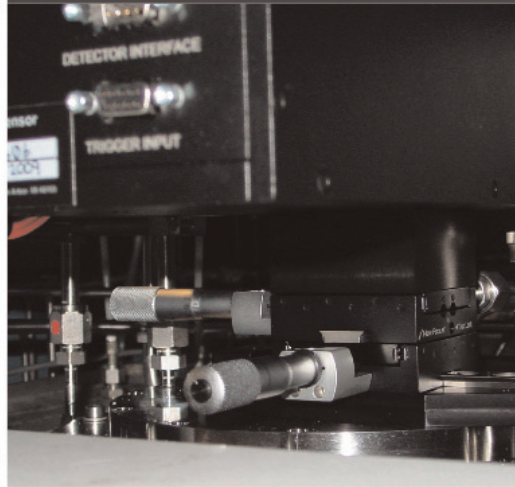
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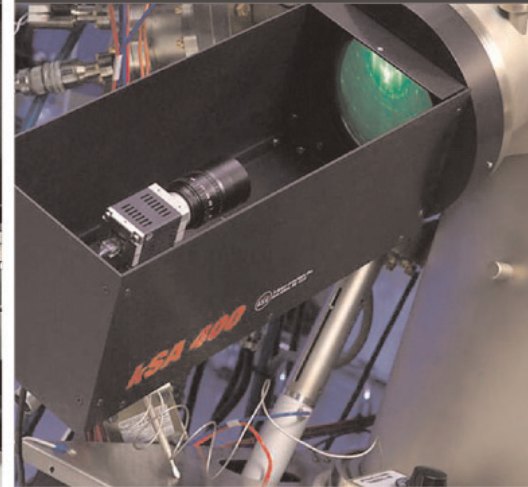
kSA BandiT Wafer Temperature



kSA MOS and kSA Mini-MOS  
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kSA 400 Analytical RHEED



kSA MOS Ultra-Scan and  
Thermal-Scan Stress Mapping



kSA Rate Rat Pro Thickness &  
Deposition Rate



kSA BandiT PV Process Tuning



## IN BRIEF

**Q2 sees rebound but losses rise during new product development**

For second-quarter 2011, Infinera Corp of Sunnyvale, CA, USA, a vertically integrated manufacturer of digital optical network systems incorporating its own InP-based photonic integrated circuits (PICs), has reported revenue of \$96m, up 3% on Q1's \$92.9m but down 13.8% on \$111.4m a year ago.

"We are encouraged by our second quarter performance, including an improvement in bookings momentum," says president & CEO Tom Fallon. "We saw a continuation of healthy tributary adapter module purchases by a broad base of customers looking to meet their current bandwidth growth needs," he adds. "The MSO space — which we placed a strategic focus on several years ago — was especially strong, with two customers from that category in our top 5 customer count. In addition, we saw growth in new optical capacity deployments by our customers, establishing a base for future TAM purchases."

However, on a non-GAAP basis, gross margin was 41%, down on 48% last quarter and 44% a year ago. Net loss has risen to \$11.7m, compared with \$4m last quarter and net income of \$3m a year ago.

"We made excellent progress in the development of our next-generation 500Gbs/s PIC solution, which will support 100G transmissions and on our 40G product with FlexCoherent technology," says Fallon. "During this period of significant product development investment and transition to new products, we remain focused on delivering on our PIC-based digital optical strategy and product roadmap in order to generate the revenue growth necessary to achieve our long-term business model objectives."

[www.infinera.com](http://www.infinera.com)

**SEACOM uses Infinera's PICs in first global 500GB/s network trial**

Infinera has announced the first global 5x 100Gb/s optical transmission trial over a distance of 1732km.

The 500Gb/s trial was run over and looped back across SEACOM's new 930km Dark Fibre Africa (DFA) route, which links the SEACOM Mtunzini cable landing station in KwaZulu Natal to the Teraco data-center in Johannesburg, South Africa.

SEACOM is a privately financed, developed and owned submarine fibre-optic cable network bringing broadband capacity to Africa via the sale of wholesale bandwidth and associated services on an open-access basis. With construction starting in November 2007, SEACOM officially launched in July 2009.

The live demonstration was witnessed by members of the scientific R&D community at Teraco's data-centre in Johannesburg. The trial used Infinera's 500Gb/s PICs, which each integrate five 100Gb/s coherent channels onto a single chip. The PICs were used for both transmitting and receiving the five 100Gb/s signals during the trial, which was the first time that PICs have been used to send and provide real-time coherent processing for all 500Gb/s simultaneously on a production network. The trial also demonstrated Infinera's FlexCoherent functionality by switching between QPSK and BPSK modulation schemes.

Infinera aims to deliver the 500Gb/s PICs as part of a system that integrates 5Tb/s OTN switching and 100Gb/s coherent optical transmission in early 2012. Enabling seamless upgrades from existing 10Gb/s networks without having to upgrade the underlying fibre infrastructure, the technology provides SEACOM's land-based network in South Africa with a total capacity of more than 8Tb/s per fibre, which is an effective 10-fold increase on its current capacity, says Infinera. This is in line and in support of SEACOM's plans to expand the marine portion of the cable to more than 4.8Tb/s.

"This event is a landmark achievement and a global first," says SEACOM's CEO Brian Herlihy. "It also signals the international science R&D community that global projects such as the Square Kilometre Array are well within Africa's reach," he adds. "The trial demonstrates SEACOM's commitment to increase the pace at which African networks are deploying cutting-edge telecommunications infrastructure technology to support Africa's rise as a primary scientific and business destination."

Fibre-optic transmission technologies have been developing greatly to satisfy demand for large-capacity digital transmission in public telecom networks worldwide, says Infinera. At the consumer level, the 500Gb/s PIC technology enables the download of 2400 high-definition Blu-Ray movie files in 60 seconds, or supports the streaming of 320,000 simultaneous high definition video channels over a single fibre pair.

At the network level, 100G systems based on PIC technology will have important implications for the economics of future networks. Infinera's 500G PICs incorporate more than 600 optical functions on a pair of InP chips enabling cost-effective 100Gb/s coherent transmission as well as integrated OTN switching. These capabilities provide an effective way for network operators to scale capacity while lowering operational costs, increasing reliability and providing superior economics, says the firm.

"With Internet traffic growing at exponential rates, driven by video, cloud computing and mobility, the 500G PIC technology is designed to support the required growth in network capacity, while reducing the per-bit cost, space, and power consumption," says CEO Tom Fallon. "These attributes are in-line with SEACOM's vision to provide world-class infrastructure as African traffic continues to rise at record speed."

[www.seacom.mu](http://www.seacom.mu)

# Optical chip and module makers launch XLMD2 MSA

## Compact low-profile TOSA/ROSA targeted for 40G pluggable transceiver modules

Mitsubishi Electric Corp, OKI Semiconductor Co Ltd, Opnext Inc, Renesas Electronics Corp and Sumitomo Electric Industries Ltd have announced a transmitter optical sub-assembly (TOSA) and receiver optical sub-assembly (ROSA) multi-source agreement (MSA) targeting 40Gbps pluggable transceiver modules. The initiative was established to meet the increased demand for pluggable 40Gbps serial modules such as the CFP pluggable transceiver MSA for 100Gbps and 40Gbps applications.

The transmission speed of 40Gbps is the highest commercially available modulation speed using the simple light on/off keying or serial transmission scheme. 300-pin MSA transceivers using 1550nm light source devices are widely available for the 2km application. Recently, 40Gbps serial transmission over 10km was demonstrated using 1310nm light source devices.

In addition to ITU-T 40Gbps serial transmission standards (VSR2000-3R2 for 2km and P1I1-3D1 for 10km), the IEEE has recently defined a 40Gbps serial interface for 2km (40GBASE-FR). The demand for 40Gbps serial transmissions is growing in telecom, data and IP communication applications.

In today's 300-pin MSA transceiver module market, XLMD MSA TOSAs and ROSAs are widely adopted for use in the 40Gbps transceivers. Following the release of the CFP MSA, 40Gbps pluggable transceiver modules are now required to offer easy handling and maintenance. New low-profile, compact TOSAs and ROSAs are essential components for future downsized pluggable transceiver modules.

The new TOSA/ROSA MSA defines both the laser transmitter devices and the PIN photodiode-transimpedance amplifier (PIN-TIA)

receiver devices that comply with 40Gbps interface standards. The MSA targets transmission modules for more than 10km applications.

In an upcoming MSA meeting, the member companies will specify the common mechanical dimensions; footprint (interface with common PCB design for 40Gbps transceiver modules); pin assignment and functions; and electrical and optical performance characteristics of the optical transmitter and receiver devices. The TOSA/ROSA MSA specifies key features including a low-profile and compact fit for pluggable modules and simple electrical interfaces providing cost-effective solutions. The MSA committee plans to release the specifications within one year.

"The TOSA/ROSA agreement will leverage the 40Gbps market to achieve compact, low-power-consumption pluggable modules, which will provide advanced 40Gbps serial solutions to high-capacity network and storage systems," says an MSA committee spokesperson. In the future, the MSA will continue to define specifications that consider future advanced technologies, such as 1310nm light source devices and direct modulation lasers.

For further information including detailed specification documents or to join the MSA, e-mail: XLMDMSA@ns.MitsubishiElectric.co.jp okisemi-xlmd2msa@adm.okisemi.com xlmdmsa@opnext.com csd\_40gmsa@lm.renesas.com or XLMD2MSA@ppd.sei.co.jp.

**The TOSA/ROSA agreement will leverage the 40Gbps market to achieve compact, low-power-consumption pluggable modules**

### IN BRIEF

## Infinera establishes Hong Kong-based full-service facility

Infinera Corp of Sunnyvale, CA, USA has opened a full-service facility in Hong Kong to provide service and support to customers in the Asia-Pacific region. With sales, engineering, technical and operational support teams, the facility offers product demonstrations, training, and support for the growing number of APAC customers who deploy Infinera's Digital Optical Network technology.

According to Infinera, recent research from market research firm Ovum indicates that the global optical networking equipment market is expected to reach \$20bn by 2015, with a compound annual growth rate (CAGR) of 5%. The Asia-Pacific region was identified as the number one growth region for optical networking sales, adds the firm.

"Infinera is focused on growing our footprint in the expanding Asian market," says CEO Tom Fallon. "Building on our success in North America, we have achieved significant growth in EMEA and are now determined to extend this success to APAC. Infinera has made optical networking faster, simpler and more efficient, and we are excited to demonstrate this innovation to our existing and future customers in APAC," he adds.

"This new facility marks the beginning of a long-term investment by Infinera in APAC," says Andrew Bond-Webster, VP APAC. "We will continue to listen to our customers, make ourselves more accessible to them, and expand our local team of expertise to create winning opportunities for everyone in the long term."

Infinera is well positioned to meet the growing need for efficient and reliable networks, reckons the firm.

[www.infinera.com](http://www.infinera.com)

## IN BRIEF

**First 40G transceiver module sampled for client-side Ethernet**

NeoPhotonics has announced sample availability of its first 40G transceiver module for high-speed Ethernet client-side applications.

The new pluggable 40G-LR4 CFP transceiver increases the data rate per module from 10G (in the case of XFP or SFP+ transceivers) to 40G, and is designed to meet increasing bandwidth demand in cloud and data-center applications. Compared to a traditional 10G approach, the new module transmits four times the data over single-mode fiber at distances up to 10km.

"We have provided samples to our customers as they serve the rapidly expanding 40G Ethernet market with cost-effective pluggable solutions," says chairman & CEO Tim Jenks. "The new module complements our existing broad portfolio of line-side products, such as our Integrated Coherent Receiver (ICR) for 40G and 100G DWDM transport applications, and underlines our commitment to the ultra-high-speed segment of the transceiver market," he adds.

The new 40G CFP module is the latest addition to the firm's expanding high-speed transceiver portfolio, which includes a range of XFP, SFP+ and 10G EPON/XG-PON1 modules plus high-speed receivers for coherent applications. The new product is designed primarily to connect gigabit and terabit routers and switches with next-generation high-capacity transport systems. The 40G transceiver is designed to comply with the IEEE 802.3ba 40GBASE-LR4 specification and to support OTU3 rates and 44.4G for future applications.

**NeoPhotonics' revenue grows 14% year-on-year to record \$52.1m Non-GAAP profit maintained for an eighth consecutive quarter**

For second-quarter 2011, NeoPhotonics Corp of San Jose, CA, USA has reported record revenue of \$52.1m, up 2% on Q1's \$50.9m and 14% on \$45.6m a year ago.

NeoPhotonics is a vertically integrated designer and manufacturer of photonic integrated circuit (PIC)-based components, modules and subsystems for bandwidth-intensive, high-speed communications networks. Products include III-V-based active semiconductor, silica-based passive PLC (photonic lightwave circuit) and silicon-based MEMS (micro-electro-mechanical system) multi-dimensional switching functions in a single product, with integration enabled by nanomaterials and nanoscale design and fabrication technologies. The firm has engineering and manufacturing facilities in both Silicon Valley and Shenzhen, China.

During the quarter, NeoPhotonics announced that it has quadrupled capacity for PIC-based Integrated Coherent Receivers (ICR) for 40 and 100Gbps fiber-optic transport systems. Its ICR is designed to convert phase-encoded optical signals into electrical signals of varying intensity, which can then be analyzed using digital signal processing, leveraging a carrier's existing fiber-optic cable investments. NeoPhotonics says that it has earned multiple design wins for the ICR with its tier 1 customer base and is now shipping ICR products to multiple customers.

NeoPhotonics also announced that, following its launch in fourth-quarter 2010 and general availability in first-quarter 2011, its PIC-based small-form-factor DQPSK demodulator (designed for use in 40Gbps direct detection fiber-optic transport systems) achieved volume production. The small-form-factor version is less

than half the size of the standard-form-factor DQPSK demodulator and saves board space in high-capacity systems.

Although down from 34.4% a year ago, non-GAAP gross margin has risen from 25.8% in Q1 to 26.2%. NeoPhotonics was profitable on a non-GAAP basis for the eighth consecutive quarter, although net income has fallen from \$4.2m a year ago and \$0.14m in Q1 to just \$7000. Adjusted EBITDA has fallen from \$7.1m a year ago and \$3.3m in Q1 to \$3m.

During the quarter, total cash, cash equivalents and short- and long-term investments rose from \$92.5m to \$107.5m. This includes investments of \$28.2m in long-term marketable securities, and proceeds of \$21.3m from the sale of an interest in an unconsolidated investee (resulting in an estimated 1.8x return on capital, and valuing the entity at an estimated 2.6x trailing 12-months revenue).

NeoPhotonics anticipates that macroeconomic conditions, including the slow recovery in the USA, European sovereign debt issues, and concerns relating to inflation in China, could impact third-quarter 2011 results. Accordingly, it currently expects revenue of \$48-53m, and non-GAAP gross margin of about 26%.

Also, the firm expects to use a portion of the \$21.3m proceeds received in Q2 for re-investment in the business, including in R&D. "We are focused on developing additional integrated and advanced products and plan to increase our R&D investments, specifically in speed and agility product areas, with a goal to accelerate the growth opportunities that we see with our broad customer base," says chairman, president & CEO Tim Jenks.

[www.neophotonics.com](http://www.neophotonics.com)

## Extended-reach 10G PON OLT transceivers sampled OLT capacity tripled to serve rapidly growing FTTH deployments

NeoPhotonics Corp of San Jose, CA, USA has announced sample availability of its first extended-reach 'XG PON1' transceiver module for 10G passive optical network (PON) applications in an XFP form factor.

The new pluggable transceiver increases the link budget from 29dB (ITU-T G987.2 Class N1) to 31dB (ITU-T G987.2 Class N2), and is designed to support network overlay of 10G XG-PON1 over existing Class B+ GPON networks (28dB link budget).

The transceiver module is for emerging 10G PON networks that require backward compatibility with existing 1G PON networks, says chairman & CEO Tim Jenks. "We have provided samples to cus-

tomers as they are starting initial deployments of 10G PON networks," he adds.

NeoPhotonics has also announced that it has tripled capacity for its current optical line terminal (OLT) transceivers over the last year to help satisfy demand from fiber-to-the-home (FTTH) deployments in Asia and North America. "As FTTH deployments grow globally, we believe we are well positioned to serve the needs of our customers with increasing volume shipments," says Jenks.

The new ITU-T G987.2 Class N2 XG-PON1 XFP OLT module is the latest addition to the firm's expanding 10G PON transceiver portfolio, which covers both ITU-T G.987.2

XG-PON1 and IEEE 802.3av PX30 and PRX30 standards. The portfolio includes Class B+ and C+ GPON OLTs, PX20 and PX20+ GEAPON OLTs, multiple ONUs, as well as 10G/1G and 10G/10G EPON OLT and ONU transceivers.

The new module is designed for operation in 10G PON overlays on Class B+ GPON networks, allowing carriers to leverage investments in existing infrastructure while upgrading their fiber-optic broadband access networks from 1.25G and 2.5G data rates to 10G data rates.

The Class N2 XG-PON1 OLT module is now available in sample quantities.

[www.neophotonics.com](http://www.neophotonics.com)

## Santur ramps-up production of 10X10 MSA-compliant 100Gbps CFP modules

Santur Corp of Fremont, CA, USA, a vertically integrated manufacturer of tunable laser arrays for metro and long-haul wavelength division multiplexed (WDM) systems as well as photonic integrated products for SMF 40Gbps and 100Gbps client and coherent applications, has announced the general availability of its 100Gbps CFP optical modules compliant with the 10X10 MSA (multi-source agreement).

Founded in December 2010, the 10X10 MSA is an industry group of 25 firms dedicated to technology and standards development for low-cost 100Gbps client interfaces based on 10G signaling. Members include Google, Brocade, Santur, JDSU, Huawei, Facebook, BTI Systems, AMS-IX, MRV, EXFO, Enablence, Cyoptics, AFOP, Oplink, Hitachi Cable America, Kotura, Efdon, Source Photonics, Verdant Networks, Kaiam, Innolight, Fourte Design, Viscore, Maxim and Cortina Systems.

The 2km reach of this new version of Santur's 100Gbps CFP optical

modules bridges the gap between 100m multi-mode and 10km single-mode fiber (SMF) solutions, enabling the roll-out of new networks capable of delivering exponentially higher bandwidth at a significantly lower cost per bit, says the firm. Unlike 100m multi-mode based on ribbons of fiber, this solution operates on a conventional single-mode fiber (SMF), enabling extended reach of 2km. Compared with other 4x25G 100Gbps implementations for single-mode fiber, this approach does not require 25Gbps electronics such as gearbox ICs to convert 10Gbps data streams to intermediate 25Gbps lanes.

"For more than 20 years, we have been discussing the possibility of integrating multiple active optical components on a single chip to reduce cost and power," says president & CEO Paul Meissner. "Over time, several companies have tried, but none offered such high level of integration that allowed us to meet

our cost and power targets," he adds. "The hybrid integration platform scales to higher data rates and wider WDM lanes to create many product variants based on a common architecture targeted at cost-effectively meeting the needs to expand the global Internet infrastructure."

Santur's new 100Gbps CFP optical modules, which entered full-scale production in early June, deliver what is claimed to be disruptive cost per bit at 100Gbps comparable to that of 10G XFP modules currently shipping. Based on volume production pricing, the new 100Gbps CFP module will have an entry point of below \$5000 in volumes of 100 units or higher. The modules further improve energy efficiency by cutting maximum power dissipation to 13W to match power-per-bit metrics comparable to 10Gbps SFP+ optical modules, the firm claims.

[www.santurcorp.com](http://www.santurcorp.com)

[www.10X10msa.org](http://www.10X10msa.org)

## Oclaro's ramp of higher-margin products delayed by optical telecom inventory correction

For its fiscal fourth-quarter 2011 (ended 2 July), optical component, module and subsystem maker Oclaro Inc of San Jose, CA, USA has reported revenue of \$109.2m, down 3% on \$112.7m on a year ago and 5.6% on \$115.7m last quarter. However, despite slowness in the optical telecom sector during an inventory correction lasting much of the year, for full-year fiscal 2011, revenue was \$466.5m, up 19% on fiscal 2010's \$392.5m.

Revenue from non-telecom products (including high-power lasers, filters and high-volume VCSEL products for consumer applications) was \$15.1m, up 10% on \$13.7m last quarter. In particular, revenue from high-power laser business was up by \$1m (about 10%).

Greater-than-10% customers for the quarter were Fujitsu (17%) and Huawei (10%, down from 18% last quarter), while both Alcatel-Lucent and Ciena were just under 10%. "Fujitsu has risen into the 'major customer' category on the strength of 40G transponder sales," notes chief financial officer Jerry Turin.

"In fiscal 2010 we transformed Oclaro into a tier-one supplier of optical components and subsystems through a series of strategic initiatives," comments chairman & CEO Alain Couder. "In fiscal 2011 we began structuring the integrated company to scale, while accelerating our investment in new product innovation," he adds. For example, Q4/2011 included initial shipments of new products including 40G coherent transponders, tunable XFP transceivers, 40G lithium niobate external modulators, and an integrated ROADM (reconfigurable optical add-drop multiplexer) line card. These revenues totaled under \$1m. "Even these modest revenue levels establish important traction on the related revenue guidance," Turin reckons. "We are well positioned for growth as the telecom optical market recovers," Couder believes.

Non-GAAP gross margin has fallen further, from 30.7% a year ago and 24.9% last quarter to 22.9%. This is due to: more than \$3m of excess and obsolete inventory reserves and related charges; and lower wafer fab overhead absorption (caused by a decline in revenue from photonic components products, which tend to be at the packaged chip level during the market softness, and the continued inventory correction in the optical market). Oclaro's inventories soared by 15% from \$87.5m to \$100.2m. Full-year gross margin fell from 28% in fiscal 2010 to 26.8%.

Compared with \$17.2m last quarter, Oclaro is now investing \$18.9m per quarter in R&D, which is \$7.4m (64%) more than a year ago. Consequently, full-year R&D spending has risen by \$24m from \$41.5m in fiscal 2010 to \$65.5m in fiscal 2011. The firm also had \$4.5m more depreciation expense in fiscal 2011, associated with capital investments in scaling the firm for long-term growth and new product launches.

Consequently, compared with +\$12.3m a year ago and +\$0.7m last quarter, adjusted EBITDA was negative \$4.7m for fiscal Q4/2011. Consequently, full-year adjusted EBITDA has fallen from \$26.5m in fiscal 2010 to \$17m for fiscal 2011.

Compared with net income of \$10.6m a year ago, non-GAAP net loss has more than doubled from \$4.5m last quarter to \$10m. So, compared with net income of \$14.1m for full-year fiscal 2010, fiscal 2011 yielded a loss of \$2m.

After capital expenditure of \$9m (up from \$6.2m a year ago, but cut from \$14m last quarter), cash, cash equivalents and restricted cash fell during the quarter from \$75.7m to \$63.4m. Although no amounts were drawn under Oclaro's \$25m line of credit as of 2 July, on 26 July the firm closed an increase to \$45m and extended its term through 1 August 2014.

For its fiscal first-quarter 2012 (ending 1 October 2011), Oclaro expects relatively flat revenue of \$103–113m, due to uncertainty for the core optical market, offset by growth in the high-power laser market. "We have not yet seen a meaningful recovery of the component-level product revenues," says Turin. The firm also expects non-GAAP gross margin of 18–24% and adjusted EBITDA of negative \$8.5–2.5m. "With our inventories up and our revenues relatively flat, it is taking longer for us to realize the benefit of cost improvements in our product," he adds. "At the same time, customer price decreases continue right on schedule with a top competitive environment among our customers reinforcing pricing pressure. The disconnect between timing of our cost improvement and timing of price reduction is not helpful for gross margin," Turin comments.

"We don't expect a significant enough ramp of higher-margin new products within September [contrary to expectation on entering this calendar year] to move the needle on overall company gross margin," Turin continues. "We plan on holding R&D spending flat in the September quarter [with capital expenditure of about \$9m]," he notes.

"As of now, we believe the potential aggregate revenues in the December quarter from all of our 40G transponders — our tunable XFP, our 40G and 100G modulators and our WSS ROADM-related products — could be in the \$25–30m range," says Turin. "While we are beginning to see some progress on these new products, the overall markets for our telecom optical product has continued to be soft." Nevertheless, as revenue growth returns, Oclaro expects R&D spending to move back towards its 13%-of-revenue target.

[www.oclaro.com](http://www.oclaro.com)

## 10X10 MSA releases 10km and 40km 100Gbps standards Longer-reach specs added to existing 10x10G-2km standard

The 10x10 MSA (multi-source agreement), an ecosystem of organizations creating 100Gbps solutions, has announced the public availability of 10km and 40km specifications to expand into new applications.

Founded in December 2010, the 10X10 MSA is an industry group of 25 firms dedicated to technology and standards development for low-cost 100Gbps client interfaces based on 10G signaling. It has established an open framework for all stakeholders in the ecosystem. Members include Google, Brocade, Santur, JDSU, Huawei, Facebook, BTI Systems, AMS-IX, MRV, EXFO, Enablence, CyOptics, AFOP, Oplink, Hitachi Cable America, Kotura, Efdon, Source Photonics, Verdant Networks, Kaiam, Innolight, Fourte Design, Viscore, Maxim and Cortina Systems.

Having garnered strong support and growing commitments through multiple deployments around the world, the MSA says that it was compelled to develop a new common specification for longer-reach applications to help mitigate development risk and eliminate the need for custom or proprietary solutions, while also reducing both development and manufacturing cost.

The 10km reach specification builds on existing 2km specifications to ensure backward compatibility and interoperability with

the existing 10X10G-2km standard. This helps service providers to extend data-center networks to campus networks and beyond. The 40km specification leverages existing 10Gbps DWDM network specifications to enable seamless upgrade of existing 10Gbps metro links to 100Gbps over up to 40km single-mode fiber without the need for regeneration or amplification.

"We are very pleased with the widespread adoption of 10X10 optical modules," says 10X10 MSA chair Scott Kipp, senior technologist at Brocade. "The new 10X10G-40km standard enables up to 800Gbps of data to transmit over a single fiber — that's the speed the industry needs," he adds.

"Optical modules based on the 10X10 standards have become the most popular single-mode 100Gbps optics," says Milind Gokhale, chief technology officer of Santur. "We have now reached another milestone which demonstrates that the 10X10 MSA specifications can easily scale to enable low-cost, power-efficient 100Gbps networks scalable from data-center networks to metro networks," he adds. "Having a large ecosystem of component suppliers and network equipment suppliers has enabled service providers to deliver a smart and easy way to expand their networks and deliver the benefits of 100Gbps networking."

"The addition of 10x10-40km to the 10x10 MSA provides a cost-effective solution scalable to 100GbE aggregation and metro applications, and the specified band-WDM option provides a low-cost solution for combining multiple 100GbE traffic in a single fiber," says Rang-Chen Yu, VP of business development at Oplink.

"CyOptics is pleased to work with the 10x10G MSA members to develop low-cost 100 Gigabit Ethernet specifications that now address 100Gbps networking applications up to 40km reach," says Stefan Rochus, CyOptics' VP of marketing & business development. "The 10x10G-40km reach implementation of 10 wavelength channels on a 100GHz DWDM grid allows cost-effective future upgrades to 4x100G or even 8x100G over a single fiber to meet the increasing bandwidth demand in metro networks," he adds. "CyOptics will make the DWDM TOSA and ROSA components commercially available leveraging our in-house laser, detector and silica PLC [photonic lightwave circuit] device technologies, and our automated hybrid integration and packaging platforms."

Other users and developers who are interested in joining the 10X10 MSA can contact MSA members at [info@10x10msa.org](mailto:info@10x10msa.org).

[www.10X10msa.org](http://www.10X10msa.org)

## Oclaro expands board with former Sun exec Peterson

Optical component, module and subsystem maker Oclaro Inc of San Jose, CA, USA has appointed industry veteran Marissa Peterson to its board of directors.

The firm says that Peterson brings substantial management and operational experience, including 17 years at Sun Microsystems, where she was executive VP, worldwide operations, services & customer advocacy in Santa Clara, CA until



her retirement in 2005.

"Marissa's experience with global customer advocacy programs and expertise in supply chain and logistics management will enable Oclaro to better serve its global customer base," says chairman & CEO Alain Couder.

"Oclaro has achieved a tremendous transformation to become a tier-one supplier of innovative optical communications and laser solutions," comments Peterson. "I look forward to working with the company's management team and board of directors to expand its market position, and further strengthen its reputation as a customer-focused, highly efficient industry leader."

[www.oclaro.com](http://www.oclaro.com)

# Emcore quarterly revenue rises 5% to \$49.5m

## Margin to recover after new-product launches

For its fiscal third-quarter 2011 (to end-June), Emcore Corp of Albuquerque, NM, USA, which makes compound semiconductor-based components and subsystems for the fiber-optics and solar power markets, has reported revenue of \$49.5m (up 6% on \$46.6m a year ago and 5% on \$47.2m last quarter). Of total revenue, 72% is from North America, 22% from Far East Asia, and just 5% from Europe.

Fiber Optics revenue was \$33.3m (67% of total revenue, up from 64% last quarter). This is up 11% on \$30m last quarter, due to broadband business being driven by robust demand for cable TV equipment, plus telecom business seeing sales of 40/100Gbps tunable lasers and ITLAs (integrable tunable laser assembly) grow more than 20%. Growth from \$31.5m a year ago was just 6%: revenue from broadband products rose 23% year-on-year, whereas revenue from digital fiber-optics products fell 14%. The latter is due mainly to parallel-optics devices shrinking \$4.9m as a result of the ruling in July 2010 by the US International Trade Commission (ITC) banning Emcore from importing parallel-optical modules (made by contract manufacturer Fabrinet Co Ltd in Thailand) that were found to infringe patents belonging to Avago Technologies.

Photovoltaics revenue was \$16.2m (33% of total revenue, down from 36% last quarter). This is down 6% on \$17.2m last quarter (in line with Space Solar business falling by \$1m) but up 7% on \$15.1m a year ago. In particular, revenue rose 8% year-on-year for space solar cells and covered interconnected cells (CICs) and 67% for service contracts, although revenue fell 28% for long-term space solar panels.

Gross margin has fallen further, from 27.5% a year ago and 22.4% last quarter to 19.1%. This was due to a large drop in Photovoltaics gross margin, from 30.7% a year

ago and 30.2% last quarter to just 18.6% (due partly to higher startup expenses on new products that should improve margins eventually). Fiber Optics gross margin was 19.4%, down on 25.9% a year ago but up from 18% last quarter. In particular, telecom and datacom division is experiencing a shift in product mix as customers move to newer technology platforms. This evolution should boost margins while new products begin to ramp in the latter part of calendar 2011.

As new products move into full production and capacity is increased, there is a rise in startup costs (non-recurring engineering expenses and capital expenses). Although down on \$21.2m a year ago, operating expenses have hence risen from \$14.8m last quarter to \$20.7m. In particular, R&D expenses were \$9.5m (19% of revenue), up on \$8m last quarter (19% of revenue) and \$7.1m (15% of revenue) a year ago. However, excluding litigation settlements, overall operating expenses rose just \$1.9m from \$17.4m last quarter to \$19.2m, due mainly to the higher R&D investment.

Net loss has risen by \$1.9m on a year ago and \$5.9m on last quarter to \$11.1m, including \$0.3m of non-operating expense related to the Suncore Photovoltaic CPV joint venture and \$4m related to the change in legal settlement.

During the quarter, cash, cash equivalents, and restricted cash rose from \$17m to \$21.1m. In May, Emcore completed an equity private placement transaction involving selling 4,407,603 shares of common stock to Shanghai Di Feng Investment Co Ltd, raising \$9.7m. In June, it paid its \$8m remaining capital contribution obligation to the Suncore JV. The firm is not required to contribute further funds in excess of its initial \$12m investment, and does not anticipate contributing any additional funds to Suncore.

During the quarter, order backlog rose by 31% from \$50.5m to \$66.2m. This included \$26.6m for Fiber Optics (up 10% on \$24.1m, driven mainly by higher backlog in Broadband, mostly for cable TV) and \$39.6m for Photovoltaics (up 50% on \$26.4m, due mainly to new contracts, including the Space Systems/Loral contract signed in May). Photovoltaics included Space Photovoltaics order backlog up from \$25m to \$29.6m. "This business will grow over the next couple of quarters," says chief financial officer Mark Weinswig.

For fiscal Q4/2011 (to end September), Emcore expects revenue to grow 3–11% sequentially to \$51–55m. Due to qualification in California of a new Tunable XFP product plus repeated growth of over 20% in 40/100Gbps tunable laser and ITLA sales, Fiber Optics revenue should grow sequentially again (unlike most other firms that are more exposed to the Chinese telecom market, says Hou, since less than 10% of Emcore's revenue comes from China). In particular, targeted Tunable XFP revenue is now \$1m. Emcore's 2–3000 units per quarter run-rate capacity at its San Francisco Bay Area facility in Newark, CA was completed by the end of the June quarter, while capacity at Fabrinet is being built up to 10,000–12,000 units per quarter by the end of September.

Photovoltaics gross margin is expected to improve significantly after completion of last quarter's major shift in Solar product mix (to Emcore's latest, most advanced designs, which led to higher-than-expected material and labor costs and lower overall yield in fiscal Q3). Overall gross margin for the firm should be flat to slightly up.

"This quarter will begin to illustrate our new product line ups and the results of our business strategy and strong execution," reckons Hou.

[www.emcore.com](http://www.emcore.com)



## Semprius wins incentives to build CPV module pilot plant in North Carolina

### State and county incentives worth \$7.88m for 5MW plant, scalable to 35MW

The North Carolina Department of Commerce has announced that Semprius Inc of Durham, NC, USA has received an incentives package worth more than \$7.88m to construct a pilot plant in Henderson, NC to produce its high-efficiency, low-cost high concentration photovoltaic (HCPV) solar modules.

The incentives package includes a State of North Carolina Job Development Investment Grant, and grants from the Golden LEAF Foundation, Vance County, the One North Carolina Fund, and the North Carolina Community College System. The plant should provide jobs for 256 people within five years.

The incentives package follows Semprius securing \$20m last month in its first tranche of Series C venture fundraising led by Siemens Venture Capital. Semprius will use the incentives package and venture funding to construct the pilot HCPV module production plant, beginning later this month.

The first phase of the plant will be 50,000 square feet and employ 60 people. Semprius plans to expand within the next several years to 150,000 square feet, and it will eventually employ 256 people at the plant. The firm will make an \$89.7m capital investment in it, and the plant should draw \$120m in investment to the region, it is reckoned.

"Semprius chose to bring their business to North Carolina because our investments in education and job training ensure they can find the work-ready employees they need," says Governor Bev Perdue.

Semprius' HCPV modules use high-performance glass lenses to focus sunlight onto very small, highly efficient triple-junction gallium arsenide-based microcells (600µm by 600µm in area and less than 10µm thick). The firm's triple-

junction cells have reached a conversion efficiency of 41.7%, as tested by the US National Renewable Energy Laboratory (NREL), according to Semprius' staff development engineer Kanchan Ghosal. Optics concentrates the sunlight 1000 times so that just 0.1% of the module area is covered with the microcells. The microcell's very small size enables use of low-cost optics and electrical interconnects, which remove the heat, eliminating the need for costly thermal management solutions. In addition, Semprius grows its cell structures on top of a release layer so that they can be epitaxially lifted-off as part of its patented micro-transfer printing process, allowing it to reuse the GaAs substrate and hence cut costs dramatically. Semprius also uses an automated manufacturing process, leveraging standard manufacturing equipment and commodity materials, to reduce capital and labor costs.

"Demand for CPV is expected to grow exponentially over the next several years to greater than 6GW by 2020," says president & CEO Joe Carr. "We've designed our modules to be efficient, low-cost and reliable," he adds. "We believe HCPV solar technology is leading us toward achieving grid parity with fossil-based fuels."

The Semprius pilot production plant, which is expected to be operational in August 2012, will have an initial capacity of 5MW and be expandable to 35MW, as needed. The pilot line will be used to scale up and optimize production for Semprius' subsequent large-capacity plants, enabling the firm to capitalize on increasing demand for HCPV systems and offer utility companies and project developers a viable route to grid-parity energy costs.

[www.semprius.com](http://www.semprius.com)

## IN BRIEF

### Emcore's IMM4J solar cells released from final Space Shuttle mission

Emcore Corp of Albuquerque, NM, USA, which makes compound semiconductor-based components and subsystems for the broadband, fiber-optic and solar power markets, says that a pair of its Inverted Metamorphic Module Quadruple-Junction (IMM4J) solar cells carried on a platform were released into low-earth orbit (LEO) from the Space Shuttle Atlantis' cargo bay on 20 July after Atlantis undocked from the International Space Station during its historic final mission.

The IMM4J large-area solar cells, with solar-to-electric conversion efficiencies in excess of 33%, are among the highest-efficiency solar cells ever launched into space, it is claimed. The IMM4J technology, currently under development at Emcore, has also demonstrated a record conversion efficiency in the laboratory of more than 36%, measured under simulated space solar illumination conditions at Emcore.

"On-orbit data from these cells provides an invaluable opportunity for Emcore to assess the performance of our latest solar cell technologies under space flight conditions," says chief operating officer Christopher Larocca.

Emcore claims to be the world's largest manufacturer of highly efficient radiation-hard solar cells for space power applications. With a beginning-of-life (BOL) conversion efficiency of the order of 30% and the option for a patented, onboard monolithic bypass diode, Emcore's multi-junction solar cells can provide the highest available power to interplanetary spacecrafts and earth-orbiting satellites, it adds.

[www.emcore.com](http://www.emcore.com)

## Magnolia demos high-voltage InGaAs QW waveguide cells

### Next phase to focus on lower-cost thin-film structures including CIGS

Magnolia Solar Corp of Woburn, MA and Albany, NY, USA says that its subsidiary Magnolia Solar Inc has demonstrated high-voltage indium gallium arsenide (InGaAs) quantum well waveguide solar cells, a unique structure capable of improving the performance of photovoltaic modules.

Chief technical officer Dr Roger E. Welser presented the latest technical results in 'High-Voltage Quantum Well Waveguide Solar Cells' at the Solar Energy + Technology Conference in San Diego, CA on 21 August as part of a special session of the SPIE Optics + Photonics Symposium focused on 'Next Generation (Nano) Photonic and Cell Technologies for Solar Energy Conversion'. The work has been performed in collaboration with colleagues at the Rensselaer Polytechnic Institute (RPI), Kopin Corp, the College of

Nanoscale Science and Engineering (CNSE), and the New York State Energy Research and Development Authority (NYSERDA).

"The absorption of photons, and the generation of electrical current, is reduced in conventional thin-film solar cell designs. Using a waveguide to help trap scattered light inside the cell can dramatically increase the amount of current that can be generated," says Welser. "In the past, the challenge with implementing waveguide solar cell structures has been maintaining the voltages necessary to achieve high conversion efficiency. In this work, we demonstrated InGaAs quantum well waveguide photovoltaic devices with record-high operating voltages," he adds.

"This is a major milestone for Magnolia Solar, as we continue to make progress towards demonstrat-

ing ultra-high-efficiency thin-film solar cells," comments president & CEO Dr Ashok K. Sood. "The aim of the work summarized in the SPIE conference is to increase both the current and voltage output of single-junction cells by using a quantum-structured active region and incorporating advanced light-trapping strategies. With this patent-pending approach, we are seeking to achieve high solar electric conversion efficiency over a wider range of operating conditions," he adds.

"While our initial work has employed III-V materials, future efforts will also focus on lower-cost thin-film materials such as next-generation copper indium gallium selenide (CIGS) thin-film structures," Sood continues. "We look forward to entering the next phase of development."

[www.magnoliasolar.com](http://www.magnoliasolar.com)

## OPEL Solar International Inc changes name to OPEL Technologies Inc

OPEL Solar International Inc of Toronto, Ontario, Canada has filed Articles of Amendments under the Business Corporation Act (Ontario), dated 25 August, changing its name to OPEL Technologies Inc. There is no consolidation of capital, and no exchange of shares is required.

The firm is also in the process of changing the name of its subsidiary OPEL Inc to OPEL Solar Inc.

Trading on the TSX Venture Exchange under the new name will commence on 29 August. The Stock Symbol 'OPL' will remain the same, but the CUSIP and ISIN numbers have been changed to 683488 10 0 and CA34881006 respectively.

The purpose of the name changes is to better reflect the two distinct segments of the firm's businesses and to avoid confusion caused by

the former name only reflecting the solar side of the business.

"The name change to OPEL Technologies better exemplifies the scope of our expanding company," says OPEL's CEO Leon M. Pierhal.

"The organization has exhibited significant growth and recognition in each of its distinct business divisions, and it is impor-

tant to establish a parent company that captures each group's mission as they gain momentum and growth in the future," he adds.

The company is engaged in: (a) the design, manufacture and marketing of high-concentration photovoltaic panels and dual- and

single-axis trackers for related concentration photovoltaic (CPV) and PV systems for energy applications worldwide (through subsidiary OPEL Solar Inc); and (b) the design of III-V semiconductor devices for military, industrial and commercial applications, including infrared sensor arrays and ultra-low-power random access memory, through US affiliate OPEL Defense Integrated Systems (ODIS Inc) of Shelton, CT, USA.

OPEL Solar Inc also has a Belgium-based subsidiary, OPL Solar Europe SPRL, which addresses business opportunities in Europe. In addition, in December 2010, OPEL Solar Inc formed OPEL Solar Asia (OSA), a joint venture with Ecotech Environmental Technology Ltd based in Hong Kong, in order to service the China market.

[www.opelinc.com](http://www.opelinc.com)

**The purpose of the name changes is to better reflect the two distinct segments of the firm's businesses**

# UC Berkeley and CPV Consortium report on environmental benefits of CPV

## UCB model provides full life-cycle environmental metrics

Concentrator photovoltaic (CPV) solar systems have distinct environmental advantages compared with other energy technologies, in most cases using less land, water and materials than other solar technologies, according to a new report issued by the Renewable and Appropriate Energy Laboratory (RAEL) at University of California, Berkeley and commissioned by the CPV Consortium, a non-profit organization supporting the development of the CPV industry. The report looks at the technology from inception to retirement, taking into consideration all aspects of the life cycle.

The study provides information on the life-cycle assessment (LCA) elements such as energy payback, embedded greenhouse gases, and cradle-to-cradle footprint, whereby CPV systems lead the industry based on data available at the time of the study, it is claimed. Taking into account its increasing efficiencies, it is projected that CPV will

continue to increase in its competitive edge in these areas.

Water and land use are also examined. Compared to solar thermal generators, CPV water usage is minimal, making the technology optimal in dry, desert areas with a high solar resource. The land footprint and impact is also found to be lower; as CPV system efficiencies increase, this will become a greater benefit, it is reckoned.

"We are always looking for technologies to allow us to dramatically increase the amount of energy output per built area in order to minimize the footprint on the ground," says RAEL director Dr Daniel Kammen. "Concentrating solar minimizes overall land area use to a degree that almost nothing can beat," he adds.

"Solar energy is a critical driver of the energy transformation taking place around the world, but as these technologies are deployed it's imperative that we consider the environmental impact of these new

systems," says CPV Consortium board chairman Nancy Hartsoch. "This study demonstrates that CPV technology is not only economically viable, but environmentally advantaged through its entire life-cycle," she adds. "With CPV, we don't need to compromise between economics and the environment."

The report uses life-cycle assessment methodology that includes energy, emissions, water use and land use. It also contains details of CPV deployment using UC Berkeley's SWITCH model (an electric power system capacity expansion model of Western North America that plans long-term grid investments while minimizing the cost of electricity in a given policy context), and emissions benefits of CPV projects in power systems. The SWITCH model demonstrates the economic viability of CPV as a power generation technology for that region.

[www.cpvconsortium.org](http://www.cpvconsortium.org)  
<http://rael.berkeley.edu>

## Amonix signs Thermax as EPC partner in India

Amonix Inc of Seal Beach, CA, USA has agreed an exclusive partnership for Thermax Ltd of Pune, India to be the engineering, procurement and construction (EPC) partner providing its turnkey concentrated photovoltaic (CPV) systems to customers in India.

Amonix's CPV systems incorporate solar cells originally developed for aerospace use. The dual-axis tracking systems use durable optics to focus sunlight onto multi-junction solar cells. As the technology needs no water for power production and uses land more efficiently compared to conventional solar technologies, CPV systems deliver more energy output from a given area at low energy production costs.

"Concentrated PV will be a game changer in solar power generation technologies because of the sub-

stantially high efficiency it offers," comments Thermax's managing director & CEO M.S. Unnikrishnan. "India, with its above-average solar incidence, is an ideal location for CPV technology, and we expect our national solar mission to act as a catalyst for its growth," he adds.

Amonix says its systems can be deployed quickly, at 0.5MW post-pedestal installation per day. They offer 31% module efficiency and 29% system efficiency (much more than competing technologies such as crystalline silicon and thin film).

"Together, we will access the Indian market by enabling developers of solar projects to build projects, supported by world-class technology from Amonix and the strong delivery track record, supply chain and construction experience of Thermax,"

says Amonix CEO & board director Brian Robertson. "This provides us the opportunity and access to the Indian market that is greatly suited for CPV solar power systems."

Amonix says that CPV technology will pave the way to meet the goals of the Indian Government's Solar Mission, which promotes sustainable growth while addressing the country's energy security. It is an integral part of the initiative to respond to the global challenge of climate change. The first phase of the mission aims to commission 1000MW of grid-connected solar power projects by 2013. In addition to helping to meet these targets in the most efficient manner, CPV will introduce a new solar technology to India, adds Amonix.

[www.thermaxindia.com](http://www.thermaxindia.com)

# First Solar raises CdTe PV solar cell efficiency record from 16.7% to 17.3%

## Production-module efficiency of 13.5–14.5% targeted by end 2014

First Solar Inc of Tempe, AZ, USA, which makes thin-film photovoltaic (PV) modules based on cadmium telluride (CdTe) as well as providing engineering, procurement and construction (EPC) services, has set a new record for CdTe solar cell efficiency, reaching 17.3% with a test cell constructed using commercial-scale manufacturing equipment and materials. The test cell's performance, confirmed by the US Department of Energy's National Renewable Energy Lab (NREL), far surpassed the previous record of 16.7% set in 2001.

"This is a significant milestone that demonstrates the ongoing potential of our advanced thin-film technology," says chief technology officer Dave Eaglesham. "This leap

forward in R&D supports our efficiency roadmap for our production modules and will recalibrate industry expectations for the long-term efficiency potential of CdTe technology," he reckons.

"First Solar's innovation in both module technology and balance of systems engineering continues to drive us closer to grid parity," claims CEO Rob Gillette.

The average efficiency of First Solar modules produced in first-quarter 2011 was 11.7%, up from 11.1% a year earlier, and the firm has recorded full-module efficiencies over 13.5%, with a 13.4% module confirmed by NREL. First Solar's module efficiency roadmap sets a goal for production-module efficiencies of 13.5–14.5% by the end of 2014.

First Solar uses a continuous manufacturing process that transforms a sheet of glass into a complete solar module in less than 2.5 hours, contributing to the firm's energy payback time and the low carbon footprint of systems using its PV modules. First Solar has also implemented what is claimed to be the industry's first comprehensive, pre-funded solar module collection and recycling program. Anyone wishing to dispose of modules can request collection at any time, at no additional cost, and the firm will pick up the modules and recycle up to 90% (by mass) of the material for use in new products, including new solar modules and new glass products.

[www.firstsolar.com](http://www.firstsolar.com)

## Germany's ABEL ReTec signs long-term deal to buy Abound Solar's CdTe PV modules

Cadmium telluride (CdTe) thin-film photovoltaic (PV) solar module maker Abound Solar Inc of Loveland, CO, USA has agreed to a long-term purchase agreement with ABEL ReTec GmbH of Engelsberg, Germany, a developer of turnkey renewable energy projects with experience in the technical planning and development of large-scale solar installations and MegaWatt-scale bio-gas plants. The agreement has been initiated with the sale of 1.2MW of AB1-series modules (shipped in second-quarter 2011).

ABEL ReTec forms one of three core businesses of the 100-year-old company Abel Group. Since 2002, Abel has specialized in developing, installing and operating photovoltaic and bio-gas projects. The firm offers project development services, including financial consulting, engineering and

assembly of turnkey systems and full operations management.

"After having successfully tested Abound Solar modules on rooftop installations, we selected Abound Solar for a long-term module supply agreement to gain a strong partner for developing solar projects," says ABEL ReTec's Roland Huber.

"Abound Solar's cadmium telluride modules are our first choice for free field installations; they provide outstanding performance and enable us to deliver reliable solutions at low cost," he adds.

The agreement is the most recent in a series of customer and partner milestones for Abound, which earlier this year announced 5.4MW of projects with juwi solar in Jatzke, Germany, and a partnership with Solar Integration Systems India Pvt Ltd (Solarsis) of Hyderabad, giving it entry into India's fast-growing

solar market. In December, the firm announced a \$400m loan guarantee from the US Department of Energy, as well as a \$110m round of equity investment to expand manufacturing capacity. Plans are currently underway to construct the largest photovoltaic module manufacturing plant in the USA in the state of Indiana.

"This deal demonstrates Abound Solar's continued ability to sell solar modules in a highly competitive market, such as Germany, and builds on our track record in expanding our exports and adding jobs," comments Abound's CEO Tom Tiller. "As Abound Solar continues to sign contracts with top-tier customers and as our modules continue to be used in large-scale projects, we can reaffirm our status as an emerging global player."

[www.abound.com](http://www.abound.com)

[www.abel-retec.de](http://www.abel-retec.de)

# First Solar dedicates Mesa factory site

First Solar Inc of Tempe, AZ, USA, which makes thin-film photovoltaic (PV) modules based on cadmium telluride (CdTe) as well as providing engineering, procurement and construction (EPC) services, has dedicated its factory site in Mesa, AZ.

The firm also announced that Todd Spangler has been appointed site director & general manager of the Mesa factory, having previously served as general manager of First Solar's factory in Perrysburg, OH. Mike Koralewski will succeed Spangler as manager of the Perrysburg facility, and was appointed VP of site operations & plant manager.

Representatives from the city of Mesa and First Solar officials hosted a reception at Chandler-Gilbert Community College in Mesa to celebrate construction progress. Vice mayor Scott Somers, Greater Phoenix Economic Council (GPEC) president & CEO Barry Broome, and Tom Alston, Solar Outreach and Policy Coordinator for US Representative Gabrielle Giffords, also took part.

"First Solar coming to Mesa is an important step to establish Arizona as a major player in the solar and clean energy industry. This cutting-edge facility brings hundreds of new high-tech jobs to the East Valley and adds to the ongoing development of the Gateway area," said mayor Scott Smith. "Projects like this don't happen without the cooperation between the private and public sectors, region and state. I'd like to thank those partners, especially First Solar and DMB, for working together to bring this facility to the Mesa Proving Grounds," he added.

"Our Mesa factory has progressed from an idea to advanced construction in just a few short months, which would not have been possible without the support and hard work of countless state and local officials. Today we dedicate this site to the many people and agencies that helped make it happen, both



**First Solar's CEO Rob Gillette and Mesa's vice mayor Scott Somers unveil a ceremonial marker commemorating construction progress for the new factory, while Barry Broome, president & CEO of the Greater Phoenix Economic Council, looks on.**

public and private," commented First Solar's CEO Rob Gillette. "The US is our fastest-growing market, and the additional production capacity from this factory will help us meet growing demand for clean, locally produced solar electricity."

The Mesa factory is expected to begin producing modules by third-quarter 2012 and will employ about 600 full-time associates. First Solar is investing just over \$300m in the four-line factory, which will produce about 250MW of thin-film modules per year.

Output is expected to be used in the construction of First Solar's

2600MW North American project pipeline, which includes the 290MW Agua Caliente project in Yuma County, AZ.

**The Mesa factory is expected to begin producing modules by third-quarter 2012 and will employ about 600 full-time associates. First Solar is investing just over \$300m**

When fully operational in 2014, Agua Caliente will generate enough energy to serve the needs of about 100,000 average homes per year, displacing about 220,000 metric tons of carbon dioxide (the equivalent of taking about 40,000 cars off the road). Output from the Mesa factory is also expected to be used in First Solar's California projects, including the 550MW Topaz project, 230MW Antelope Valley Solar Ranch One, and the 550MW Desert Sunlight project.

Todd Spangler joined First Solar in February 2007 as director of manufacturing. In December 2008, he was promoted to plant manager of the Perrysburg campus. Prior to joining First Solar, he managed multiple plants and distribution centers for lighting controls firm Lutron Electronics.

Mike Koralewski has been with First Solar since August 2006, leading global quality and product reliability initiatives. Prior to First Solar, he was employed by Dana Corp for 10 years in quality functions throughout different business units.

[www.firstsolar.com](http://www.firstsolar.com)

## First Solar sells 10MW PV plant in Spain to KGAL

First Solar Inc of Tempe, AZ, USA, which makes thin-film photovoltaic (PV) modules based on cadmium telluride (CdTe) as well as providing engineering, procurement and construction (EPC) services, has sold a 9.9MW (DC) solar power plant near Zamora, Spain to European Solar Power Fund — a renewable energy-focused fund for institutional investors managed by KGAL GmbH & Co KG of Grünwald, Germany.

Currently under construction by Gehrlicher Solar España S.L. (the Spanish branch of German-based PV project developer and system integrator Gehrlicher Solar AG) with an expected completion in December, the 37.6 hectare solar farm will produce an estimated 15,000 megawatt hours (MWh) of electricity annually (equivalent to the needs of about 3400 Spanish households and CO<sub>2</sub> savings of about 5600 metric tons/year).

“The total capacity of solar farms owned and operated by KGAL’s

investment funds now exceeds 200MW,” says KGAL’s managing director Dr Klaus Wolf.

The solar farm is located in Peregruela in the province of Zamora, Spain, about 250km northwest of Madrid. The Zamora area is one of the sunniest in Europe, with about 1700 kWh/m<sup>2</sup> of sunlight a year.

“Based on our long-term experience and the high potential of the Spanish PV market, we look forward to installing many more PV systems in this region as well as in the rest of the world,” comments Gehrlicher Solar España’s CEO Guillermo Barea Herranz.

As with other large, ground-mounted solar farms such as the 53MW Lieberose solar farm in Germany and the 26.3MW Badajoz solar farm in Spain, First Solar helped to organize third-party financing in addition to supplying solar modules — in this case, 122,000 FS Series 3 thin-film modules.

“Large-scale projects are essential to greenhouse-gas reductions and driving economies of scale that make us more competitive with fossil fuels,” says Peer Guenzel, managing director of First Solar’s Utility Systems business group in Europe, the Middle East and Africa. “We are pleased to be able to continue to enable a market for large-scale solar power plants in Spain.”

The long-term financing for the Zamora project was structured by HSH Nordbank AG. “We have been active in the renewable energy sector for several years now,” notes Jürgen H. Lange, head of energy at HSH Nordbank. “Knowing the international network, the financial and technical developments, and specific regional requirements for solar projects, we were able to structure the Zamora transaction in a way that satisfied the needs of all parties,” he adds.

[www.kgal.de](http://www.kgal.de)

[www.firstsolar.com](http://www.firstsolar.com)

## NRG acquires 290MW Agua Caliente solar project from First Solar

NRG Energy Inc of Princeton, NJ, USA has completed its acquisition of the 290MW Agua Caliente solar project from First Solar Inc of Tempe, AZ, USA, which makes thin-film photovoltaic (PV) modules based on cadmium telluride (CdTe) as well as providing engineering, procurement and construction (EPC) services. The acquisition was contingent upon the financial closing of the project’s loan guarantee of up to \$967m from the US Department of Energy’s Loan Programs Office (announced last December).

Situated in Yuma County on 2400 acres of land between Yuma and Phoenix in Arizona, Agua Caliente is the world’s largest solar photovoltaic project currently under construction. The project has obtained all permits and approvals from both federal and state agencies, and is expected to cre-

ate up to 400 construction jobs through its completion date in 2014.

“Agua Caliente demonstrates the extraordinary progress the US has made to achieving energy independence through public-private collaboration and technological innovation,” says Tom Doyle, CEO of NRG subsidiary NRG Solar LLC. “Construction of the Agua Caliente system will create hundreds of new jobs in local communities, supporting economic growth alongside environmental sustainability. The sheer scale of the project will also help drive developments needed to deploy even larger and more efficient clean-energy resources in the future,” he adds.

“Agua Caliente is a major milestone for utility-scale solar,” reckons Frank De Rosa, First Solar’s senior VP of

North American project development. “We are pleased to continue working with NRG in adding significant renewable generation resources to the US electrical grid, delivering both economic and environmental benefits,” he adds.

Electricity from Agua Caliente will be sold under a 25-year power purchase agreement with Pacific Gas and Electric Co, helping California to meet its renewable energy goals.

At full capacity, the electricity generated by Agua Caliente will be enough to serve more than 225,000 homes. The project is expected to offset approximately 5.5 million metric tons of CO<sub>2</sub> over 25 years (equivalent to taking more than 40,000 cars off the road annually).

[www.nrgsolarenergy.com](http://www.nrgsolarenergy.com)

[www.firstsolar.com](http://www.firstsolar.com)

# First Solar's Q2 sales fall 6% to \$533m

## Full-year 2011 guidance cut again to \$3.6–3.7bn, up 42% on 2010

For second-quarter 2011, First Solar Inc of Tempe, AZ, USA, which manufactures thin-film photovoltaic modules based on cadmium telluride (CdTe) as well as providing engineering, procurement and construction (EPC) services, has reported revenue of \$533m.

This is down 6% on first-quarter 2011's \$567.3m, due mainly to lower average selling prices (ASPs) as solar photovoltaic policy uncertainties in Italy, Germany and France adversely impacted demand. It is also down 9.3% on \$588m a year ago, due mainly to lower ASPs and a drop in revenue recognized by the systems business, partially offset by higher module volume.

Net income was \$61.1m (\$0.70 per diluted share), down from \$116m (\$1.33 per diluted share) in Q1 (driven mainly by lower ASPs and a higher tax rate, partially offset by higher volume sold) and \$159m (\$1.84 per diluted share) a

year ago (driven by lower ASPs and increased investment in the Utilities Systems Business and R&D).

Nevertheless, during the quarter, cash and cash equivalents rose slightly, from \$355.7m to \$357.5m.

"First Solar continued to execute in the quarter despite a challenging European market, and our 2011 outlook remains solid due to our differentiated and resilient business model," says CEO Rob Gillette. "We expect stronger performance in the second half of 2011 as we build projects from our systems pipeline, develop promising new markets, execute our cost-reduction roadmaps, and continue to improve module efficiencies," he adds.

In late February, First Solar reduced the top end of its guidance for net sales in 2011 from the \$3.7–3.9bn forecast of mid-December to \$3.7–3.8bn (up 46% on 2010's \$2,564m). It has now reduced this again, to \$3.6–3.7bn (up 42%).

After increasing its guidance for operating income from \$875–975m to \$910–980m in February then in May cutting it back to \$900–970m, First Solar has now cut this again, to \$900–960m.

Also, guidance for earnings per fully diluted share was originally raised from \$8.75–9.50 to \$9.25–9.75 (including \$60–70m of manufacturing start-up expenses and \$15–20m of factory ramp costs). This has now been cut back to \$9.00–9.50 (including just \$35–40m of manufacturing start-up expenses and \$8–10m of factory ramp costs).

Finally, the mid-December forecast for total capital spending of \$1–1.1bn has been cut to \$800–900m. Also, after guidance for operating cash flow was cut from mid-December's \$1.0–1.1bn to May's \$0.8–1bn, it has been cut again, to \$500–600m.

[www.firstsolar.com](http://www.firstsolar.com)

## CdTe PV panel maker First Solar to supply Sempra's 150MW Nevada plant expansion for PG&E

Pacific Gas and Electric Company of San Francisco, CA, USA (a subsidiary of PG&E Corp) and Sempra Generation (a subsidiary of San Diego-based Sempra Energy) have entered into a 25-year contract for 150MW of renewable power from an expansion of Sempra Generation's Copper Mountain Solar complex in Boulder City, NV.

First Solar Inc of Tempe, AZ, USA will provide the ground-mounted cadmium telluride (CdTe) thin-film photovoltaic (PV) panels and serve as the engineering, procurement and construction (EPC) contractor for the project.

Construction on the 1100-acre solar plant should begin in early 2012. The first 92MW of panels at Copper Mountain Solar 2 should be installed by January 2013, with the

remaining 58MW due for completion by 2015. Under the terms of the contract, PG&E has the option to accelerate the commercial operation date of the second phase. When fully developed, Copper Mountain Solar 2 will produce enough electricity to power about 45,000 homes.

Copper Mountain Solar 2 is a step in Sempra's plan to construct 1000MW of additional renewable capacity by 2015, says its president & CEO Jeffrey W. Martin. The plant is Sempra's third and largest solar project in Nevada, and will supply power to California consumers. The power supply contract between PG&E and Sempra is subject to approval by the California Public Utilities Commission.

"The combination of First Solar's

advanced thin-film PV modules with our industry-leading EPC capabilities enables us to rapidly deploy utility-scale solutions like Copper Mountain Solar 2, bringing down the cost of renewable energy," says Jim Lamon, First Solar's senior VP of EPC, operations & maintenance.

Sempra Generation and First Solar have previously teamed-up on the construction of two other large-scale solar projects in Nevada, including Copper Mountain Solar 1. The 48MW installation was completed in late 2010 and is currently the largest photovoltaic solar power plant in the USA. PG&E is currently delivering the power produced at the plant to its customers.

[www.firstsolar.com](http://www.firstsolar.com)

[www.semprageneration.com](http://www.semprageneration.com)

[www.pge.com](http://www.pge.com)

# High-performance 150nm mHEMT on GaAs grown using MOCVD

**Highest  $f_T$  value for 150nm device sets stage for potential high-volume production.**

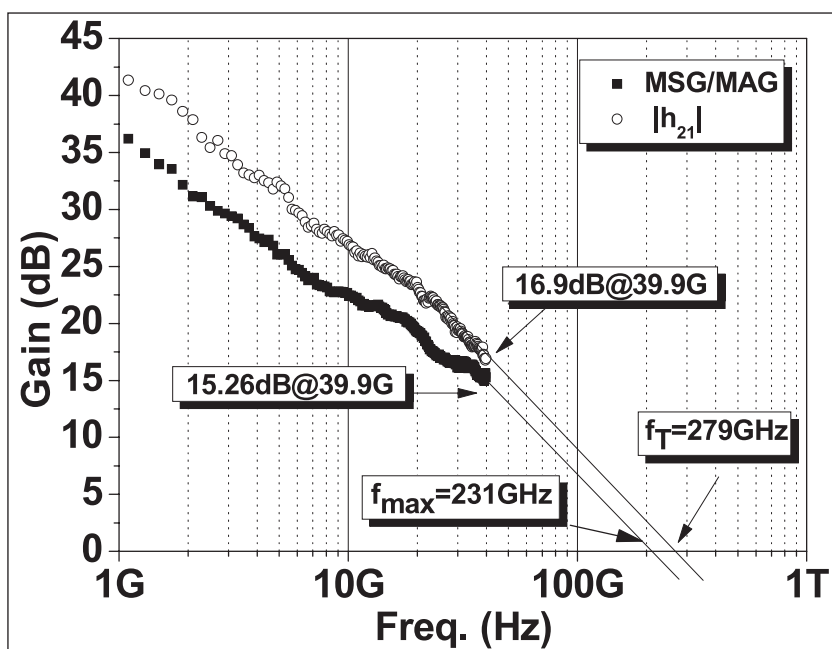
**R**esearchers at Hong Kong University of Science and Technology (HKUST) have produced high-performance metamorphic high-electron-mobility transistors (mHEMT) with indium aluminum arsenide (InAlAs) barriers and indium gallium arsenide (InGaAs) channels using GaAs substrates and metal-organic chemical vapor deposition (MOCVD) [Haiou Li et al, IEEE Electron Device Letters, published online 22 July 2011].

InAlAs/InGaAs pseudomorphic HEMT devices on indium phosphide (InP) substrates have achieved cut-off frequencies ( $f_T$ ) of more than 562GHz. Unfortunately, InP substrates remain expensive, in part due to the downturn in the photonic industry after 2000. Hence, it is attractive to explore other ways to produce such high-performance devices, preferably using MOCVD and GaAs substrates.

The HKUST device has unity current-gain cut-off ( $f_T$ ) and maximum oscillation ( $f_{max}$ ) frequencies of 279GHz and 231GHz, respectively (Figure 1). This is comparable to the work of others with InGaAs/InAlAs devices grown with molecular beam epitaxy (MBE) on GaAs or InP (Table 1). The HKUST researchers note that their device has the highest  $f_T$  yet reported for 150nm gate-length HEMTs.

The researchers add: "We believe that these results are the best reported for MOCVD-grown mHEMTs and sufficient for high-frequency high-speed applications. With the anticipated demand of commercial high-speed and high-performance transistors, mHEMT technology by MOCVD is very attractive for manufacturing".

Up to now, metamorphic (i.e. low strain) InAlAs/InGaAs devices on GaAs substrates have been mainly grown using MBE, a



**Figure 1. Current gain and MSG/MAG as functions of frequency for HKUST 150nm mHEMT.**

technique not favored in manufacturing. MOCVD meta-morphic growth has tended to lag behind these developments.

A particular challenge is reducing threading dislocation densities that arise from lattice mismatch (4% between GaAs and InP) and thermal expansion coeffi-

**Table 1. Comparison of AlInAs/GaInAs HEMTs performance. The HKUST device is given in the last row.**

Substrate	Growth	Mobility cm <sup>2</sup> /V-s	L <sub>g</sub> nm	G <sub>m</sub> mS/mm	f <sub>T</sub> GHz	f <sub>max</sub> GHz	Date
GaAs	MBE	N/A	100	750	154	300	2004
GaAs	MBE	N/A	100	890	189	334	2004
GaAs	MBE	9100	150	740	150	240	2003
InP	MBE	8800	150	800	151	172	2008
GaAs	MBE	7850	100	700	210	N/A	2005
<b>GaAs</b>	<b>MOCVD</b>	<b>8740</b>	<b>150</b>	<b>1074</b>	<b>279</b>	<b>231</b>	<b>2010</b>



cient differences. This is usually handled using a series of buffer layers to bridge the differences in lattice parameters. However, these layers can be less resistive than desired due to unintended impurities, leading to leakage currents in the buffer. These leakage currents hinder the achievement of 'pinch-off'.

The HKUST reports: "We have developed a growth technique of a comparatively thin multi-stage buffer to obtain high resistivity in the buffer layer, leading to good device performance. This sets the stage for potential high-volume production of mHEMTs by MOCVD."

The researchers plan to further reduce buffer leakage by optimizing the buffer layer growth in future.

The  $f_T$  value was derived from short-circuit current gain ( $|h_{21}|$ ) extrapolation, and de-embedding structures were used to subtract the effect of parasitic capacitance of the probe pads. The  $f_{max}$  value came from extrapolation of maximum stable gain and maximum available gain (MSG/MAG) measurements.

The optimum bias position was determined to be at gate ( $V_{GS}$ ) and drain ( $V_{DS}$ ) potentials of  $-0.6V$  and  $1.0V$ , respectively (Figure 2).

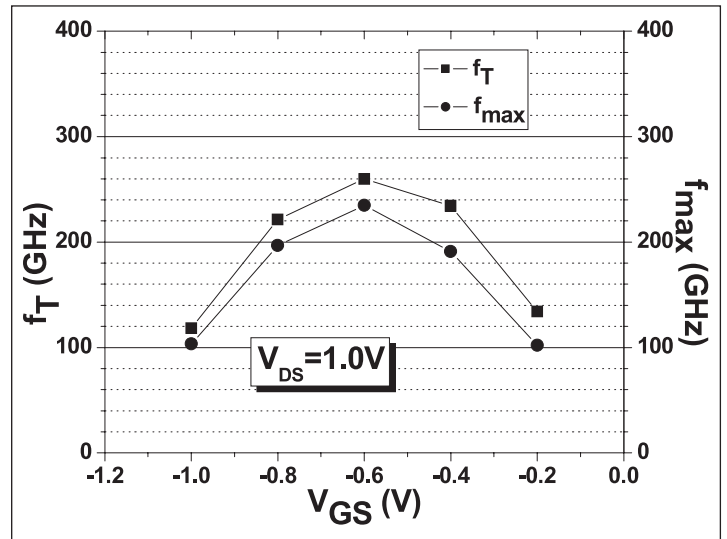
The epitaxial material for the HEMTs (Figure 3) was grown using MOCVD on semi-insulating (SI) 4-inch (001) GaAs substrates. The resulting structure (with cap layer removed for Hall measurements) showed a room-temperature electron concentration in the two-dimensional electron gas (2DEG), which creates the channel, of  $4.6 \times 10^{12}/cm^2$  and mobility of  $8740 cm^2/V\cdot s$ . These values result in a sheet resistance of  $156 \Omega/sq$ . Some  $60^\circ$  threading dislocations were observed in the buffer layers.

The devices were made with mesa isolation. The ohmic source/drain contacts consisted of a non-alloyed 6-metal system of nickel-germanium-gold-germanium-nickel-gold with transmission-line method measurements giving contact resistances down to  $0.02 \Omega\cdot mm$ . The low resistance value is attributed to "higher doping concentration of cap layer and optimization of ohmic contact metal systems".

The 150nm T-gate was created using two-stage electron-beam lithography and etch processes on layers of silicon dioxide and silicon nitride deposited using plasma-enhanced chemical vapor deposition. The Schottky gate metal structure on the AlInAs barrier consisted of titanium-platinum-gold.

The device works in depletion-mode (normally-on) with a threshold voltage  $V_{th}$  of about  $-0.8V$ . There was some variation in threshold between mHEMT devices in the range from  $-1.0V$  to  $-0.8V$ . The researchers attribute this to surface roughness, which has a root-mean-square value of more than  $2.9nm$  across a scan area of  $20\mu m \times 20\mu m$ . It is hoped in future to optimize the growth of the HEMT material to reduce this.

The maximum drain current of the device was



**Figure 2. Dependencies of  $f_T$  and  $f_{max}$  on gate bias for 150nm mHEMTs, where  $V_{DS}$  is fixed at 1.0V.**

1130mA/mm at a gate potential ( $V_{GS}$ ) of  $0.4V$  and a drain bias ( $V_{DS}$ ) of  $1.5V$ . The maximum extrinsic transconductance was found to be  $1074 mS/mm$  at  $V_{GS}$  of  $-0.25V$  and  $V_{DS}$  of  $1.0V$ . ■

<http://dx.doi.org/10.1109/LED.2011.2159824>

Author: Mike Cooke

Cap	Ga <sub>0.47</sub> In <sub>0.53</sub> As	15nm
Schottky contact	Al <sub>0.49</sub> In <sub>0.51</sub> As	25nm
Delta-doping	Silicon	
Spacer	Al <sub>0.49</sub> In <sub>0.51</sub> As	5nm
Channel	Ga <sub>0.47</sub> In <sub>0.53</sub> As	25nm
Buffer 4	HT- Al <sub>0.49</sub> In <sub>0.51</sub> As	100nm
Buffer 3	LT- Al <sub>0.49</sub> In <sub>0.51</sub> As	200nm
Buffer 2	LT-InP:C	100nm
Buffer 1	HT-InP	650nm
Nucleation	LT-InP	110nm
Substrate	SI (001) GaAs	

**Figure 3. Epitaxial metamorphic HEMT structure.**

# Kyoto University makes record current-gain SiC BJTs

Surface recombination and deep-level reduction more than doubles performance of silicon carbide bipolar junction transistors.

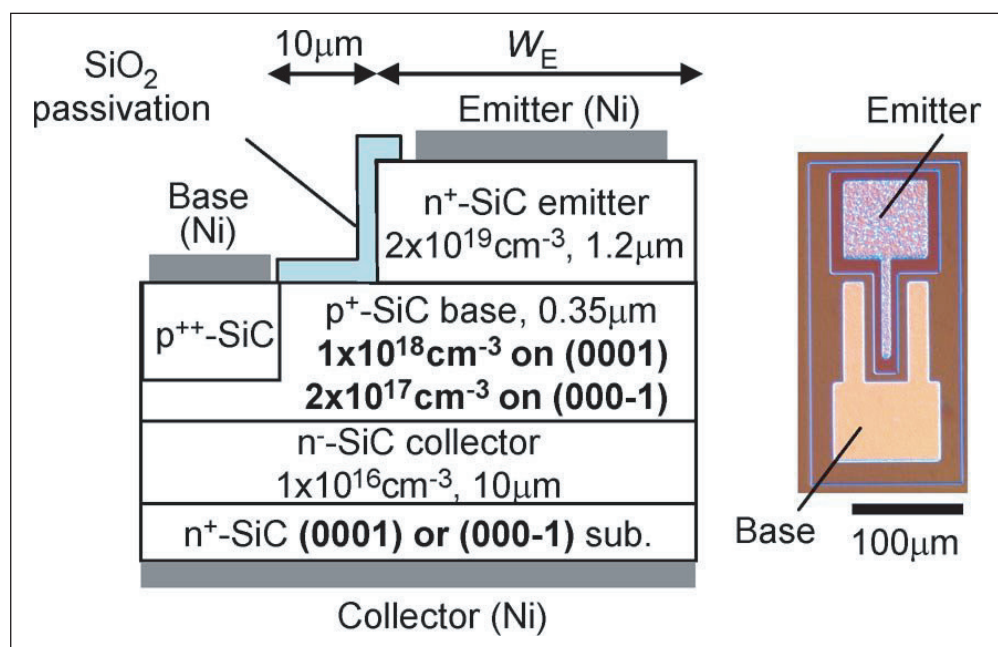
**K**yoto University has produced silicon carbide (SiC) bipolar junction transistors (BJTs) with record current gains that have more than doubled previous achievements using the 4H polytype crystal structure [Hiroki Miyake et al, IEEE Electron Device Letters, published online 7 June 2011]. By reversing the polarity of the structure (0001) to give a carbon face, the scientists created a device with a gain of 335, which is the highest value for BJTs built using any SiC polytype. Using the traditional Si-face (0001), the gain of 257 was almost double the previous best for 4H-SiC of 134.

The Kyoto researchers are developing the devices with power applications in mind, where high breakdown voltages and low on-resistance can be achieved. Also, BJTs do not suffer from the gate oxide reliability issues of MOSFETs resulting from high-temperature operation.

To improve the device performance, Kyoto focused on reducing surface recombination currents on the emitter mesa sidewall and increasing carrier lifetimes in the p-SiC base region of the BJT by reducing the number of deep levels in the material. Deep levels encourage the recombination of carriers through the Shockley-Read-Hall mechanism.

Two types of BJT were grown on n-type 4H-SiC substrates oriented with (0001) Si face and (000 $\bar{1}$ ) C face using chemical vapor deposition (Figure 1). The surface was mis-oriented by 8° in the [11 $\bar{2}$ 0] direction. Such mis-orientation is frequently used to improve growth quality since the effect of mis-cutting the surface is to create a series of steps for new material to attach to as deposition proceeds. Mis-cutting has also been found to affect surface recombination at mesa sidewalls.

The p-type base layer was achieved using aluminium doping, while the n-type emitter layers were created using nitrogen doping. The heavily p-type base contact



**Figure 1. Schematic cross section of a fabricated 4H-SiC BJT and optical image of a fabricated single-finger BJT.**

was formed using aluminium ion implantation at 500°C to create an Al concentration of  $3 \times 10^{20}/\text{cm}^3$ .

Two 1150°C thermal oxidation processes were carried out before and after the annealing process for the base contact activation (1800°C for 10 minutes). To get the same oxide thickness required 5 hours on the (0001) devices and only 15 minutes on the (000 $\bar{1}$ ) devices.

The purpose of the oxidation process is to reduce the major deep levels often labeled as Z1/2 and EH6/7, associated by some researchers with such defects as Si/C di-vacancies and carbon vacancies that form charge traps.

Although the oxidation treatment does reduce these levels, it generates the HK0 center/level that is also seen with carbon tetrafluoride (CF<sub>4</sub>) reactive ion etch (RIE). However, the HK0 center/level anneals out at 1550°C, so the activation process removes it, but then reintroduces Z1/2 and EH6/7 levels, giving the need for the second oxidation.

Surface levels were handled with a passivation process that involved a nitrided oxide deposition using a 10% dilute nitric oxide (NO) treatment at 1300°C for 30 minutes.

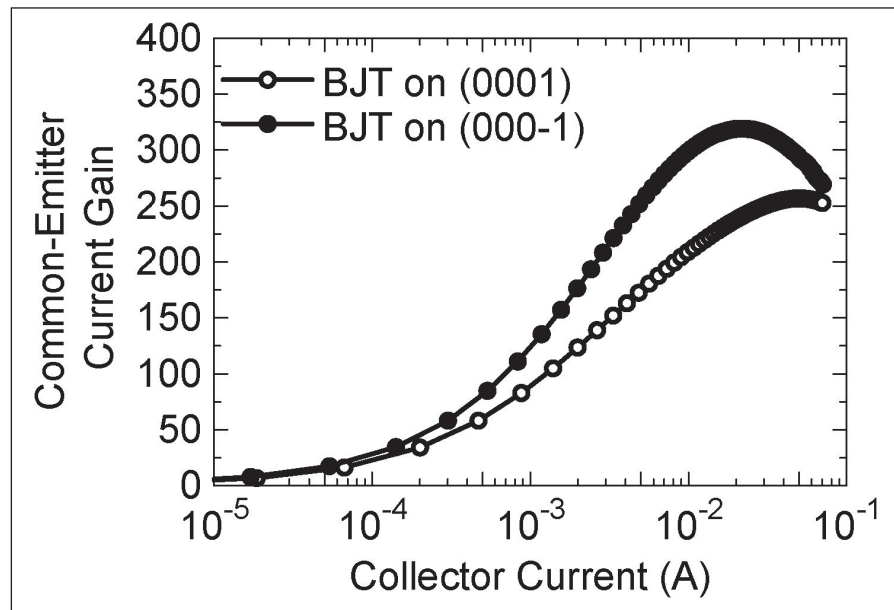
▶ The single emitter finger contact was 100 $\mu\text{m}$  long, deposited in different crystal directions with  $\{11\bar{2}0\}$  or  $\{1\bar{1}00\}$  sidewalls to vary the effect of surface recombination. Emitter-base contact separation was 10 $\mu\text{m}$ .

For the achievement of a high current gain of 257 with a Si (0001) face structure,  $\{1\bar{1}00\}$  sidewalls, and 20 $\mu\text{m}$  finger width, it was found to be important to grow the heterostructure in a continuous process in a single reactor. A comparison device with the base and emitter layers grown in separate runs had a current gain of around 80.

Since the Kyoto heterostructure is almost the same as that of these previous devices, the researchers "assume that not only continuous growth but also well-optimized surface passivation combined with an intentional deep-level-reduction process described in this letter contributed to such high current gains."

Wider fingers with  $\{1\bar{1}00\}$  sidewalls have higher current gain due to reduced surface recombination compared with  $\{11\bar{2}0\}$  sidewalls (242 gain). The improvement for wider fingers saturates at widths beyond 20 $\mu\text{m}$ .

The BJTs on C(000 $\bar{1}$ ) face substrates demonstrate the even higher gains of 335, which the researchers say is the highest value ever reported for SiC BJTs (Figure 2). The peak occurs for a lower collector current because the doping concentration of the base



**Figure 2.** Current gains as function of collector current for BJTs with 20 $\mu\text{m}$ -wide fingers and  $\{1\bar{1}00\}$  sidewalls fabricated on (0001) and (000 $\bar{1}$ ).

layer for the C(000 $\bar{1}$ ) face device is a factor of five smaller than that for the Si(0001) face BJTs.

The researchers comment: "It should be noted that we applied the surface passivation process and DLR-process optimized for SiC (0001); thus, there is still room for improvement in the fabrication processes. However, the operation of C-face BJTs with such high current gain described in this letter indicates the future possibility of C-face BJTs." ■

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# Si implant enhances AlN spacer HEMT drain current

Japanese researchers achieve maximum current density of 1.3A/mm “competitive with other reported values for AlGa<sub>N</sub>/AlN/GaN HEMTs”.

Researchers in Japan have improved the performance of nitride high-electron-mobility transistors (HEMTs) with aluminum nitride (AlN) spacers by using silicon (Si) implanted source–drain regions [Takuma Nanjo et al, *Jpn. J. Appl. Phys.*, vol50, p064101, 2011].

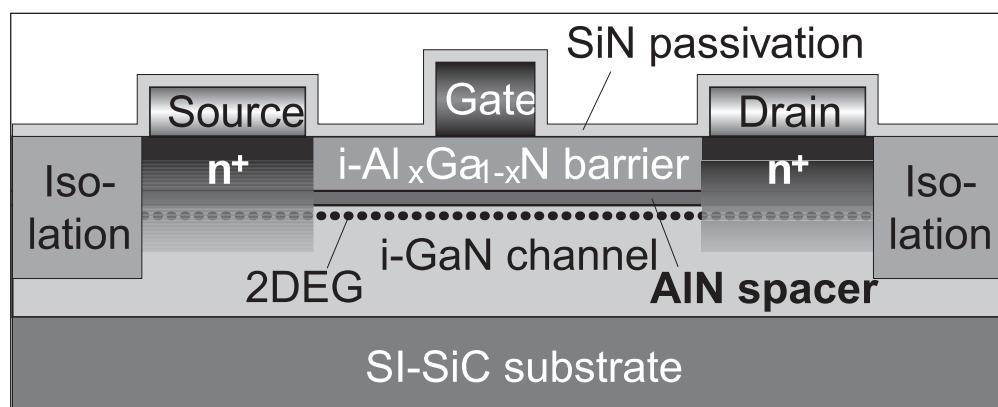
AlN spacers placed between the gallium nitride (GaN) buffer and aluminum gallium nitride (AlGa<sub>N</sub>) barrier layers significantly increase the conductivity of the two-dimensional electron gas (2DEG) that is used as the channel in nitride HEMTs. However, AlN is usually highly insulating and thus makes the channel difficult to access through the source–drain regions.

The researchers from Mitsubishi Electric Corp and Okayama Prefectural University used Si implantation to reduce the source–drain contact resistance. They comment: “We showed a remarkable enhancement in the drain current density, which is a result of the successful combination of the use of an AlN spacer in the structure design and that of Si ion implantation doping in the process design.”

The epitaxial structures with layers of GaN buffer, AlN spacer and AlGa<sub>N</sub> barrier (Figure 1) were grown on silicon carbide (SiC) substrates using MOCVD. The thickness of the buffer was 2μm, the barrier 19nm, and the spacer 1nm. Devices with 20nm barrier and no spacer were also grown for comparison purposes. Two AlGa<sub>N</sub> barriers were tested with Al contents of 20% or 25%.

The source–drain regions were formed using 50keV <sup>28</sup>Si ion implantation with a dose concentration of 10<sup>15</sup>/cm<sup>2</sup>, followed by a rapid thermal anneal in nitrogen for 5 min at 1150°C. During these processes, the wafer was covered with silicon nitride (SiN), deposited using plasma-enhanced chemical vapor deposition (PECVD). The source–drain electrodes consisted of titanium-aluminum that was annealed for 2 minutes at 600°C.

Isolation regions were then formed using a multi-stage zinc ion implant, followed by applying the nickel-gold Schottky gate electrode. The final SiN passivation layer was applied using catalytic chemical vapor deposition.



**Figure 1. Schematic cross-sectional structure of AlGa<sub>N</sub>/AlN/GaN HEMT fabricated employing Si ion implantation doping.**

Hall and transmission-line method (TLM) measurements were made to extract the characteristics of the 2DEG and ohmic contacts, respectively (Figure 2).

As expected, the insertion of the AlN spacer increases 2DEG carrier concentration and mobility with a 20% Al barrier. In fact, the carrier concentration is equivalent to that of a 25% Al barrier without spacer. In both cases, the increased amounts of carriers are attributed to polarization effects resulting from growing high-aluminum-content layers on the GaN buffer.

Increased Al-content of the barrier, however, reduces mobility due to alloy scattering and interface roughness effects. Insertion of the AlN spacer is effective at ameliorating alloy scattering effects in the 2DEG.

Without implanted source–drain regions, the AlN spacer yields non-ohmic contacts due to the increased potential barrier from the very wide energy bandgap of the material (~6eV). Implantation of Si created comparable ohmic behavior for all epitaxial structures, and reduced contact resistance for material without AlN spacers.

Apart from silicon being a donor of electrons in nitride semiconductors, another effect of implantation — destruction of the layer structure with indistinct boundaries being produced — was seen under scanning electron microscopy (SEM). The structure alteration of mixing the AlN with the surrounding GaN and AlGa<sub>N</sub> layers is thought to reduce the potential barrier.

The researchers comment: “Because this mixed layer structure might almost be the same as the no-spacer structure with Si ion implantation doping, similar

excellent ohmic characteristics, as mentioned before, could be obtained in spite of the AlN spacer layer insertion."

In terms of the Schottky gate, it is found that, while the reversed-bias performances were similar across the devices, the AlN spacer reduced forward currents

substantially. The reduced forward current was attributed to an increased band discontinuity at the heterointerface due to polarization effects. The gate leakage in the devices without AlN spacer increased significantly above gate voltages of +3V.

The HEMTs that were tested had gate length and width of 1 $\mu$ m and 50 $\mu$ m, respectively. The gate-source and gate-drain distances were 1 $\mu$ m and 2 $\mu$ m.

The devices with AlN spacer and high-Al-content barriers had lower threshold voltages (i.e. more negative). The measured and intrinsic (i.e. minus contact resistance effects) transconductances were similar (Table 1).

This is taken as an indication by the researchers that the saturation velocity of the 2DEG is not improved by the AlN spacer.

However, the transconductance is high over a wider region with an AlN spacer, and there is a tail into the region with gate voltages above +3V (Figure 3). Also, the maximum drain current at a gate voltage of +4V was 25–30% greater than without an AlN spacer. The researchers comment: "The obtained maximum drain current density was 1.3A/mm, which is sufficiently competitive with other reported values for AlGaN/AlN/GaN HEMTs. It should be noted that we could not have obtained these favorable results had the Si ion implantation doping not been employed in the fabrication of the HEMTs."

Breakdown performance was not affected by the AlN spacer — all devices tested at a gate voltage of -5V had increasing drain current

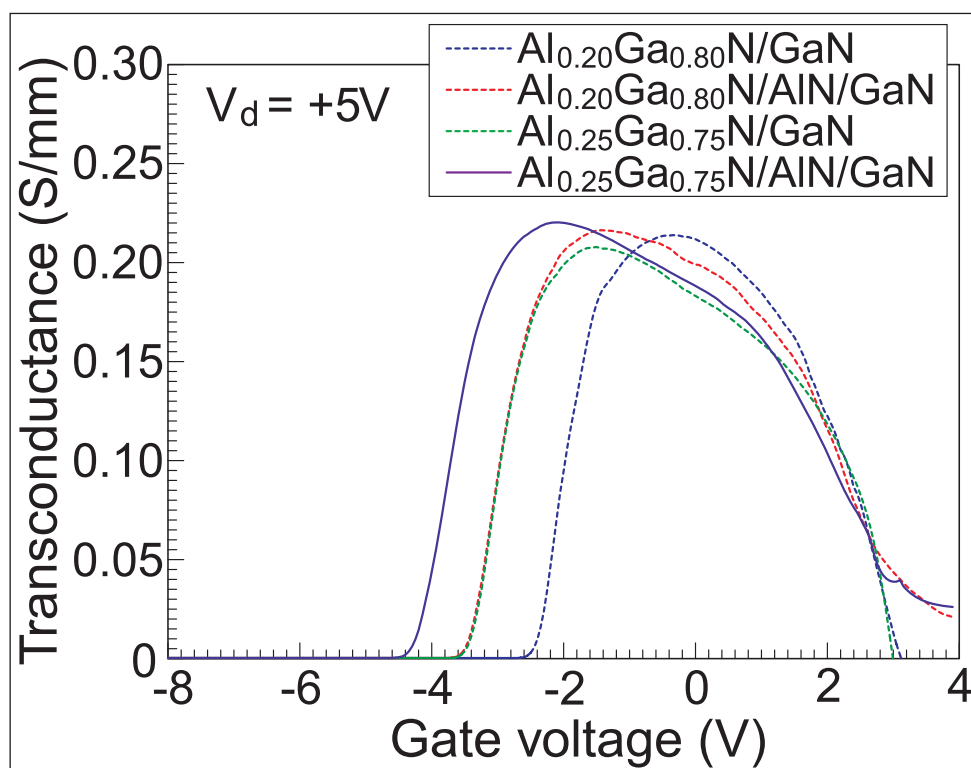
Structure	Al content (x)	0.2	0.2	0.25	0.25
	AlN spacer (nm)	0	1	0	1
Hall	Sheet carrier concentration (/cm <sup>2</sup> )	6.6x10 <sup>12</sup>	8.9x10 <sup>12</sup>	9.1x10 <sup>12</sup>	1.1x10 <sup>13</sup>
	Mobility (cm <sup>2</sup> /V-s)	1686	1946	1546	1828
	Epitaxial sheet resistance ( $\Omega$ /sq)	558	357	443	306
TLM	Epitaxial contact resistance ( $\Omega$ -cm <sup>2</sup> )	5.9x10 <sup>4</sup>	Non-ohmic	7.0x10 <sup>4</sup>	Non-ohmic
	Implanted contact resistance ( $\Omega$ -cm <sup>2</sup> )	1.4x10 <sup>6</sup>	1.1x10 <sup>6</sup>	1.7x10 <sup>6</sup>	2.4x10 <sup>6</sup>
	Implanted sheet resistance ( $\Omega$ /sq)	215	251	251	269
HEMT	Source resistance ( $\Omega$ -mm)	0.95	0.77	0.90	0.83
	Measured maximum transconductance (S/mm)	0.21	0.22	0.21	0.22
	Intrinsic maximum transconductance (S/mm)	0.27	0.26	0.26	0.27

**Figure 2. Hall characteristics, ohmic characteristics and transconductance of four samples.**

(more than the gate current) beyond 50V drain bias, and breakdown occurred at about 150V. "We consider that these breakdowns occurred as a result of the relatively large amount of residual impurities in the deep-channel-layer region or buffer layer in all of present four epitaxial wafers, which are not associated with the AlN spacer layer and Si ion implanted region." All the devices also demonstrated similar current collapse effects in both DC and pulsed operation. ■

<http://jjap.jsap.jp/link?JJAP/50/064101>

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**Figure 3. Gate voltage dependences of transconductance at drain voltage of +5V for the four HEMTs fabricated with Si ion implantation doping.**

# Quaternary nitride HEMT with record cut-off frequency

University of Notre Dame and epiwafer maker Kopin have produced an InAlGaN/AlN/GaN transistor with an  $f_T$  cut-off frequency of 220GHz.

University of Notre Dame and epiwafer supplier Kopin Corp of Taunton, MA, USA are claiming a record current-gain cut-off frequency ( $f_T$ ) of 220GHz for a nitride semiconductor high-electron-mobility transistor (HEMT) with quaternary indium aluminum gallium nitride (InAlGaN) barrier layer [Ronghua Wang et al, IEEE Electron Device Letters, published online 27 June 2011].

Nitride HEMTs normally use an AlGaN barrier, but recent work has suggested that lattice-matched InAlN with ~17% In can improve DC and radio frequency (RF) performance. However, the mobility of the electrons in the two-dimensional electron gas (2DEG) that forms the channel at the barrier/GaN buffer interface can be low. The 2DEG is used as the source of channel carriers in nitride HEMTs.

The problem of low mobility seems to stem from the tendency of the InN and AlN components of the InAlN alloy to separate (immiscibility) during crystal formation. This leads to increased interface roughness arising from microscopic variations in the strain field of the material. In turn, the interface roughness creates increased scattering of carriers and hence reduces mobility (~1600cm<sup>2</sup>/V-s for InAlN/AlN/GaN, as opposed to ~1800–1900cm<sup>2</sup>/V-s for AlN/GaN). Predictions suggest that InAlGaN has a narrower immiscibility gap than InAlN, and lattice-matched In<sub>0.16</sub>Al<sub>0.74</sub>Ga<sub>0.01</sub>N/AlN/GaN has achieved mobility of more than 1700cm<sup>2</sup>/V-s.

In addition to the depletion-mode (normally-on) HEMT that was demonstrated, the Notre Dame/Kopin researchers see possibilities for quaternary use in ultraviolet light-emitting diodes and enhancement-mode (normally-off) HEMTs, arising from the greater freedom to adjust the strain and bandgap energy. On the negative side, quaternary growth is more complicated and it is presumably less easy to control crystal quality.

Kopin grew the epitaxial structure (Figure 1) on a silicon carbide substrate using metal-organic chemical vapor deposition (MOCVD). The InAlGaN barrier was in tension in comparison to the GaN lattice structure. Mesa isolation was achieved using a chlorine-based reactive ion etch. Ohmic contacts consisted of silicon-titanium-aluminum-nickel-gold, annealed at 860°C in

In <sub>0.13</sub> Al <sub>0.83</sub> Ga <sub>0.04</sub> N	Barrier	10.3nm
AlN	Spacer	1nm
GaN	Channel	55nm
GaN	Semi-insulating buffer	1.8μm
SiC	Substrate	

**Figure 1. Schematic epitaxial structure, as determined using high-resolution x-ray diffraction and transmission electron microscopy, and secondary-ion mass spectroscopy.**

nitrogen. The contact resistance was measured through transmission-line method (TLM) structures at 0.36Ω-mm. Non-recessed rectangular gates consisted of nickel-gold. The physical dimensions of the HEMT were 1.6μm source-drain distance, with a source-gate distance of 300nm. The gate length was 66nm, and the width was 2μm x 50μm.

A dielectric-free passivation process was used, consisting of oxygen plasma treatment. The passivation reduced the sheet resistance from 227Ω/sq to 190Ω/sq, with an increase in carrier sheet concentration from 1.5x10<sup>13</sup>/cm<sup>2</sup> to 1.8x10<sup>13</sup>/cm<sup>2</sup>. The passivation did decrease the mobility somewhat from 1900cm<sup>2</sup>/V-s to 1790cm<sup>2</sup>/V-s, attributed to enhanced scattering resulting from the higher carrier sheet concentration. "These mobilities are both among the highest reported, leading to the lowest sheet resistance in InN-containing HEMT structures."

The mobility in these quaternary InAlGaN structures was some 38% higher than that for InAlN devices created by the same group. The achievement is credited to reduced interface roughness and alloy scattering effects.

The maximum drain current with a 6V drain bias was 2.1A/mm (Figure 2a), measured at a gate potential of 3V. The threshold voltage was -4.8V. The maximum extrinsic transconductance was 548mS/mm, corresponding to an intrinsic value of 710mS/mm (i.e.

subtracting the effect of source resistance). The researchers are investigating the reason for the small second peak in the transconductance curve shown in Figure 2a. A similar second peak has also been seen in InAlN/GaN HEMTs.

The drain-induced barrier lowering (DIBL) of 260mV/V was determined by comparing the gate potentials needed to give a drain current of 10mA/mm with drain biases of 6V and 0.1V (i.e. 100mV). This is a high value, showing the presence of unwanted 'strong' short-channel effects. The on/off current ratio was  $\sim 10^5$ . The researchers comment: "To suppress the observed short-channel effects, use of back barriers and thinner top barriers is needed."

Radio frequency measurements were performed in the range 250MHz–60GHz. The peak current gain cut-off frequency ( $f_T$ ) condition was achieved at 4.7V drain and -3.7V gate biases. The measured cut-off was 220GHz, with maximum oscillation frequency ( $f_{MAX}$ ) of 60GHz (153/54GHz, respectively, without de-embedding). The relatively low  $f_{MAX}$  was blamed on the use of a resistive rectangular gate.

The researchers comment: "To the best of our knowledge,  $f_T = 220$ GHz reported in this letter is the highest achieved in quaternary barrier GaN-based HEMTs to date and is also among the highest reported in all GaN-based HEMTs. Accordingly, a high  $f_T \times L_g$  product of 14.5GHz- $\mu$ m was achieved for a gate-length:barrier-thickness aspect ratio of 5.8."

Kopin claims that it is "the world's dominant provider of GaAs (gallium arsenide) heterojunction bipolar transistor (HBT) wafers with a dominant share of the worldwide merchant market". It produces a variety of structures using AlGaAs, InGaP and even GaAsInN compound semiconductor material.

The Notre Dame/Kopin work was supported by US Defense Advanced Research Projects Agency (DARPA), US Air Force Office of Scientific Research, and US Air Force Research Laboratory/Missile Defense Agency. ■

<http://dx.doi.org/10.1109/LED.2011.2158288>

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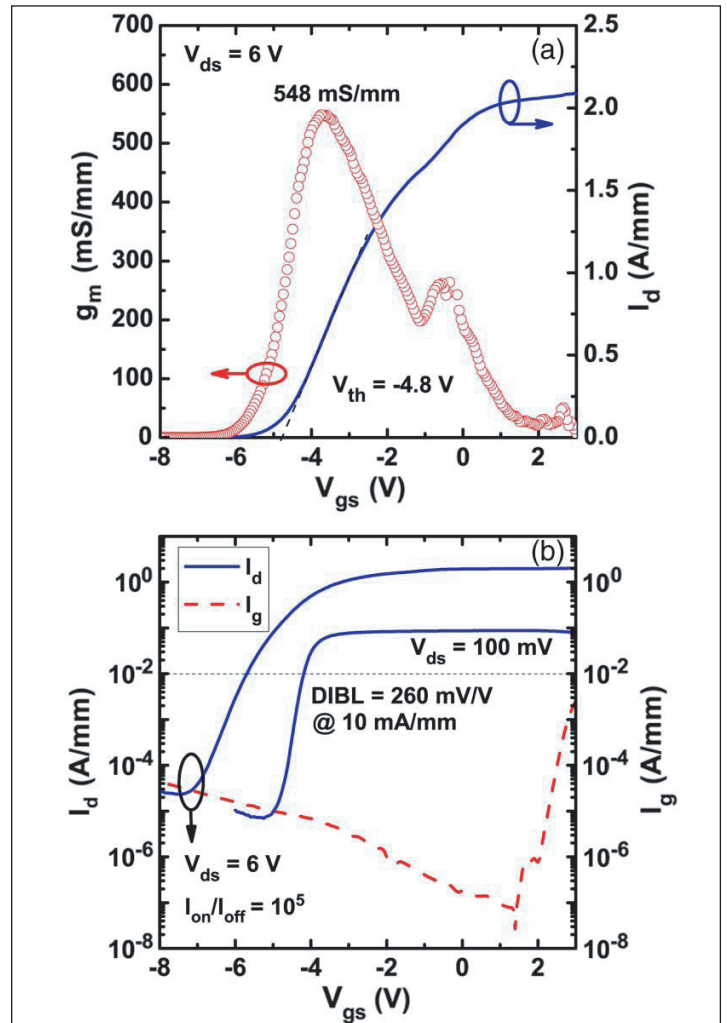


Figure 2. Transfer characteristics of the device measured drain voltages of 6V and 100mV (0.1V), in (a) linear scale and (b) semi-log scale.

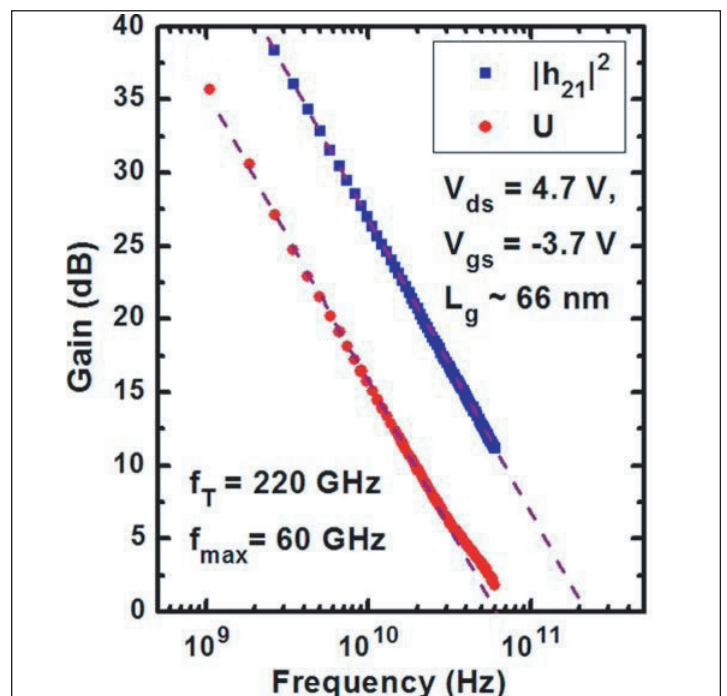


Figure 3. Current gain and unilateral gain of the device, showing  $f_T/f_{MAX} = 220/60$ GHz.

# High electron velocity for high HEMT frequencies

HRL/UCSD use aggressive lateral scaling to achieve record  $f_T/f_{max}$  frequencies of 260GHz/394GHz for nitride HEMTs.

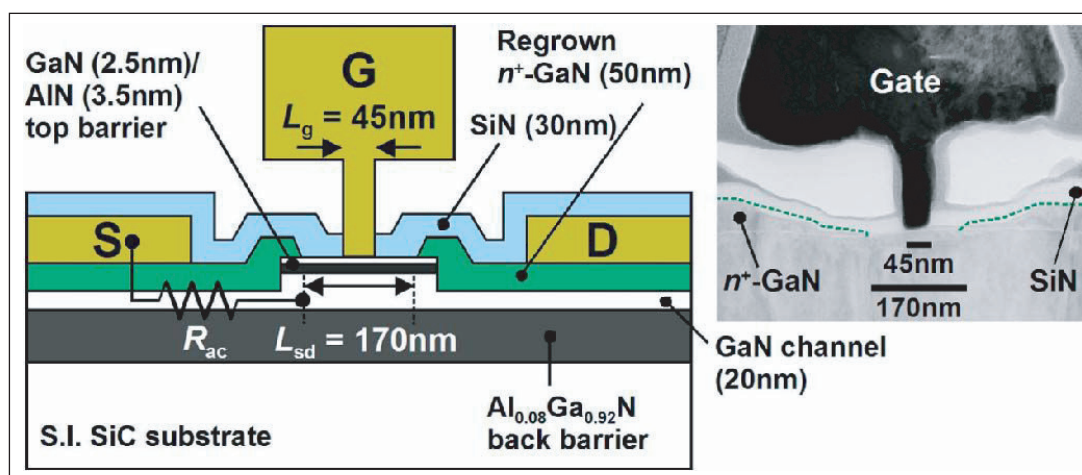
**H**RL Laboratories and University of California San Diego (UCSD) have reported a record cut-off/maximum oscillation frequency ( $f_T/f_{MAX}$ ) combination of 260GHz/394GHz for a nitride semiconductor high-electron-mobility transistor (HEMT) [K. Shinohara et al, IEEE Electron Device Letters, published online 27 June 2011].

The researchers believe that the high-frequency performance benefits from an increasing electron velocity with drain voltage (estimated from delay time-analysis as being at least +24% between 1V and 5V drain bias, and increasing the transconductance 22% from 926mS/mm to 1130mS/mm) "observed here for the first time in a GaN HEMT" due to a combination of aggressive lateral scaling and drain delay suppression. In particular, the source-drain distance was reduced, cutting the drain delay.

In previous HEMT devices, the electron velocity had been limited to less than  $1.1 \times 10^7$  cm/s, while the theoretical peak expected is more than  $2 \times 10^7$  cm/s.

The new HRL/UCSD device has a 'double heterostructure' (DH-HEMT) with a top and back barrier for the channel (Figure 1). The epitaxial structure was grown on three-inch semi-insulating silicon carbide substrates, using molecular beam epitaxy (MBE). The top barrier was designed to be thin (6nm), while maintaining a high carrier density two-dimensional electron gas (2DEG) and low gate leakage. The back barrier increased carrier confinement and suppressed the effects of having a short gate length (short-channel effects).

A sacrificial silicon nitride (SiN) passivation layer, applied using plasma-enhanced chemical vapor deposition (PECVD), boosted the performance of the 2DEG to a carrier density of  $1.3 \times 10^{13}$ /cm<sup>2</sup> and mobility of  $1140$ cm<sup>2</sup>/V-s.



**Figure 1. Cross-sectional schematic and TEM image of a laterally scaled 45nm AlN/GaN/Al<sub>0.08</sub>Ga<sub>0.92</sub>N DH-HEMT with re-grown n<sup>+</sup>-GaN ohmic contact.**

The SiN was patterned over the gate region to provide a mask for a chlorine-based reactive ion etch (RIE) designed to cut down through the GaN/AlN top barrier and 10nm of the GaN channel layer for the ohmic contacts that were re-grown as silicon-doped n<sup>+</sup>-type GaN, again using MBE. The n<sup>+</sup>-GaN overlapped 0.4μm onto the top barrier layers.

The SiN layer was then removed and non-alloyed titanium-platinum deposited as ohmic source-drain electrodes. Transmission-line method measurements gave a total contact resistance between the ohmic metal and 2DEG channel of 0.1Ω-mm.

A mesa-isolation chlorine-based RIE was followed by a new 30nm layer of PECVD SiN passivation. A 45nm gate foot was patterned and etched on the SiN using carbon tetrafluoride inductively coupled-plasma RIE. The gate metal consisted of platinum-gold. The source-drain distance was 170nm, as defined by the edges of the two regions of re-grown n<sup>+</sup>-GaN. The gate width was 2μm x 40μm.

The on-resistance was a record low value of 0.44Ω-mm and the maximum output current was 'high' at 2.3A/mm. Three-terminal OFF-state breakdown for a source-drain current of 1mA/mm was 13.1V corresponding to an average field of 2.1MV/cm, falling short of the material breakdown field of ~3MV/cm, attributed 'possibly' to field non-uniformity.

The frequency performance was tested over the



range 0.5–65GHz (Figure 2). Parasitic pad capacitance and inductances were de-embedded from the measurements. The peak cut-off and maximum oscillation frequencies were obtained from suitable extrapolations as 260GHz and 394GHz, respectively, at a drain voltage of 5V and a gate potential of  $-0.25V$ . The 'extrinsic' values, without de-embedding, were 217GHz and 389GHz, respectively.

The RF and DC intrinsic peak transconductances ( $g_m$ ) were consistent at 1060mS/mm and 1130mS/mm, respectively. The peak extrinsic DC transconductance was 905mS/mm.

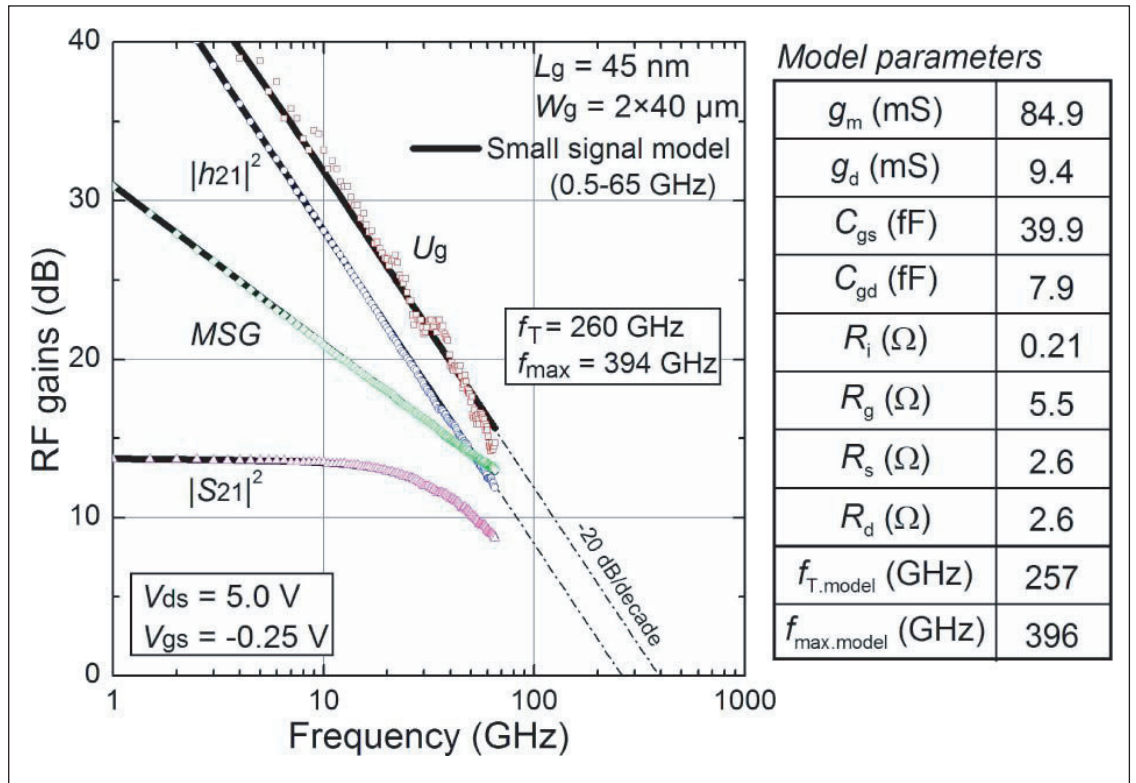
Funding for the work came from the US Defense Advanced Research Projects Agency (DARPA) Microsystems Technology Office (MTO) Nitride Electronic NeXt-Generation Technology (NEXT) program. ■

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**Figure 2. RF characteristics (0.5–65GHz) of DH-HEMT. Thick solid lines represent simulated RF gains using a small-signal equivalent circuit model with extracted parameters in table.**

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# Hot electrons in nitride semiconductors

**UCSB demonstrates the first hot-electron transistor in the III-nitride system, promising faster operation through near-ballistic transport.**

University of California Santa Barbara (UCSB) has reported on its first demonstration of hot-electron transistors (HETs) built with the aluminium gallium nitride material system [Sansaptak Dasgupta et al, IEEE Electron Device Letters published online 5 July 2011]

Although nitride bipolar transistors have been made, the difficulties of producing p-type regions and poor conduction properties of holes limit the performance of such devices. The hot-electron transistor is unipolar and can be built based on just n-type electron conduction.

Preliminary simulations on AlGaN/GaN/AlGaN HETs have suggested that up to terahertz performance might be possible eventually. Further motivation for constructing such devices is as a spectroscopic tool for analyzing high-field and high-carrier-velocity effects for devices such as nitride semiconductor high-electron-mobility transistors (HEMTs). Nitride HEMTs are being widely developed for radio-frequency amplification and power switching applications.

In an HET (Figure 1a), electrons are injected over a barrier into a transit region and then collected. Since the electrons that enter the transit region have higher energy than the Fermi level of the transit region, they are labeled 'hot'. The injection, transit and collection regions are labeled 'emitter', 'base' and 'collector', in line with bipolar transistor terminology.

The potential operating speeds of such devices are

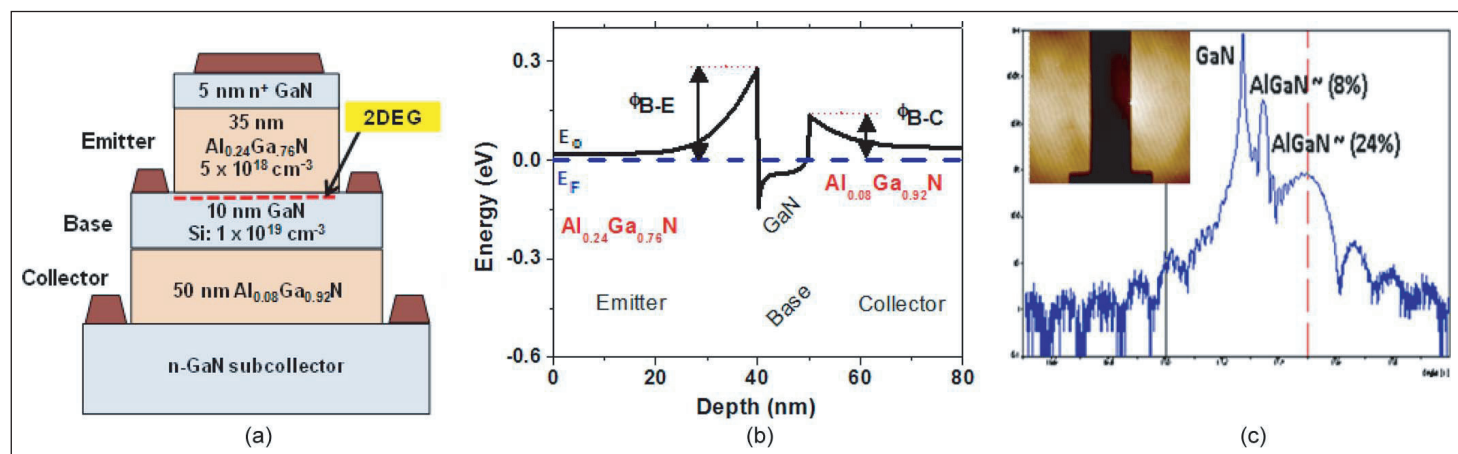
high. Unlike in bipolar transistors with various n- and p-type regions, where the main current flow across the base is through minority carriers, the HET is a unipolar structure that uses majority electron carriers. In nitrides, producing the n-type regions with silicon doping is much easier than p-type with magnesium doping, and velocities for electrons are much higher than those for holes.

The use of majority electron carriers thus reduces the resistance of the base region. If the base is also made very thin, one can arrange for the transit to be made quickly or 'near-ballistic', avoiding elastic and inelastic collisions (e.g. with phonons, lattice defects, ionized doping impurities, etc).

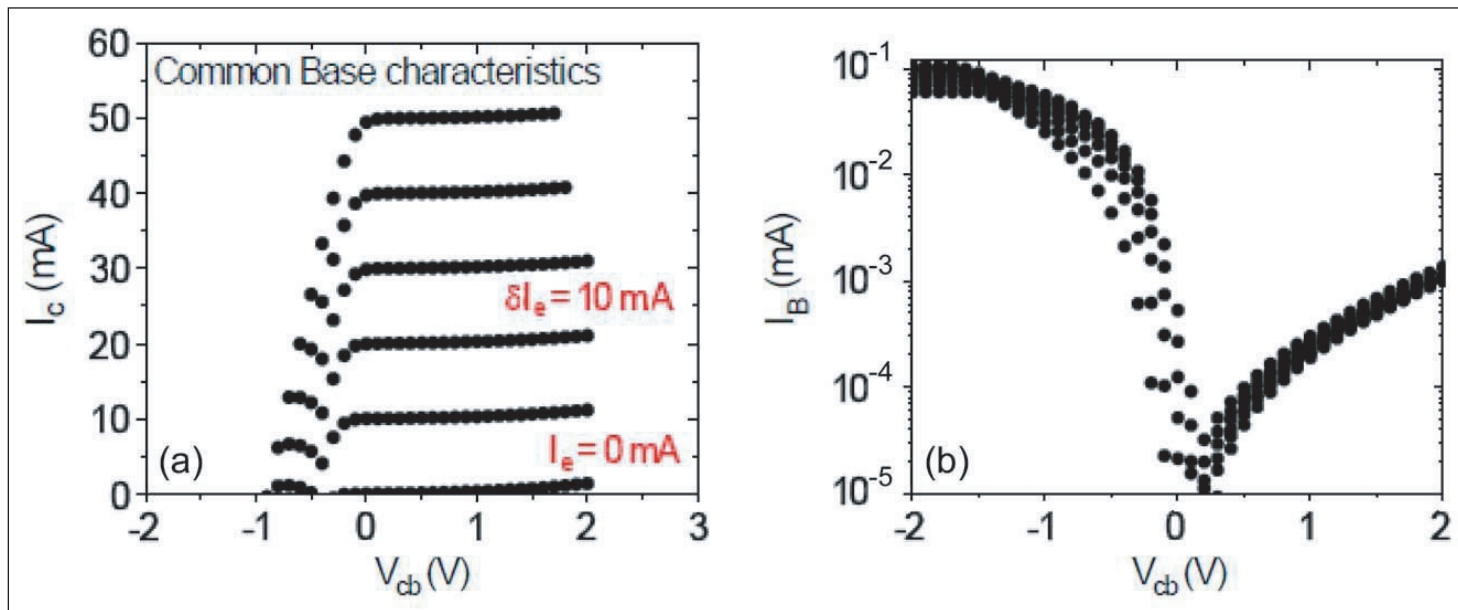
A low base resistance reduces RC delays for charging the base-emitter capacitance, creating the conditions for high cut-off and maximum oscillation frequencies ( $f_T/f_{MAX}$ ).

Nitride semiconductors are particularly attractive for HETs, since large band discontinuities can be formed between the various regions of the device, creating higher injection energies and hence carrier velocities through the base.

The polarization-induced two-dimensional electron gas (2DEG) that forms at AlGaN/GaN junctions also reduces the sheet resistance component of the base resistance. A further advantage is that the separation of the lowest valley from the others in the conduction band structure is much larger for nitrides than for the



**Figure 1. (a) Device structure and (b) band diagram of fabricated HET. (c) High-resolution x-ray diffraction (HRXRD) scan for accurate thickness calibration; and (inset) atomic force micrograph (AFM) after emitter etch.**



**Figure 2 (a) Common base characteristics of III-nitride HET. (b) Base current vs collector voltage during common base measurement.**

arsenide system (GaN  $\sim 1.3\text{eV}$ , GaAs  $\sim 0.3\text{eV}$ ). This allows a wider range of injection energies before intervalley scattering events can occur.

Possible drawbacks are that nitrides have large scattering rates (reducing ballistic transport in the base) and a high longitudinal optical phonon energy of  $\sim 92\text{meV}$ .

The UCSB researchers used commercial c-plane (0001) GaN templates from Lumilog as substrates for molecular beam epitaxy (MBE) growth at  $710^\circ\text{C}$ . Silicon doping was used to achieve n-type conduction in the emitter and base. The HET fabrication (Figure 1) began with a reactive-ion etch with a bromine tetrachloride/chlorine mix performed at low power to ensure smooth surfaces down to the base. The device mesa down to the collector was then etched, and non-alloyed ohmic aluminum/gold applied for the emitter, base and collector contacts.

Base-emitter current-voltage characteristics were measured to confirm the thermionic nature of the injection over the barrier, as opposed to tunneling. Temperature-dependent (300–650K) measurements confirmed the dominance of thermionic emission. Base-collector characterization was also performed.

The common base transfer ratio of collector/emitter currents ( $\alpha = I_c/I_e$ ) for collector-base voltages ( $V_{CB}$ ) greater than 0.5V were in the range 0.97–0.98, corresponding to a current gain ( $\beta = \alpha/(1 - \alpha)$ ) of 30–45.

Complete pinch-off was achieved for increased reverse bias  $V_{CB}$ : with the given device's equilibrium B-E barrier of 0.27eV (the B-C barrier was 0.13eV), the  $V_{CB}$  value for near-zero collector current was around  $-0.3\text{V}$ . With higher barriers, the electrons are reflected back from the collector interface and exit through the base contact (Figure 2).

For positive  $V_{CB}$  the base current is limited to an extremely low value of  $10\mu\text{A}$ . The fact that the base current remains low is taken as an indication of near-ballistic transport from emitter to collector. Significant scattering would drop the electrons in the base to the Fermi level, below the base-collector barrier, increasing the base current.

Some preliminary spectroscopic measurements were also made using the device that showed peaks of Maxwellian shape in conductance measurements that reflect the electron energy distribution at the base-emitter interface.

"From conductance measurements, we find that the distribution remains similar after the electrons cross the base and get collected at the collector," comments the lead author of the paper, Sansaptak Dasgupta. "This is a signature of the near-ballistic transport. However exactly how many electrons are ballistic depends critically on matching the injection energy ( $V_{EB}$ ) with the collection energy ( $V_{CB}$ )," he adds.

"That is tough for these devices, where the emitter series resistance was high," Dasgupta continues. "In subsequent devices, we have lowered the emitter contact and series resistances, and thus can get a true indication of  $V_{EB}$  as we inject the electrons," he adds. "However, that would be the subject of a different paper."

The researchers also report that they have also produced devices with higher B-C barriers to reduce leakage currents, enabling efficient common emitter operation that will be reported on in the future.

The work was partially funded by the US Office of Naval Research (ONR). ■

<http://dx.doi.org/10.1109/LED.2011.2158980>

Author: Mike Cooke

# Blocking stacking faults with aluminium nitride

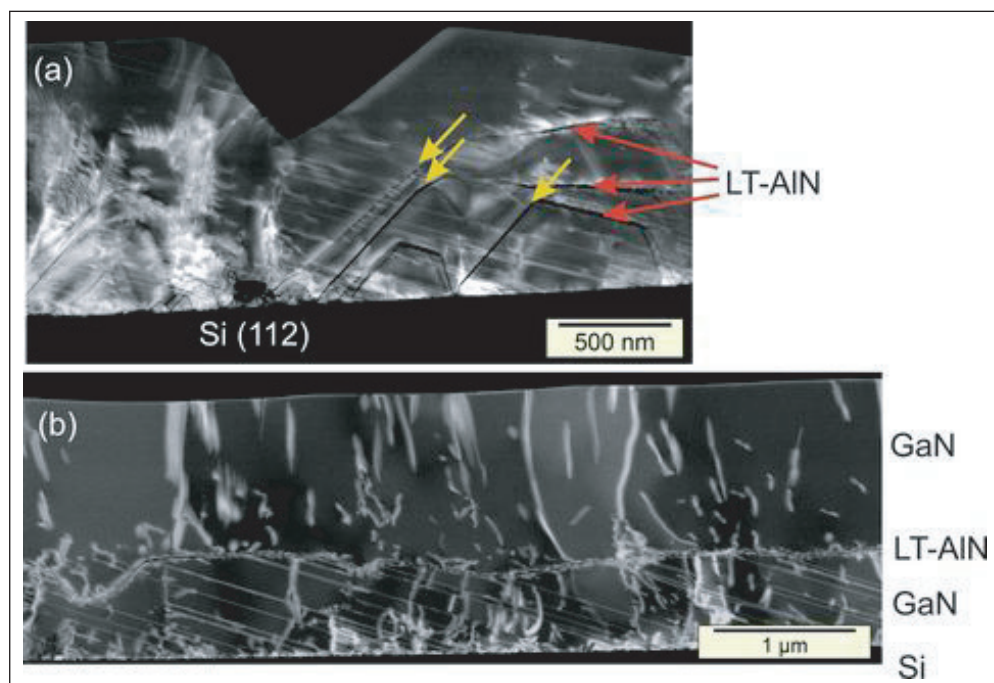
German researchers investigate prospects for semi-/non-polar nitride semiconductor devices on lower-cost heterosubstrates.

**R**esearchers at Otto-von-Guericke-Universität (OVGU) Magdeburg, Germany have been investigating the effect of aluminium nitride (AlN) layers for reducing stacking faults in semi-/non-polar gallium nitride (GaN) crystal structures [A. Dadgar et al, *App. Phys. Lett.*, vol99, p021905, 2011]. The researchers believe that their method "enables low-cost virtually stacking-fault-free semi-polar GaN layers on heterosubstrates and an interesting route for polarization-free long-wavelength LEDs."

Stacking faults are a roadblock to improved green and longer-wavelength light emission in nitride semiconductor material grown on lower-cost substrates. Semi-/non-polar oriented crystal structures can reduce or eliminate polarization electric fields that pull electrons and holes apart. This 'quantum-confined Stark effect' (QCSE) reduces radiative recombination and thus reduces a light-emitting device's efficiency.

Although semi-/non-polar devices have been developed in the laboratory with longer wavelengths than traditional c-plane devices, the substrate material is presently expensive, using extra processes such as epitaxial lateral over-growth (ELOG) or cutting very small pieces of high-quality nitride semiconductor material from c-plane crystals from hydride vapor phase epitaxy (HVPE) processes. Manufacturers want low-cost production derived from simple processing and inexpensive materials.

The OVGU materials were grown on silicon substrates using MOCVD. By changing the crystal orientation of the substrates, different orientations of nitride semiconductor resulted. Silicon oriented with a (112) surface tilted the c-axis of the hexagonal gallium nitride semiconductor layers about 18° in the  $[1\bar{1}00]$  direction,



**Fig. 1** STEM images of sample I (a) and sample II (b). For sample I, the LT-AlN layers are grown during the early 'island growth mode'. BSFs propagate at an angle of  $\sim 18^\circ$  to the substrate surface and are usually not blocked by the AlN layer (e.g. below yellow arrows). For sample II with an LT-AlN layer grown on a nearly planarized growth surface, BSFs are stopped at the LT-AlN layer but not at positions where it is not parallel to the growth surface as, for example, at a growth pit (left) and also at larger growth steps (not shown).

while Si(113) increased the angle to  $22^\circ$ . The GaN on Si(112) layers were found to be oriented close to  $(10\bar{1}6)$ .

The seeding layer consisting of AlN has to be kept very thin to maintain a constant axis tilt. To avoid meltback etching of the nitride layers in the further GaN growth process, Al-rich buffer layers or a layer of low-temperature AlN (LT-AlN) were applied in one set of samples. In other samples, an LT-AlN layer was applied later, after about 600nm. This latter technique was found to reduce basal plane stacking faults (BSFs) in subsequent material. The samples were subjected to cathodoluminescence (CL), scanning transmission electron microscopy (STEM), and STEM-CL analyses.

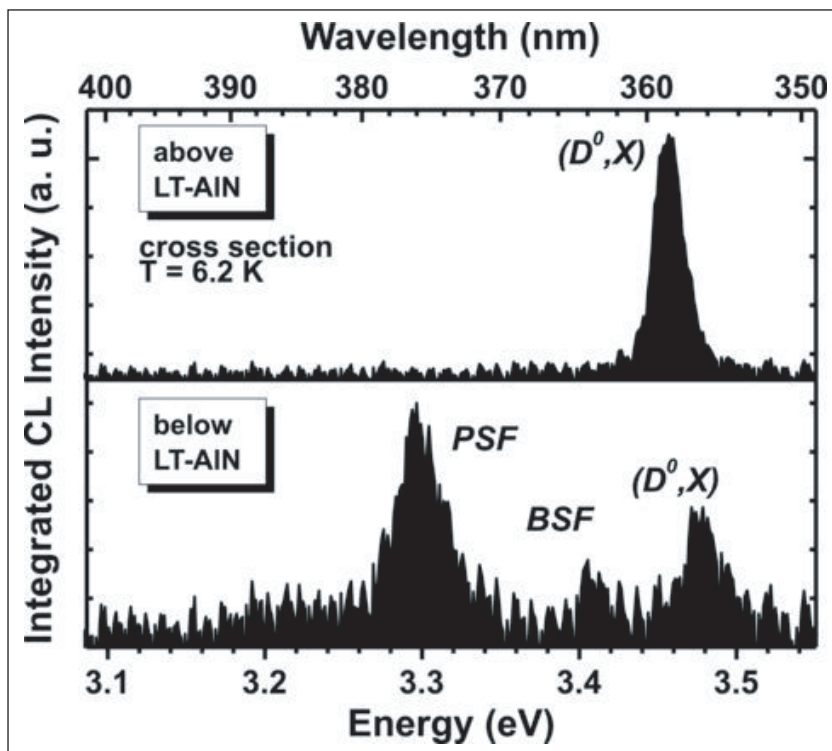
Previous OVGU work on depositing GaN on high crystal index silicon showed layers with rough pyramidal undulations with (0001) plateaus. LT-AlN layers

deposited at an early stage in such growth (sample I) tend to follow these undulations (Figure 1a). The previous work also performed photoluminescence measurements that showed emissions from a bound donor exciton ( $D^0, X$ ) and from strong basal plane stacking fault (BSF), and donor acceptor pair band (DAP) and/or prismatic plane stacking fault (PSF) features.

Inserting LT-AIN later in the growth (sample II), when the GaN is nearly planar (Figure 1b), results in the apparent elimination of local cathodoluminescence from BSF and PSF features in material grown above the LT-AIN (Figure 2). Where the LT-AIN layer is parallel to the substrate surface, STEM-CL images show annihilation of the BSFs — however, where there are interruptions, such as at growth pits or large faceted steps, the faults penetrate through to the upper growth region.

The OVGU researchers comment: "The very low density and, on large areas, even the complete absence of BSFs in the upper GaN layer in sample II is a surprising result since LT-AIN layers are only known to lead to lattice relaxation, typically via misfit dislocations at the GaN/LT-AIN interface."

The team suggests that misfits that eliminate the faults are preferentially produced by the LT-AIN due both to its different lattice constant and higher stacking fault formation energy ( $0.22\text{mJ}/\text{m}^2$ ). The absence of BSF reduction at growth pits etc could be related to the reduced thickness ( $\sim 7\text{nm}$ , as opposed to  $11\text{nm}$  in planar regions) of the AIN layer in these areas, leading to less lattice relaxation. "Consequently the method requires a critical tensely stressed layer (AIN or AlGaIn) thickness to be successful." The problem in the non-planar regions may also be related to the crystal orientation or inclination angle of the facet surface.



**Fig. 2 CL spectra of sample II above and below the LT-AIN layer, demonstrating disappearance of stacking-fault-related luminescence.**

The OVGU group expects the same effect of LT-AIN layers reducing BSFs on m-plane GaN, possibly with an AlGaIn grading into GaN after the fault blocking layer. The researchers report that they have not seen any BSF reduction in a-plane material from the use of an LT-AIN layer.

Some funding for the OVGU came from Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) in the framework of the PolarCon research group. ■

<http://link.aip.org/link/doi/10.1063/1.3610467>  
[www.uni-ulm.de/in/iui-polarcon.html](http://www.uni-ulm.de/in/iui-polarcon.html)

Author: Mike Cooke

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# First room-temperature blue/'green' VCSELs with current injection

**Nichia has made a VCSEL laser emitting blue light in continuous-wave mode with power output of 0.7mW at an injection current of 11mA.**

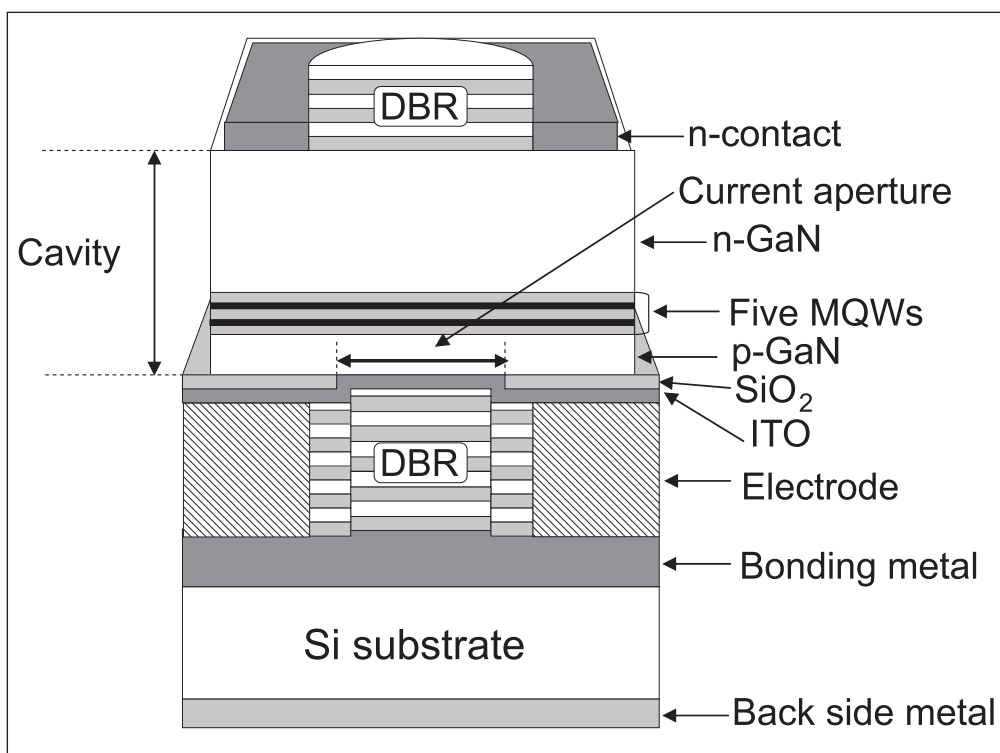
**J**apan's Nichia Corp has developed room-temperature blue and 'green' vertical-cavity surface-emitting lasers (VCSELs) "for the first time, by current injection", using nitride semiconductor technology for the active region [Daiji Kasahara et al, Appl. Phys. Express, vol4, p072103, 2011].

The thresholds for some of the blue devices (451nm wavelength) and 'green' devices (503nm wavelength, actually more blue-green, with true green starting at longer than 520nm) were measured, respectively, as 3.0 and 28kA/cm<sup>2</sup> for current density (assuming uniform injection of 1.5 and 22mA over current aperture), and 3.3V and 6.3V for forward voltage. The current apertures for the blue and 'green' devices were 8μm and 10μm, respectively.

While the blue device was subjected to continuous-wave (CW) operation, the more challenging green device was only tested under pulsed operation (width/period 1/500μsec). The maximum output power for the blue device was 0.7mW at 11mA. Within the limitations of the pulsed test set-up, the maximum green output power is estimated at more than 0.8mW.

The epitaxial material structures were grown on c-plane gallium nitride (GaN) substrates using metal-organic chemical vapor deposition (MOCVD). The active region consisted of indium gallium nitride (InGaN) wells in GaN barriers. Further processing to make the VCSEL (Figure 1) consisted of a series of steps involving lithography, sputtering, inductively couple plasma (ICP) reactive ion etching, wafer bonding, and chemical mechanical polishing (CMP).

First, a current aperture was patterned, followed by application of an indium tin oxide (ITO) transparent



**Figure 1. Schematic illustration of structure of blue and green GaN-based VCSELs.**

conducting contact and current-spreading layer, then an electrode around the current aperture. The backside mirror consisted of silicon dioxide/niobium pentoxide (SiO<sub>2</sub>/Nb<sub>2</sub>O<sub>5</sub>) layer pairs as a distributed Bragg reflector (DBR). The structure was then flipped and bonded onto a highly conductive silicon substrate. The GaN substrate and n-type layer were then removed/thinned to create suitable cavities before the n-type contact and another SiO<sub>2</sub>/Nb<sub>2</sub>O<sub>5</sub> DBR.

Further characterization of the devices involved looking at spectra below, near and above threshold and at the near-field emission patterns. The 'green' device shifts its wavelength by about 4nm, going from 499nm to 503nm, in moving from spontaneous to stimulated emission. The researchers report: "This abnormal behavior of the laser emission peak may be due to refractive index changes induced by thermal effects. The characteristics of GaN-based

VCSELs above 480nm are not well understood and we are currently investigating them."

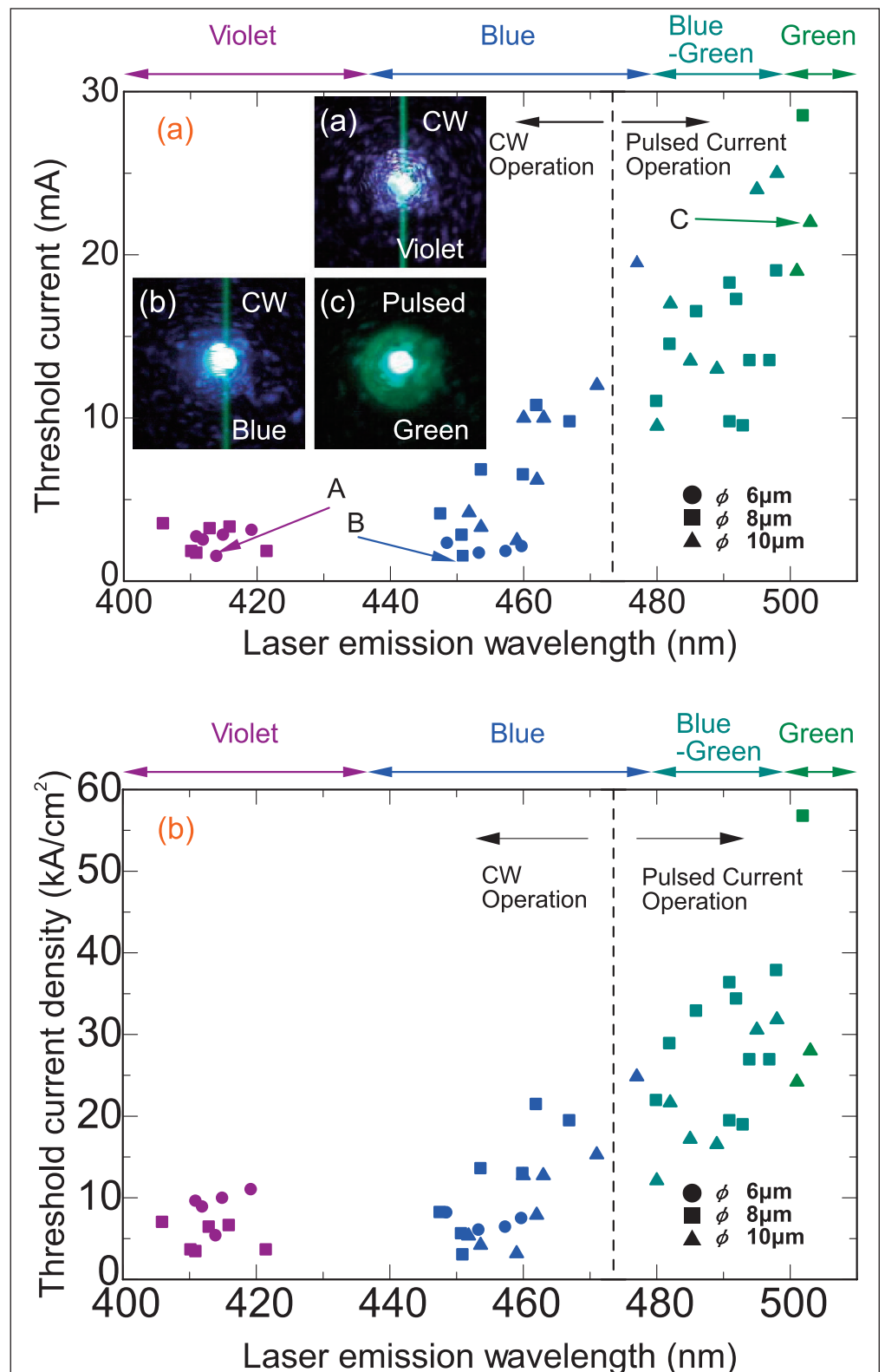
The lasing near-field patterns were found to vary with spot sizes and locations shifting between devices with violet to green emission. The team comments: "We regard this phenomenon to be critical in controlling laser performance. We speculate that it may be related to some kind of inhomogeneity (e.g. material composition, surface morphology, cavity length, current spreading, transverse optical confinement), but it is not possible to make firm conclusions at this stage."

Nichia has produced numbers of devices with various apertures emitting in the 'green', blue and violet (Figure 2). The researchers find a trend of increasing threshold currents as the devices become longer wavelength. In general, it is found that devices with wavelengths less than 471nm can sustain room-temperature CW lasing, while those above cannot.

"We speculate that the increase in the threshold current is due to the quantum confinement Stark effect (QCSE) that mainly originates from the piezoelectric polarization caused by the high crystal strain due to the large lattice mismatch between GaN and InGaN," say the researchers. "The QCSE is responsible for separating the hole and electron wave-functions, which reduces the radiative recombination probability and thus increases the threshold current."

The Nichia team believes that 'green' thresholds could be reduced, possibly using non- or semi-polar nitride semiconductor structures, as developed by other research groups for edge-emitting lasers.

The researchers conclude: "Many characteristics of GaN-based VCSELs still need to be clarified before reproducible and high-performance GaN-based VCSELs can be fabricated." ■



**Figure 2. Dispersion diagram for CW operation and pulsed current operation at room temperature. Circles, squares, and triangles indicate results for 6-, 8-, and 10µm-diameter devices, respectively. Insets (a)–(c) show near-field patterns of violet (414nm), blue (451nm), and 'green' (503nm) VCSELs corresponding to devices A–C, respectively.**

<http://apex.jsap.jp/link?APEX/4/072103>

The author Mike Cooke is a freelance technology journalist who has worked in the semiconductor and advanced technology sectors since 1997.

# China developing supply chain after its LED sector grows 33.8% in 2010

GaN epi output to surpass AlGaInP epi in 2011, says China's CCID Consulting.

China's LED industry has seen significant development after the initiation of the National Semiconductor Illuminating Project in 2003, says Beijing-based CCID Consulting Co Ltd. In 2008, the industry's growth rate was affected by sluggish downstream demand resulting from the global financial crisis. However, in 2009, due to the state's various supporting policies, the industry's growth rate began to pick up.

In 2010, driven by rapid development of the downstream full-color LED display, LED backlights, LED lighting and other applications, the size of China's LED industry (including substrates, epitaxy, chips and packaging) surged by 33.8% to RMB29.46bn. Meanwhile, the compound annual growth rate (CAGR) of China's LED industry was 18.7% from 2006 to 2010.

Although the substrate sector still features low-end products, the sapphire sector has geared up for expansion. In recent years, the development of China's substrate sector has been relatively slow compared with the epitaxy, chip, and packaging sectors due to its lagging technology and fierce market competition. In 2010, as various sapphire substrate projects were still under construction or in the process of equipment testing (retarding production capacity from significant expansion), the substrate sector still featured low-end products with limited production capacity for sapphire substrate. Nevertheless, in 2010, China's substrate sector grew in capacity by 34.4% to 3.525 million square inches, and in output value by 50.8% to RMB140m.

Supported by the National Semiconductor Illuminating Project and the State 863 Program, China's GaAs/InP/GaP substrate technologies (used for red and green LED production) have made great progress, says CCID. Mass production of the materials has been realized in enterprises such as Compound Crystal Technology Co Ltd, Guorui Electronic Materials Co Ltd, Shanghai Pujia

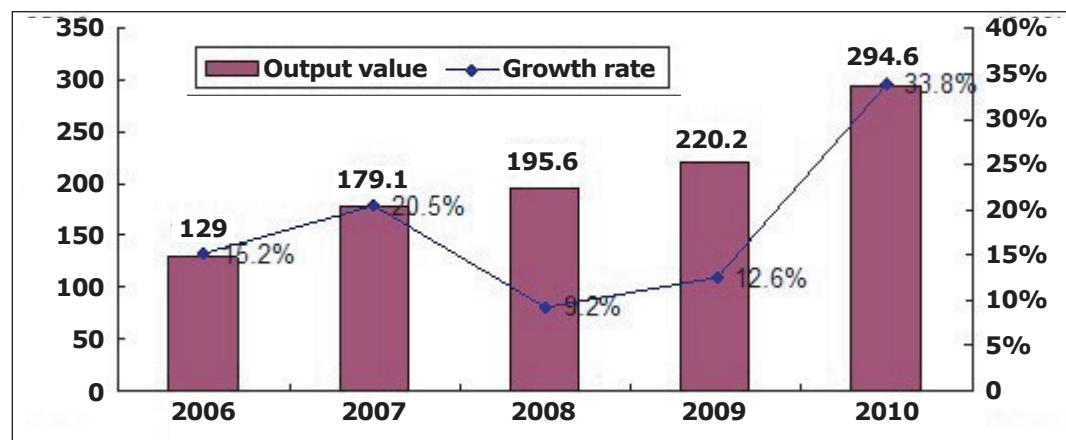


Figure 1. Size of China's LED industry (2006–2010).

Optoelectronic Materials Co Ltd, and the 46th Research Institute of CETC. Their total LED substrate output accounts for about 30% of the country's total, making China self-sufficient in such substrates.

In 2010, driven by rapid development of the downstream LED backlight and LED illumination sectors and rapid expansion of GaN epitaxy and chip production capacity, the supply of upstream sapphire, silicon carbide (SiC) and gallium nitride (GaN) substrates used for blue and white LEDs became tight, with prices continuing to rise. Despite the still immature technologies for such materials and a shortage of qualified talent, in 2010 many domestic enterprises began to enter the sapphire substrate field in pursuit of the high profits available, as they continued to increase investment and introduce key technologies. Most of those enterprises are located in the eastern coastal area and in the southwest, along with a few in inland areas.

Among them, Tianjin Sapphire, Qingdao iStarWafer and Peter Stone Love have begun to supply sapphire substrate products, while Silian Group (which entered the sapphire substrate sector in 2008 by acquiring Honeywell's sapphire substrate factory in Canada and its technologies) is constructing a sapphire substrate base in Chongqing Municipality. By the end of 2010, the first phase of Silian Group's sapphire substrate project had been commissioned, and production had begun at partial capacity.



Meanwhile, Yunan Crystaland, Harbin Aurora Optoelectronics Technology Co Ltd and other enterprises with independent crystal boule technology have been producing sapphire substrate on a small scale. Xiexin Optoelectronics, Eurasian Rainbow Optoelectronics Technology and TDG Holding began to enter the sapphire crystal boule and substrate sector in 2010, while Zhejiang Crystal-Optech and Xi'an Shengguang Anrui

Optoelectronics Technology are preparing to enter in 2011, and the first phase of ZheJiang East Crystal Electronic Co Ltd's upgrade project to produce 7.5 million sapphire wafers for LEDs is planned to start mass production by the end of 2012.

Generally speaking, judging from the capacity expansion rate, the supply of sapphire substrates will remain tight for the next three years at least, reckons CCID. However, as the sector starts to absorb massive investment in 2011 to expand production capacity, sapphire substrate output as a proportion of total LED substrate output is sure to surge and overtake substrate output for quaternary system products, the firm adds.

The epitaxial sector is seeing rapid capacity expansion and product upgrade, says CCID. Driven by rapid development of China's downstream application market, GaN MOCVD has seen explosive growth in China since 2009, providing great momentum for the epitaxy sector of China's LED industry. In 2010, the number of MOCVD systems being installed and commissioned was nearly 300 (more than 200 of which had begun mass production) and the output value of China's LED epitaxy sector rose by 78.4% to RMB1.25bn.

Regarding specific products, AlGaInP epitaxy (used mainly in red LEDs) is a leading product in China due to its stable growth mechanism and material properties.

However, the growth rate is far behind that for GaN epitaxial wafers because demand from its relatively mature application market is growing more slowly.

In 2010, output of AlGaInP/AlGaAs/GaAsP/GaP epiwafers accounted for 60.2% of total epiwafer output, down 15.8% from 2009. In contrast, supported by the rapidly expanding application market for blue and white light LEDs in landscape light-

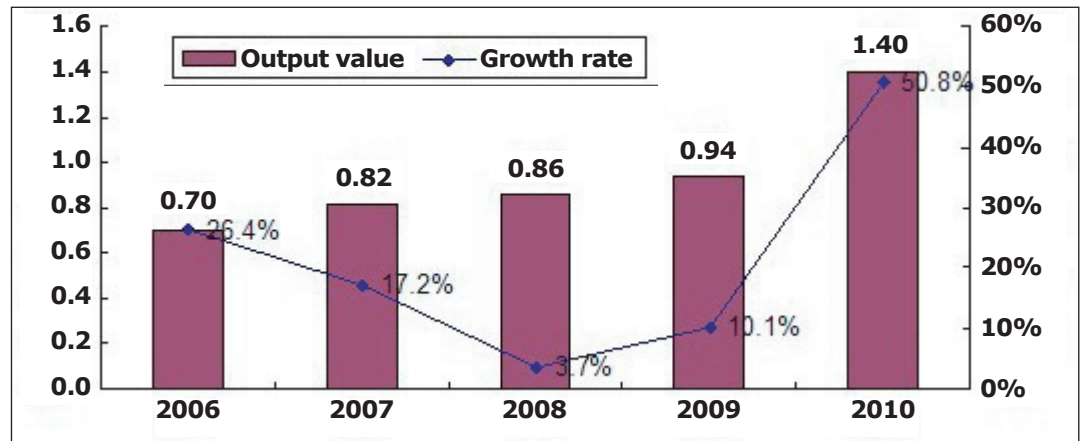


Figure 2. Size of China's LED substrate sector (2006-2010).

ing and backlighting (as well as technical breakthroughs), GaN epiwafer output accounted for 39.8% of China's total epiwafer output in 2010. It is expected that GaN epiwafer output will exceed that of AlGaInP epiwafers in 2011.

China is basically self-sufficient in epiwafer supply for normal-brightness red light LEDs, but still relies on imports of quality AlGaInP epiwafers from Taiwan and Korea for super-bright red light LEDs, says CCID. In addition, the country also has to import GaN epiwafers due to the small production capacity and inferior quality of domestic products.

As the production of LED epitaxial products requires massive investment, advanced technologies and experienced professionals, most epiwafer makers are located in China's wealthy areas in the east and south, notes CCID. But with epi market demand expanding, new enterprises will continue to enter this sector, while existing enterprises will aim to expand capacity. For example, Sanan Optoelectronics has started to establish LED facilities in Tianjin and Anhui Provinces' Wuhu City in addition to its existing plants in Xiamen. Meanwhile, apart from the favored locations of Shanghai, Xiamen and Yangzhou, newcomers are also beginning to locate their facilities in central China, notes CCID. ■

<http://en.ccidconsulting.com>

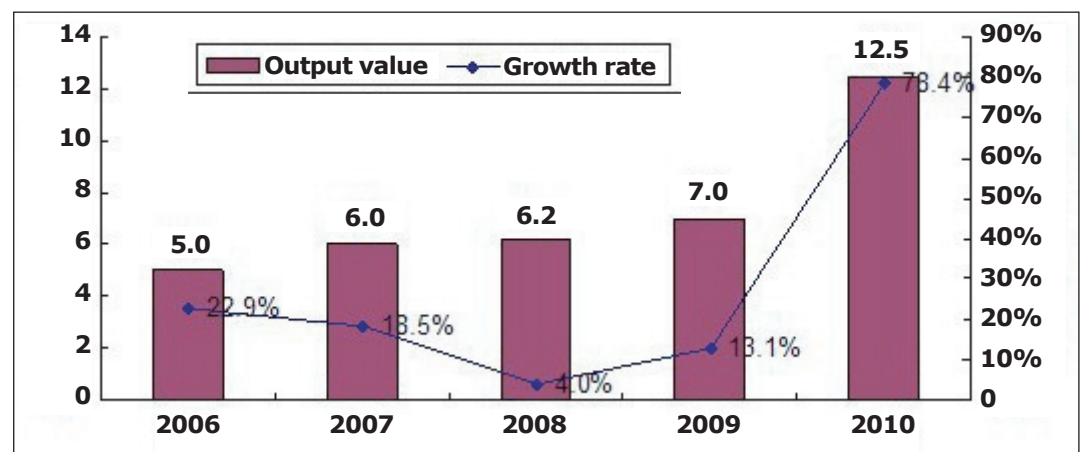


Figure 3. Size of China's LED epitaxial sector (2006-2010).

# Reducing LED droop at high current with nitrides

UCSB and Mitsubishi Chemical produce first blue-violet LEDs on  $(20\bar{2}1)$  GaN.

University of California Santa Barbara (UCSB) and Japan's Mitsubishi Chemical Corp have produced blue-violet light-emitting diodes (LEDs) with high output power and low droop by using  $(20\bar{2}1)$  indium gallium nitride (InGaN) structures "for the first time" [Yuji Zhao et al, Appl. Phys. Express, vol4, p082104, 2011].

The reduced droop of the device up to injection current of  $200\text{A}/\text{cm}^2$  is described as "outstanding" (Table 1), being only 14.3% at the upper limit. "To the best of the authors' knowledge, such a low droop has not been reported at current densities of  $200\text{A}/\text{cm}^2$ ," the team comments.

The researchers are working to improve the performance of LEDs for general lighting. This requires more cost-efficient devices with higher output power. Unfortunately, nitride-based LEDs have a tendency to be less efficient at higher injection currents/output power — a phenomenon often referred to as 'droop'.

Although UCSB's own theoretical team under professor Chris Van de Walle blames an indirect Auger recombination process for droop ([www.semiconductor-today.com/news\\_items/2011/APRIL/UCSB\\_200411.html](http://www.semiconductor-today.com/news_items/2011/APRIL/UCSB_200411.html)), other research groups continue to dispute this.

One approach that might ameliorate the droop effect is to use nitride semiconductors oriented in semi-/non-polar directions, rather than the usual c-plane crystals that have strong polarization fields. These polarization effects lead to electric fields in the active region of the device, which tend to separate the electrons and holes that researchers want to recombine as light emission.

The semi-polar  $(20\bar{2}1)$  orientation has recently been investigated for producing longer-wavelength green-emitting devices, including lasers. The UCSB devices use the opposite orientation of  $(20\bar{2}1)$  (Figure 1).

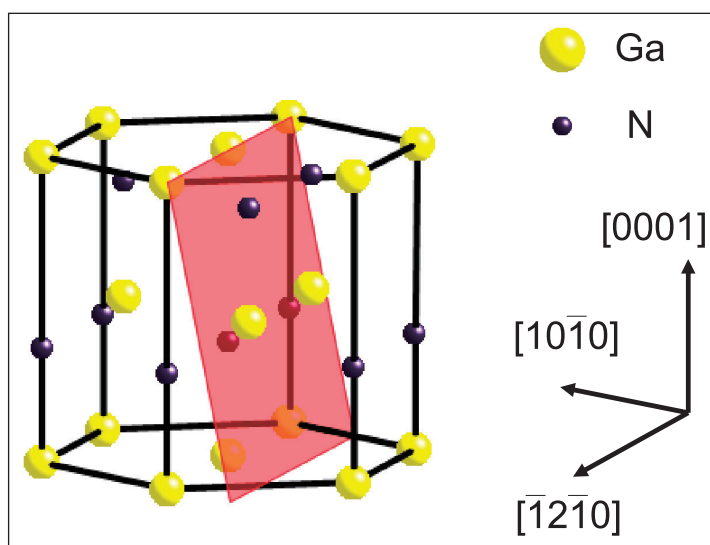


Figure 1. Schematic view of semi-polar  $(20\bar{2}1)$  plane in the wurtzite crystal structure.

Table 1. EQE and droop performance of semi-polar blue-violet  $(20\bar{2}1)$  LED at various current densities.

Current density ( $\text{A}/\text{cm}^2$ )	35	50	100	200
EQE (%)	52.6	50.7	48.4	45.3
Droop (%)	0.7	4.3	8.5	14.3

p-GaN	Mg-doped	60nm
5x p-AlGaIn/GaN	Mg-doped electron blocking superlattice	
3x InGaIn/GaN	Multi-quantum well (MQW)	3x(3nm/13nm)
10x n-InGaIn/GaN	Si-doped superlattice	
n-GaN	Si-doped	1 $\mu\text{m}$
Freestanding (20-2-1) GaN substrate		

Figure 2. Epitaxial structure used in UCSB LEDs.

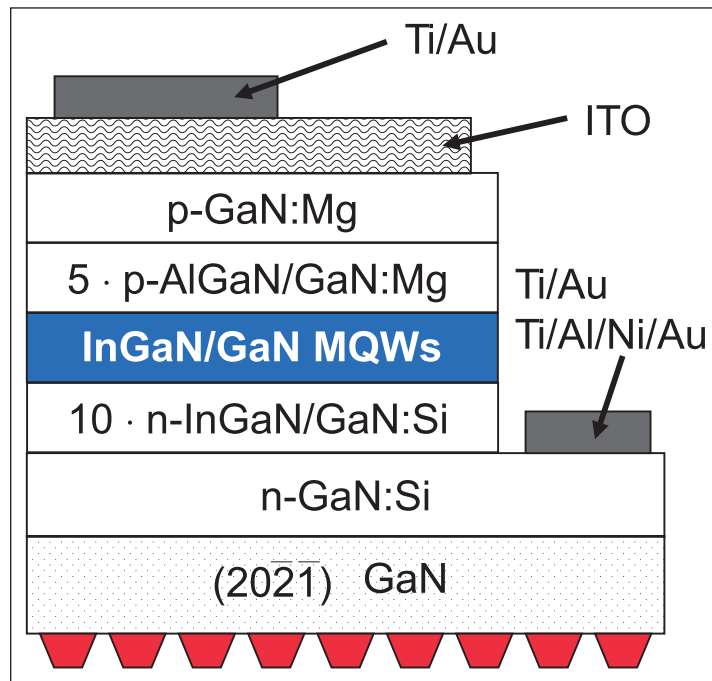
Mitsubishi Chemical supplied the free-standing (20 $\bar{2}\bar{1}$ ) GaN substrates on which the epitaxial structures (Figure 2) were grown using MOCVD.

To make the LEDs, the epitaxial material was covered with an indium tin oxide (ITO) current-spreading layer before rectangular mesa structures were etched with chlorine-based inductively coupled plasma and then metal contacts and pads were applied (Figure 3). Backside roughening of the LED structure was performed to enhance light extraction by reducing reflection back into the device at the GaN–air interface due to refraction index differences. The devices were packaged in transparent vertical-stand structures.

Room-temperature pulsed electroluminescence measurements with 1% duty cycle were carried out up to injection current densities of 200A/cm<sup>2</sup> (Figure 4). The researchers comment that the 20mA output power of 30.6mW and external quantum efficiency (EQE) of 52% “are comparable to the best values ever reported for semi-polar or non-polar LEDs”. These ‘best values’ were reported in 2010 by UCSB and Mitsubishi themselves [http://apex.jsap.jp/link?APEX/3/102101/] as being 31.1mW and 54.7%, respectively.

The spectral properties of the emissions at different injection currents were also investigated. The peak wavelength shift up to 200A/cm<sup>2</sup> is described as ‘negligible’, “indicating greatly reduced polarization-related electric fields inside the QWs [quantum wells]”. The peak wavelength is about 423nm. The ‘very small’ full-width at half maximum (FWHM) of the emission peak varies in the range 16–21nm, which suggests “good compositional and structural uniformity for the InGaN QWs”.

**The researchers comment that the 20mA output power of 30.6mW and external quantum efficiency of 52% are comparable to the best values ever reported for semi-polar or non-polar LEDs**

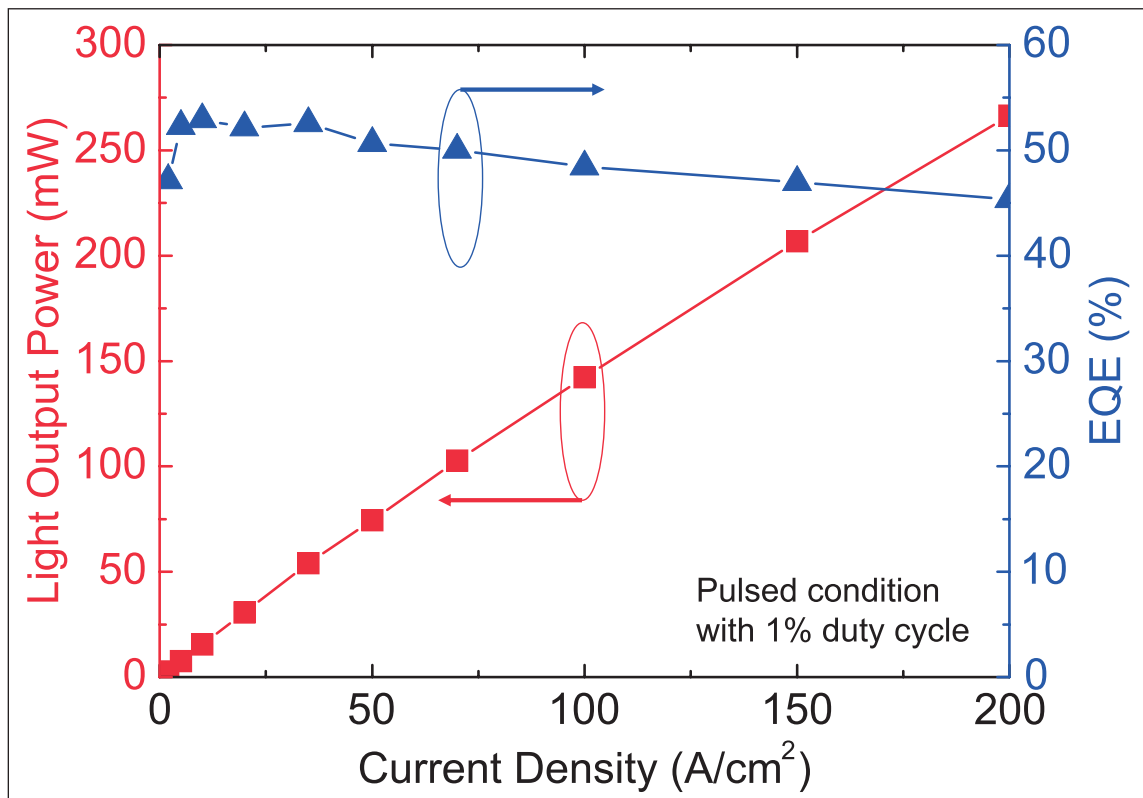


**Figure 3. Schematic of semi-polar (20 $\bar{2}\bar{1}$ ) LED device with backside roughening structures.**

The researchers are still investigating the underlying cause of the low efficiency droop on semi-polar (20 $\bar{2}\bar{1}$ ) LEDs. ■

<http://apex.jsap.jp/link?APEX/4/082104>

The author Mike Cooke is a freelance technology journalist who has worked in the semiconductor and advanced technology sectors since 1997.



**Figure 4. Light output power vs current density and EQE vs current density curves for a packaged (20 $\bar{2}\bar{1}$ ) LED under pulsed operation.**

# Driving forward microLED video displays

**Micron-size light-emitting diode arrays based on nitride semiconductors have been developed for displays and light sources for more than a decade. By combining such arrays with silicon CMOS active drive circuits, US researchers have now created microdisplays capable of delivering video images. Mike Cooke reports.**

**U**S university, commercial and military researchers have reported the realization of high-resolution solid-state self-emissive microdisplays based on III-nitride semiconductor micro-size light-emitting diodes ( $\mu$ LEDs) capable of delivering video graphics images [Jacob Day et al, Appl. Phys. Lett., vol99, p031116, 2011]. The research team is variously based at Texas Tech University, III-N Technology Inc, and the US Army's Night Vision and Electronic Sensors Directorate.

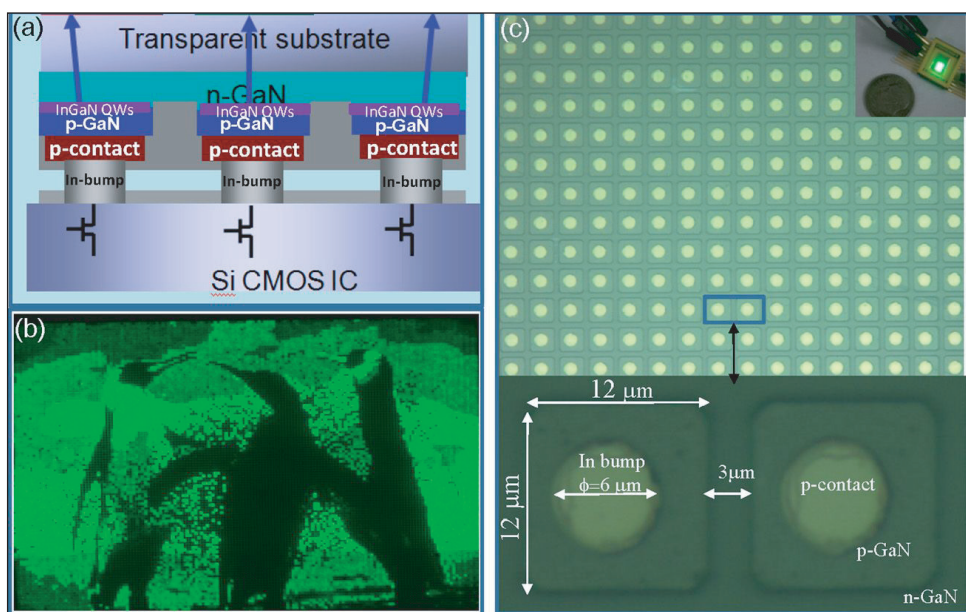
According to the Texas/III-N/US Army researchers, their work "clearly demonstrated that III-nitride microdisplays are a favorable competing technology compared to liquid-crystal display (LCD), organic LED (OLED), digital light processing (DLP), and laser beam steering (LBS) for ultra-portable products such as next-generation pico-projectors, wearable displays, and head-up displays."

Potential advantages of  $\mu$ LEDs for display applications, according to these researchers, include compact format and lower power use, compared with systems that require an external light source, such as LCD (Table 1).

Also the angle of view does not create color shifts or contrast degradation, as happens in LCD systems. Similar problems arise with DLP/LBS systems that use micro-electro-mechanical systems (MEMS) to direct light in particular directions.

Organic LEDs are another possibility for self-emissive displays, but the present efficiency of such devices is low. Lifetimes are also limited in many systems using laser diode or MEMS parts in their operation.

Further attractions of  $\mu$ LEDs for self-emissive displays include high brightness, contrast, resolution, reliability,



**Figure 1. (a) Flip-chip bonding between  $\mu$ LED matrix array and CMOS driver IC via indium bumps making highly integrated single-package microdisplay. (b) Grayscale projected image of penguins from green InGaN microdisplay (pixel size  $12\mu\text{m}$ , pitch  $15\mu\text{m}$ ) operating at  $1\mu\text{A}/\text{pixel}$  drive current. (c) Zoom-in image of segment of InGaN  $\mu$ LED array chip showing  $\mu$ LED pixels and indium bumps viewed from transparent sapphire side. Top inset shows fully assembled green InGaN microdisplay ( $160\times 120$  pixels) in operation.**

and long-life. The  $\mu$ LED displays can also be viewed under bright sunlight, unlike standard LCD systems.

Displays based on nitride semiconductor LEDs also have features of particular interest for the military since they can be operated in harsh environments of high and low temperature with high humidity conditions. Operational lifetimes can also reach beyond 100,000 hours.

Despite fast response times of 0.2ns previously being measured in III-N  $\mu$ LEDs, up to now video performance has not been reached in nitride  $\mu$ LED technology.

One drawback has been that previous attempts to use  $\mu$ LED arrays to form 'monolithic' displays incorporating all the wiring to the n- and p-contacts of the individual LED pixels have been restricted to passive drive circuits that access the devices a row at a time with the pixel columns

**Table 1. Texas/III-N/US Army comparison of various technologies for microdisplays.**

Technology	Liquid crystal	Organic LED	III-N $\mu$ LED	Digital light processing	Laser beam steering
Mechanism	Backlight/LED	Self-emissive	Self-emissive	Backlight/LED	Backlight/LD
Luminous efficacy	Medium	Low	High	High	High
Luminance (cd/m <sup>2</sup> )	3000 (full color) $\sim 10^4$ (green)	1500 (full color) $\sim 10^3$ (yellow)	$\sim 10^5$ (full color) $\sim 10^7$ (blue/green)	$\sim 1000$ (full color)	$\sim 1000$ (full color)
Contrast ratio	200:1 (intrinsic)	Very high >10,000:1	Very high >10,000:1	High	High
Response time	ms	$\mu$ s	ns	ms	Ms
Operating temperature	0 to 60°C requires heater	-50 to 70°C	-100 to 120°C	To be determined	To be determined
Shock resistance	Low	High	Medium	Medium	
Lifetime	Medium	Medium	Long	Medium (limited by MEMS)	Short (limited by laser diodes)
Cost	Low	Low	Low	High	High

driven in series. This requires a source voltage of about 30V, which is not convenient for mobile devices. Heat dissipation is also a problem from such operation.

### Active hybrid

The Texas/III-N/US Army team adopted instead a hybrid approach (Figure 1) that allowed direct 'active' connection between a driver IC and the individual  $\mu$ LED devices.

The nitride semiconductor structures were grown on sapphire substrates using MOCVD. The  $\mu$ LED arrays were produced through etching and metallization of this material. The pixel size was 12 $\mu$ m and the pitch between pixels was 15 $\mu$ m.

The researchers were particularly concerned about the poor hole transport properties in p-GaN that result from the high activation energy of the magnesium (Mg) doping (lowering sheet carrier density) and the low hole mobility in the material. These physical characteristics tend to create hole injection problems and high contact resistance. In practical terms, these properties lead to self-heating, high threshold currents and turn-on voltages, reduced reliability and shortening of operating life. In the  $\mu$ LEDs, the researchers used heavy Mg doping to minimize contact resistance.

The researchers also designed matching silicon CMOS active matrix 640x480 and 160x120 microdisplay controller ICs to provide the 0.5–1.0 $\mu$ A drive current for the  $\mu$ LEDs. An active-matrix display stores the value and provides the drive current for individual pixels in parallel, as opposed to the series arrangement of passive-mode.

The  $\mu$ LED array was flipped on to the driver IC and bonded using indium bumps that provided thousands of connections through this hybrid integration of the two devices. The anode (n-type contact) was the

common terminal and the cathode (p-type contact) provided the lighting control.

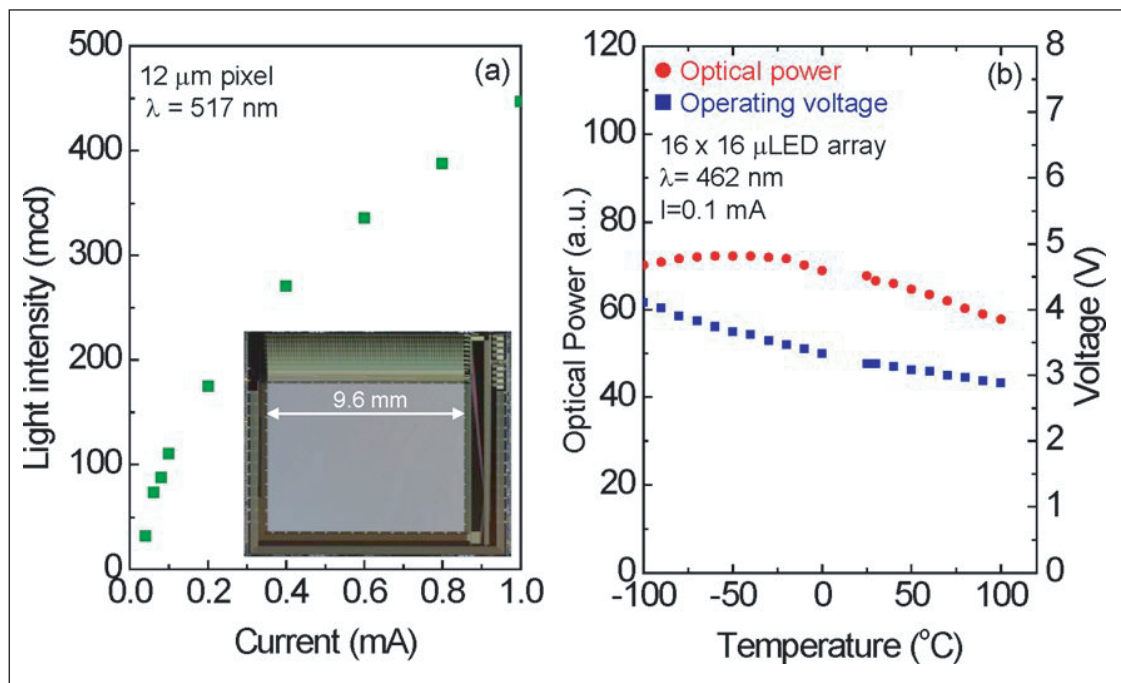
The measured light output (Figure 2a) from green 12 $\mu$ m pixels was 1millicandela/microamp (mcd/ $\mu$ A), with almost linear dependence up to 100 $\mu$ A drive current. The wavelength of 517nm corresponds to blue-green, but is pretty close to true green (520–570nm). With 1 $\mu$ A driving each pixel in an array of 15 $\mu$ m pitch, one gets a brightness of 4x10<sup>6</sup>cd/m<sup>2</sup> (=1mcd/(15 $\mu$ m)<sup>2</sup>). "This luminance level is several orders of magnitude higher than those of LCDs and OLEDs," the team says.

The forward voltage for 1 $\mu$ A drive current was 2.6V. This gives power dissipation of 0.8W (640x480x1 $\mu$ Ax2.6V) for a full 640x480 VGA display. A normal image would generally require less (~25%).

Current density in the 12 $\mu$ m pixels for 1 $\mu$ A is 0.7A/cm<sup>2</sup> (1 $\mu$ A/(12 $\mu$ m)<sup>2</sup>). Conventional 300 $\mu$ m x 300 $\mu$ m indicator LEDs driven at 20mA are subjected to current densities around 22A/cm<sup>2</sup>, i.e. about 30x the value for the video graphics array (VGA) pixels. Since high drive currents are associated with shortened lifetimes, the ability to drive at low current densities implies that the VGAs should be reliable beyond the 100,000 hours of 20mA standard indicator LED operation.

Temperature dependence was also assessed for 462nm blue  $\mu$ LED arrays (Figure 2b). It was found that increasing to 100°C reduced the intensity of  $\mu$ LED emission by about 10%. In the opposite direction, reducing to -100°C had no significant effect on emission.

The operating voltage at 0.1mA varied between 4.1V at -100°C and 2.9V at +100°C. The reduced voltage at high temperature is attributed to the higher equilibrium hole concentrations in the devices under these thermally activated conditions. The activation energy of the magnesium acceptors in GaN is about 160meV. ▶



**Figure 2. (a) Luminance of single green  $\mu$ LED pixel as function of drive current; inset shows micrograph of fully assembled VGA microdisplay (640x480 pixels). (b) Temperature dependence of relative emission optical power of InGaN  $\mu$ LED array.**

► The  $k_B T$  values of  $-100^\circ\text{C}$ , room temperature (300K,  $\sim 27^\circ\text{C}$ ) and  $+100^\circ\text{C}$  are 15meV, 26meV, and 32meV, respectively.

The researchers comment: "The T dependence of the  $\mu$ LED emission intensity in Figure 2b represents the lowest thermal quenching ever reported for any type of microdisplay." This thermal stability is attributed to the use of nitride semiconductors.

### $\mu$ LED light works

Work on  $\mu$ LED arrays has not just been on the self-emissive display application, but also includes various light source circuits such as single-chip high-voltage AC-LEDs for solid-state lighting, biophotonics, and for microscopy.

Three of the researchers from the Texas/III-N/US Army group — J. Li, J. Y. Lin, and H. X. Jiang — have been working on  $\mu$ LED arrays since 1999, when they were based at Kansas State University. Since then, husband and wife team professors Hongxing Jiang and Jingyu Lin have co-founded III-N Technology Inc and AC LED Lighting LLC. These companies hold several patents concerning the application of  $\mu$ LED arrays to high-voltage DC/AC (110V, 220V, etc.) and general lighting.

Optogenetics [www.stanford.edu/group/dlab/optogenetics] is a new biological research technique that combines genetic engineering and light to control events in targeted cells. These cells can be located in living tissue, such as freely moving animals, including mammals. The control signals can have a millisecond timescale.

The genetic engineering involves incorporating light-sensitive parts from one species into cells of other

species. In particular, a light-activated ion channel in the cell wall of a species of swamp algae was discovered in 2003 by the Max-Planck Institute for Biophysics in Germany. This was followed by genetic engineering efforts to incorporate this ChannelRhodopsin-2 (Ch-R2) structure in the cells of other animals (including mice). The channel can transport sodium and calcium ions, which are used in neural cells to create and suddenly change potential differences. The Ch-R2 channel has a blue absorption peak around 470nm that can be matched by nitride semi-

conductor blue light-emitting structures.

Nitride semiconductor  $\mu$ LEDs have been used by UK-based researchers at the Institute of Biomedical Engineering and the Department of Neuroscience of Imperial College, King's College and University of Strathclyde to control the firing of neurons with light in this way. In addition to optogenetic neuromodulation, Imperial College has used nitride semiconductor  $\mu$ LEDs as controllable light sources for microscopy.

(Incidentally nitride semiconductors may provide more suitable substrates for neuronal growth in-vitro than silicon, making nitride semiconductors a suitable candidate for microelectrode arrays. Otto-von-Guericke-University-Magdeburg has recently reported the use of unipolar source-drain voltage pulses from GaN/AlGaIn high-electron-mobility transistors (HEMTs) to stimulate cultured neuronal networks obtained from embryonic rat cerebral cortex.)

Nitride semiconductor sources would seem suitable for further biophotonic applications. For example, nitride LEDs are being developed to produce ultraviolet (UV) radiation to sterilize surfaces and purify water. University of Strathclyde has produced 370nm UV 8x8 arrays of 72 $\mu$ m-diameter  $\mu$ LEDs. ■

<http://link.aip.org/link/doi/10.1063/1.3615679>

[www.3n-tech.com/index.html](http://www.3n-tech.com/index.html)

[www.cerdec.army.mil/directorates/nvesd.asp](http://www.cerdec.army.mil/directorates/nvesd.asp)

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*The author Mike Cooke is a freelance technology journalist who has worked in the semiconductor and advanced technology sectors since 1997.*

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### Power + Energy Inc

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[www.samcointl.com](http://www.samcointl.com)

### SPP Process Technology Systems Ltd

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[www.spp-pts.com](http://www.spp-pts.com)

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(see section 16 for full contact details)

### Veeco Instruments Inc

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## 9 Materials & metals

### Goodfellow Cambridge Ltd

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### Cambridge Fluid Systems

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Tel: +44 (0)1954 786800

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[www.cambridge-fluid.com](http://www.cambridge-fluid.com)

### CS CLEAN SYSTEMS AG

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[www.cscleansystems.com](http://www.cscleansystems.com)

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## 11 Process monitoring and control

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[www.kla-tencor.com](http://www.kla-tencor.com)

## LayTec AG

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## 12 Inspection equipment

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[www.bruker-axs.de](http://www.bruker-axs.de)

## 13 Characterization equipment

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Lincoln, NE 68508,  
USA  
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Fax: +1 402 477 8214

[www.jawoollam.com](http://www.jawoollam.com)

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Westerville, OH 43082,  
USA

Tel: +1 614 891 2244

Fax: +1 614 818 1600

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## 14 Chip test equipment

### Keithley Instruments Inc

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Fax: +1 440.248.6168

[www.keithley.com](http://www.keithley.com)

### SUSS MicroTec Test Systems

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Waterbury Center,  
VT 05677,  
USA

Tel: +1 800 685 7877

Fax: +1 802 244 7853

[www.suss.com](http://www.suss.com)

## 15 Assembly/packaging materials

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Fax: +1 512 231 8183

[www.epak.com](http://www.epak.com)

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### Wafer World Inc

(see section 3 for full contact details)

### Williams Advanced Materials

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Buffalo, NY 14214,  
USA

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Fax: +1 716 833 2926

[www.williams-adv.com](http://www.williams-adv.com)

## 16 Assembly/packaging equipment

### Ismeca Europe Semiconductor SA

Helvetie 283,  
La Chaux-de-Fonds, 2301,  
Switzerland

Tel: +41 329257111

Fax: +41 329257115

[www.ismeca.com](http://www.ismeca.com)

### Kulicke & Soffa Industries

1005 Virginia Drive,  
Fort Washington,  
PA 19034,  
USA

Tel: +1 215 784 6000

Fax: +1 215 784 6001

[www.kns.com](http://www.kns.com)

### Palomar Technologies Inc

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Tel: +1 760 931 3600

Fax: +1 760 931 5191

[www.PalomarTechnologies.com](http://www.PalomarTechnologies.com)

### TECDIA Inc

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[www.tecdia.com](http://www.tecdia.com)

Tecdia is a **TECDIA** manufacturer of single-layer chip capacitors, chip resistors, DC boards, bias-Ts, diamond scribing tools and dispensing nozzles.

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CA 92127,  
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[www.quikcpak.com](http://www.quikcpak.com)

## 18 Chip foundry

### Compound Semiconductor Technologies Ltd

Block 7, Kelvin Campus,  
West of Scotland, Glasgow,  
Scotland G20 0TH,  
UK

Tel: +44 141 579 3000  
Fax: +44 141 579 3040

[www.compoundsemi.co.uk](http://www.compoundsemi.co.uk)

### United Monolithic Semiconductors

Route departementale 128,  
BP46, Orsay, 91401,  
France

Tel: +33 1 69 33 04 72  
Fax: +33 169 33 02 92

[www.ums-gaas.com](http://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](http://www.marlerenterprises.net)

## 20 Facility consumables

### W.L. Gore & Associates

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[www.gore.com](http://www.gore.com)

## 21 Computer hardware & software

### Ansoft Corp

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Fax: +1 412 471 9427

[www.ansoft.com](http://www.ansoft.com)

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## 22 Used equipment

### Class One Equipment Inc

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Fax: +1 770 808 8308

[www.ClassOneEquipment.com](http://www.ClassOneEquipment.com)

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Fax: +44 (0)20 7405 9772

[www.henrybutcher.com](http://www.henrybutcher.com)

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Fax: +49 711 8804 1950

[www.mw-zander.com](http://www.mw-zander.com)

### TECDIA Inc

(see section 16 for full contact details)

## 24 Consulting

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Tel: + 33 (0)1 30 47 29 03

E-mail: [jean-luc.ledys@neuf.fr](mailto:jean-luc.ledys@neuf.fr)

## 25 Resources

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San Jose, CA 95134, USA

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Fax: +1 408 428 9600

[www.semi.org](http://www.semi.org)

### Yole Développement

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**6–9 September 2011**

## 13th China International Optoelectronic Exposition (CIOE 2011)

Shenzhen Convention & Exhibition Center, China

**E-mail:** [shirly@cioe.cn](mailto:shirly@cioe.cn)

[www.cioe.cn/html/list\\_543.html](http://www.cioe.cn/html/list_543.html)

**11–16 September 2011**

## International Conference on Silicon Carbide and Related Materials (ICSCRM 2011)

Renaissance Cleveland Hotel, Cleveland, OH, USA

**E-mail:** [Barbara.L.Kakiris@nasa.gov](mailto:Barbara.L.Kakiris@nasa.gov)

[www.icscrm2011.org](http://www.icscrm2011.org) [Neudeck@nasa.gov](mailto:Neudeck@nasa.gov)

**12–16 September 2011**

## Solid-State Device Research — 41st European Conference (ESSDERC-2011) and Solid-State Circuits Research — 37th European Conference (ESSCIRC-2011)

Helsinki, Finland

**E-mail:** [cor.claeys@imec.be](mailto:cor.claeys@imec.be)

[www.esscirc.org](http://www.esscirc.org)

**13–15 September 2011**

## LED Lighting Institute

Rensselaer Polytechnic Institute's Lighting Research Center (LRC), Troy, NY, USA

**E-mail:** [frerid@rpi.edu](mailto:frerid@rpi.edu)

[www.lrc.rpi.edu/education/outreachEducation/InHouseInstitute.asp](http://www.lrc.rpi.edu/education/outreachEducation/InHouseInstitute.asp)

**14–16 September 2011**

## 8th IEEE International Conference on Group IV Photonics (GFP 2011)

The Royal Society, London, UK

**E-mail:** [r.bankowski@ieee.org](mailto:r.bankowski@ieee.org)

[www.photonicsconferences.org/GFP2011](http://www.photonicsconferences.org/GFP2011)

**19–22 September 2011**

## SPIE Remote Sensing 2011 and SPIE Security & Defence Europe 2011

Clarion Congress Hotel, Prague, Czech Republic

**E-mail:** [customerservice@spie.org](mailto:customerservice@spie.org)

<http://spie.org/security-defence-europe.xml>

<http://spie.org/remote-sensing-europe.xml>

**19–22 September 2011**

## SPIE Photomask Technology 2011

Monterey, CA, USA

**E-mail:** [customerservice@spie.org](mailto:customerservice@spie.org)

<http://spie.org/photomask.xml>

**21–23 September 2011**

## SOLARCON Korea 2011

COEX, Seoul, Korea

**E-mail:** [jkim@semi.org](mailto:jkim@semi.org)

[www.solarconkorea.org/SOLARKOREA-EN](http://www.solarconkorea.org/SOLARKOREA-EN)

**27–29 September 2011**

## LED professional Symposium + Expo 2011

Bregenz, Austria

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**E-mail:** symposium@led-professional.com  
[www.led-professional-symposium.com](http://www.led-professional-symposium.com)

**28–30 September 2011**

**LED Japan Conference & Expo/  
Strategies in Light**

Pacifico Yokohama, Japan

**E-mail:** Lubah@pennwell.com

[www.sil-ledjapan.com](http://www.sil-ledjapan.com)

**28 August – 1 September 2011**

**ICSI-7 (7th International Conference on Si  
Epitaxy and Heterostructures)**

Leuven, Belgium

**E-mail:** annemie.kumps@imec.be

[www.icsi7.com](http://www.icsi7.com)

**2–7 October 2011**

**36th International Conference on  
Infrared, Millimeter, and Terahertz Waves  
(IRMMW-THz 2011)**

Hyatt Regency Hotel, Houston, TX, USA

**E-mail:** daniel@rice.edu

[www.irmmw-thz2011.org](http://www.irmmw-thz2011.org)

**4–6 October 2011**

**Strategies in Light Europe Conference and  
Exhibition (SIL Europe 2011)**

Crowne Plaza Milan Linate, Milan, Italy

**E-mail:** emilyp@pennwell.com

[www.sileurope.com](http://www.sileurope.com)

**4–6 October 2011**

**2011 US Workshop on the Physics and  
Chemistry of II-VI Materials (II-VI Workshop)**

Chicago, IL, USA

**E-mail:** jamodeo@pcm411.com

[www.ii-viworkshop.org](http://www.ii-viworkshop.org)

**4–8 October 2011**

**CEATEC JAPAN 2011**

Makuhari Messe, Japan

**E-mail:** contact@ceatec.com

[www.ceatec.com](http://www.ceatec.com)

**5–6 October 2011**

**Deutscher MBE-Workshop 2011**

Berlin, Germany

**E-mail:** dmb2011@pdi-berlin.de

[www.dmb2011.de](http://www.dmb2011.de)

**9–13 October 2011**

**IEEE Photonics 2011 Conference (IPC11)**

Arlington, VA, USA

**E-mail:** m.hendrickx@ieee.org

[www.photonicsconferences.org/PHOTONICS2011](http://www.photonicsconferences.org/PHOTONICS2011)

**9–14 October 2011**

**220th Electrochemical Society (ECS) Meeting**

Boston, MA, USA

**E-mail:** meetings@electrochem.org

[www.electrochem.org/meetings/biannual/fut\\_mtgs.htm](http://www.electrochem.org/meetings/biannual/fut_mtgs.htm)

**9–14 October 2011**

**14th European Microwave Week (EuMW2011)**

Manchester, UK

**E-mail:** GenChair@EuMW2011.eu

[www.eumweek.com](http://www.eumweek.com)

**16–19 October 2011**

**2011 IEEE Compound Semiconductor  
Integrated Circuit Symposium (CSICS 2011)**

Hilton Waikoloa Village, Hawaii, USA

**E-mail:** customer.service@ieee.org

[www.csics.org](http://www.csics.org)

**18–20 October 2011**

**Solar Power International 2011**

Dallas Convention Center, TX, USA

**E-mail:** spi@experient-inc.com

[www.solarpowerinternational.com](http://www.solarpowerinternational.com)

**20–21 October 2011**

**11th International Conference on  
Condensed Matter and Statistical Physics  
(ICCMSP-2011)**

Agadir, Morocco

**E-mail:** iccm2011@gmail.com

[www.univ-ibnzohr.ac.ma/iccm2011](http://www.univ-ibnzohr.ac.ma/iccm2011)

**24–26 October 2011**

**LEDs 2011: Bringing Lighting to Life**

San Diego, CA, USA

**E-mail:** john.buss@pira-international.com

[www.ledsconference.com](http://www.ledsconference.com)

**14–15 November 2011**

**3rd Concentrated Photovoltaic Summit USA**

San Jose, CA, USA

**E-mail:** matt@pv-insider.com

[www.pv-insider.com/cpv](http://www.pv-insider.com/cpv)

**15–16 November 2011**

**Netherlands MicroNanoConference '11**

Conference Centre De ReeHorst, Ede, The Netherlands

**E-mail:** m.reinhold@fhi.nl

[www.micronanoconference.nl](http://www.micronanoconference.nl)

**28 November – 2 December 2011**

**2011 MRS Fall Meeting**

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