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RFMD acquiring Amalfi • EV Group doubles cleanroom space
5N opens Malaysian recycling plant • GT acquires Twin Creeks

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p46 NGK's GaN wafers nearly double green LED efficiency. Chip facet size, 0.3mm x 0.3mm; injection current, 200mA; central wavelength, 525nm.



p50 Osram's high-power Displix black/blackprint multi-chip SMT LED for high-contrast displays in extreme outdoor conditions.



p52 Brolis Semiconductors' new MBE and laser diode manufacturing facility, being opened in December.



Cover: Fairchild has launched its first silicon carbide bipolar junction transistor, which it claims provides the most efficient 1200V power conversion switch ever made, with lower conduction and switching losses enabling the achievement of higher output power in the same system form factor. **p24**

Increasing profile for silicon carbide & gallium nitride power devices

The image on the cover of this issue (courtesy of Fairchild launching its first silicon carbide bipolar junction transistors) highlights the focus in our feature article on pages 90–93 on developments in silicon carbide devices.

As mentioned by Fairchild on page 24, the higher efficiency of SiC bipolar junction transistors (BJTs) enables higher switching frequencies due to lower conduction and switching losses, providing higher output power in the same system form factor. SiC's superior material properties compared to silicon (as detailed on page 90) also enable other device types (e.g. Schottky diodes, MOSFETs and JFETs) with improved performance for various applications, including inverters in solar power systems and electric vehicles and hybrid electric vehicles (EV/HEV), signal conditioning in power factor correction (PFC) circuits in power supplies etc.

As well as device makers that have traditionally focused on silicon carbide (such as Cree), other, more diversified manufacturers such as Microsemi are increasingly focusing on SiC, while established silicon chip firms like Fairchild (which acquired Swedish SiC bipolar power transistor maker TranSiC in April 2011) are commercializing their interests in SiC.

This was manifested by the heightened profile of power semiconductor products based on both silicon carbide and fellow wide-bandgap semiconductor material gallium nitride at trade shows such as Electronica 2012 in Munich, Germany in mid-November. There, as well as Fairchild making SiC a focus of its exhibit (demonstrating its new SiC BJTs), Japan's Rohm (which acquired German SiC wafer manufacturer SiCrystal in 2010) also exhibited its SiC Schottky barrier diodes and MOSFETs (first showcased at July's TECHNO-FRONTIER 2012 event in Tokyo). Also at Electronica, Cree launched what it claims is the industry's first fully qualified, production-ready all-SiC power module (see page 26), while Microsemi launched 1200V SiC Schottky diodes, as well as GaN-on-SiC 500-Watt S-band RF power transistors for air-traffic control applications (page 23). Also exhibiting its GaN-based RF components at Electronica was RF Micro Devices, launching a new series of high-power GaN broadband power transistors and announcing the production release of a new family of highly linear GaN RF unmatched power transistors (page 25). Meanwhile, power management specialist International Rectifier exhibited its 'GaNpowIR' GaN-based power device platform.

Another development in SiC (as covered on page 22) is Raytheon's testing of SiC mixed-signal devices at temperatures up to 400°C. The firm notes that high-temperature integrated circuits are desirable in applications such as aero engines (monitoring engine performance in the heart of the engine) or in deep hydrocarbon and geothermal drilling applications. As SiC power-discrete devices proliferate, there is a growing need for more control functions capable of operating in the same temperature and power management conditions, without heat dissipation constraints, the firm adds.

So, while discrete SiC devices are gaining in applications, there is also the prospect of SiC CMOS technology creating logic and analog functions on the same chip, for operation in harsh environments.

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

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

Regular issues contain:

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

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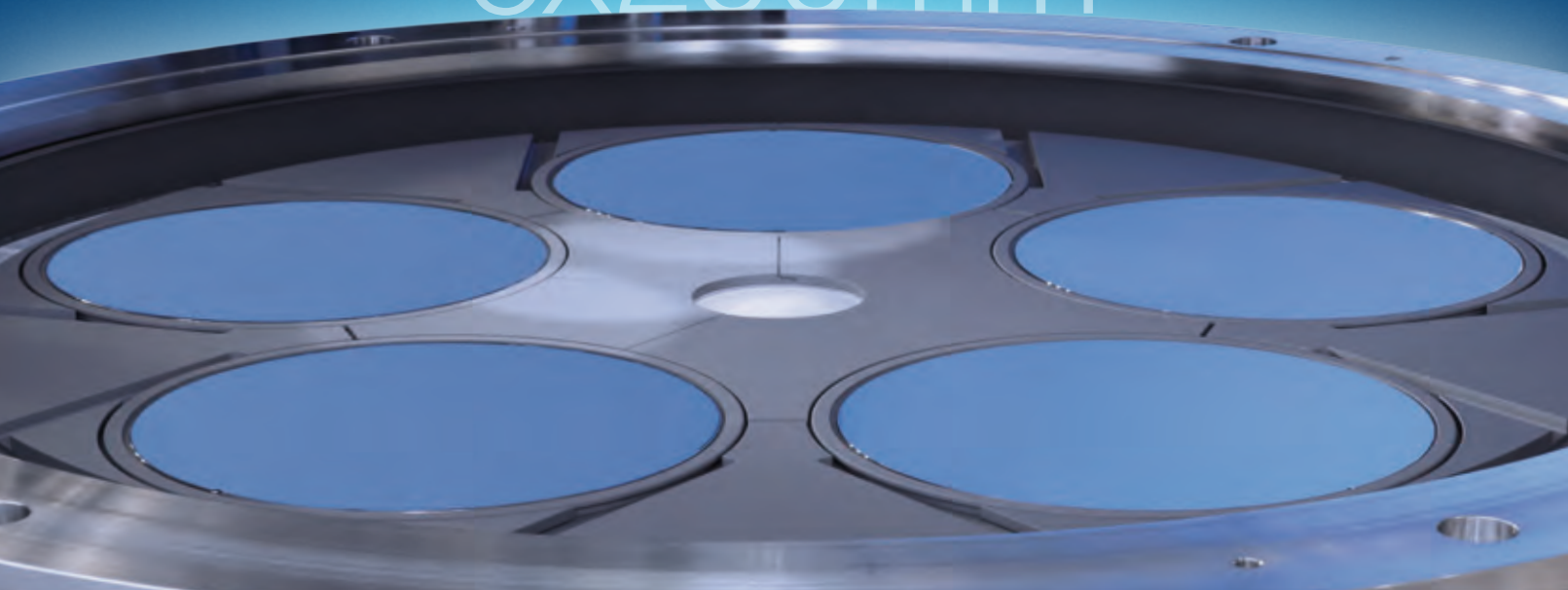
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Bulk GaN cost to fall 60% to \$730 for 2" substrate by 2020

GaN can displace cheaper silicon through 360–380% better performance

Wide-bandgap semiconductor materials such as gallium nitride (GaN) offer far higher performance than traditional silicon but cost significantly more. However, by 2020 GaN costs will drop enough for it to become competitive based on performance gains, reckons market analyst firm Lux Research in its new report 'Price or Performance: Bulk GaN Vies with Silicon for Value in LEDs, Power Electronics and Laser Diodes'.

Bulk GaN currently costs about \$1900 or more for a 2-inch substrate, compared with \$25–50 for a far larger 6-inch silicon substrate. But GaN materials offer higher efficiencies than silicon, leading to greater energy savings in devices such as power electronics, laser diodes, and light-emitting diodes. These gains can offset cost disadvantages – the price-to-performance ratio is the key to adoption, says Lux Research.

"The future of bulk GaN is going to come down to how it faces off against silicon substrates," says analyst Pallavi Madakasira, lead author of the report. "Bulk GaN wins in laser diodes and it can become relevant in LEDs and power electronics by boosting yield and performance."

Lux Research analysts broke down the manufacturing costs for the ammonothermal and hydride vapor phase epitaxy (HVPE) processes for making bulk GaN, as well as for GaN epitaxy on both silicon and GaN substrates, and determined where the price/performance trade-off will land. Their findings include the following:

- HVPE is the cheaper alternative: 2-inch ammonothermal substrate costs will fall by more than 60% to \$730/substrate in 2020. While 4-inch HVPE substrate costs will fall by 40% to \$1340/substrate in 2020, the larger size makes it the

more economical choice.

- Performance boost is key: Bulk GaN can overcome high cost by boosting performance, in terms of lumen (lm) output in LEDs or of volt-amp (V-A) capacity in power electronics, by allowing the use of smaller dies and providing higher yields. In LEDs, GaN can match silicon with a 380% relative performance – an ambitious but realistic goal. For power electronics, performance at 360% of devices on silicon makes bulk GaN a winner.

- New materials on the horizon: Emerging materials such as aluminium nitride (AlN) are suited to very low-wavelength ultraviolet LED, green laser diode and high-switching-frequency power electronics applications, and can be an effective alternative to bulk GaN.

The report is part of Lux Research's Energy Electronics Intelligence service.

www.luxresearchinc.com

Samsung's Galaxy Appeal shows shift from GaAs to CMOS for power amplifiers in 3G handsets

Samsung's Galaxy Appeal is one of the first mass-produced phones to ship with a high-performance 3G CMOS silicon power amplifier (PA), according to ABI Research in its 'SAMSUNG GALAXY APPEAL (I827) Teardown' report.

Despite the historical presence of CMOS in the 2G handset market, concerns over performance have severely limited its progress in the 3G domain, notes the firm. The incumbent manufacturers of GaAs-based PAs — such as Avago Technologies, TriQuint Semiconductor, RF Micro Devices, Skyworks Solutions and Anadigics — have not felt any real impact to date. However, new products such as the J5501 Band 1 PA from Javelin Semiconductor Inc

of Austin, TX, USA — as found in the Galaxy Appeal — indicate that this performance gap has been narrowed significantly, reckons ABI.

"Even though the CMOS PA is over 3 times the die area of a typical GaAs PA (3.3mm² vs 1mm² in the Appeal, for example), the lower CMOS wafer cost, simple packaging, and the added digital content (that reduces test times) allow the CMOS PAs — such as the ones produced by Black Sand and Javelin — to compete competitively on cost as well as performance," says Jim Mielke, VP of engineering at ABI. The market should, "Expect single-digit market share numbers for CMOS PAs in 2013," he adds. "The CMOS PA market volumes could be

even higher if Qualcomm is successful with their penta-band CMOS PA they are actively presenting now."

ABI says that product testing of the Galaxy Appeal and the Javelin J5501 Band 1 provided some conclusions that may be central to this evolving market:

- CMOS PAs match GaAs efficiency across all power levels up to 22.5dBm;

- CMOS PAs have an efficiency advantage at low power levels (up to 20% low current);

- GaAs PA die are significantly smaller than CMOS equivalents (1mm² vs 3.3mm²); and

- both GaAs and CMOS PAs can be manufactured for under \$0.40.

www.abiresearch.com

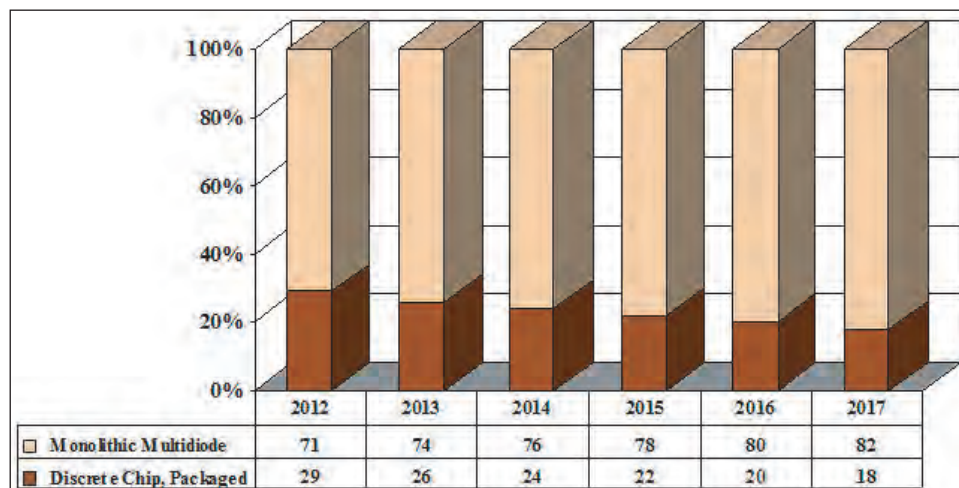
Monolithic multi-diode integrated devices to increasingly dominate semiconductor optical amplifier market

Discrete chip packaged SOAs to fall from 29% share to 18% in 2017

Of the global market for semiconductor optical amplifiers (SOAs), the integrated SOA chip packaged devices (monolithic multi-diode) are expected to hold 71% share of global consumption (by value) in 2012, and rise to 82% in 2017, according to a new market forecast and analysis report by Electroni-Cast Consultants.

In the study, the SOA market is segmented into two fabrication configuration categories: discrete chip packaged device and monolithic multi-diode integration (the 'monolithic multi-diode' value is the pro-rated SOA share of total device value on complex photonic integrated circuits).

SOAs have a similar structure to Fabry-Pérot laser diodes but with anti-reflection design elements at the end-faces. High optical non-linearity makes the SOA an attractive solution for all optical signal processing, such as photonic



SOA market share value forecast (%), by fabrication configuration.

switching and wavelength conversion, says ElectroniCast. There has been much research on SOAs as elements for optical signal processing, wavelength conversion, clock recovery, signal demultiplexing, and pattern recognition, the firm adds. The report is therefore also segmented by functional product-type:

optical switch element, optical amplifier, and wavelength converter.

Integrated with other optical components, SOAs provide high fiber-to-fiber gain, optical gates, entire transceivers, wavelength converters and optically controlled switches and demultiplexers.

www.electronicast.com

LED lamps to comprise 66% of lighting by 2020, but market shrinking after 2015

According to the report 'The World Market for Lamps & Luminaires in General Lighting' from IMS Research, by 2016 it will be much more common for LEDs to produce greater than 200 lumens per watt, as LEDs are continually improving in efficiency and the quality of light they emit, all while decreasing in cost.

In particular, the development of several new methods of building replacement LED lamps (light guides, remote phosphors, liquid cooling) is creating new lighting products that can better mimic current lighting technologies at lower prices.

The greatest impact from these improvements is that LED lighting will not be boxed into niche lighting markets, but in the long term

should be able to penetrate all viable lighting markets that currently use an array of different technologies.

In the medium term, the rapid adoption rate of LEDs in certain applications, in conjunction with their long life, will have a profound effect on the global lamp market, reckons IMS. As more and more sockets are filled with LEDs, the market for replacement lamps will decrease. This, in conjunction with

In the medium term, the rapid adoption rate of LEDs in certain applications, in conjunction with their long life, will have a profound effect on the global lamp market

the year-on-year decrease in prices for LED lamps, will lead to market growth slowing in 2015 and then decreasing in 2016. By 2020, it is forecasted that LED lamps will make up 66% of the market, and the market will be shrinking.

IMS notes that the forecasting of different lamp shapes by technology and wattage is extremely important in the lighting sector, as different light sources are needed for different applications. For example, the penetration of LEDs into office settings (where fluorescent technologies are used) will be much different than the penetration of LEDs into retail applications (where directional reflector lamps are installed on a large scale).

www.ledmarketresearch.com

Skyworks beats quarterly forecast; better 2013 predicted

Despite challenges, portfolio and market pull give rise to optimism

Skyworks Solutions Inc of Woburn, MA, USA, which makes analog and mixed-signal semiconductors, has reported its fiscal fourth-quarter and full-year 2012 results to end-September.

For fiscal Q4, revenue was \$421.1m, up 8.2% on \$389m last quarter (and exceeding its revised guidance of \$420m, given in September).

Non-GAAP operating income was \$103.6m, up 13% on Q3's \$91.7m. Diluted earnings per share were \$0.53, up on \$0.45 last quarter.

For fiscal full-year 2012, revenue was \$1.57bn, up 11% on 2011's \$1.42bn. Diluted earnings per share were \$1.90.

"Skyworks is capitalizing on global mobile connectivity ubiquity and demand for high-performance analog solutions across a diverse set of vertical markets," says president & CEO David J. Aldrich. "Interrelated macro trends such as social networking, cloud-based content and the explosion of audio and video streaming are driving increased semiconductor content and complexity in smart-phones, tablets, ultrabooks and e-readers as well as within the supporting network infrastructure.

"At the same time, wireless and power management functionality is rapidly proliferating across adjacent applications spanning machine-to-machine, automotive, broadband, home automation, smart grid and medical markets," he adds. "Given our differentiated product portfolio, engagements with all key OEMs and scale, Skyworks is well positioned to continue to gain market share, capture additional content per platform and, as a result, significantly outperform our targeted markets throughout fiscal 2013."

Skyworks' Q4 highlights included: launching a suite of custom ZigBee sensors supporting home monitoring and security systems; supporting NetGear's 802.11ac deployments with nearly 20 analog devices per router; ramping silicon-on-insulator

antenna switch modules (ASMs) as part of LTE smart-phones and tablets; capturing RF sockets at Alcatel-Lucent, Cisco, Ericsson, Huawei, Siemens Nokia and ZTE for 3G/4G base-stations; and shipping more than 7 million camera flash drivers.

"Our visibility is strongly driven by new platform ramps, design-win momentum and the depth of our product pipeline," says VP & chief financial officer Donald Palette. For fiscal Q1/2013, Skyworks expects revenue to rise 14% year-on-year and 7% sequentially to about \$450m, with further improvement in operating margin to above 25% and diluted earnings per share of \$0.54.

"I'd like to highlight four key elements of our strategy that underpin our growth and expectations: we are connected to high-growth markets; we are broadly diversified across customers, products and markets; our competitive differentiation provides a sustainable advantage; and our business model enables us to efficiently convert strong top line growth into superior operating results," says Aldrich.

The booming mobile broadband market provides Skyworks with one of "the highest growth markets within [our] technology space today", Aldrich added. "The mobile broadband phenomenon continues to advance on a global basis, slowly displacing traditional computing. Internet stalwarts like Google, Amazon and Microsoft, who historically have not participated in mobile devices, today see mobility as a critical component of their long-term strategies. This has

spurred a race to provide the next generation of leading-edge smart-phones and tablets as a gateway for e-commerce, for on-demand content, location-based advertising, mobile apps, cloud-based services and social networks."

Next he considered the benefits of Skyworks' diversification strategy: "There are three elements to this: diversification across our OEM customers, within our product offering and across a broad array of end markets. The result is that today we are the supplier of choice with a leading share position at every mobile device OEM and baseband partner, helping to insulate us somewhat from customer share shifts."

Aldrich considers the variety of Skyworks' product portfolio to be another strength: "We're experts in RF and analog system design, leveraging a global force of system and applications engineers. We offer an unmatched technology portfolio that includes deep expertise in SOI, CMOS, GaAs, BiFET and silicon germanium, along with a library of nearly 1000 patents."

Finally, the "explosion in mobile connectivity" constituted another reason for optimism. "Over the course of 2013, we expect to see a wave of 802.11ac-enabled notebooks, tablets and smart-phones enter the market with higher addressable dollar content for Skyworks. We already have significant traction in the 802.11ac market and have been designed into some of the first ultrabooks and smart-phones to incorporate this technology."

www.skyworksinc.com

New stock repurchase program announced

Skyworks' board of directors has authorized the repurchase of up to \$200m of its common stock on the open market or in privately negotiated transactions.

Any repurchased shares will be

available for use in connection with the firm's stock plans and for other corporate purposes.

The program will be funded using working capital (cash reserves were \$307m at end-September).

Skyworks widens lead again in power amplifier market

Complete front-end platform solutions helping top PA suppliers

Skyworks Solutions increased its share of the market for RF power amplifiers (PAs) used in cellular terminals in 2011 and first-half 2012, increasing its lead on second-ranked RF Micro Devices Inc and most other suppliers, according to the report 'Cellular PA and RF Front-End Module Market Share: 2011 and 1H 2012' from market research firm Strategy Analytics. The report outlines unit shipments, PA revenue and developments over the past 18 months for the top ten

suppliers of cellular PAs (as well as breaking out estimated shipments by air interface).

"The PA market has shifted toward multi-mode, multi-band PAs and complete front-end platform solutions aligned with the leading chipsets," says Christopher Taylor, director of the Strategy Analytics RF & Wireless Components market research service. "This has favored Skyworks, RFMD, Avago, TriQuint and Murata, and has made competing more difficult for PA suppliers

that lack filters, duplexers, RF switches and modules that combine these with PAs," he adds.

"For the first time, we are now seeing CMOS PAs for W-CDMA register in the market share rankings, and a more realistic assessment by CMOS suppliers on how to compete with GaAs," comments Eric Higham, director of the Strategy Analytics GaAs and Compound Semiconductor market research service.

www.StrategyAnalytics.com

High-efficiency front-ends to boost range for water and gas metering

Skyworks has launched a family of highly efficient front-end solutions enabling size and cost reductions for smart water and gas metering. Many of them also allow plug-and-play functionality, reducing design time for new products. The firm says its solutions are being used by 40 tier-1 utility and smart energy providers throughout Europe.

"Skyworks' newest front-end solutions offer increased range, high power efficiency and robust design flexibility — three critical features

in smart metering applications," says Liam K. Griffin, executive VP & general manager of high-performance analog. Skyworks is delivering highly integrated modules that are enabling smart utility grids to improve their capacity and successfully manage customer demand, while allowing consumers to monitor and use energy and water more resourcefully, he adds.

According to the GSM Association, the utilities sector is set to invest \$200bn in smart grids through 2015

as the need to provide growing populations with enough water and energy — without causing potentially catastrophic damage to the environment — is one of the biggest challenges facing governments and societies. Systematically using embedded mobile connectivity to create smart utility grids and smart energy environments can improve suppliers' ability to effectively manage demand and enable consumers and businesses to use resources more efficiently.

Skyworks makes leadership changes to drive alignment across product portfolio

Skyworks has announced executive management changes that aim to increase collaboration between its front-end and analog teams, driving development of next-generation solutions.

Liam Griffin, executive VP & general manager of the high-performance analog business, has been promoted to executive VP & corporate general manager. Encompassing responsibility for all business units, the newly created role is designed to enhance product line performance, leverage organizational synergies, and best capitalize on market opportunities. Prior to his leadership role in high-

performance analog, Griffin was senior VP of sales & marketing, gaining an in-depth knowledge of Skyworks' product portfolio.

"Skyworks is enabling mobile connectivity across some of the world's most exciting communications platforms, including smartphones, tablets and e-readers," says president & CEO David J. Aldrich. "We are capturing more content per platform than ever before and rapidly expanding our footprint in complementary new vertical markets such as automotive, medical and home automation," he adds. "With our customers demanding

higher levels of analog and RF integration and placing greater value on total solutions, we are proactively driving alignment across all Skyworks teams to create a more integrated and rapid development cycle for our next-generation products."

As part of the realignment, Gregory Waters will be leaving Skyworks following a transition period. "We thank Greg for his instrumental role in building Skyworks' front-end solutions franchise and are grateful for his many contributions over the years," Aldrich commented.

www.skyworksincl.com

TriQuint's revenue grows 13% in Q3

Profitability regained faster than expected

For third-quarter 2012, RF front-end component maker and foundry services provider TriQuint Semiconductor Inc of Hillsboro, OR, USA has reported revenue of \$200.8m, down 7% on \$216m a year ago but up 13% on \$178m last quarter, driven by increased demand from major smartphone customers and order strength for both infrastructure and defense products.

Compared with last quarter, Mobile Devices revenue grew 13% from \$112.3m to \$126.9m (remaining 63% of total revenue), boosted by the launch of Apple's iPhone 5 in mid-September (since Apple contractor Foxconn contributes more than a third of TriQuint's sales). Networks revenue grew 11% from \$44.8m to \$49.9m (remaining 25% of total revenue). Defense revenue was up 16% from \$20.8m to \$24m (12% of total revenue).

In particular, during the quarter, TriQuint grew design wins for multi-

mode power amplifier (MMPA) modules (a second-generation device delivers 15% more browsing time) and captured a design win in small-cell base-station applications. The firm also launched what is claimed to be the first dual-channel 40/100G driver for high-speed optical networks. In addition, TriQuint won a \$2.7m contract from the US Defense Advanced Research Projects Agency (DARPA) to triple the power handling performance of gallium nitride (GaN) circuits.

Although still down on 36.3% a year ago, gross margin has rebounded from 27.9% last quarter to 32.5% (above the guidance of 30–32%), driven by improved product mix and factory utilization. Although up on \$58.7m a year ago, operating expenses have been cut from \$64.3m (operating margin of 36% of revenue) last quarter to \$62.1m (31% of revenue).

After entering into a net loss

last quarter (of \$15m, or \$0.09 per share), earnings rebounded to a net income of \$2.5m (\$0.02 per diluted share, better than the expected breakeven), although this is still down on \$19m (\$0.11 per diluted share) a year ago.

During the quarter, cash and investments fell further, by \$17.8m from \$162.4m to \$144.6m, due mainly to higher sales volume later in the quarter resulting in a higher accounts receivable ending balance.

For fourth-quarter 2012, TriQuint expects revenue to grow 10–12% to \$220–225m, with continued strength in each of its major markets but with pressure on gross margins due to planned inventory reductions. Non-GAAP gross margin is expected to fall back to about 30%, impacted by an improvement in inventory turns. Net income per diluted share should be \$0.01–0.03.

www.triquint.com

TriQuint showcases new products at European Microwave Week

At October's European Microwave Week in Amsterdam, TriQuint showcased new products including packaged transistors and amplifiers (four GaN-based; four GaAs-based) supporting commercial and defense applications (e.g. emergency responder radios, electronic warfare, radar solutions and test equipment).

The four GaN RF power transistors (in EAR99 packages) deliver output of 30–37W (CW) for applications from commercial and defense radar to communications, test equipment, electronic warfare (EW) and similar broadband systems:

- the 28V flangeless T1G6003028-FS and the flanged T1G6003028-FL both operate at DC–6GHz and output 30W with 55% drain efficiency and 14dB gain at 3.5GHz and 44% drain efficiency and 10dB gain at 6GHz. Operating current is 200mA.
- the 32V flangeless T1G4003532-

FS and the flanged T1G4003532-FL both operate at DC–3.5GHz and output 37W with gain of over 16dB at 3.5GHz and 10dB at 6GHz and power-added efficiency (PAE) of 60% at 5GHz and 49.6% at 6GHz. Operating current is 2.4A, suiting S-band radar applications etc.

All can withstand output impedance (VSWR) mismatches up to 10:1 without functional damage and are optimized for high drain bias conditions, reducing system cost and thermal management overhead.

The four GaAs pHEMT RF power amplifier modules deliver high output power, gain and efficiency with frequency coverage of 6–38GHz.

Each is packaged for easier assembly including designs supporting multi-layer PCB layouts:

- the TGA2502-GSG (in a 14-lead flange-mount package) delivers 2.8W over 13–16GHz for VSAT

systems, with 20dB large-signal gain, 25dB small-signal gain, 25% PAE, and 7V at 1.3A;

- the TGA2704-SM (in a 7mm x 7mm x 1.27mm leadless SMT package) delivers 8W over 9–11GHz for microwave radio and radar, with 19dB large-signal gain, 22dB small-signal gain, 40% PAE, and 9V at 1.05A;

- the TGA2710-SM (in a 7mm x 7mm x 1.27mm leadless SMT package) delivers 8W over 9.5–12GHz for microwave radio and radar, with 19dB large-signal gain, 20dB small-signal gain, 36% PAE, and 9V at 1.05A; and

- the TGA2575-TS (with a die mounted to an 8.92mm x 5.31mm thermal spreader) delivers 3W over 32–38GHz for communications and defense radar systems, with 19dB small-signal gain, 22% PAE, and 6V at 2.1A.



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Anadigics grows 14% in Q3, driven by wireless and CATV

New products like MMPAs offset decline in legacy business

For third-quarter 2012, GaAs-based broadband wireless and wireline communications component maker Anadigics Inc of Warren, NJ, USA has reported net sales of \$28.6m, down 23.1% on \$37.3m a year ago but up 14.1% on \$25.1m last quarter.

Revenue for Infrastructure (formerly termed Broadband) was \$7.5m (up 5.8% on \$7.1m last quarter), driven mainly by growth in CATV infrastructure to \$3.8m, plus \$1.1m from CATV subscriber, \$1m from WiMAX, and \$1.3m from WiFi.

Wireless revenue was \$21.1m, up 17.3% on \$18m last quarter, due largely to greater 3G content per device at top customers, fueled by increased dual-band shipments.

There were three greater-than-10% customers (Samsung, ZTE, Huawei) and four customers in the 5–10% range (Cisco and Sierra Wireless — which last quarter replaced BlackBerry-maker Research In Motion — plus two distributors Richardson and World Peace Group).

“Revenue from the ramping of new products exceeded declines in legacy products,” says president & CEO Ron Michels. “These results serve as evidence that our growth initiatives are beginning to take hold as we maintain our focus on introducing innovative products and expanding our served available markets.”

Specifically, Anadigics started generating revenue for two new product ranges: its ProEfficient power amplifiers (with single-band products launched in June now

shipping in production volumes to OEMs including Samsung and Huawei); and its multi-mode multi-band power amplifier (MMPA) products (shipping in volume to Samsung for the Galaxy Express and Galaxy S Relay 4G smart-phones). In addition, dual-band ProEfficient Plus products were launched in September (“Working closely with a reference design leader, we are now sampling a key OEM”, says Michels). Regarding MMPAs, design wins for more smartphones are pending. “To build upon this success, we’ve developed our next-generation penta-band MMPA and are starting to sample key customers,” Michels adds.

“We have continued to accelerate new product introductions and at the same time, we are effective in managing R&D expenses to a 3% sequential reduction [down again, from \$11.3m last quarter to \$10.8m],” says chief financial officer Terry Gallagher. “Selling & administrative expenses fell by about 8% to \$5m as we eliminated non-critical expenses through past restructurings and remain tough on costs going forward,” he adds.

Although still down on the low 50s percent a year ago, capacity utilization has risen from 40% last quarter to 45%. Favorably impacted by the incremental contribution of the increase in revenue and improved absorption of manufacturing costs, non-GAAP gross margin rebounded from negative 7.5% last quarter to

just above break-even (though still down on +6.7% in Q1/2012 and 20% in Q3/2011).

Combining the gross profit improvement with lower operating expenses, non-GAAP net loss was cut from \$17.9m last quarter to \$15.3m. However, this is still nearly double the \$7.8m a year ago.

Capital expenditure (was cut further, from \$0.7m last quarter to just \$0.25m (compared with \$1.5m a year ago). During the quarter, cash, cash equivalents and short- and long-term marketable securities fell from \$73.1m to \$62.2m.

“Although there was a reduction in R&D, it was not at the expense of future growth, as new products introduction and investments in R&D remain critical to our growth strategy,” notes Gallagher. Most recently, in October, Anadigics launched a new gallium nitride (GaN) line amplifier MMIC.

“Looking to the fourth quarter, we expect sequential [double-digit] growth in wireless, with new products continuing to more than offset the decline in legacy business,” says Gallagher. Infrastructure business will probably be flat. Capacity utilization should increase further.

“With a robust product development pipeline, strong design-win activity and outstanding manufacturing prowess, we believe that Anadigics is well positioned for continued revenue growth and gross margin improvement,” concludes Michels.

www.anadigics.com

Production volumes of power amplifiers shipped for Galaxy Note II

Anadigics is shipping production volumes of its ALT6702, ALT6725, AWC6323, AWC6325 and AWT6624 LTE, CDMA, and WCDMA power amplifiers to Samsung Electronics for its new Galaxy Note II phablet.

Verizon Wireless’ model uses the AWC6323; the Sprint model uses the ALT6702 and AWC6323. Other

models for several wireless carriers in the USA and Asia use one or a combination of the firm’s single-band and dual-band PAs.

The ALT6702 and AWT6624 single-band and ALT6725, AWC6323 and AWC6325 dual-band PAs leverage patented design architectures and InGaP-Plus technology to deliver

efficiency across all power levels.

“By working closely with top-tier wireless manufacturers, we have developed a comprehensive portfolio of power amplifier solutions that are optimized to deliver longer battery-life in smartphones and tablets,” says Michael Canonico, senior VP of worldwide sales.

Hybrid line amplifier module family expanded to 1GHz

Anadigics Inc of Warren, NJ, USA has introduced four new hybrid line amplifier module power doubler modules for CATV infrastructure networks.

The firm says that its rugged hybrid line amplifier modules are optimized for demanding applications. To maximize flexibility and ease of use, the modules include passive components in a pin-compatible SOT-115J package.

"In addition to new modules for 870MHz systems, we are introducing 1GHz hybrid modules with outstanding distortion characteristics," says Anadigics' Tim Laverick. "This level of performance, combined with our proven track record of delivering industry-leading reliability, provides manufacturers with a compelling solution for distortion-free video and audio, while minimizing field failures and costly truck rolls," he adds.



The 40MHz–1GHz ACA2786 and ACA2788 and 40MHz–870MHz ACA3748 and ACA3754 24V line amplifier power doublers use the firm's proven GaAs MESFET technology to provide high output power, linearity and reliability (a high mean-time-to-failure) for 1GHz and

870MHz applications. Performance includes low composite triple beat (CTB), composite second order (CSO), and cross modulation distortion characteristics for optimal performance in a fully loaded spectrum; positive slope cable equivalent; and controlled gain limits that minimize lot-to-lot variation and ensure uniformity, the firm says.

The new modules are designed to provide the industry's highest electro-static discharge (ESD) rating and withstand the largest ringwave transient for greater ruggedness, especially for in outdoor applications.

The hybrid line amplifier module family is offered in a wide range of gains and output power levels, while using the industry-standard SOT-115J package to provide greater design flexibility across systems.

Samples of the hybrid line amplifier modules are available now.

Anadigics' WiFi front-end specified on leading reference designs to start shipping in first-quarter 2013

RF component maker Anadigics Inc of Warren, NJ, USA has launched four new front-end integrated circuits (FEICs) for 802.11n and 802.11ac WiFi applications: the AWL9280 and AWL9281 (operating at 2.4GHz) for 802.11b/g/n and 802.11b/g/n/ac standards respectively, and the AWL9580 and AWL9581 (operating at 5GHz) for the 802.11a/n and 802.11a/n/ac standards respectively.

The firm says that its FEICs provide a combination of integration, efficiency and linearity to minimize time-to-market, increase battery-life, and maximize throughput for mobile devices, such as smartphones, tablets, netbooks, notebooks, and gaming systems. The solutions have been selected by multiple leading reference design companies and are gaining OEM traction worldwide, adds Anadigics.

The new family of WiFi FEICs use Anadigics' exclusive InGaP-Plus technology and patented design architectures to combine a power amplifier (PA), low-noise amplifier (LNA), low-insertion-loss Tx/Rx RF switch and high-directivity coupler with integrated power detector on a single die within a 2.5mm x 2.5mm x 0.4mm QFN package (with all RF ports internally matched to 50Ω). This level of integration reduces space requirements and simplifies RF front-end design.

Anadigics claims that its WiFi FEICs provide exceptional error vector magnitude (EVM) and noise figure performance in the Rx path, enabling ultra-high data throughput and connectivity over greater range. EVM is 2.5% for the AWL9280 and AWL9580 at +19dBm and +18dBm respectively, and 1.5% for the AWL9281 and AWL9581 at +17dBm and at

+16dBm respectively. The solutions also deliver high efficiency with low current consumption to conserve battery-life in mobile applications.

"By combining our high-performance PA, LNA, and RF switch in a compact, low-profile package, we are enabling manufacturers to develop the next generation of mobile devices with extended battery-life and greater connectivity speeds," says Dave Cresci, VP of WiFi Products. "The advantages of our new FEICs have been validated by multiple wins on major WiFi reference designs." High-volume production shipments are expected to start in first-quarter 2013.

Anadigics says that samples of the AWL9280, AWL9281, AWL9580 and AWL9581 front-end ICs are available now for qualified programs.

www.anadigics.com

Cellular transceiver RFICs for wideband infrastructure

Hittite Microwave Corp of Chelmsford, MA, USA (which designs and supplies analog, digital and mixed-signal RF, microwave and millimeter-wave ICs, modules and subsystems as well as instrumentation) has launched a receiver (Rx) and transmitter (Tx) radio-frequency integrated circuit (RFIC) chipset that suits frequency conversion applications in wireless infrastructure equipment such as base transceiver stations, remote radio units, small cells, and repeaters from 700–3500MHz.

The HMC1190LP6GE is a high-linearity dual-channel downconverter with integrated phase-locked loop and voltage-controlled oscillator (PLL/VCO) that operates at 700–3500MHz and is designed specifically for multi-standard receiver applications requiring a compact and low-power solution. The device delivers 8dB conversion gain, with IP3 and input P1dB performance of +24dBm and +11dBm, respectively. In support of high-IF receivers and antenna diversity architectures, 2x2 spurious products are typically below –70dBc. The HMC1190LP6GE's RF and LO inputs

are single-ended, while an enable/disable pin makes it possible to reduce power consumption dynamically as conditions allow. Balanced high-linearity passive mixer cores combined with high-linearity IF amplifiers deliver LO-to-RF, LO-to-IF, and RF-to-IF isolation.

For transmit applications, the HMC1197LP7FE is a low-noise, high-linearity direct quadrature modulator with integrated fractional-N PLL/VCO that is rated for operation at 100–4000MHz. The wideband transmitter solution delivers high output IP3 of +30dBm, with up to +10.5dBm of output power and a low noise floor of –160dBm/Hz. The single-ended RF output port is matched to 50Ω with no external components, while the auxiliary LO output enables the device to distribute identical frequency and phase signals to multiple destinations within the transmitter or receiver. An integrated programmable bandwidth low-pass filter (LPF) in the LO path ensures little or no LO contribution to modulator sideband rejection. Sixteen programmable LPF bands enable true wideband

operation and allow agile LO frequency filtering for different band plans during and after deployment.

Both the HMC1190LP6GE and HMC1197LP7FE include a feature-rich PLL and wideband VCO. The PLL has a very low figure of merit (FOM) of –230dBm/Hz in integer mode. The internal VCO section can generate frequencies of 50–4100MHz. The integrated phase detector (PD) and delta-sigma modulator within the HMC1190LP6GE and HMC1197LP7FE are capable of operating at up to 100MHz, permitting wider loop-bandwidths with excellent spectral performance. The PLL/VCO section can phase adjust and synchronize multiple Hittite Tx and Rx RFICs, enabling scalable MIMO and beam-forming radio architectures. Additional PLL/VCO features include a configurable output mute function, and an Exact Frequency Mode that enables both products to generate fractional frequencies with 0Hz frequency error and the ability to synchronously change frequencies without changing the phase of the output signal.

www.hittite.com

Hittite launches 1–20GHz SDLVA module with 250V ESD rating

Hittite has launched a successive detection log video amplifier (SDLVA) that operates over the full 1–20GHz frequency range and carries a class 1A ESD rating (250V HBM). Specified as an improved-ESD-performance replacement for the HMC-C052 SDLVA, the HMC-C088 features miniature connectorized module packaging, suiting space- and power-constrained applications including EW (electronic warfare) and ELINT (electronic intelligence) receivers, DF (direction finding) radar, ECM (electronic counter-measures) and IFM (instantaneous frequency measurement) systems.

Also suiting pulsed signal applications requiring high amplitude accuracy, the HMC-C088 is a broadband SDLVA device that con-

verts RF signals at its input to an output voltage that is proportional to the logarithm of the RF input signal amplitude. It uses a successive compression topology, which delivers a high logging range of 59dB and allows for the processing of high-level signals up to +5dBm. During typical operation, the HMC-C088 provides a nominal slope of 14mV/dB and a typical intercept of –119dBm at 10GHz.

Hittite says the HMC-C088 also provides high value for laboratory and high-reliability applications and is capable of processing RF pulses with amplitudes from –54dBm to +5dBm with less than 10ns rise/fall times, and with only 21ns of recovery time. The HMC-C088 exhibits frequency flatness of

better than ±2dB at –30dBm input power, while logarithmic linearity is less than ±1dB. It also features an integrated voltage regulator that allows operation from a single supply voltage between +7V and +16V without any appreciable change in performance. The device draws much less power than competing discrete and module SDLVAs (just 1W from a +12V supply).

The HMC-C088 is supplied standard with two female SMA field-replaceable connectors, but can be used with blind mate SMP connectors or as a drop-in module. Specified for operation over the full –55°C to +85°C range, it is housed in a miniature connectorized package of dimensions 1.086" x 0.85" x 0.23" (27.58mm x 21.6mm x 5.84mm).

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RFMD's revenue rises 3.5% quarter-on-quarter, but falls 14% year-on-year

Next quarter should rise 17% to \$245m, due to diversification, category expansion, content gains

For fiscal second-quarter 2013 (to end-September 2012), RF Micro Devices Inc of Greensboro, NC, USA has reported revenue of \$209.7m, up 3.5% on \$202.7m last quarter. This is attributed to increased sales by RFMD's Cellular Products Group (CPG), "reflecting diversification, category expansion, and content gains in 3G/4G components". However, revenue was still down 14% on \$243.8m on a year ago.

On a non-GAAP basis, gross margin rose 110 basis points sequentially to 35.2%, operating income was \$9.2m, and net income was \$7.8m.

Strategic highlights of the quarter included the following:

- RFMD continued to increase its content in the world's leading smart devices and reference designs;
- CPG commenced volume shipments of 3G/4G LTE components to multiple customers in support of multiple flagship smartphones;
- CPG increased sales of 3G/4G components to greater than 75% of revenue (up from 66% last quarter);
- RFMD's Multi-Market Products Group (MPG) grew WiFi revenue more than 15% quarter-on-quarter;
- MPG commenced production shipments of 802.11n WiFi front ends in support of multiple applications, including smartphones, tablets, enterprise equipment, and consumer products;
- MPG captured a 802.11ac WiFi front-end design win in support of a leading smartphone maker.

RFMD said it expects further sequential revenue growth in the fiscal Q3 December quarter (up 17% to \$245m), reflecting its continued diversification, category expansion, and content gains, "combined with the benefit of multiple new customer product ramps".

"Our September 2012 quarterly results highlight our product and technology leadership and the

strength of our multi-pronged growth strategy of diversification, category expansion, and content gains," said president & CEO Bob Bruggeworth. "Of note, sales of RFMD's 3G/4G cellular components grew to more than 75% of total CPG revenue in the September quarter, led by PowerSmart, our ultra-high-efficiency 3G/4G power amplifiers (PAs), and our new switch-based solutions in support of flagship LTE devices," he added.

"In the December 2012 quarter, we expect to see robust sequential growth in 3G/4G components across a broad set of products and customers," continued Bruggeworth. "We are increasing our content in the world's leading baseband reference designs and smart devices, and we expect to outpace the rate of growth of our underlying markets, beginning in the December quarter and continuing into calendar 2013."

Dean Priddy, chief financial officer & VP of administration, added, "RFMD's key R&D investments are beginning to produce share gains and broad-based revenue growth. With this growth, we have begun to see robust leverage in RFMD's financial model. In the December quarter, we plan to grow revenue faster than our underlying markets, and we anticipate our sequential growth in operating income will substantially outpace our sequential growth in revenue. In addition, we anticipate continued improvement in multiple balance sheet metrics, supported by a substantial increase in free cash flow."

Following its formal presentations of results and forecast, the RFMD executive team took questions from press and analysts. Bruggeworth described aspects of the company's plans for product development and diversification, while Norman Hilgendorf, VP corporate develop-

ment & MPG president, considered likely changes in the mobile marketplace that could be beneficial for the company's portfolio.

"The company's commitment to product leadership is the engine behind our diversification, category expansion and content gains," said Bruggeworth. "It brought us PowerSmart and our new PowerSmart TD for China Mobile, as well as our ultra-high-efficiency PAs and our expanding portfolio of switches and antenna control solutions," he added.

"Soon, we'll introduce exciting new products that leverage our investment and advanced RF power management schemes, like envelope tracking, and in important new industry requirements, like carrier aggregation. In both cases, this will be highly differentiated RF front-end solutions derived from years of research on system architectures and featuring the best available process technologies," Bruggeworth continued.

"In the meantime, our guidance for the December quarter reflects our expectations for continued diversification, category expansion and content gains, combined with the benefit of multiple new customer product launches."

On business outlook, Hilgendorf added, "For Wi-Fi, we're seeing increased mobile data rates are driving the need for higher performance, especially in really small spaces such as handsets, tablets and other equipment. So this is driving significant activity throughout the industry today. RFMD has the right products. We're working with the right channel partners. We have the manufacturing scale. And so [our] 802.11n shipments are strong and growing, and we see the 802.11ac [market-place] coming around the bend."

www.rfmd.com

Matthew Peach, Contributing Editor

Highly integrated front-end module introduced for smart metering/smart energy and ISM-band applications

RF Micro Devices Inc of Greensboro, NC, USA has announced availability of the RFFM6903 front-end module (FEM), which meets or exceeds the system requirements for AMI/AMR smart meter applications operating in the 868–960MHz frequency band. The highly integrated FEM supports multiple applications, including Smart Energy/advanced metering infrastructure (AMI), portable battery-powered equipment, and general 868/915MHz ISM (industrial, scientific & medical)-band systems.

The feature-rich RFFM6903 integrates a +30.5dBm power amplifier (PA) with a Tx harmonic output filter in the transmit path, a Tx path bypass mode with harmonic filter, and a low-noise amplifier (LNA) with bypass mode in the receive path,

and is packaged in a 6mm x 6mm x 1mm laminate package.

The RFFM6903 also includes a low-insertion-loss, high-isolation, single-pole three-throw (SP3T) switch and separate Rx/Tx 50Ω ports that simplify matching and provide input and output signals for both the Tx and Rx paths. In the receive path, the Rx chain provides 16dB of typical gain with only 5mA of current and a noise figure of 1.7dB.

"The RFFM6903

Integration and industry-leading form factor minimize the footprint and reduce the number of discrete components and manufacturing assembly costs

is ideal for advanced metering systems requiring high efficiency and minimum output power of 1 Watt," says Rohan Houlden, general manager of RFMD's Wireless Connectivity business unit. "The high level of integration and industry-leading form factor minimize the footprint and reduce the number of discrete components and manufacturing assembly costs," he adds. "The fully integrated front-end module design approach shortens customer design time and accelerates time-to-market, while delivering industry-leading product performance."

The RFFM6903 is now available for sampling and mass production. RFMD showcased a broad portfolio of RF components at the Electronica 2012 trade show in Munich, Germany (13–16 November).

RFMD unveils series of 3V LTE linear power amplifier modules

RF Micro Devices says that the components in its new RF73xx series of high-power, high-efficiency linear power amplifiers are designed for use as the final amplification stage in 3V, 50Ω LTE mobile cellular equipment developed for E-UTRAN/LTE band operation.

Developed for 5–20MHz LTE channel bandwidths, the products and their frequency-band coverage

are as follows: the RF7303 (multi-mode: LTE/UMTS 3, 4, 9, and 10; CDMA 15); the RF7317A (LTE 17); the RF7320 (LTE 20); and the RF7321 (LTE 11 and 21).

Each device has two digital control pins to select one of three power bias states to optimize performance and current drain at lower power levels, boosting LTE efficiency. The 10-pin, 3mm x 3mm x 0.8mm module also con-

tains an integrated directional power coupler (eliminating the need for an external discrete coupler at the output) and integrated blocking and decoupling capacitors. Features include optimized use with DC–DC converter operation.

Applications include LTE wireless handsets and datacards. The products are currently available in production quantities.

www.rfmd.com

RFMD debuts 5–1000MHz, push-pull, high-linearity InGaP HBT amplifier

RF Micro Devices says that its new RFCA1008 is a heterojunction bipolar transistor (HBT) monolithic microwave integrated circuit (MMIC) amplifier designed with indium gallium arsenide (InGaP) process technology for high reliability. The heterojunction increases breakdown voltage and minimizes leakage current between junctions.

For broadband performance, a

Darlington configuration is used. The RFCA1008 contains two amplifiers for use in wideband push-pull CATV amplifiers requiring excellent second-order performance (the second- and third-order non-linearities are greatly improved in the push-pull configuration).

Features include: a 5V single supply; excellent linearity performance at +34dBmV output power per

tone; two amplifiers in each SOIC-8 package, simplifying push-pull configuration PC board layout; and availability in lead-free, RoHS-compliant packaging.

Applications include CATV head-end driver and pre-driver amplifiers and CATV line driver amplifiers. Currently available in production quantities, pricing begins at \$2.60 each for 750 pieces.

RFMD to acquire RF CMOS IC firm Amalfi for \$47.5m

Aim is to accelerate market adoption for entry-level smartphones

RF Micro Devices Inc of Greensboro, NC, USA has announced a definitive agreement to acquire Amalfi Semiconductor of Los Gatos, CA, USA (a fabless semiconductor firm specializing in highly integrated CMOS silicon RF and mixed-signal ICs for the entry-level smartphone market) using cash on hand for about \$47.5m (net of cash received).

RFMD says it intends to accelerate market adoption of Amalfi's RF CMOS and mixed-signal ICs by combining Amalfi's targeted product portfolio and proprietary RF CMOS and mixed-signal expertise with RFMD's customer relationships, broad product portfolio, in-house

manufacturing scale, and global supply chain.

"The acquisition of Amalfi is consistent with RFMD's strategy of matching the most appropriate process technology to each customer's performance and cost requirements," says RFMD's president & CEO Bob Bruggeworth. "Amalfi's proprietary RF and mixed-signal expertise in RF CMOS are a great fit for RFMD and a strong addition to our long-term technology strategy. RFMD gives Amalfi the global presence, market credibility, manufacturing scale, and blue-chip customer access to take their business to the next phase of growth," he adds.

"The addition of Amalfi's RF CMOS PA technology with RFMD's market leadership and significant resources is a powerful combination," believes Amalfi's CEO & president Mark Foley. "We expect the acquisition will accelerate the delivery of new disruptive RF CMOS power amplifiers to the cost-driven entry-level smartphone market," Foley adds.

RFMD expects to achieve immediate product and cost synergies and anticipates that the transaction will be accretive to earnings within two quarters.

www.amalfi.com
www.rfmd.com

RFaxis launches CMOS 5GHz WLAN RF front-end IC

Fabless semiconductor firm RFaxis Inc of Irvine, CA, USA, which designs RF semiconductors and embedded antenna solutions for the wireless connectivity and cellular mobility markets, has launched the RFX5000 and RFX5000B 5GHz WLAN RF front-end ICs (RFeICs), which are slated for production in December to support the ramp-up schedule of multiple customers.

The RFX5000 and RFX5000B are RFaxis' second-generation, pure CMOS-based single-chip/single-die RFeICs, optimized for the rapidly growing 5GHz WLAN market (including support of the emerging 802.11ac standard). RFaxis is offering the 5GHz RF front-end solutions at what it claims are unprecedented price points, while maintaining pin-to-pin compatibility with primary solutions currently on the market, such as Skyworks Solutions' SE5007T, SE5007BT, SE5012T and SE5012BT.

"We have received overwhelming response to our pure CMOS 5GHz RFeICs since we announced these parts at Computex in Taipei in June," says chairman & CEO Mike Neshat. "As Wi-Fi products migrate from

dominantly single-band 2.4GHz to dual-band 2.4/5GHz solutions, the BOM [bill-of-materials] cost of the 5GHz RF front-ends is becoming a bottle neck. The problem is further exacerbated by the fact that more Wi-Fi products are now implemented as MIMO [multiple input, multiple output] systems that require multiple RF front-ends," he adds. "By adopting these unique, pure CMOS-based RFeICs, our customers can reduce the total BOM cost significantly, while providing uncompromised RF performance to their end users," he claims. "We are also in the process of rolling out our next-generation 5GHz RFeIC, which is smaller in size and will support direct battery operation," says Neshat. "The new product will greatly increase our presence in the dual-band smartphone space."

The RFX5000 and RFX5000B integrate all key functionality for a 5GHz WLAN RF front-end, including the linear power amplifier, low-noise amplifier (LNA), antenna switch, input/output/inter-stage impedance matching, as well as RF decoupling, high-linearity/low-current mode control, and a directional-coupler

based power detector into a single-chip bulk CMOS die housed in a 3mm x 3mm, low-profile 0.5mm plastic QFN package.

The new devices deliver up to +18dBm output power with 3% EVM (error vector magnitude) for 64QAM/OFDM in the full 5GHz 802.11a/n/ac frequency band, including all losses of the antenna switch and impedance-matching network. In low-current mode, the CMOS RFeICs achieve +17dBm linear output power at the antenna port with 170mA current from a 3.3V power supply, while maintaining 3% EVM for 802.11n HT40/MCS7. They also feature extremely low EVM floor (<1.5%) and meet the stringent EVM requirements for 802.11ac with MCS9/256QAM and 80MHz channel bandwidth. Combined with high gain (32dB), good thermal stability and multiple mode controls with simple CMOS logic, the RFX5000 and RFX5000B outperform all same-class 5GHz front-end solutions on the market, including those based on GaAs HBT/pHEMTs and SiGe BiCMOS, claims RFaxis.

www.rfaxis.com

Soitec increases bonded silicon-on-sapphire wafer production for Peregrine

Peregrine raises its STeP5 UltraCMOS RFIC manufacturing capacity to 2million/day for 4G LTE smartphones and wireless devices

Soitec of Bernin, France, which makes engineered substrates including silicon-on-insulator (SOI) wafers (as well as III-V epiwafers through its Picogiga International division), has more than doubled production of bonded silicon-on-sapphire (BSOS) substrates to meet increased demand from strategic partner Peregrine Semiconductor Corp of San Diego, CA, USA.

Peregrine, a fabless provider of radio-frequency integrated circuits (RFICs) based on silicon-on-sapphire, has increased peak-production capability of its latest-generation STeP5 UltraCMOS-based RF switches to more than 2 million units per day to support design wins in the radio-frequency front ends (RFFE) of the most advanced 4G smartphones, as well as other wireless-communication applications. Soitec comments that these wins established Peregrine as the market leader for the main RF antenna switch for cellular handsets (according to the 'RF Devices/Modules For Cellular Terminal Quarterly Market Report CY2012 2Q' from Navian Inc).

Soitec's direct wafer-bonding technologies are used to produce the BSOS substrate employed in the manufacture of Peregrine's highly tuned semiconductor wafers. Soitec says the combination of its substrate with Peregrine's UltraCMOS process technology and IC design expertise enables high-performance RFICs for a variety of applications.

"We are experiencing powerful traction in the market with the latest STeP5 UltraCMOS RF switches, and we believe these products enable the high level of RF performance that is critical for new, 4G LTE smartphones and wireless devices," says Mark Miscione, Peregrine's VP of RF technology solutions. "Soitec's expertise has been important in the development of a substrate technol-

ogy that offers the reliability, yield, and process scalability of equivalent bulk CMOS technologies," he adds.


"As a result of supporting Peregrine Semiconductor's continued strong growth, we have reached a new level in high-volume manufacturing for our bonded-SOS," notes

Bernard Aspar, VP of Soitec's Layer Transfer Solutions business unit.

"Bonded SOS is part of our strategy to deliver leading-edge engineered substrates for mobile electronic-device markets."

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AWR launches Analyst, integrating 3D FEM EM simulation within Microwave Office circuit design software

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 commercial release and immediate availability of Analyst 2012.

Analyst is a full-featured, 3D electro-magnetic (EM) industry-standard finite-element method (FEM) simulator that is completely integrated into AWR's Microwave Office circuit simulation environment, effectively making 3D FEM EM analysis as straightforward as a mouse click, the firm says.

The ability to perform 3D EM analysis on interconnects commonly found within high-frequency ICs such as MMICs, RFICs and microwave integrated circuits (MICs) as well as packages, boards and modules is the driving force behind Analyst being tightly and fully integrated

into the AWR Design Environment.

AWR says that Analyst benefits circuit designers who need to rely on 3D FEM EM analysis for both the design and verification of their circuits prior to manufacture. It is now possible to seamlessly include 3D EM simulation in critical circuit simulations such as optimization, tuning, sensitivity and yield analysis, and even non-linear circuit simulation using harmonic balance. Analyst's ease-of-use and minimal simulation setup time, coupled with the elimination of manual drawing, leads to maximum EM accuracy with minimal overhead, claims AWR.

Typical applications for Analyst include: MMIC, RFIC and MIC on-chip passive components; RF PCB, module, and packaging interconnects; finite dielectrics (IC packaging/PCB edges/inhomogeneous boards); and hierarchical designs (SoC, SiP).

Key features include:

- Integrated layout environment: The Microwave Office layout environment has been enhanced to support 3D parameter controlled layout cells (Pcells) for common 3D objects like bond wires, BGA balls, tapered vias and bond straps.
- Pre-configured for circuit designers' typical technologies: Analyst has been set up to work seamlessly with Microwave Office for chip, board, and module layouts.
- Visualization features: Analyst supports standard 3D simulation visualization features, including 3D mesh viewing and animated field viewing.
- Configurable solver technology: Analyst's simulation engine uses a state-of-the-art finite-element simulation algorithm. The default settings have been developed as optimal for the above class of problems.

www.awrcorp.com/Analyst

Agilent ships latest GoldenGate 2012 software release

Agilent Technologies has announced shipment of GoldenGate 2012.10, the latest release of its RFIC simulation, verification and analysis software.

The 2012 release offers technology enhancements for accelerated design verification, extended design-for-manufacturing solutions and improved links to system design. Additionally, new licensing models offer users greater purchasing flexibility, the firm says.

GoldenGate 2012 accelerates design verification through technology enhancements that allow users to set up distributed simulations, run them with unmatched performance, and display and analyze massive amounts of data.

Agilent is also offering GoldenGate users an extended parallel simulation license at a fraction of the cost of the base GoldenGate simulator license. It is supported in any scenario launching a parallel simulation, including ADE-XL in Cadence Virtuoso.

Another key capability of GoldenGate 2012 is the generation of X-parameters. This allows designers to capture the nonlinear behavior of active components such as amplifiers and save the data for quick use in simulation models in RF system or circuit designs, while also hiding all intellectual property.

Other new and improved capabilities in GoldenGate 2012 include:

- AC stability analysis, which provides simplified setup, analysis and results processing for Bode stability analysis using the Middlebrook technique. The analysis allows the circuit's open-loop gain and phase characteristics to be determined while the loop remains closed and requires no changes to the schematic.
- Improved links to system-level simulation, including enhancements to the Fast Circuit Envelope model export from GoldenGate to SystemVue and export and evaluation of Application Extension Language

expressions during Virtual Testbench evaluation with Ptolemy.

- A broad range of usability enhancements, including improvements in RFIC simulation, support for advanced analysis and millimeter-wave design, and wireless standard-compliant verification.
- Licensing improvements and enhancements enabling more robust license behavior with improved licensing logic. A new License Manager and Product Selector ensure an easier license experience.
- A design-for-manufacturing enhancement that integrates GoldenGate 2012 into the MunEDA WiCkED tool suite for the analysis, sizing and modeling of circuits. The integration enables automatic compensation of process variations and parasitic influences, and helps reduce the overall power consumption and noise in RF circuits.
- Expanded foundry support.

www.agilent.com

Microsemi launches SiGe-based monolithic RF front-end for Broadcom's 5G WiFi mobile platforms

Microsemi Corp of Aliso Viejo, CA, USA (which makes analog and RF devices, mixed-signal integrated circuits, FPGAs and customizable SoCs, and subsystems, based on silicon, gallium arsenide and silicon carbide) has delivered what it claims is the first monolithic silicon germanium (SiGe) RF front-end (FE) for the 5th generation of Wi-Fi devices based on the IEEE 802.11ac standard.

The LX5586 RF FE is designed to be used in conjunction with Broadcom's BCM4335 combo chip for mobile platforms such as smartphones and tablets. BCM4335 is the industry's first combo chip solution based on the IEEE 802.11ac standard, also known as 5G WiFi, says the firm.

LX5586's technical features include:

- fully integrated, single-chip 802.11ac 5GHz power amplifier (PA), low-noise amplifier (LNA)

- with bypass and SPDT (single-pole double-throw) antenna switch;
- small footprint of 2.5mm x 2.5mm and only 0.4mm height;
- ultra-linear power of 16dBm at 1.8% EVM, 256QAM modulation over 80MHz bandwidth; and
- high ESD protection of 1000V (HBM) on all pins.

"We're pleased to enter the 802.11ac market in collaboration with Broadcom," says VP & general manager Amir Asvadi. "The LX5586 is the smallest, most reliable, highest-performance solution in the marketplace today and the first in a series of highly integrated Wi-Fi subsystems we are introducing," he adds.

Microsemi's new RF power amplification solutions further underscore the traction behind 5G WiFi

"Broadcom is enabling the 5G WiFi ecosystem across all major wireless product segments," says Rahul Patel, Broadcom's VP, Mobile Wireless Connectivity Combos Group.

"Microsemi's new RF power amplification solutions further underscore the traction behind 5G WiFi, which has been recognized as one of the most significant wireless innovations of the year," he adds.

Industry analyst firm NPD In-Stat says that 802.11ac will grow rapidly. Chipset shipments will surpass 650m by 2015, with total Wi-Fi chipset revenue reaching \$6.1bn. By 2015, the three biggest markets for 802.11ac are forecast to be smart phones, notebooks and tablets.

LX5586 is fixed at 2.5mm x 2.5mm 16-pin QFN package.

www.microsemi.com

www.5GWiFi.org

www.broadcom.com

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Raytheon tests SiC mixed-signal devices up to 400°C

Target is silicon carbide CMOS for harsh, long-term environments

Raytheon Company of Waltham, MA, USA says that its technology facility in Glenrothes, Scotland, UK has successfully tested silicon carbide (SiC) mixed-signal devices at temperatures up to 400°C.

"Raytheon UK's aim is to offer design and manufacturing services for customized mixed-signal integrated circuits in silicon carbide, which operate in harsh, long-term environments," says Neil MacTavish, semiconductor business development executive for Raytheon UK. "Raytheon's leadership is based on advanced manufacturing processes and technology, which has the potential to be a game changer for energy, sustainability and green-related applications in both com-

mercial and military domains," he reckons.

High-temperature integrated circuits are desirable in applications such as aero engines, monitoring engine performance in the heart of the engine, or in deep hydrocarbon and geothermal drilling applications

As SiC power-discrete devices proliferate, there is a growing need for more control functions capable of operating in the same temperature and power management conditions, without heat dissipation constraints

where operation interruption to replace sensor technology is a constant cost pressure. Raytheon says that, as SiC power-discrete devices proliferate, there is a growing need for more control functions capable of operating in the same temperature and power management conditions, without heat dissipation constraints.

The firm says the test results show that SiC complementary metal-oxide-semiconductor (CMOS), fabricated on 4H SiC wafers, can be used to create the circuit building blocks required for logic and analog functions together on the same chip, which can operate in the harsh environments that users demand.

www.raytheon.com

Japanese manufacturer chooses DCG's ELITE for inspecting silicon carbide power devices

DCG Systems Inc of Fremont, CA, USA, which supplies diagnostic, characterization and defect localization solutions, says that a major Japanese power device maker has purchased its ELITE (Enhanced Lock-In Thermal Emission) system for the inspection of next-generation silicon carbide (SiC) power devices. The system features the newly developed laser marker, full IR lens options, double-sided probing and high-voltage power analysis capability. DCG did not disclose the name of the customer.

"Sensitivity of the system is much better than we had expected and beyond even some of the claimed specifications provided by DCG," says the manager of the customer's device development department. "The new laser marker was delivered on time and its performance has been much better than what had previously been available in the market."

"This solution will help customers develop faster leading-edge power



DCG's ELITE inspection system.

devices," reckons Randy Schussler, VP & general manager of DCG's IRIS (InfraRed Imaging Systems) business unit. "Employing new semiconductor materials such as SiC and GaN introduce increasing development and reliability challenges," he adds. "The ELITE system is helping our customers

strengthen their competitive edge in this growing market."

ELITE uses Lock-In Thermography (LIT) to accurately and efficiently locate defects. It incorporates what is claimed to be the highest-sensitivity thermal emission camera on the market (capable of detecting down to 20nW of local power dissipation), high-resolution midwave-infrared (MWIR) imaging with large-format indium antimonide (InSb) cameras, 3D localization for through-package imaging and stacked die analysis, and contactless absolute temperature mapping. Further real-time, pixel-wise IR lock-in thermography requires no post-processing or integration time limitations, while the custom MWIR lenses and thermal SIL (solid immersion lens) ensure optimal resolution and sensitivity. Applications of ELITE beyond power devices extend to general non-destructive testing (NDT).

www.dcgsystems.com

Microsemi launches 1200V SiC Schottkys to boost power conversion efficiency in high-power, high-voltage industrial applications

Microsemi Corp of Aliso Viejo, CA, USA (which designs and makes analog and RF devices, mixed-signal integrated circuits and sub-systems) has launched a family of 1200V Schottky diodes based on silicon carbide (SiC) material and technology. The new diodes are targeted at a wide range of industrial applications including solar inverters, welding, plasma cutters, fast vehicle charging, oil exploration, and other high-power, high-voltage applications where power density, higher performance and reliability are important.

Compared to silicon, SiC offers benefits including higher breakdown field strength and improved thermal conductivity, says Microsemi. These attributes allow designers to create devices with better performance characteristics encompassing zero reverse recovery, temperature-independent behavior, higher-voltage

capability, and higher-temperature operation to achieve new levels of performance, efficiency and reliability, adds the firm.

Microsemi claims that, in addition to the device's inherent benefits, it is the only manufacturer to offer a SiC Schottky diode in a large surface-mount backside-solderable D3 package, allowing designers to achieve increased power density and lower manufacturing costs.

"We applied our more than 25 years of power semiconductor device design and manufacturing know-how to deliver a family of SiC diodes that offers unparalleled levels of performance, reliability

Next-generation power conversion systems require higher power densities, higher operating frequencies and higher efficiencies

and overall quality," claims Russell Crecraft, general manager of Microsemi's Power Products Group. "Next-generation power conversion systems require higher power densities, higher operating frequencies and higher efficiencies — and our new silicon carbide devices help system designers meet those needs," he adds.

The new 1200V SiC Schottky diode product portfolio includes the following devices:

- APT10SCD120BCT (1200V, 10A, common-cathode TO-247 package);
- APT20SCD120B (1200V, 20A, TO-247 package);
- APT30SCD120B (1200V, 30A, TO-247 package);
- APT20SCD120S (1200V, 20A, D3 package); and
- APT30SCD120S (1200V, 30A, D3 package).

Microsemi's new SiC Schottky diodes are in production now.

Microsemi introduces 500W S-band GaN-on-SiC RF power transistor for air-traffic control airport surveillance radar applications

Microsemi has expanded its family of radio-frequency transistors based on gallium nitride on silicon carbide (GaN-on-SiC) technologies with a new S-band 500W RF device.

The 2729GN-500 is targeted at high-power air-traffic control airport surveillance radar (ASR) applications. ASR is used to monitor and control aircraft in the terminal within about 100 miles of an airport.

The 2729GN-500 transistor delivers performance of 500W of peak output power with >11.5dB (minimum) of power gain and 53% drain efficiency over the 2.7–2.9GHz band to provide the maximum power in a single device covering this band. Other key features include: standard pulse burst

format (100µs, 10% duty factor); a drain bias (V_{dd}) of +65V; and low thermal resistance of 0.2°C/W.

Microsemi says that systems benefits achieved with GaN-on-SiC high-electron-mobility transistors (HEMTs) include:

- a single-ended design with simplified impedance matching (replacing lower-power devices that require additional levels of combining);
- the highest peak power and power gain for reduced system power stages and final stage combining;
- a single stage pair provides 1.0kW of peak output power with margin, four-way combined to provide full system peak output power of 2kW;
- a high operating voltage of 65V,

which reduces the power supply size and the DC current demand;

- rugged performance improves system yields; and
- the amplifier size is 50% smaller than devices built with silicon bipolar junction transistor (Si BJT) or laterally diffused metal oxide semiconductor (LDMOS) technology.

The 2729GN-500 is offered in a single-ended package and is built with 100% high-temperature gold (Au) metallization and wires in a hermetically solder-sealed package for long-term military reliability.

Loaner demonstration units are available to qualified customers, and technical datasheets are available.

www.microsemi.com

Fairchild launches its first SiC BJTs, offering low power loss at high temperature

Firm claims most efficient 1200V power conversion switch

Fairchild Semiconductor of San Jose, CA, USA, which makes silicon chips for power and mobile designs, has announced silicon carbide (SiC) technology suitable for power conversion systems.

The firm notes that, in an effort to achieve higher power density — and to meet strict efficiency regulations and system up-time requirements — industrial and power electronic designers are challenged with constantly reducing power losses and improving reliability in their designs. However, improving these critical design capabilities in applications such as renewable energy, industrial motor drives, high-density power supplies, automotive, and down-hole can complicate a design as well as drive overall system costs higher.

Fairchild says that, by introducing SiC-based offerings, it is helping designers to meet these challenges, as well as reinforcing its product range in high-performance power transistor technology.

The firm's SiC capabilities include:

- optimized, semi-standard, and customized solutions that take advantage of the firm's large portfolio of semiconductor devices and module packaging technologies;
- technologies that simplify engineering challenges with functional integration and design support resources that minimize components while reducing engineering time; and
- meeting the needs of device makers and chipset suppliers by integrating device technologies into smaller packages that offer size, cost and power advantages.

Among the first products to be released in the SiC portfolio is a family of bipolar junction transistors (BJTs) that offer high efficiency, high current density, robustness, and easy high-temperature operation, the firm claims. By leveraging high-



Fairchild's SiC BJT, claimed to be the most efficient 1200V power conversion switch.

efficiency transistors, the SiC BJTs enable higher switching frequencies due to lower conduction and switching losses (from 30–50%) that provide up to 40% higher output power in the same system form factor.

Enabling the use of smaller inductors, capacitors and heat sinks, the robust BJTs can lower overall system costs up to 20%, reckons Fairchild. With performance levels that drive much higher efficiency and superior short-circuit and

reverse-bias safe operating area, the SiC BJTs can play a significant role in optimizing the power management of high-power conversion applications, the firm adds.

As part of a complete SiC solution, Fairchild has also developed plug-and-play discrete driver boards (a 15A and 50A version) that, when used in conjunction with its SiC BJTs, not only provide increased switching speeds for reduced switching losses and better reliability, but also allow designers to easily implement SiC technology into their applications, it

is claimed. Application notes (providing designers additional support needed to design with SiC devices) and reference designs (allowing the development of driver boards to meet specific application needs) are also available and are intended to reduce design time and shorten time-to-market.

Engineering samples of the SiC BJTs are available (in a TO-247 package) for qualified customers.

www.fairchildsemi.com/sic

SiC BJT versus other silicon carbide devices

Fairchild lists the properties of its SiC BJT devices (compared with other SiC devices) as follows:

- Most efficient 1200V power conversion switch ever made (the lowest total losses, including switching, conduction and driver losses, and the lowest switching loss at any given R_{ON} , of all 1200V devices);
- Straight-forward driving (normally-off feature reduces

risks, complexity and performance limiting designs; stable base input that is not sensitive to over/under-voltage peaks);

- Robust and reliable (high-rated operating temperature of $T_J=175^{\circ}\text{C}$; easy paralleling due to positive temperature coefficient for R_{ON} and negative temperature coefficient for gain; and stable, rugged V_{be} forward voltage and reverse blocking capability).

RFMD launches family of linear GaN power transistors

Following the previous release of the RF393X series of unmatched power transistors (UPTs) targeting continuous wave (CW) and pulsed peak power applications, RF Micro Devices Inc has production released two highly linear gallium nitride (GaN) RF unmatched power transistors (UPTs): the RFHA3942 (35W) and the RFHA3944 (65W).

The series of discrete amplifiers is optimized for broadband applications requiring linear back-off operation or reduced spurious performance. RFMD plans further releases of 10W and 95W linear GaN devices over the next 12 months, expanding the GaN UPT options available.

RFMD's highly linear GaN UPTs target new and existing communication architectures requiring improved broadband linear performance in support of high peak-to-average modulation waveforms. The RFHA3942 and RFHA3944 are tunable over a broad frequency range

(DC to 4GHz) and provide CW peak power of 35W and 65W, respectively. They also offer high gain of 15dB and high peak efficiency of >55%. Using an IS95 9.8dB PAR (peak-to-average energy ratio) signal tuned to 2.1GHz, the RFHA3942 achieves -43dBc adjacent channel power (ACP) at a power output (P_{OUT}) of 34dBm and the RFHA3944 achieves -54dBc ACP at 37dBm P_{OUT} .

Also, the RFHA3942 and 3944 offer high terminal impedance at the input and output of the package, enabling wideband gain and power performance advantages in a single amplifier. The devices are packaged in a flanged ceramic two-leaded package that leverages RFMD's heat-sink and power-dissipation technologies to deliver good thermal stability and conductivity.

RFMD showcased its RF components at the Electronica 2012 show in Munich, Germany (13–16 November).

www.rfmd.com

125W & 150W HEMT broadband PAs

RFMD says that its new RFHA104x series of high-power GaN broadband power transistors (BPTs) are optimized for military communications, commercial wireless infrastructure, and general-purpose applications.

Each device is an input-matched GaN transistor packaged in an air-cavity ceramic package providing good thermal stability. Ease of integration is accomplished through the incorporation of simple, optimized, matching networks external to the package that provide wideband gain and high efficiency, all in a single amplifier ideal for linear correction circuits.

Using a 65V high-power-density GaN process optimized for high peak-to-average ratio applications, the amplifiers achieve high power (125W for the RFHA1042 and 150W for the RFHA1043) with high

efficiency and flat gain over a broad frequency range (225–450MHz for the RFHA1042 and 1.2–1.85GHz for the RFHA1043) in a single amplifier design.

For 48V modulated performance, output power (P_{OUT}) is 45.2dBm; gain is 18.5dB (RFHA1042) and 15.5dB (RFHA1043); drain efficiency is 42% (RFHA1042) and 30% (RFHA1043); and adjacent channel leakage power (ACP) is -26dBc (RFHA1042) and -30dBc (RFHA1043).

For 48V CW broadband performance (for the RFHA1042 and RFHA1043, respectively) output power (P_{OUT}) is 51.4dBm and 52dBm; gain is 16dB and 13.5dB; and drain efficiency is 60% and 51%.

The new devices are optimized for video bandwidth and minimized memory effects. Large-signal models are available.

IN BRIEF

Mitsubishi launches SiC module-equipped CNC drive unit

Tokyo-based Mitsubishi Electric has launched a drive unit equipped with a silicon carbide (SiC) power module for computerized numerical controllers (CNCs). MDS-DM2-SPHV3-20080 is a multi-hybrid, multi-axis integrated-drive unit for drive control of spindle and servo motors. SiC power modules are superior to conventional silicon modules in terms of their significantly reduced switching loss and high tolerance to temperature, says the firm.

Power conversion modules are used in inverters and converters of household appliances and industrial equipment. To date, Mitsubishi has commercialized SiC power modules for inverters in air conditioners and railcars. The new module for CNC drive units offers higher speed and torque for driving machine tool spindles and servo motors, which is expected to improve manufacturing productivity in factories.

Key features of the MDS-DM2-SPHV3-20080 are as follows:

- High-speed switching operation can increase spindle motor speed up to twice that of its previous model (MDS-DM Series).
- Reduced power loss can result in 15% higher torque for spindle motors than MDS-DM Series.
- The Safe Torque Off function for shutting off the power supply to motors (reducing the number of magnetic reactors required) is available as a standard feature.
- An interface for linear scale enables direct detection and feedback of machine positions, requiring no external interface unit.

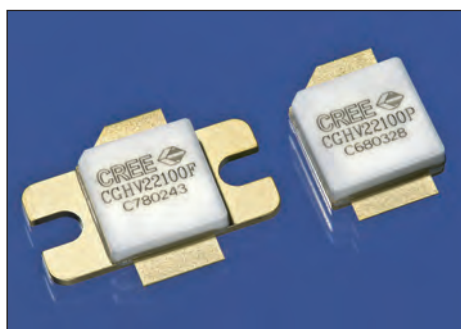
The CNC drive unit was showcased at the 26th Japan International Machine Tool Fair (JIMTOF 2012) in Tokyo (1–6 November). Sales begin on 3 December.

Cree launches new-generation 50V GaN HEMT technology to reduce cellular-network energy needs

Cree Inc of Durham, NC, USA has launched a range of 50V gallium nitride high-electron-mobility transistor (HEMT) devices that, it is claimed, enable a significant reduction in the energy needed to power cellular networks.

The world's cellular network is estimated to consume more than 100TWh of electricity per year (costing about \$12bn), and 50–80% of the power is consumed by the systems' power amplifiers and feed infrastructure. Cree says that, leveraging its new technology, radio base-station power amplifiers have demonstrated performance improvements of over 20% on incumbent technology at 2.6GHz, operating under the latest 4G LTE signals. This increased power amplifier (PA) efficiency could save an estimated 10TWh per year (the equivalent power output of two nuclear power plants), it is reckoned.

While operational cost savings from increased efficiency can be significant, additional substantial savings are also possible in the acquisition cost of the system, says



Cree's new 50V GaN HEMT devices.

Cree. A higher-efficiency PA can help original equipment manufacturers (OEMs) to save capital equipment costs through simplified cooling, and the higher-voltage GaN components can lower the cost of AC-to-DC and DC-to-DC converters, the firm adds. The impact on the total bill of materials can be as much as 10%, leading to much lower system costs.

"Our 50V GaN HEMT products can have a large impact in not only helping cellular network operators and OEMs reduce operational and capital expenses but also in helping to reduce global energy consumption," believes Jim Milligan, business director, Cree RF. "Several

tier-one telecom OEMs have already incorporated lower-voltage versions of our technology to begin realizing these benefits," he adds. "To date, even at an early stage of deployment, we estimate as much as 2400MWh of energy has already been saved as a result. This is an equivalent carbon offset of 1400 metric tons of CO₂ and represents the offset created by planting approximately 36,000 trees."

Cree's new 50V GaN HEMTs, operating at output powers of 100W or 200W, are now released for both the 1.8–2.2GHz and 2.5–2.7GHz frequency bands. The devices are internally matched for optimum performance, enabling wide instantaneous bandwidths. The devices suit use in high-efficiency Doherty power amplifiers where power gains higher than 18dB at 2.14GHz and 16dB at 2.6GHz can be achieved, respectively.

Cree exhibited the devices at European Microwave Week (EuMW 2012) in Amsterdam, The Netherlands (28 October–2 November).

www.cree.com/rf

Fully qualified, production-ready all-SiC power module

At electronica 2012 in Munich, Germany (13–16 November), Cree announced commercial availability of what it claims is the industry's first fully qualified, production-ready all-SiC (silicon carbide) power module.

Rated at 100A current handling and 1200V blocking, the new high-frequency module allows higher efficiency, compact and lighter-weight systems that can result in lower total system costs compared with conventional silicon-based technologies, it is reckoned.

"An all-SiC module with these specifications enables us to meet our transit customers' demands for reduced size and weight of auxiliary power converters, while meeting efficiency and cost targets,"

comments Fisal Al-Kayal, innovation and research engineer at Alstom Belgium Transport.

The module includes SiC MOSFETs and SiC Schottky diodes in a 50mm half-bridge configuration rated to a maximum junction temperature of 150°C. The SiC components enable the module to be operated at very high switching frequencies that can reduce the size, weight and cost of the power conversion system. The new module has demonstrated up to 100kHz switching frequency. Target applications include high-power converters, industrial motor drives, solar inverters and uninterruptible power supplies.

"The 1200V, 100A dual module extends our existing discrete

MOSFET and diode products into higher-power applications," explains Dr Mrinal Das, product marketing manager, Cree Power and RF.

"The efficient switching characteristics of an all-SiC module should allow system designers to meet customer demands for reduced size, weight and cost of the end-system, while reducing global energy consumption," he adds. "Already, Cree SiC power devices have eliminated an estimated 1 million metric tons of annual CO₂ emissions — the equivalent to planting 95 million trees."

Sample gate drivers are available upon request to Cree for module customers.

www.cree.com/sic-modules

Fraunhofer ISE demonstrates GaN transistors switching at 1MHz in 1kW DC/DC converter

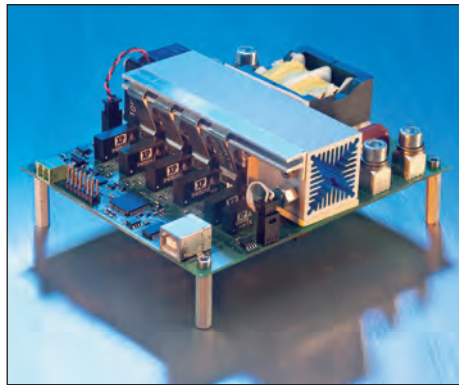
Smaller, lighter, more efficient inverters, power converters and supplies targeted for electric vehicles, aircraft and server farms

Scientists at the Fraunhofer Institute for Solar Energy Systems ISE in Freiburg, Germany have successfully tested power transistors made of gallium nitride (GaN) in power electronic systems. By using such transistors the researchers says that, for example, the size of charging inverters in electric vehicles and the weight of power converters in aircraft can be reduced, and power supplies in server farms can be more gain efficiency.

GaN has long been in the focus of interest of many researchers, and prototype devices are now available. "With power transistors made of gallium nitride, significantly higher switching frequencies are achievable than with ordinary silicon power transistors," says professor Bruno Burger, head of the Power Electronics department at Fraunhofer ISE. "In contrast to silicon carbide, gallium nitride is particularly suited for the lower voltage range."

In particular, resonant topologies can fully utilize the advantages of gallium nitride power transistors, he adds.

Despite still needing substantial research, Fraunhofer ISE says that impressive results have been obtained in an internal study. A DC/DC converter with rated output power of 1kW was operated at a switching frequency of 1MHz, providing 94% peak efficiency. "With regard to



Developed 1MHz LLC resonant converter with rated output power of 1kW, equipped with 600V GaN power transistors.

the 600V gallium nitride transistor, the switching frequency and also the efficiency of the DC/DC converter could have been raised to an even higher level," says Arne Hendrik Wienhausen, who performed the experiments. "The limiting factor was the high-frequency transformer."

Until now, only transistors made of silicon have been used in power electronic systems with voltages up to 600V, says Fraunhofer ISE. The switching and conduction losses of these transistors are significantly higher than those of transistors made of gallium nitride. Large losses generated in the transistors hence need to be dissipated in a complex way.

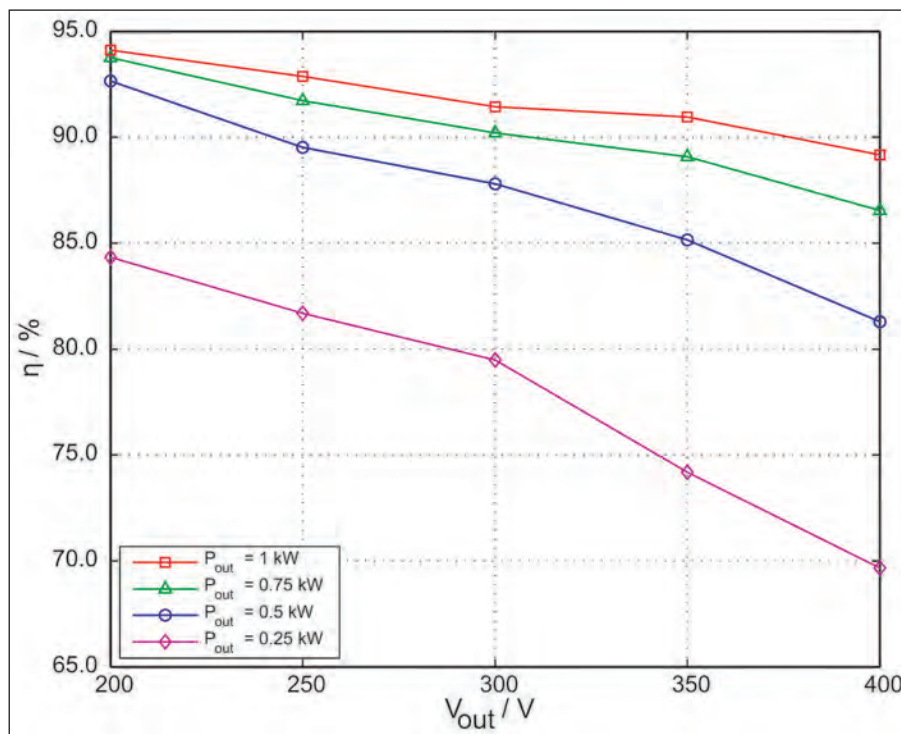
In addition to the higher efficiency, GaN provides the opportunity to increase the switching frequency to many times greater than the state-of-the-art. As a result, passive components such as inductors, transformers and capacitors can be much smaller, leading to more compact and lighter-weight designs. Also, expensive material can be saved.

Fraunhofer ISE predicts that GaN will permanently change the world of power electronics since, in all applications where system weight

and volume are crucial, power transistors made of GaN and operated at high frequency offer great advantages over other technologies. It can be assumed that the 1MHz switching frequency demonstrated in the DC/DC converter is just a first step towards much higher switching frequencies while maintaining high efficiency, reckons Fraunhofer ISE.

The GaN power transistors that have been used in the converter were produced by Japanese firm Panasonic.

www.ise.fraunhofer.de



Measured efficiency of 1MHz resonant converter for various values of output power and output voltage at an input voltage of 380V.

IN BRIEF

Integra launches GaN-on-SiC HEMTs for S-band radar

Integra Technologies Inc of El Segundo, CA, USA, which supplies high-power pulsed RF transistors, has launched two internally pre-matched, GaN-on-SiC high-electron-mobility transistors (HEMTs) designed for S-band radar applications.

The IGN2729M500 operates over the 2.7–2.9GHz instantaneous frequency band. Under 300µs pulse width and 10% duty-cycle pulsing conditions, it supplies a minimum of 500W of peak output power with typical performance of 560W, typically 12dB gain and over 60% efficiency. The device is rated for peak output power of 500W with 10% duty factor and average power of 50W.

The IGN3135M130 operates over the 3.1–3.5GHz instantaneous frequency band. Under 300µs pulse width and 20% duty-cycle pulsing conditions, it supplies a minimum of 130W of peak output power with typical performance of 150W with 12dB gain. The device is rated for peak output power of 130W with 20% duty factor and average power of 26W.

Specified operation is with Class AB bias. When appropriately rated, the new GaN HEMTs are operable under a wide range of pulse widths and duty factors. All devices are 100% screened for large-signal RF parameters in a fixed tuned broadband matching circuit/test fixture.

www.integratech.com



Northrop Grumman begins sampling GaN MMIC product line for military, challenging commercial high-power amplifier needs

Northrop Grumman Corp has developed a line of gallium nitride (GaN) monolithic microwave integrated circuits (MMICs) for military and commercial uses, representing the first commercial availability of GaN-based components from the firm.

Initial engineering evaluation sampling has begun with quantities of three GaN MMIC products, developed for defense and commercial ground satellite communication terminal markets and the commercial wireless infrastructure market.

"We have been producing GaN-based devices since 2002 at Northrop Grumman's dedicated wafer fabrication facility in Redondo Beach, which the Department of Defense has designated as a Trusted Foundry," says Frank Kropschot, general manager of the Microelectronics Products and Services (MPS) business unit of Northrop Grumman Aerospace Systems. "We have achieved outstanding performance and reliability from our high-frequency gallium nitride process and are extremely confident that these GaN MMICs will improve performance, efficiency and bandwidth for military and commercial users."

Of the initial set of three MMICs: ● APN149 is a GaN high-electron-mobility transistor (HEMT) MMIC power amplifier chip operating at 18–23GHz. It provides 20dB of linear gain, +36dBm (4W) of output power at 1dB gain compression and +38dBm (6.3W) in saturation with physical address extension (PAE) of greater than 30%.

● APN180 is a GaN HEMT MMIC power amplifier chip operating at 27–31GHz. It provides 21dB of linear gain, +38dBm (6.3W) of output power at 1dB gain compression and +39dBm (8W) in saturation with PAE of 30% at midband. For less

demanding applications, the APN180 can be operated from a drain voltage as low as +20V while still producing +37dBm (5W) of saturated output power.

● APN167 is a GaN HEMT MMIC power amplifier chip operating at 43–46GHz. It provides 20dB of gain, +35.5dBm (3.5W) of output power at 1dB gain compression and +38.5dBm (7W) in saturation with a PAE of 19% at midband.

"These new products are the first of several we plan to introduce into the marketplace during the next few months as we roll out a new family of products using Northrop Grumman's 0.2µm GaN HEMT process developed partially under the Defense Advanced Research Projects Agency's (DARPA's) Wide Band Gap Semiconductors for Radio Frequency program

These new products are the first of several we plan to introduce into the marketplace as we roll out a new family of products using Northrop Grumman's 0.2µm GaN HEMT process

(WBGS-RF)," Kropschot says. The DARPA program was the first of several key GaN technology development contracts awarded to Northrop Grumman beginning in 2002. GaN devices are

key components of the new low-cost terminals introduced recently by an industry team consisting of Northrop Grumman, Lockheed Martin Space Systems and TeleCommunication Systems, Kropschot adds.

Limited engineering prototype samples are available from stock to qualified customers by e-mailing MPS at as-mps.sales@ngc.com.

www.as.northropgrumman.com

Fujitsu achieves 2.5kW output power from power supply units based on GaN-on-Si devices

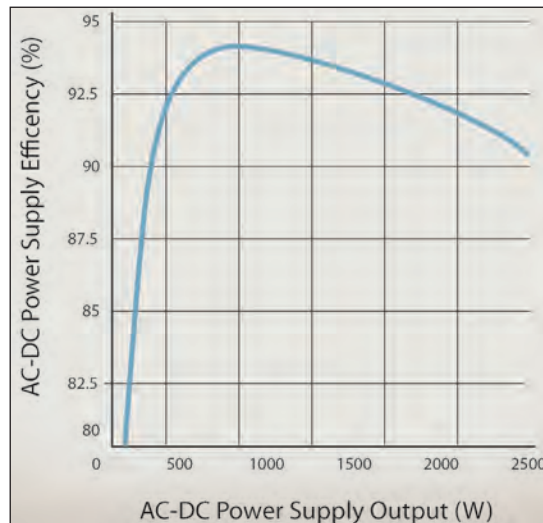
Mass production to start in second-half 2013

Japan's Fujitsu Semiconductor says it has achieved high output power of 2.5kW in server power-supply units equipped with gallium nitride (GaN) power devices built on a silicon substrate. The firm exhibited the device for the first time at Embedded Technology 2012 Conference and Exhibition at the Pacifico Yokohama Convention Center in Japan (14–16 November), and will start volume production by second-half 2013.

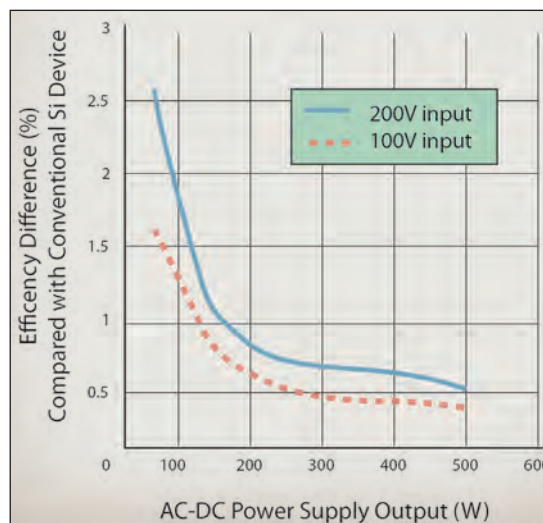
The use of GaN technology in power supply applications enhances power efficiency and helps to reduce the carbon footprint, notes Fujitsu. Compared with conventional silicon-based power devices, GaN-based power devices feature lower on-resistance and the ability to perform high-frequency operations. These characteristics improve the conversion efficiency of power supply units and make them more compact.

Fujitsu Semiconductor plans to commercialize GaN power devices on a silicon substrate, increasing the diameters of the wafers and enabling low-cost production. The firm began work on GaN technology in 2009 and has provided specific power-supply-related partners with sample GaN power devices since 2011. Since then, Fujitsu has worked on optimizing them for use in power supply units.

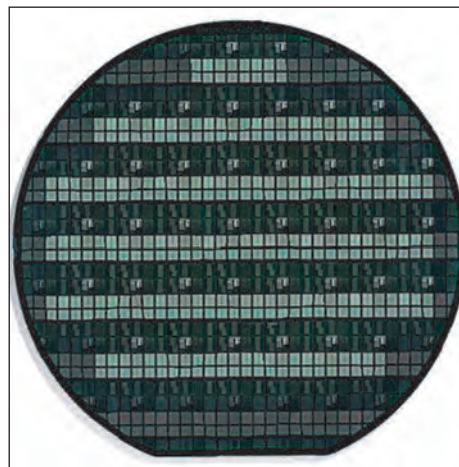
Fujitsu Semiconductor collaborated with Kawasaki-based Fujitsu Laboratories Ltd on several key technical initiatives, including development of the process technology for growing high-quality GaN crystals on a silicon substrate. The collaboration also developed device technologies, such as optimizing the design of electrodes to control the rise of on-resistance during switching, and devising a circuit layout for power supply units that can support high-speed



Output of power supply unit for servers with Fujitsu GaN power device.



Difference in efficiency with conventional silicon-based power device.



Power devices on 6" silicon wafer.

switching of GaN-based devices.

The results have enabled Fujitsu Semiconductor to achieve conversion efficiency that exceeds the performance of conventional silicon devices by using a GaN power device in a power factor correction (PFC) circuit. For example, the firm created a prototype server power-supply unit incorporating a PFC circuit based on GaN technology that achieved output power of 2.5kW. This performance makes GaN power devices suitable for use in high-voltage, large-current applications, the firm reckons.

Fujitsu Semiconductor has established a mass-production line for 6" wafers at its Aizu-Wakamatsu plant, and will begin full-scale production of GaN power devices in second-half 2013. It reckons that, by offering GaN power devices optimized for customer applications and technology support for circuit designs, it can support the development of low-loss, compact power supply units for a wide range of uses.

www.fujitsu.com



Device prototype in TO247 package.

5N Plus opens Malaysian recycling facility; acquires JV's Shenzhen gallium refining plant

5N Plus Inc of Montreal, Quebec, Canada, a producer of specialty metal and chemical products, says that its new Malaysian recycling facility is now operational.

Sited in the Kulim High Technology Park (one of Malaysia's highest-profile industrial areas for technological firms), the facility was completed under budget. Providing recycling services for solar cell manufacturers, it is expected to gradually increase its range of products and services to address broader requirements and to capture opportunities in the South-Asian market.

5N 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 pre-

cursors for the growth of crystals for electronic applications, including solar photovoltaic, radiation detector and infrared markets. Also, in April 2011, 5N acquired MCP Group SA of Tilly, Belgium, a producer and distributor of bismuth and bismuth chemicals (with a 50% global market share) as well as other specialty metals (including gallium, indium, selenium and tellurium).

5N Plus has now also acquired the remaining 50% ownership stake in joint venture company MCP Metals (Shenzhen) Co Ltd, a gallium refining facility in Shenzhen, China.

"Expansion of our activities in Asia is part of our growth strategy as we expect to see increasing demand for our products in this part of the world," says president & CEO Jacques L'Écuyer. "Our Shenzhen and new Malaysian facilities will be instrumental in allowing us to

leverage this demand and the corresponding business opportunities," he adds.

● 5N Plus has ranked among the Deloitte Technology Fast 50 and Technology Fast 500 for a third consecutive year.

Deloitte's Technology Fast 50 is a ranking of the 50 fastest growing technology companies in Canada, based on the percentage of revenue growth over six years. 5N Plus' revenues rose 717% from 2006 to 2011, placing the firm 14th in the rankings.

Also, 5N Plus ranked 138th on Technology Fast 500 list, Deloitte's ranking of 500 of the fastest growing technology, media, telecoms, life sciences and clean technology companies in North America.

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France's UMI Georgia Tech-CNRS installs Aixtron CCS reactor to grow nitride alloy materials

Deposition equipment maker Aixtron SE of Herzogenrath, Germany says that existing customer UMI Georgia Tech-CNRS in Metz, France has bought a 3x2"-wafer Close Coupled Showerhead (CCS) metal organic chemical vapour deposition (MOCVD) system, to be dedicated to growing nitride alloy R&D materials for light-emitting sources, solar cells, sensors and other applications. Aixtron Europe's service support team has installed and commissioned the new reactor at the Georgia Tech-Lorraine campus in Metz.

"We are very familiar with Aixtron MOCVD systems," says professor Abdallah Ougazzaden, director of UMI Georgia Tech-CNRS. "The CCS system perfectly matches our R&D plans in respect of GaN, InN, BN and related alloys for light-emitting sources, solar cells, sensors and other applications, depending on



Aixtron's 3x2" CCS MOCVD system.

how the semiconductor market evolves," he adds.

"We formed a strong relationship with professor Ougazzaden in France and professor Russell Dupuis from Georgia Tech in the US, both of whom have excellent teams covering all aspects of MOCVD nitride R&D," says Aixtron's chief operating officer Dr Bernd Schulte. "The Georgia Tech-CNRS International Joint Unit produces excellent scientific output and is


actively involved in national and international research programs focusing on secure networks and innovative materials for optics and electronics."

The Georgia Tech-CNRS International Joint Unit (Unité Mixte Internationale, or UMI) was established between the USA's Georgia Institute of Technology and France's CNRS (Centre National de la Recherche Scientifique) to further collaborative research in telecoms and innovative materials. Programs include optoelectronic techniques for signal encryption and secure transmission for optical and wireless systems, nonlinear optics, new materials and nanostructures for photonics and electronics, multi-functional materials, the ultrasonic characterization of materials, and the development of new ultrasonic sensors.

www.umi2958.eu

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Aixtron's Q3 upturn not enough to avoid heavy 2012 loss

Writes down €51.5m inventory; fiscal 2012 loss to hit €125m, pins hopes on LED lighting picking up

Deposition equipment maker Aixtron SE of Herzogenrath, Germany has seen its third-quarter 2012 equipment orders pick up by 15% sequentially to €34.5m. The firm says that Q4/2012 quotation levels suggest a continuation of this development, implying that "the order trough point in the current investment cycle has been passed". Q3 revenue grew 35% sequentially to €62.2m. However, the boost in order intake and revenues during Q3 was not as strong as expected.

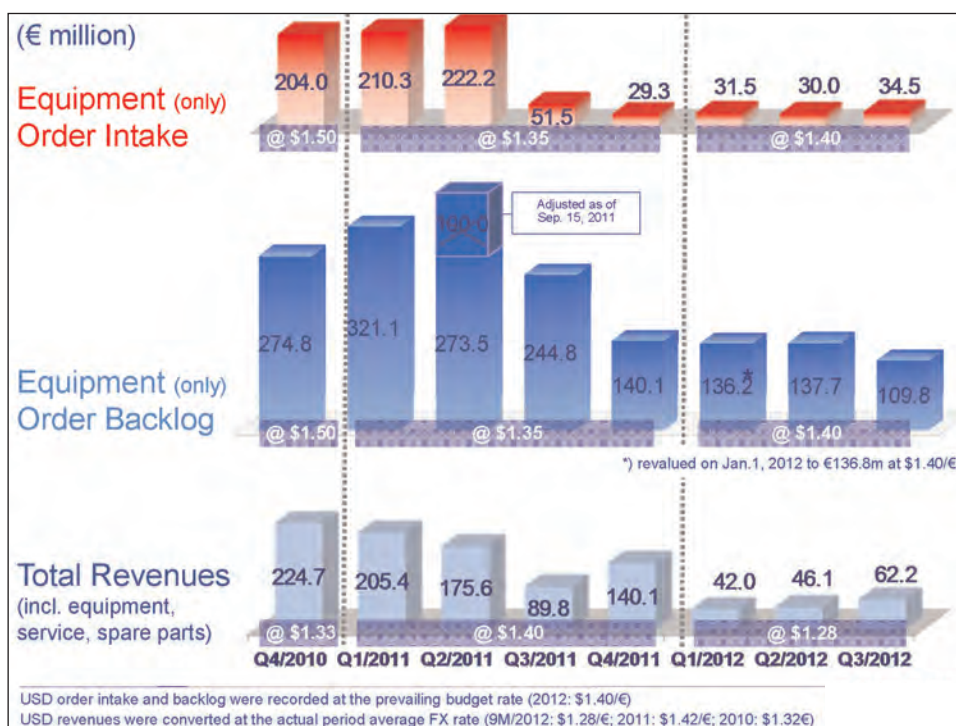
Looking at the longer 9-month business period, from January to September 2012, and comparing it with the 2011 equivalent, paints a different picture, with this year's three quarters' sales having dropped 68% to €150m (from €471m), gross profit down to -€17.3m (from €220m) and earnings before interest and taxes (EBIT) down to -€113m (from €129 m).

Management has hence reviewed its outlook in relation to inventories held and concluded that, despite the positive long-term outlook for the LED industry, the existing stock held was inappropriately high for the current subdued level of demand in the market.

"Management has decided to write down €51.5 m of inventories as excess to requirement," the firm stated. "As it is now evident that Aixtron will not return to profitability during 2012, the company has now guided towards a 2012 EBIT loss of around €125m, based on likely revenues of €220m for the fiscal year 2012."

Q3 gross profit was -€42.3m, much lower than Q2's €14.7m due mainly to the inventory write-downs, but also influenced by a less favorable product mix that included fewer final customer acceptances and softer pricing on some legacy products.

Despite high MOCVD utilization (historically seen as a precursor to an imminent pickup in equipment orders), in the current environment



Aixtron's 24-month business development, showing recovery in revenue from Q1 to Q3/2012.

customers remain hesitant about adding new LED production capacity. This is perceived to be influenced also by the recent highly competitive pricing development in consumer end-markets and the consequent margin pressure on LED makers.

Aixtron has seen non-LED business gaining further traction throughout 2012. This includes Silicon Semiconductor equipment, with rising demand for the new QXP-8300 ALD (atomic layer deposition) system, offering a cost-effective technology solution for memory producers.

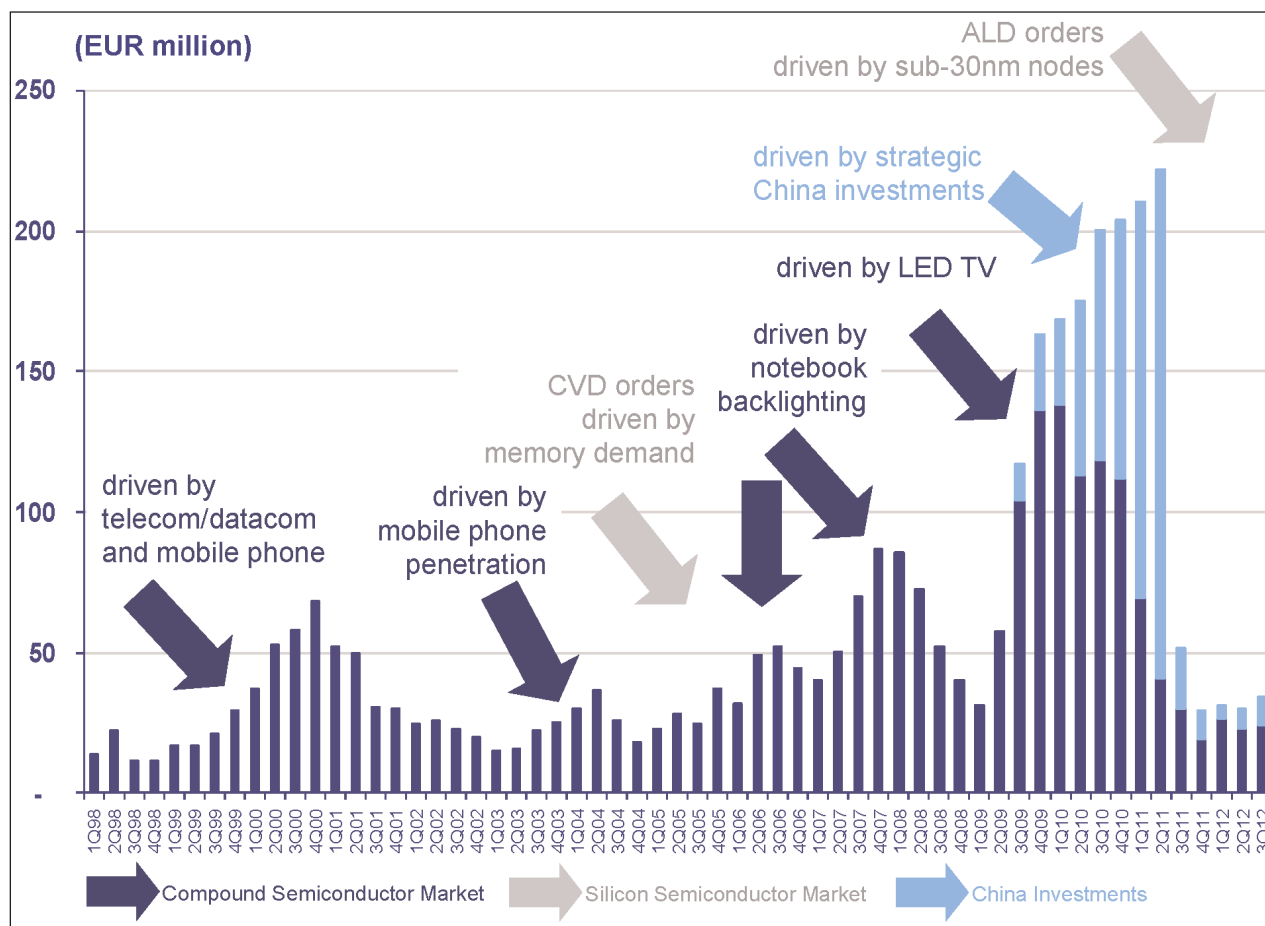
Similarly, the firm is seeing more interest from Power Electronics and LED customers in the recently launched AIX G5+ systems, which are optimized for both power electronics devices and gallium nitride on silicon (GaN-on-Si) LED structures.

President & CEO Paul Hyland remains confident that Aixtron has the appropriate strategy to capitalize on the next LED lighting investment cycle and to be able to pursue adjacent growth market opportunities:

"We are clearly getting closer to the start of the third major LED investment cycle, namely for LED general lighting. It is not a question of 'if' this substantial market arrives; it is only a question of 'when'. Despite the difficult macro-economic circumstances we are all contending with, we continue to draw cautious optimism from the frequent evidence of increasing adoption momentum towards LED lighting.

"It is however increasingly difficult in the current economic environment to predict accurately the exact timing of that solid-state lighting inflection point. This difficulty is evidenced by a much slower-than-expected pick up in orders and revenues, which has led to the €51.5m write-down on inventories we reported in Q3," he added.

"What is certain is that the absolute volume growth being predicted for LED lighting adoption will eventually require a very substantial build up of LED manufacturing capacity over the next years. We are confident that we are well positioned for this



Aixtron's quarterly equipment orders, with Q3/12 showing a recovery from Q2.

next market up-cycle with our market-driven R&D investments, our technology track record, our strong local footprint and solid customer relationships," Hyland continued.

"We have the necessary support of a strong balance sheet with a solid cash position and no debt, and will continue to look for business-efficient cost-saving measures to optimize our cost structure."

For fiscal 2012, Aixtron expects sequentially stronger fourth-quarter revenues, albeit considerably less than previously expected. However, as a result of the unexpected slower demand recovery, the firm will not report a profit in fiscal 2012. It expects to achieve full-year 2012 revenues of €220m and an EBIT loss of about -€125m.

Management expects to see an increase in demand for manufacturing equipment in 2013, driven by projected stronger equipment demand from the LED general lighting market as well as other non-LED applications, and expects

to return to profitability during 2013. Aixtron also expects to gain further traction in emerging MOCVD non-LED applications and other technology markets, including silicon semiconductor, power electronics and organic semiconductor applications.

"Aixtron has passed the trough point in the current order cycle, which is reflected in that orders and shipments are both picking up, albeit modestly at this point in time," believes Hyland. "We continue to be optimistic about the development and growth potential of our largest market for MOCVD equipment, namely the LED market."

"We remain particularly positive about the growing adoption of LEDs in general lighting. During Q3, for instance, we saw the first sub-€10, 60W-equivalent LED light bulb being offered for sale by a major European supermarket retailer. We anticipate significantly greater demand at these price levels, given the longevity and low maintenance of these products compared to conventional lighting,"

does offer the prospect of more diversity from another MOCVD end-market opportunity."

"Aixtron is still engaged in optimizing [our] cost structure," notes executive VP & chief financial officer Wolfgang Breme. For the first nine months of 2012, general & administration expenses of €14.7m were down 41% year-on-year from €24.9m, due mainly to a reduced number of temporary staff, lower consultancy costs, and lower IT infrastructure costs, as well as less profit-related expenses. Selling expenses have also fallen by 8%.

"The semiconductor equipment business in general is notorious for its 'feast and famine' cyclical characteristics," noted Hyland. "What is new for compound semiconductors is that it has been further exaggerated by the unprecedented level of government subsidies seen in recent years, which fueled non-market-driven LED equipment demand."

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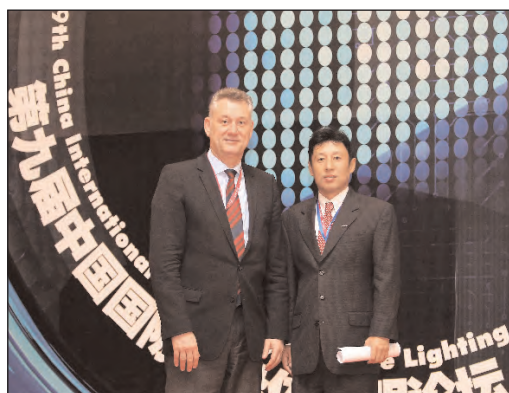
Matthew Peach, Contributing Editor

he adds. "We also continue to gain traction in our non-LED business. Non-LED MOCVD compound semiconductor equipment enquiries for power applications have continued to grow, reflecting the increasing interest, principally from the power electronics customers focused on the buoyant mobile market. Whilst not yet significant in volume terms, it

Aixtron hosts MOCVD short course at China SSL 2012

Deposition equipment maker Aixtron SE of Herzogenrath, Germany, along with the China Solid State Lighting Alliance (CSA), has again hosted a seminar on metal-organic chemical vapour deposition (MOCVD) at the China International Exhibition & Forum on Solid State Lighting (China SSL 2012) at the Guangzhou Poly World Trade Center, China (5–7 November). More than 200 decision makers from industry and research attended the seminar.

"Prices for LED bulbs as replacements for 40W incandescent bulbs in some countries are below the \$10 mark," said Dr Bernd Schulte, chief operating officer and member of Aixtron's executive board, in his presentation. "This is good news, because it will significantly expand the market for LED lighting. The question now is how to reduce manufacturing costs even further,



Aixtron's COO Bernd Schulte and Aixtron China Ltd's general manager Tim Wang.

which turns the focus onto MOCVD as a decisive manufacturing step," he adds. "I am convinced that we can only achieve quality and cost efficiency by constantly improving the reactor design and through maximum process control. If we continue to strictly focus on these areas and, at the same time, help

our customers to migrate to silicon wafers of up to 8 inches in diameter, we will be able to achieve a considerable further reduction of production costs," he continued.

"China has the potential to become the world's biggest market of end consumers for LEDs over the next few years," said Tim Wang, general manager of Aixtron China Ltd. "Over the past few months we have realigned and restructured our China organizations to be more customer focused," he added.

"Our Demo & Training Center is currently experiencing strong demand for supported process demo, training and development, which shows us that our customers recognize the benefit we have created for them locally."

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UOC plans laser production capacity ramp with purchase of AIX 2600G3 planetary reactor

Union Optronics Corp (UOC) of Yangmei City, Taoyuan County, Taiwan has purchased an AIX 2600G3 planetary reactor from Aixtron SE of Herzogenrath, Germany, to expand production of GaAs-based laser diodes. Purchased in Q2/2012 and due for delivery in Q4, the system is capable of handling 49x2-inch wafers in each run.

"Based on the good experience with our existing Aixtron AIX 2600G3 system, we are now preparing capacity for expanded business opportunities with this new AIX 2600G3," says UOC's president Dr Hir-Ming Shieh. "We consider this configuration to be the most suitable choice to ramp up our advanced laser production capacity."

UOC was founded in 1996 with its main products being optical laser diodes with wavelengths ranging



Aixtron's AIX 2600G3 MOCVD planetary reactor for 12x4-, 49x2- or 7x6-inch configurations.

from infrared (1550nm) to red (630nm). The firm also sells epitaxial wafers, chips, and packaged laser diodes.

www.aixtron.com

SINANO to develop GaN-based power devices with order for two Aixtron MOCVD systems

Aixtron says that in Q3/2012 China's Suzhou Institute of Nanotech and Nano-bionics (SINANO) ordered two Aixtron Close Coupled Showerhead (CCS) MOCVD systems to extend its nitride semiconductor research. Deliveries are planned for Q4/2012 and Q1/2013.

One system, capable of handling 6x2" substrates, focuses primarily on R&D. The other, a CRIUS, is designed for mass production, handling up to 31x2" or 3x6" substrates in one run.

"Our Nano-Devices and Materials Division will use these systems to develop new applications such as gallium nitride lasers on the 2-inch R&D system and GaN growth on silicon substrates and high-electron-mobility transistors (HEMT) on the CRIUS system," says Dr Hui Yang, director of SINANO, which was founded in 2006 by the Chinese

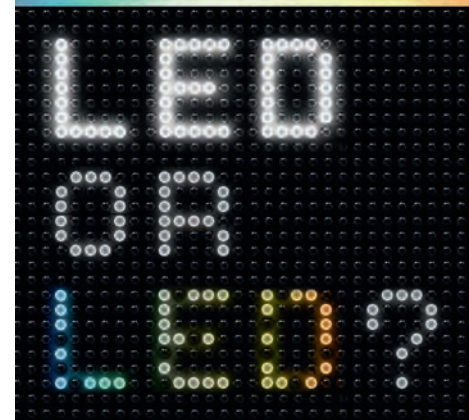
Academy of Science (CAS), the government of Jiangsu Province and the government of Suzhou city.

The Nano-Devices and Materials Division was established in 2006, with one of its research groups focusing on GaN-based high-power LEDs and laser diodes using an Aixtron CCS 6x2" system. The division will now extend its research into the field of power electronics.

GaN-based HEMTs are being widely developed on silicon as a route to the mass production of high power density devices for radio frequency and power switching applications. Systems built with such devices could be more compact and more power efficient, needing less complex circuitry with fewer passive components and reduced cooling requirements.

www.sinano.cas.cn

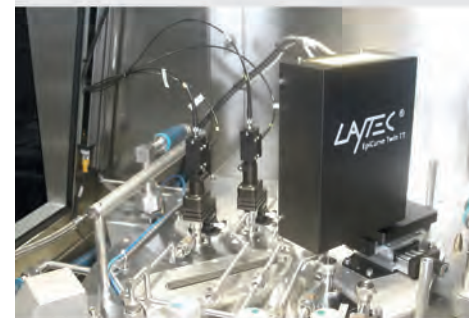
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Knowledge is key

Veeco's Q3 results reflect stubborn market

LED market is up, MOCVD remains flat, and MBE business dives

For third-quarter 2012, epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA has reported total revenue of \$127m, while its adjusted EBITA (earnings before interest, income taxes and amortization) and earnings per share were \$17m and \$0.34, respectively (on a non-GAAP basis).

John R. Peeler, Veeco's chairman & CEO, commented that these headline results were in line with the company's guidance, adding, "Veeco generated \$46m in cash flow from operations, ending the quarter with \$574m in cash and short-term investments." Third-quarter LED & Solar revenues were \$94m: approximately \$79m in MOCVD and \$15m in MBE. Data Storage revenues were \$33m.

"Third-quarter bookings were weak at \$84m, representing trough levels in all businesses. LED & Solar orders totaled \$68m: MOCVD continued to bump along the bottom at \$63m — as LED customers work through overcapacity and delay significant fab expansions," Peeler continued.

"MBE bookings declined 33% sequentially to \$5m, with customer consolidation causing a slowdown in production buys for wireless applications. Data Storage customers froze spending due to hard-drive overcapacity and a weakening demand outlook, resulting in a 37% sequential decline in orders to \$16m." Veeco's book-to-bill ratio was 0.66:1 and quarter-end backlog was \$187m.

Veeco forecasts that its fourth-quarter 2012 revenue would fall to \$100–115m and earnings per share would be \$0.04–0.16. But the company warned that in the fourth quarter it is likely to have to take additional restructuring actions.

Peeler added, "Veeco's 2012 total revenue is forecast to be over \$500m, which will mean that we will have delivered double-digit profitability, successfully managing through this challenging year."

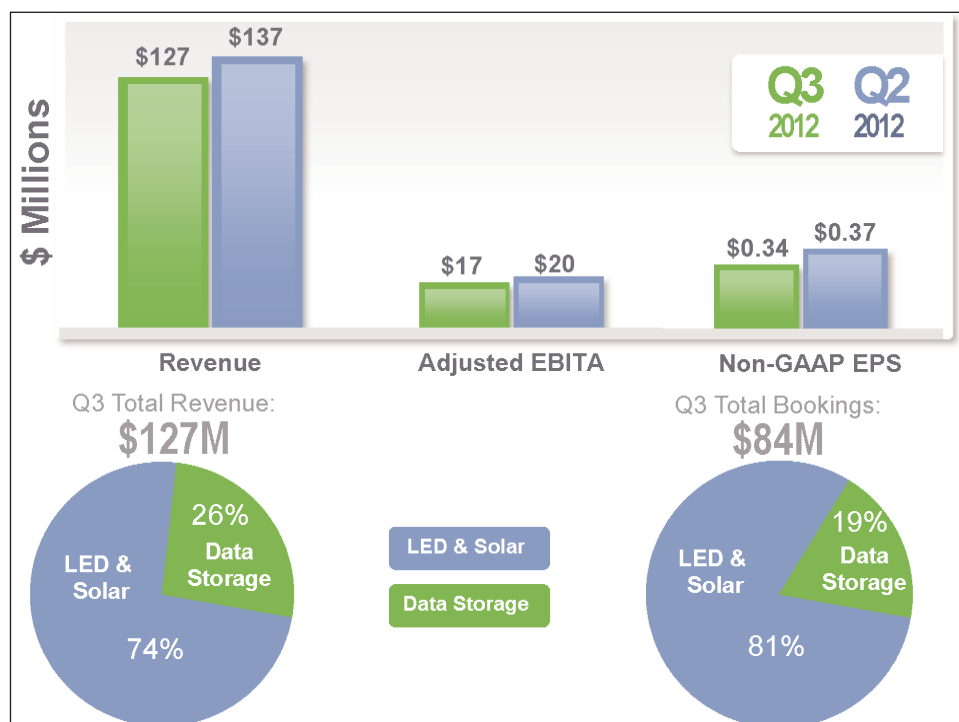


Figure 1: Veeco's revenue and earnings as well as orders in Q3 vs Q2/2012.

One year ago the company was forecasting that its Q4 revenue would "fall to \$175–215m", although by the full 2011 year-end the firm achieved record sales of \$979m, announced in February 2012.

"We are cautious about short-term business conditions since there is still no clear sign that the economy is improving. However, the LED market is getting better — general lighting is growing, excess capacity is being absorbed, and customers are reporting more stable business conditions," Peeler notes.

"An MOCVD order snap-back is inevitable as LEDs progress from 5% of all lighting to over 30% over the next few years. Insatiable demand for storage will drive future hard-drive industry capital expenditures and technology investments. We anticipate that Veeco's orders will improve in the coming quarters."

"In the meantime, we are focused on lowering our cost structure while protecting investments in R&D and new products. Our goal is to remain profitable while funding our future. We are market leaders with excep-

tional technology and customer roadmap alignment. We are well positioned for future growth as our end-markets recover and the world adopts solid-state lighting," Peeler believes.

Following the firm's announcements, the subsequent press conference addressed several key market issues and potential developments by the company. "Given the overall challenges in the market, we delivered pretty good results this quarter," said Peeler. "While MOCVD orders remained low in Q3, there are some positive trends in LED. General lighting is growing, and customer tool utilization rates are up. Korean customers report utilizations in the 60–80% range. Taiwan is 80–100%, and in China leaders are over 90%."

"On another positive note, Veeco service revenue grew 36% through the first nine months of the year. As hundreds of MOCVD tools are coming off warranty, we're selling more consumables, spare parts, and service contracts, and in fact our service revenue is better in

every quarter of 2012 than in 2011."

Considering some of the difficult aspects of the company's marketplaces, Peeler added, "A quarter ago [end of Q2] we thought that orders would start to improve in the second half of 2012. They in fact worsened in data storage and MBE while MOCVD continued at the previous low levels. As far as R&D is concerned, we expect to spend about as much on this in 2012 as we did in 2011, and we'll be in great shape to win as our markets recover."

Veeco's chief financial officer David Glass commented on the firm's guidance for the current [fourth] quarter: "Given the anemic bookings in our Data Storage and MBE businesses the last couple of quarters, we expect that Q4 revenues will decline in both businesses, whereas MOCVD should remain relatively flat. Gross margins are expected to be around 40-41%, and our goal is to keep OpEx relatively flat at right around \$43m. This achieves our July [2012] target to bring OpEx back to Q1/2012 spending levels."

Asked about market share, Peeler remarked, "We were at about 50-plus percent in 2011, and I think in the last quarter we calculated 62%. It's pretty high. I think as you get above that point it does get harder and harder to shift it more. So we will continue to put out great products and do a great job supporting our customers, and hope to grow it."

Acknowledging that the general marketplace downturn had endured longer than Veeco had expected, Peeler said, "but we're confident

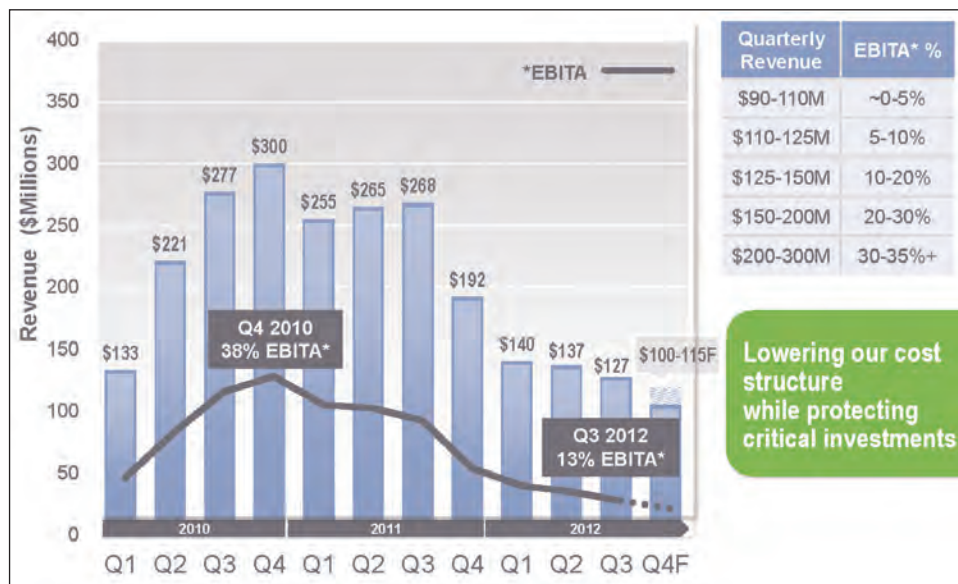


Figure 2: While protecting critical investments, Veeco plans to lower its cost structure to maintain its profitability.

that the market will come back, which is why we have continued to fund our R&D and make sure that we keep our leadership position in having the best products that have the lowest cost of ownership in the market. We've been able to do that without dropping into a loss position or building up years of inventory."

So what shape and position would Veeco have when the downturn finally ends? Peeler answered, "We do anticipate being in a better position. We think we are in a better position, and have the strategy that enables us to maintain that."

During the conference, analyst Jed Dorsheimer (managing director, Equity Research, at Canaccord Genuity) referred to Veeco having "\$15 a share in cash on the balance sheet, and only \$40m of that tied to customer deposits," before

asking Peeler whether with this cash-rich position meant that "further merger & acquisition activity was one of his priorities?"

Peeler replied, "First of all, the \$15 a share we got the old fashioned way, we earned it from a lot of hard work. So we treat that very carefully, and we think it's important to have that as a buffer in case we need it someday. We are looking at acquisitions. We've been looking at acquisitions for the last several years, and intend to be very selective. We've done some technology acquisitions already that have been successful for us as a company, and some tuck-ins. But we'll keep looking until we find the right deal. I don't really have any feeling of urgency to spend our money."

www.veeco.com

Matthew Peach, Contributing Editor

Veeco delays SEC filing as it reviews timing of revenue recognition

Veeco has filed a form 12b-25 'Notification of Late Filing' with the Securities & Exchange Commission relating to its 10-Q report for Q3. More time is needed while it reviews the timing of revenue recognition for the sale of certain MOCVD systems and related upgrades.

"The accounting issues do not relate to product performance or

customer acceptance of our products," says chairman & CEO John R. Peeler. "The systems which are the subject of these transactions were delivered, accepted and paid for in full by our customers. Our review focuses on determining whether revenue was recognized in the appropriate accounting periods," he adds.

Veeco is working with its independent auditor Ernst & Young LLP to address these matters. If it is required to change the timing of recognition of any revenue, there could be a shift in revenue between accounting periods that could constitute material changes to results of operations and financial condition for various periods.

Plasma-Therm hosts plasma processing workshop at University of Texas Microelectronics Research Center

Plasma process equipment maker Plasma-Therm LLC of St Petersburg, FL, USA has provided a one-day plasma processing workshop at The University of Texas at Austin Microelectronics Research Center (MRC), which is part of the NNIN (National Nanofabrication Infrastructure Network).

Presentations addressed both fundamental and advanced plasma etching as well as deposition technologies used primarily in semiconductor device fabrication and materials science research. Attendees included graduate students, facility staff, post-doctoral researchers, and engineers, many involved in projects requiring

process capability spanning a broad range of research topics as diverse as solar energy, nanostructures, data storage, opto-telecommunications, and MEMS.

Plasma-Therm has held similar one and two day workshops at prominent institutions in Singapore, USA, Sweden, China, and Israel during the last year.

"The recent workshop on plasma etching and deposition provided by Dr David Lishan of Plasma-Therm was attended by over 70 people from the University of Texas and other schools and industrial labs," says professor Sanjay Banerjee, director at UT Austin's MRC.

"Extremely valuable training was

provided about the fundamental physics of plasma processing, as well as practical insights about plasma etching and deposition," he adds.

"The high attendance at these workshops is evidence of significant enthusiasm for information relating to semiconductor and materials processing," says Dr David Lishan, Plasma-Therm principal scientist and workshop organizer. "Providing technical communities such as the one in Austin, with these plasma processing workshops is personally very satisfying and exposes Plasma-Therm to leaders in R&D in many different disciplines."

www.mrc.utexas.edu

www.plasmatherm.com

Plasma-Therm and SINANO CAS host plasma processing workshop

Plasma-Therm has provided a plasma processing workshop at Suzhou Institute of Nano-tech and Nano-bionics Chinese Academy of Sciences (SINANO CAS), with presentations on fundamental and advanced plasma etching and deposition technologies used primarily in semiconductor device fabrication and materials science research.

The workshop was hosted by the Nanofabrication Facility (NFF) of SINANO, which offers processing capability for research projects of other departments within SINANO and provides services for local companies' R&D, training technicians for state and local enterprises acting as an incubator for the micro/nano optoelectronic industrial base in Suzhou City.

More than 130 attendees included graduate students, facility staff, post-doctoral researchers and engineers, involved in projects requiring process capability spanning topics such as MEMS, biosensors, graphene research and optoelectronic devices.



Plasma-Therm plasma processing workshop at SINANO.

"The Plasma-Therm Plasma Processing workshop was informative and substantial, which is very valuable for students and engineers in the academic and industrial technology communities," said Professor Jianjun Zhu, at the SINANO NFF. "The course was well arranged, covering the basics of plasma knowledge, dry etch and deposition processes and principles, with intuitive and deep explanations. Although I have little experience on semiconductor processing line, the workshop showed me an impressive picture of how to utilize the magic power of plasma in device fabrication. The presentations gave me as well as many other attendees a clear

and to future workshops."

"The attendance for a weekend technology workshop event was very impressive and is indicative of the interest in plasma processing technology" added Dr David Lishan, Plasma-Therm's principal scientist and organizer of the workshop series. "Participants come from a wide background. It is rewarding to present material to such an audience and challenging to make plasma processing concepts accessible. With these events, Plasma-Therm gains better insight into research directions and researchers are able to better utilize their plasma equipment and improve their process results."

<http://english.sinano.cas.cn>

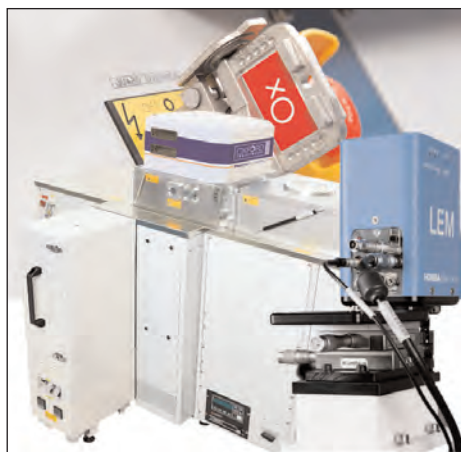
view of the processing III-V and Si-based devices. I look forward to incorporating concepts

OIPT launches upgrades for plasma and ion beam etch and dep systems

UK-based Oxford Instruments Plasma Technology (OIPT) has launched a new range of system upgrade options for its etch and deposition tools. They include:

- The X20 Control System, offering excellent scan speeds and processing resulting in accurate control and precise data logging.
- The Maglev Turbo replaces the current traditional bearing turbo pumps for superior pumping speeds and up to 15% higher throughput. Maglev Turbo is robust and provides high performance and more up-time.
- Etch and deposition end-point detection options for achieving optimal process conditions and results. The optical end points enable real-time chamber clean end-point detection, increasing the availability of the tool, and lowering cost of ownership.

"This new range of upgrades aims to offer our customers the latest



hardware so that they have the opportunity for improved performance and extended lifetime of their Oxford Instruments system," says sales, CS & marketing director Mark Vosloo.

The upgrades add to the range of options already offered for the Plasmalab, PlasmaPro and Ionfab families of systems, adds the firm.

www.oxford-instruments.com/upgrades

IN BRIEF

IQE named 'Company of the Year' at Welsh award ceremony

At the Western Mail/Institute of Welsh Affairs Business Awards in Cardiff City Hall on 9 November, epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK was named 'Company of the Year' in the category for large companies with a turnover of more than £10m (which was sponsored by Cardiff School of Management at Cardiff Metropolitan University).

The award was presented by economics and media commentator Faisal Islam at a gala dinner celebrating the best in Welsh business, sponsored by business advisory firm PwC.

www.iwa.org.uk/businessawards
www.iqep.com

Instrumental in change

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www.oxford-instruments.com/plasma

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Lake Shore firmware and software updates for download

Lake Shore Cryotronics Inc of Westerville OH, USA, which makes scientific sensors, instruments and systems for precise measurement and control, is instituting a new service enabling customers to download Ethernet and instrument firmware and software updates to its instruments in the field, without requiring returns to Lake Shore. The updates will be available to all users of Lake Shore instruments through the firm's website.

The first firmware upgrade offered is to the Model 336 cryogenic temperature controller, and can be accessed through the web-site's product page. The primary new feature is an added chart recorder utility, enabling users to log and chart data from the temperature controller via built-in software.

Other updates include closed-loop PID modes available on outputs 3 and 4, setpoint 'press-and-hold' loading of current temperature to setpoint bypassing ramping, and added capacitance option card support. Lake Shore is offering this upgrade free to all existing Model 336 users.

The upgrades are available through a simple download, and

are accompanied by detailed instructions on how to perform the upgrade. All Lake Shore products come with a standard 3-year warranty.

"Our goal is to offer a convenient and efficient way for our customers to ensure their instruments are current, while posing minimal disruption to their research," says instruments engineering manager David Plaga.

Lake Shore at Materials Research Society Fall Meeting

At the Materials Research Society Fall Meeting 2012 (26–30 November) in Boston, MA, USA, Lake Shore highlighted its range of sensors, instruments and systems for high-precision materials characterization research, including its line of cryogenic and cryogen-free probe stations, new 8404 Hall effect measurement system and its Model 336 cryogenic temperature controller.

Also featured were a Model TTPX probe station, an entry-level tabletop micro-manipulated probe station for non-destructive testing of materials. The TTPX is part of Lake Shore's line of cryogenic probe stations for a variety of

research applications. Lake Shore probe stations offer controlled environments for characterizing electronic and magneto-transport properties of materials from cryogenic to elevated temperatures, and are available with and without magnets. The line includes liquid cryogen-based stations or cryogen-free CCR-based units.

Lake Shore also spotlighted the 8404 AC/DC-field Hall effect measurement system and its new extended-range sample oven, which enables evaluation of the electronic transport properties of materials to temperatures as high as 1000°C. A closed-cycle refrigerator option for measurements down to 15K is also available. The 8404 features an optional AC field measurement capability, which can measure mobilities down to $10^{-3}\text{cm}^2/\text{V}\cdot\text{s}$, enabling the exploration of the electronic and magneto-transport properties of low-mobility electronic materials.

Applications for the system include the measurement of solar cell materials, organic electronics, transparent conducting oxides, and III-V semiconductors.

www.mrs.org/fall2012

Lake Shore boosts magnetic field and vacuum performance for CRX-VF cryogenic probe station

Lake Shore Cryotronics has introduced updated specifications for its Model CRX-VF cryogen-free micro-manipulated probe station (launched in February), featuring increased maximum magnetic field, improved magnetic field at elevated sample temperatures, and improved vacuum performance.

The versatile Model CRX-VF is used for non-destructive testing of devices on full and partial wafers up to 51mm (2") in diameter. Its superconducting magnet platform generates higher fields than are possible with an electromagnet-based station without the operat-

ing cost of liquid helium, says the firm. Suitable for measuring electrical, electro-optical, parametric, high Z and Hall effect, as well as DC, RF and microwave properties of materials and test devices, the CRX-VF is used to measure nanoscale electronics, quantum wires and dots, semiconductors, and spintronic devices.

The CRX-VF's specifications have been improved and updated, making it more flexible. The maximum magnetic field capability at base temperature has been improved from $\pm 2.25\text{T}$ to $\pm 2.5\text{T}$. In addition, the CRX-VF can now be operated up to $\pm 2\text{T}$ from 10K to 400K and

up to $\pm 1\text{T}$ from 400K to 500K. Previously, only $\pm 0.5\text{T}$ was possible above 400K and no magnetic field was possible above 450K.

Also, a new high-vacuum option has been added as a standard option for users whose applications require lower base pressures. The PS-HV-CPX improves vacuum to $<5 \times 10^{-7}\text{Torr}$ with the station at base temperature (an improvement of two orders of magnitude over the standard vacuum configuration). The high-vacuum option is recommended for applications sensitive to contamination.

www.lakeshore.com

EV Group doubles cleanroom space, and opens R&D labs and customer training center

Expansion supplements first-phase doubling of production floor-space

EV Group (EVG) of St Florian, Austria, a supplier of wafer bonding and lithography equipment for the MEMS (micro-electro-mechanical system), nanotechnology and semiconductor markets, has completed its newly expanded cleanroom IV facility.

As part of its long-term growth strategy to address high-volume tool orders and speed time to market for its worldwide customer base, EVG has doubled its cleanroom space for process development and pilot-production services. In addition, it has increased the size of its application labs, added new R&D facilities for internal tool development and testing, and opened a new customer and employee training center.

In tandem with the cleanroom expansion, EVG has increased the number of fully automated high-volume manufacturing (HVM) systems (for different wafer sizes) to strengthen its customer demon-

stration and process development capabilities. While manufacturing and product development are centralized at EVG's corporate headquarters, technology and process development teams in Austria work closely with the firm's subsidiaries in Tempe, AZ and Albany, NY in the USA, Yokohama and Fukuoka in Japan, Seoul in South Korea, and Chung-Li in Taiwan, where additional application labs and cleanroom facilities are available for onsite customer demonstration and technology process development. EVG says that it works closely with leading universities and R&D institutes worldwide, and plays a key role in industry associations and consortia to progress R&D on semiconductors, MEMS, light-emitting diodes and other high-tech devices.

The new customer and employee training center provides several new rooms for instructional training courses, as well as a large number of manual and automated EVG

tools for training. The new training center provides additional flexibility and increased capability for customers and employees worldwide who regularly attend training courses on EVG technologies, manufacturing processes, products and software, as well as equipment operation.

Earlier this year, the addition of a manufacturing facility doubling the production floor space marked the completion of the first phase of EVG's long-term expansion plans. Already contributing to continued, steady growth from the beginning of 2012, EVG has increased its order intake in fiscal 2012 (to end-September 2012) by 5% over fiscal 2011, while increasing revenue by 20%. Also, in the last 12 months EVG has added more than 100 new staff (to a current total of about 600 worldwide) and continues to recruit new employees in all departments.

www.EVGroup.com

Texas State chooses EVG wafer bonding system for compound semi and silicon-based power device R&D

EV Group has installed an EVG501 wafer bonding R&D system at Texas State University. The system, which is configurable for a variety of wafer bonding processes, will be used for compound semiconductor and silicon-based power device R&D.

"Following a thorough evaluation of a number of wafer bonding systems, we selected EVG's solution for its superior technology capabilities," says Edwin Piner, associate professor, Physics, at Texas State. "The affordable R&D system demonstrated outstanding results, with high pressure conformity and bond consistency," he adds.

"EVG has a strong support network and we will work closely with their experienced process teams to further the development of bonding processes for specialized compounds."

The EVG501 can handle small substrate pieces up to 200mm wafers, and supports a variety of bonding processes, such as anodic, glass frit, eutectic, diffusion, fusion, solder and adhesive bonds, as well as other thermal processes, including oxide removal and high-temperature bakes under a controlled atmosphere. The system also offers quick re-tooling

with a conversion time of less than 5 minutes, suiting universities and R&D as well as small-volume production applications, says the firm.

"Working with Texas State marks a further step in our partnering with leading universities and research firms around the world in their efforts to develop solutions to today's challenges as well as exploring advancements that will address future industrial needs," says Garrett Oakes, North American director of Technology for EVG. "We look forward to a long-term collaborative partnership with Texas State University."

www.txstate.edu

Hyperion enters mass production of large-diameter sapphire using ARC's CHES furnaces

Suzhou Hyperion Geocrystal Co Ltd has achieved volume production of large-diameter c-axis sapphire cores using CHES (Controlled Heat Extraction System) furnaces from Advanced RenewableEnergy Company LLC (ARC Energy) of Nashua, NH, USA, which provides c-axis sapphire growth technologies and turnkey solutions for the LED solid-state lighting market.

Hyperion is now at volume production levels and can supply 50mm, 100mm, 150mm and 200mm (2", 4", 6" and 8") diameter cores, epi-ready wafers, and PSS (patterned sapphire substrate) wafers. It has already received orders from multiple high-brightness LED (HB-LED) makers and has begun shipping material to a broad customer base. ARC says that Hyperion prefers CHES furnaces because of their high material utilization and automated operation.



CHES c-plane sapphire cores in small to large diameters, ready for processing into HB-LED chips.

"Our CHES furnace customers are in a unique position to deliver large-diameter sapphire with high quality at low costs due to the high material utilization inherent with our on-axis growth technology," claims ARC Energy senior VP Hap Hewes.

Hyperion purchased CHES furnaces and related ARC products to grow and sell sapphire to the HB-LED industry. CHES furnaces grow sapphire directly on the c-axis, providing benefits including high material utilization that improves as substrate diameter increases, claims ARC. This scalable yield prepares users as the industry moves to larger wafer sizes, the firm adds.

ARC says that CHES furnaces are automated and require minimal operator input and training. Automation software takes on complex adjustments with precision and repeatability, resulting in more consistent sapphire growth and less operator dependency, it claims. The firm adds that, at Hyperion, this ensures higher throughput and uniform size sapphire boules with consistently high quality.

www.hyperion-gc.com

www.arc-energy.com

ARC claims 75% material utilization for large-diameter sapphire

ARC Energy has announced 'CHES Foundations Series Part 2: Sapphire That Scales' as the latest publication in its CHES Foundations series, explaining the advantages of its CHES (Controlled Heat Extraction System) c-axis sapphire growth technology and furnaces.

The firm says CHES reaches 75% or greater material utilization across large-diameter sapphire substrate sizes compared with 10–20% for a-axis grown sapphire boules. CHES large-diameter wafers cost less, lead to higher LED production throughput per MOCVD run, and have properties (such as lower, more uniform bow) that enable lower cost per lumen, claims ARC.

"The industry must move to large-diameter wafers to reduce costs, but older sapphire technology has significant limitations moving in that direction," says ARC Energy senior VP Hap Hewes.

"That's exactly why we developed CHES technology: to reduce costs for large-diameter LED sapphire wafers."

The high-brightness LED (HB-LED) industry is searching for dramatic cost savings to reduce the price of solid-state lighting to enable mass adoption by the general lighting market, notes ARC. A key component to reduce costs is moving to large-diameter substrates, similar to the move the silicon industry made over 20 years ago. 'Sapphire That Scales' outlines the advantages of moving to 150mm (6") and 200mm (8") substrates. A single MOCVD run simulated using 150mm wafers results in 55% more LED chips. With 200mm wafers the improvement increases to 77% more LED chips over using standard 50mm wafers.

Although large-diameter substrates have significant benefits,

older sapphire growth technology has very low material utilization when growing these substrates, reckons ARC. Also, due to a non-uniform growth time signature, older technologies result in larger and uneven bowing (warp) during epitaxy in a MOCVD reactor, reducing LED chip yield and requiring expensive workarounds, it adds.

CHES technology was designed to overcome the drawbacks of older sapphire technologies at large diameters. ARC says it provides high material utilization on the c-axis together with low defect levels. Also, growing along the c-axis produces wafers with a single time signature, which can result in less bow and warp during MOCVD, the firm claims. CHES furnaces grow near-net-shape c-axis boules for 150 and 200mm cores in production today, suiting HB-LED production on large-diameter sapphire substrates, ARC adds.

Rubicon reports positive third-quarter results

Quarterly revenue rises 17%, gross margin exceeds break-even, but LED market recovery 'slow'

For third-quarter 2012, Rubicon Technology Inc of Bensenville, IL, USA, which makes monocrystalline sapphire substrates and products for the LED, RFIC, semiconductor and optical industries, has reported revenue of \$19.9m, up 17% on \$17m last quarter, driven by strong 6-inch sapphire wafer sales. Revenue from 6-inch wafer sales alone rose 62% sequentially as demand increased from both the silicon-on-sapphire (SoS) and LED markets. However, due to low industry pricing for 2–4" core products, Rubicon decided to sell "a limited quantity" of those products in Q3.

"We saw strong demand for our 6" polished wafers in this quarter from both key markets, SoS and LED," commented president & CEO Raja Parvez. "While the recovery of the LED market is slower than expected, the strength of our technology has allowed us to outperform our peers by enabling us to take a leadership position in supporting emerging technologies such as silicon-on-sapphire, large-diameter LED substrates and large-area optical windows."

Gross margin rose to 12.3%, up from break-even last quarter. Operating loss was reduced to \$1.1m from \$3.1m, and earnings per share were \$0.01 after recording a foreign currency gain and additional income tax credits.

"While the LED market in general continues to remain fairly weak, we are seeing signs of improvement, and the SoS market remains strong," Parvez says. "During the current LED industry cycle we continue to focus on enhancing our competitive position by developing new products, adding intellectual property and reducing our cost structure," he added.

Commenting on the outlook for Q4/2012, chief financial officer William Weissman commented, "We expect revenue to be similar to

that of Q3, with most of our revenue again coming from 6" polished wafer sales. Pricing for 2–4" cores has not yet started to rebound, so we will likely [continue to] sell limited volume of these products again in Q4. Gross margin will likely be in the high single digits, as average pricing for 6-inch wafers will be somewhat lower," he added.

"The down cycle in the LED market has certainly delayed broader adoption of 6" substrates among LED chip manufacturers, and 6" usage remains limited at this time. We are now beginning to see some chip manufacturers re-engage their development work on 6" and expect strong growth in the 6" market in the second half of next year," Weissman continued. "However, in the near term we expect to see some pricing pressure on 6-inch, given the limited demand and competitors trying to qualify for that business. Consequently, we expect a loss per share between \$0.02 and \$0.05 in Q4."

In the subsequent analysts' conference (on 8 November), Parvez expanded on his earlier summaries of Rubicon's recent and likely next-quarter performance as well as the conditions facing the firm's wider markets.

"Rubicon continues to be the largest provider of 6" wafers to the LED market due to our strength in both large-diameter crystal growth and large-diameter polishing," he commented. "The down cycle in the LED market has certainly delayed broader adoption of six-inch sub-

strates by LED chip manufacturers and six-inch usage remains limited at this time. However, we continue to believe that large-diameter substrates are the future of LED chip manufacturing and we are now beginning to see some chip manufacturers re-engage their development work on 6" wafers. We have also begun discussing 8" wafers with some of our customers," he noted.

"One analyst said in September [2012] that they anticipate that, within two to three years, 25% of the total sapphire wafer surface area processed will be on 6" wafers, and in a few more years that number is expected to be 50%," Parvez continued. "We will begin to see greater 6-inch adoption in the second half of next year, which will be a strong growth driver for us," he believes. "However, in the near term we expect to see some pricing pressure on 6-inch wafers, given the limited demand and competitors trying to qualify for their business."

"Global consumption of LED in general lighting applications is expected to increase approximately 37% per year over the next few years before accelerating to an annual growth rate of over 50%. However, while the LED market is slowly improving we anticipate that it will likely be a couple of more quarters before we see some price improvement for 2–4" cores," Parvez adds.

"[Recently] it has been a difficult cycle for the LED industry, but the market is slowly improving while the silicon-on-sapphire market continues to grow," Parvez concluded. "During this [coming] cycle we'll continue to focus on extending our vertical integration and refining our processes in order to further extend Rubicon's competitive position."

www.rubicon-es2.com

Matthew Peach, Contributing Editor

GT streamlines operations, including 25% staff cut

Business consolidated into a Crystal Growth Systems group while targeting diversification

At the end of October, GT Advanced Technologies Inc of Nashua, NH, USA (a provider of polysilicon production technology as well as sapphire and silicon crystalline growth systems and materials for the solar, LED and other specialty markets) said that it is streamlining global operations to better align its cost structure with current market conditions and enhance its ability to pursue strategic growth initiatives, including the consolidation of existing business units into a single Crystal Growth Systems (CGS) group and cost-reduction actions including a reduction in staffing of about 25%. When fully implemented, the workforce reduction is expected to cut annualized expenses by about \$13m. GT expects to record associated restructuring charges of about \$4.2m in the December quarter.

"Some of our Asian customers are experiencing severe financial difficulties brought on by a number of economic- and trade-related challenges," said president & CEO Tom Gutierrez. "We are not

immune to these headwinds and we are taking actions to prepare for what is likely to be a challenging 2013 in our core markets by lowering our cost structure and at the same time improving our ability and flexibility to make strategic investments in R&D, next-generation technology and diversification initiatives that we believe will drive future growth," he added.

"In the long term, we continue to expect renewed growth in the LED market as general lighting adoption accelerates and a turn-around in the solar industry driven in large part by the adoption of new technologies that provide critical cost reductions," Gutierrez continued. "We also remain optimistic about the opportunities in our sapphire business for emerging applications such as the mobile cover and touch-screen markets."

Under the new business structure, Dan Squiller has taken on the role of president of the new CGS business group, reporting directly to Gutierrez. The CGS group combines

the PV, Polysilicon and Sapphire business units, as well as worldwide operations. David Keck assumes the role of executive VP & general manager of the PV and polysilicon unit. Cheryl Diuguid continues to lead the sapphire business unit as executive VP & general manager. David Gray (chief strategy officer), Vikram Singh (executive VP of advanced systems development and R&D) and Jeff Ford (VP & general manager of DSS business development) will report directly to Gutierrez to drive business development, diversification and next-generation technology initiatives.

"It remains our strategy to invest through these challenging times," said Gutierrez. "Combined with our healthy balance sheet with nearly \$480m of cash and cash equivalents, the actions we announced today solidly position GT to execute on this growth strategy, laying the groundwork for us to emerge as a stronger, more diversified global technology leader."

www.gtat.com

GT's revenue falls 34% in Q3, but sapphire orders rebounding

For third-quarter 2012, GT Advanced Technologies reported revenue of \$110.1m, down 34% on \$167.3m last quarter and 49% on \$217.7m a year ago (and at the low end of the \$110–140m guidance).

Revenue by business segment was

- \$95.9m in polysilicon (down from \$121.5m last quarter);
- \$1.6m in photovoltaic (down from \$9.4m last quarter);
- \$12.6m in sapphire (down from \$36.3m last quarter).

Operating expenses have been cut from \$41.3m a year ago and \$35.6m last quarter to \$30m.

However, operating margin has still fallen further, from 24.7% a year ago and 14.7% last quarter

to just 4.6%.

Non-GAAP net income is down from \$45.8m a year ago and \$19.3m last quarter to \$0.7m. During the quarter, cash and cash equivalents rose from \$332.4m (including \$145m of total debt) to \$479.2m (although this includes \$298.1m of debt).

However, new orders have rebounded from just \$13.8m last quarter to \$49.2m. This included \$11.1m for polysilicon (recovering from just \$0.4m), \$5.2m for PV (down from \$8.5m) and \$33m for sapphire (rebounding from \$4.9m).

The firm had \$56.3m of negative adjustments to order backlog, related primarily to the termination

of a polysilicon contract with a startup Chinese firm that GT had previously indicated was at risk due to the customer's failure to perform. During the quarter, total order backlog fell from \$1.6bn to \$1.5bn. This included \$617.7m for polysilicon (down from \$758.6m), \$141.4m for PV (up slightly from \$137.8m) and \$717.6m in sapphire (up from \$697.5m), as well as \$93.2m of deferred revenue.

"We remained profitable and achieved the upper end of our EPS guidance in Q3 in spite of the softer demand environment in our core markets, demonstrating the resilience of our business model," said president & CEO Tom Gutierrez.

www.gtat.com

GT acquires Twin Creeks for \$10m

Hyperion ion implantation to be commercialized in late 2014 to produce engineered substrates for power semis and thin wafers for PV

GT Advanced Technologies Inc of Merrimack, NH, USA (a provider of polysilicon production technology as well as sapphire and silicon crystalline growth systems and materials for the solar, LED and electronics markets) has acquired certain capital assets and intellectual property of Twin Creeks Technologies Inc of San Jose, CA, USA, which has developed ion implanter technology that enables the production of lower-cost thin substrates with minimal material (kerf) loss. The assets were purchased from Twin Creeks' lenders in a private sale for about \$10m plus royalties that will be based on future sales.

GT expects that Twin Creeks' unique Hyperion ion implanter technology will have broad application in the production of engineered substrates for power semiconductors and thin wafers for solar applications. Also, GT expects to pursue the development of thin sapphire laminates for applications such as cover and touch-screen devices. Hyperion could minimize, or in some cases eliminate, the need for wafering saws, which could significantly lower the cost of production, it is reckoned.

The assets acquired by GT relate mainly to the Hyperion ion implanter as well as Twin Creeks' portfolio of about 30 granted US patents and over 70 pending US and international patent applications. GT's ion implanter engineering team will be based in Danvers, MA.

"Hyperion's

unique ion source and beamline design will enable a wide range of exfoliation applications in markets where thin silicon, silicon carbide, sapphire, germanium and other crystalline material substrates can enable breakthroughs in perform-

Hyperion's unique ion source and beamline design will enable a wide range of exfoliation applications in markets where thin silicon, silicon carbide, sapphire, germanium and other crystalline material substrates can enable breakthroughs in performance and cost

ance and cost," says Vikram Singh, executive VP of advanced systems development. "Hyperion will enable the production of high-throughput and optimum-thickness substrates that can not be achieved with other ion implant technologies," he adds.

"The acquisition of these assets from Twin Creeks, coupled with our operational expertise and proven ability to commercialize innovative technology, will allow us to develop a new line of products that can deliver advancements in performance and value in the core markets we serve today as well as new markets that we have identified," says GT's president & CEO Tom Gutierrez. "We are particularly excited about the potential applications in the cover and touch-screen markets," he adds. "This continues GT's strategic diversification into new and promising markets with technology that delivers superior value to customers over existing products currently available."

GT expects to start commercialization of the technology in late 2014.

www.twincreeks technologies.com
www.gt at.com

BluGlass' RPCVD-grown GaN layers demonstrate reduced impurity levels on a par with MOCVD

BluGlass Ltd of Silverwater, Australia says it is now able to produce gallium nitride (GaN) with industry-standard impurity levels using its low-temperature remote-plasma chemical vapor deposition (RPCVD) technology. The RPCVD-grown GaN layers are now demonstrating reduced levels of key impurities (carbon, hydrogen and oxygen) on a par with the industry-standard metal-organic chemical vapor deposition (MOCVD) process, adds the firm.

Impurity levels were measured by

independent, global materials characterization firm Evans Analytical Group (EAG) using secondary-ion mass spectrometry (SIMS).

EAG confirmed that BluGlass has demonstrated carbon, oxygen and hydrogen impurities at levels less than 1×10^{17} atoms per cm^3 .

BluGlass now aims to optimize the p-GaN layer in order to show the advantages of RPCVD to customers, including improved LED device efficiency over the current industry-standard MOCVD-produced devices.

"This achievement is a breakthrough for the company and is a critical step in proving to the industry and future customers the potential of our technology," says CEO Giles Bourne. "Carbon and oxygen are well known inhibitors of RPCVD, and their reduction will be viewed by the industry as a significant achievement," he reckons. "These reductions in impurities will greatly assist BluGlass in achieving its technical and commercial milestones."

www.bluglass.com.au

NGK's GaN wafers nearly double green LED efficiency

Japan's NGK Insulators Ltd has developed gallium nitride wafers that greatly reduce defects and roughly double luminous efficiency of green LEDs over previous models.

The GaN wafers have low defect density across the entire 2" diameter of the surface, as well as a colorless transparency. NGK says it achieved this through proprietary improvements to liquid phase epitaxy (LPE) technology for single-crystal growth.

In joint research with Nagoya University, green LED chips formed on NGK's GaN wafers showed internal quantum efficiency of 60% (for an injection current density of about 200A/cm²). This is roughly double that of green LED chips currently on the market, it is reckoned. The results were jointly announced at October's International Workshop on Nitride Semiconductors 2012 (IWN 2012) in Sapporo, Japan.

In previous LED chips using sapphire substrates, defects in the light-emission layer have been common, especially for green LEDs. These limited operating current, which in turn prevented the LEDs from achieving sufficient brightness.

NGK says that this issue can be addressed by using its low-defect GaN wafers as substrates, enabling



LED chip under test — facet size, 0.3mm x 0.3mm; injection current, 200mA; central wavelength, 525nm.

dramatically improved quality of the light-emission layer. The resulting reduction in current loss allows a higher current, making high-brightness green LEDs a reality. When these are used to make up green LED light sources, the result is a more than 20-fold improvement in brightness compared with previous models, says NGK. Light sources can also be made more compact due to the simplified heat dissipation structure (since less heat is generated from current loss). This control of heat-related degradation also enables longer product life, the firm adds.

The realization of high-brightness (HB) green LED light sources means

that HB-LED light sources are now available for all three primary colors of light (red, green and blue). "We can thus expect to see advancements in the development of new applications for LEDs, specifically for use in projectors and other imaging applications," says NGK.

This emerging potential for green LED applications follows NGK's announcement in April of applications for blue LEDs. NGK is now poised to also apply its technology to inverters used in hybrid and electric vehicles, power amplifiers for wireless communications base-stations, and other power devices. NGK hence aims to take steps to further reduce defect density in its GaN wafers, and to produce larger wafers (greater than 6" in diameter).

Sample shipments of 2"-diameter wafers are already underway, with 4" wafers set to follow before the end of 2012. Monthly production capacity is planned to increase from the current level of 200 wafers (2" wafer) to more than 1000 wafers during fiscal 2012. By 2014, NGK aims to have a wide-ranging line-up of wafers, extending from 2–6" diameter, ready for LED and power device applications.

www.ngk.co.jp

Soraa lamps selected for IES product progress report

Soraa Inc of Fremont, CA, USA, which develops solid-state lighting technology built on 'GaN on GaN' (gallium nitride on gallium nitride) substrates, says that its MR16 Vivid and Outdoor LED lamps have been recognized by the Illuminating Engineering Society (IES) Progress Committee as providing important advancements in the science of light. The products are part of the 2012 IES Progress Report, which presents significant improvements in the lighting industry in the past year.

An alternative to halogen 50W MR16 lamps, the Vivid LED MR16 lamps feature full-spectrum light; a color rendering index (CRI) of 95

and R9 of 95 (higher than most halogen lamps); produce no UV or IR; last up to 10 times as long; use 75% less energy; run cooler; produce a much more consistent and efficient beam; and are compatible with existing lamp fixtures and lighting infrastructure, says the firm. The Vivid lamp is designed for demanding display applications in museums, galleries, designer retail, and premier hotels and resorts.

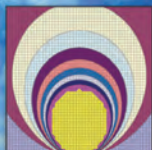
Outdoor LED MR16 lamps are designed and tested to operate in difficult environments. Suitable for use in outdoor fixtures, or indoors in enclosed recessed or small non-ventilated track fixtures, the Outdoor

lamp is intended for diverse applications where lamp reliability and quality of light are as important as saving energy. Designed to replace standard 40W MR16 halogen lamps, the lamp meets and exceeds the performance of halogen lamps, while saving 75% of the energy.

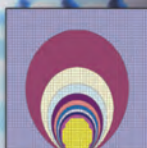
The Progress Report submittals (consisting of new products, applications, research, design tools, and publications) are reviewed by the IES Progress Committee of lighting industry professionals (responsible for monitoring developments in the art and science of lighting worldwide).

www.ies.org

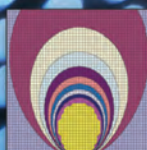
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Bridgelux ranks on Deloitte's Technology Fast 500 list

Bridgelux Inc of Livermore, CA, USA has ranked 128th on Deloitte's Technology Fast 500 (conducted by Deloitte & Touche LLP), a ranking of the 500 fastest-growing technology, media, telecoms, life sciences and clean-tech firms in North America. Technology Fast 500 award winners are selected based on percentage fiscal year revenue growth from 2007 to 2011. Bridgelux grew 876%. In 2011, Bridgelux ranked 135th on the list.

After originally focusing on designing and making its power LED chips — based on ITO/InGaN (indium tin oxide/indium gallium nitride) on 4" sapphire substrates

— Bridgelux launched its first LED array product line in January 2009, followed 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.

In October 2011, Bridgelux raised \$15m in financing, specifically to accelerate research, development, and scaling of its GaN-on-Si LED chip technologies (targeted for commercialization in 2013), driving a transition from 4" sapphire to 8" silicon substrates. Also, this May

development partner Toshiba made an equity investment in Bridgelux.

"Bridgelux has focused on developing light source technologies that simultaneously increase design flexibility for our customers and drive down the cost of light to enable rapid market adoption," says CEO Bill Watkins. "In addition, we have established strong strategic relationships both in manufacturing and technology development, leveraging our core competencies to drive rapid revenue growth and new market penetration. I appreciate the tremendous support of our strategic partners."

www.bridgelux.com

Bridgelux and EBV Elektronik sign distribution agreement

Bridgelux says that Avnet company EBV Elektronik has become a distributor for its products in Europe, the Middle East and Africa (EMEA). The agreement relates to Bridgelux's full line of LED chips, as well as LED packaged products consisting of array and emitter products like the new Micro SM4.

"Together, Bridgelux and EBV will benefit our customers by providing the infrastructure and resources required to help them bring to market the right products at the right time and at the right cost," says Bridgelux's chief sales & marketing officer Jim Miller.

"EBV's team of Illumineers (LED application engineers) will use their LightLab capabilities to assist our customers in their product design process from product definition through final design verification. With the availability of this tremendous technical resource, in combination with Bridgelux's own applications support capabilities, Bridgelux and EBV customers will be supported by a very knowledgeable team. We believe this will help speed the design and delivery of innovative products to a global market that is demanding LED lighting," he adds.

"Our customers will leverage Bridgelux's technology to replace traditional lamp and luminaire technologies with solid state products for the fast growing interior and exterior application areas such as street lights, track and downlights," says EBV Elektronik's president & CEO Slobodan Puljarevic. "Also, very important for EBV is the fact that Bridgelux's products support global clean energy initiatives by reducing energy consumption and offering environmentally friendly solutions for general lighting applications."

www.ebv.com

Bridgelux ranks 17th on San Francisco Times' 100 Fastest Growing Private Companies list

Bridgelux has been named in the annual San Francisco Business Times list of the 100 Fastest Growing Private Companies in the Bay Area. Ranked 17 on the list, Bridgelux was selected because of its rapid growth since it was founded in 2002. The list recognizes private companies, and their entrepreneurs, from a broad range of market segments that share a common willingness to take risks and

embrace innovation.

"We continue to invest in the advancement of solid-state lighting with our breakthrough in GaN-on-silicon technology, while we continue to deliver the industry's most comprehensive range of GaN-on-sapphire array solutions," says Bridgelux's CEO Bill Watkins.

Additional recent award wins from Bridgelux include being named to the 2012 Global Cleantech 100 list,

which highlights companies in the market that are most likely to make a significant market impact over the next 5–10 years. Bridgelux was also included for the second consecutive year on the Inc. 5000 list (Inc. Magazine's sixth annual ranking of the fastest-growing private companies in America).

www.bizjournals.com/sanfrancisco/blog/2012/10/fastest-growing-bay-area-companies.html



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Osram launches Displix multi-chip LEDs for high-contrast displays in extreme outdoor conditions

Osram Opto Semiconductors GmbH of Regensburg, Germany has launched the Displix black and Displix blackprint multi-chip LEDs, for which large-format outdoor displays (e.g. at rock concerts, at sporting events or for perimeter advertising) are the key target applications. The robust high-contrast high-power LEDs can withstand high humidity levels, wide fluctuations in temperature, and even torrential rain, says the firm.

Displix black has a black package with a black reflector and Displix blackprint has a white package with black overprinting and a white reflector. Displix black offers high contrast even in direct sunlight as well as precise color rendering even after a long operating time, claims the firm. Typical light intensity at the Illuminant D65 white point (at a color temperature of 6504K) is 1450 millicandela (mcd) at an operating current of 20mA, which appears very bright in the black package. Under the same operating conditions, Displix blackprint is even more intense, at 2950mcd, with good contrast.



Osram's high-power Displix black/blackprint SMT LED.

The 4.5mm x 4.5mm x 2.1mm package for both Displix versions contains three chips with typical wavelengths of 625nm (red), 528nm (green) and 470nm (blue). So, individual LEDs do not have to be combined into an RGB cluster. This reduces the pixel spacing and improves resolution for the same area.

"People are more and more used to seeing HD images in their homes and on HD-compatible devices, so the requirements placed on outdoor displays are changing," says Sven Weber, marketing manager for LED Displays at Osram Opto.

"The two new Displix versions enable long-life displays with high resolution, high intensity and excellent contrast to be produced for a wide variety of applications."

Due to surface-mount technology (SMT), the LEDs can be processed at reduced cost.

With a height of just 2.1mm there is enough space for further standard processes (such as silicon encapsulation) for added protection against harsh outdoor conditions. Special shading elements can also be easily fitted. Both measures extend the life of the LED, which may be more than 100,000 hours, depending on the ambient temperature.

At the same time, they provide the basis for long-term stability, as evidenced by approval of the components for various harsh ambient conditions such as specialty corrosive gases, aging in direct sunlight and resistance to heavy rain.

The Displix LEDs could be seen for the first time at the electronica 2012 trade show in Munich, Germany (13–16 November).

www.osram-os.com

Everlight LED lighting components complete LM80 testing

Everlight Electronics Co Ltd (Taiwan's largest LED assembly manufacturer) has introduced several low-, mid- and high-power LED lighting components that adopted the LM80 test.

Standardization has become a key factor in LED adoption in the global lighting market — not only in safety standards and performance standards but also, more importantly, in reliability and lifetime testing, says Everlight. LM80 is the lighting standard for lumen maintenance testing with which all major LED makers are now complying. All lighting-class LEDs are required to pass a standardized test method of at least 6000 hours and at certain controlled conditions. So, each LED



Everlight lighting components

that is tested — regardless of manufacturer — can be judged against other tested LEDs on an equal basis and hence compared.

Everlight says that, as it is one of the world's largest LED makers (and lighting is its main focus), all existing Everlight lighting LEDs will be fully tested by 2013. So far, five of the more popular LED products have already completed LM80 testing. These range from low-power (PLCC 3528 and 3020) to mid-

power (PLCC 5630) to high-power (Ceramic 3535 and 3045) series, giving users a thorough lumen-maintenance reference for each category of LED.

These LEDs have been tested to a full 6000 hours and three LED case temperatures by a fully accredited NVLAP laboratory. Official test reports are available upon request and will soon be posted to Everlight's website.

www.everlight.com

Best Buy debuts Insignia light bulb using Cree LEDs

Consumer electronics retailer Best Buy Co Inc has announced a new light bulb powered by LEDs made by Cree Inc of Durham, NC, USA.

The new bulb is designed with improved features to make the adoption of LED lighting easier for consumers. Available exclusively at Best Buy, the Insignia LED bulb was developed in partnership with local Twin Cities inventor Dave Carroll.

Unlike other LED bulbs on the market, it is claimed, the Insignia looks like a traditional incandescent bulb and provides a more ambient, omnidirectional light. Also, the bulb provides immediate full brightness when turned on, unlike compact fluorescent lamp (CFL) bulbs on the market, which require a 'warm-up' period. Mercury- and gas-free, the Insignia avoids CFL toxic hazards and disposal hassles.

"It was important to me to create a LED bulb that would solve some of the current pain points for consumers," says Carroll.

"Consumers have traditionally resisted other high-efficiency light bulbs due to their unattractive shapes, strange lighting and high costs. Teaming with my Insignia partners at Best Buy and the lighting experts at Cree enabled me to bring a better-quality bulb to market at a more affordable price," he adds.



Best Buy's Insignia bulb, incorporating Cree LEDs

"Customers will appreciate its quality and features, while earning back in energy savings the cost of the bulb within one to two years, depending on usage," reckons Richard Rommel, senior VP of exclusive brands for Best Buy.

The bulb has completed comprehensive Cree TEMPO (Thermal, Electrical, Mechanical, Photometric and Optical) analysis, a rigorous eligibility requirement for all products carrying the Cree ingredient brand. In addition, it was designed in accordance with ENERGY STAR requirements and is currently undergoing testing to obtain certification. The bulb comes with a 10-year warranty.

The Insignia LED bulbs are priced at: \$13.99 (450 lumens, 40W-equivalent) and \$16.99 (800 lumens, 60W-equivalent).

The bulb uses 75% less energy than incandescent bulbs. Based on the 800 lumen (60W-equivalent) bulb: the energy used is 13W; the light appearance measures 3000K on a warm-to-cool light spectrum; and the estimated annual energy cost is \$1.57 (based on 3 hours use per day, 11 cents/kWh, and cost depending on rates and use). The bulb is designed for a product life of 22.8 years (based on 3 hours use per day).

www.bestbuy.com

www.cree.com



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Brolis opening MBE and laser diode manufacturing facility in December

Brolis Semiconductors Ltd of Vilnius, Lithuania is opening its new facility on 5 December. Established by brothers Augustinas Vizbaras, Kristijonas Vizbaras and Dominykas Vizbaras in 2011, the firm specializes in mid-infrared type-I GaSb laser diodes for wavelengths of 1800–4000nm and offers high-throughput molecular beam epitaxy (MBE) services, manufacturing epitaxial wafers for antimonide and arsenide materials on GaSb, InSb, InAs, GaAs and InP substrates for thermal imaging focal plane arrays (FPAs), concentrated photovoltaics (CPV) and custom devices for the industrial, defense and scientific markets.

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Brolis Semiconductors' new MBE and laser diode facility.

MBE and optoelectronic device testing and packaging, the facility was completed in less than nine months, accelerated by investments from the venture capital fund LitCapital and European Union structural grants.

"Our goal was to launch the facility as fast as possible, so that we do not lose the momentum, both technological and competitive," says CEO Dominykas Vizbaras. "We are pretty much on schedule with the opening," he adds. "Our second milestone is to deliver first R&D laser diode products by February 2013."

Brolis' first laser products will emit at 2090nm, 2330nm, 2730nm, 3300nm and 3400nm. "Some of these wavelengths will also be high-power products," says chief operating officer Augustinas Vizbaras.

www.brolis-semicon.com

Brolis receives Veeco MBE system ready for new epiwafer facility

Brolis has received a GEN200 Edge MBE production system from Veeco Instruments Inc of Plainview, NY, USA. The system will be installed at Brolis' new epitaxial wafer production facility, which is opening on 5 December.

"The mission of our company is to become a world-leading provider of complex epitaxial structures for long-wave optoelectronics, such as thermal imaging, concentrator photovoltaic and other custom devices," says Brolis' CEO

Dominykas Vizbaras. "Veeco is the world's leading provider of production MBE systems, so we anticipate that the GEN200 will enable us to be extremely competitive in terms of wafer quality, speed to market, and cost effectiveness of our products," he adds.

"Brolis has chosen Veeco as their MBE equipment supplier as they open their new state-of-the-art epitaxial manufacturing fab," a Jim Northup, VP & general manager of Veeco's MBE Operations.

"The GEN200 will support Brolis' market penetration goals with its production-proven performance and the industry's lowest cost of ownership."

Veeco reckons that the GEN200 Edge system is the most cost-effective and highest-capacity multi-4" production MBE system on the market, and delivers superior throughput, long campaigns and excellent wafer quality in growing epitaxial wafers for custom devices.

www.veeco.com

Princeton Optronics launches 15W, 650nm red laser array for medical and illumination applications

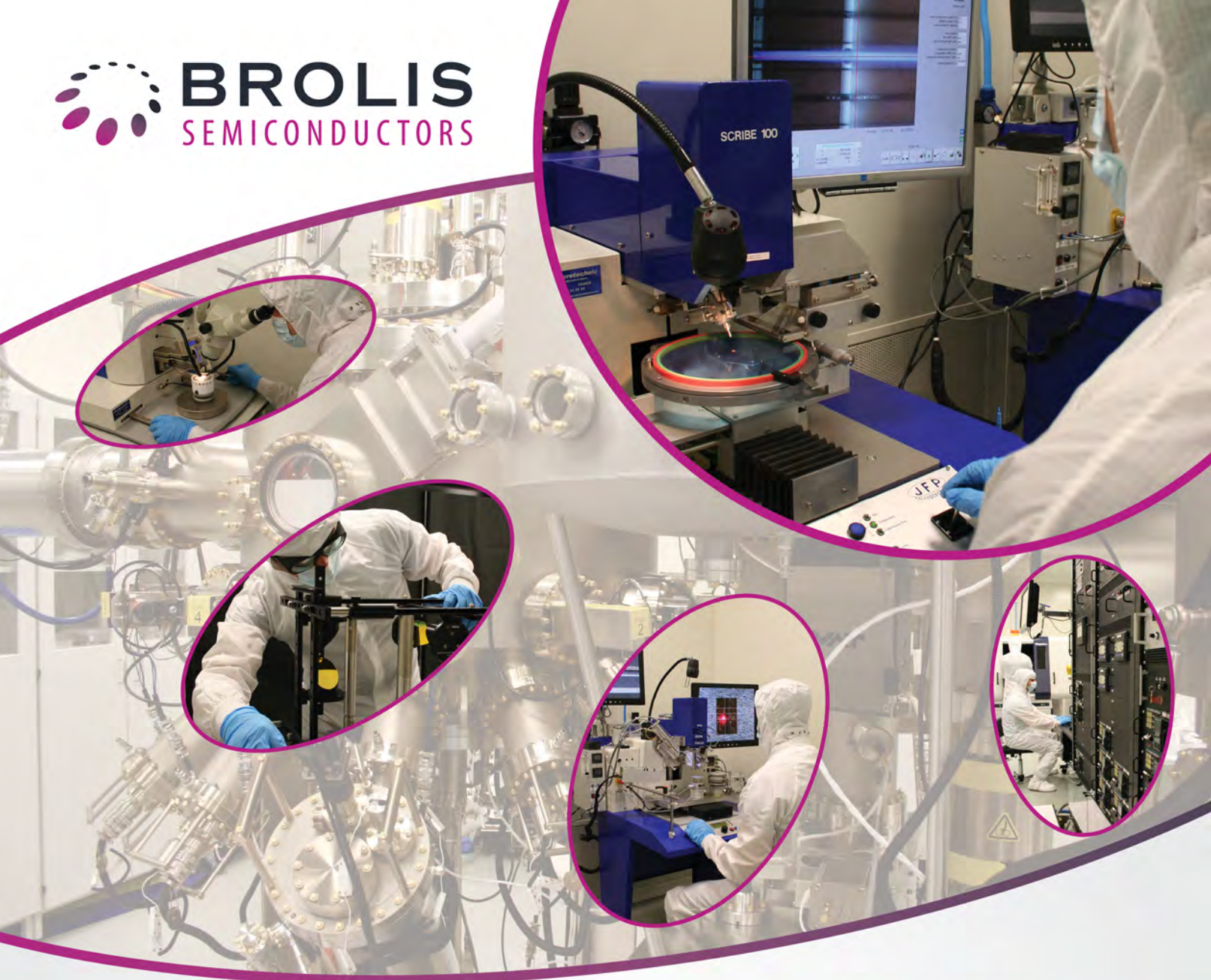
Princeton Optronics Inc of Mercerville, NJ, USA, which manufactures high-power single- and multi-mode vertical-cavity surface-emitting lasers (VCSELs) and VCSEL arrays, has announced the availability of 15W red laser devices and arrays emitting at a wavelength of 650nm for medical and illumination applications.

The lasers have an efficiency of >20%, a spectral width of about 1nm and a circular beam with divergence of 18° (full angle). The array has a size of 3mm x 3mm and is mounted on submounts.

Princeton Optronics says it can deliver such arrays in high volume through its high-volume manufac-

turing operation. In addition, it can deliver single devices and lower-power versions, as well as addressable arrays at red and other wavelengths. The firm is also able to make custom devices and arrays of other configurations and other wavelengths in red.

www.princetonoptronics.com



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CSTG/Glasgow mid-IR laser project makes finals of KTP Best Partnership Award

Finalists for the Knowledge Transfer Partnership (KTP) Best Partnership Award (announced in London on 22 November) included a laser engineering research partnership involving Compound Semiconductor Technologies Global Ltd (CSTG) of Hamilton Technology Park, High Blantyre (near Glasgow), Scotland, the University of Glasgow and KTP associate Thomas Slight. The Glasgow-based work has resulted in advances in semiconductor laser engineering, contributing to driving 40% revenue growth in the business between 2010 and 2012 and yielding research publications and recognition for both the university and company. This latest new announcement follows the project recently winning the KTP Scottish Regional Best Partnership Award.

Knowledge Transfer Partnerships aim to help UK businesses to improve their competitiveness, productivity and performance by accessing the knowledge, technology and skills available within its Knowledge Base (universities, colleges and research organizations) through the development of collaborative partnerships that stimulate innovation. Each partnership is part-funded by the UK Government, with the balance of costs coming from the company partner.

CSTG supplies semiconductor devices to the defence, oil and gas, telecoms and medical industries, serving clients in the UK as well as in the USA and Asia. In excess of 70% of revenue is derived from high-value export products. However, says the firm, continued expansion of the business depended on being able to offer higher-value-added laser device technology and manufacturing processes.

CSTG says that it was aware of the commercial potential for emerging mid-infrared laser technology, but had very limited knowledge of elements of the relevant design and optical characterization. Nor were there any commercially available modelling packages or turn-key equipment to address this gap in the firm's capabilities. Thomas Slight was hence instrumental in initiating the partnership with the university's department of Electronics and Electrical Engineering, represented by Charles Ironside (professor of Quantum Electronics).

The firm says that success has been embodied by new fabrication processes and novel laser chip designs, addressing the market need for innovative semiconductor processes for the manufacture of compact, mid-infrared micro-chip laser sources.

The technology can be applied to a number of topical sectors, including counter-terrorism, homeland security, environmental monitoring and low-environmental-impact oil and gas prospecting.

It is claimed that both CSTG and the university have developed a global reputation in this technology area in a relatively short time-scale and are seeing economic benefits that are spreading to other UK academic institutions and commercial partners.

Following on from the KTP, the university has established a global relationship with the laser supply chain and application specialists and has won funding from ERANET, Wellcome Trust and the European Space Agency (ESA).

"This project clearly demonstrates that the UK has the expertise to lead laser engineering research," comments Iain Gray, chief executive of the Technology Strategy Board (the UK Government's innovation agency), which funded the project. "Semiconductor business applications can be complex to market, but this research shows it can be done on a global scale with great success."

www.compoundsemi.co.uk

www.ktponline.org.uk

www.innovateuk.org

DILAS launches fiber-coupled diode laser system delivering up to 1kW

Diode laser maker DILAS of Mainz, Germany has launched the SF1000/400 next-generation fiber-coupled system, which can deliver up to 1kW of output power from a 400µm fiber at a single wavelength of 976nm, and has been developed to suit the needs of volume production in industrial applications.

The fiber-coupled system is based on macro-channel cooled diode laser bars featuring a compact footprint

and convenient aiming beam. With a beam parameter product of 44mm-mrad, the system delivers 1kW through a cladding-mode-free QBH high-power 400µm-core-diameter fiber with a numerical aperture (NA) of 0.22, or an optional 800µm-core-diameter 0.12NA fiber. The laser is also available with a Q5 (LLK-B) industrial fiber connector.

The turnkey system comes with a water-air-chiller, diode laser power

supply, and control unit providing external interfaces, chassis and metal-armored fiber. A user-friendly interface enables ease of integration of material processing workstations, says the firm.

The system suits material processing applications such as soldering, heat treatment and thin metal welding as well as scientific research such as fiber-laser pumping.

www.DILAS.com



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Advanced Photonix's quarterly sales fall 10%

Fiscal H2/2013 forecast cut from 35% to 15–25% up on fiscal H1

For fiscal second-quarter 2013 (to end-September 2012), Advanced Photonix Inc of Ann Arbor, MI, USA (which designs and makes silicon, InP- and GaAs-based APD, PIN, and FILTRODE photodetectors, HSOR high-speed optical receivers, and T-Ray terahertz instrumentation) has reported sales of \$5.6m, down 33% on \$8.1m a year ago and down 10% on \$6.2m last quarter.

Gross margin has fallen further, from 42.7% a year ago and 36.1% last quarter to 35.3%. Price pressures in the high-speed optical receiver (HSOR) product line prior to cost-reduction efforts and lower volumes affected the rate and gross margin dollars, says the firm.

Although cut from on \$3.9m a year ago (47% of revenue) and level with \$3.2m last quarter (52% of revenue), operating expenses of

\$3.2m comprised as much as 58% of revenue this quarter.

Compared to +\$469,000 a year ago, adjusted EBITDA (earnings before interest, taxes, depreciation, amortization and stock compensation) has worsened from negative \$456,000 to negative \$717,000.

"As with the other telecommunications suppliers, we have seen weakness in network spending recently. This has caused us to be more cautious in our total year outlook," says CEO Richard Kurtz.

"Our recent success in securing increased 100G business from one of our large OEM's for calendar year 2013 is a positive sign amid general softness we have seen from China and Europe due to challenging macro economic conditions," Kurtz adds. "Our terahertz (THz) product platform is continuing to gain trac-

tion in industrial process control markets and we expect this growth to continue during the balance of the fiscal year and beyond."

"However, due to the more challenging international macroeconomic environment, reduced US military activities, and the looming US fiscal cliff and their corresponding impact on our customer's expansion plans in the industrial and defense markets, we are projecting a more cautious outlook for the fiscal year," Kurtz continues.

"Due to these conditions we are changing revenue growth for the second half of our fiscal 2013 to a range of 15–25% higher than the first half [cut from the prior forecast of 35% higher]," he adds. However, "We continue to believe that our fiscal 2013 will have a much better second half."

Advanced Photonix receives \$5.9m telecom 100G commitment

Picometrix LLC of Ann Arbor, MI, USA, a subsidiary of Advanced Photonix Inc (which designs and makes silicon, InP- and GaAs-based APD, PIN, and FILTRODE photodetectors, HSOR high-speed optical receivers, and T-Ray terahertz instrumentation), has secured a \$5.9m commitment for calendar year 2013 for its 100Gb/s and 40Gb/s high-speed optical receivers from a "leading telecoms network equipment customer".

The annual commitment is estimated at more than \$5.2m for the firm's 100G family of coherent receivers for DP-QPSK (dual-polarization quadrature phase-shift keying) modulation and \$760,000 for its 40G receivers for DPSK (differential phase-shift keying) modulation, both of which are used in long-haul dense wavelength division multiplexing (DWDM) systems. Shipments are expected to begin in the firm's fiscal fourth-quarter 2013.

The CR-100A 100G optical receiver uses the firm's patented photodiode arrays, an optical photonic integrated circuit (PIC), and high-speed linear amplifiers. The product comes in the industry-standard CCRx multi-source agreement (MSA) form factor, is consistent with OIF (the Optical Internet-working Forum), and supports data rates up to 128Gb/s. Picometrix claims that it offers the industry's most complete line of 100G and 40G HSOR solutions for both client-side and line-side equipment.

This agreement demonstrates that 100G coherent network deployment is in the early growth stage as service providers continue to selectively spend on capacity expansion

"We are pleased to have received a substantial increase in commitment for 2013 from our lead customer," says API's chief operating officer Robin Risser. "This further validates our success in developing optical receivers that support our network equipment customers' deployment of next-generation optical networks to global telecom service providers," he adds. "This agreement demonstrates that 100G coherent network deployment is in the early growth stage as service providers continue to selectively spend on capacity expansion, despite a weak macroeconomic environment, to accommodate traffic growth driven by video, mobile video, the proliferation of network-attached devices, and social networking applications that are enabling consumers to access bandwidth-intensive content anytime and anywhere over fixed and wireless networks."

www.advancedphotonix.com

Kotura ranked 131st fastest-growing company in North America on Deloitte's 2012 Technology Fast 500

Kotura Inc of Monterey Park, CA, USA, which designs and makes silicon photonics application-specific integrated circuits (ASICs) for the communications, computing, sensing and detection markets, has been ranked 131st on Deloitte's Technology Fast 500 ranking of the 500 fastest-growing technology, media, telecoms, life sciences, and clean technology companies in North America. Award winners were selected based on percentage fiscal year revenue growth from 2007 to 2011. During that period, Kotura revenue increased by 848%.

Kotura says that it focuses on advancing communications through the application of silicon photonics to create faster, limitless access to digital information. The firm's recently introduced Optical Engine provides an inexpensive, small form factor that reduces power consumption to deliver fast, high-speed communications. Photonic integrated chips from Kotura address the bandwidth and performance needs of cloud computing, virtualization, and high-performance computing among other data-intensive applications.

"The silicon photonics market continues to grow at a very rapid pace," notes president & CEO Jean-Louis Malinge. "Our expertise in applying silicon photonics to the telecommunications industry has expanded to additional markets like data centers and high-performance computing that have new requirements for high-speed, low-power data transfer," he adds.

"These ground-breaking companies have outpaced their competition and are reinventing the way we do business," says Eric Openshaw, vice chairman, Deloitte LLP and US technology, media and telecommunications (TMT) leader.

"Companies on the Fast 500 list are among those that have demonstrated remarkable innovation, creativity and business savvy," says

Bill Ribaud partner, Deloitte & Touche and national TMT leader for audit and enterprise risk services (AERS). "As a result, these companies have continued to successfully forge ahead in a challenging economic environment. We applaud the leadership and employees of Kotura for

this impressive accomplishment."

Overall, 2012 Technology Fast 500 companies achieved revenue growth ranging from 128% to 279,684% from 2007 to 2011, with an average growth of 2774%.

www.fast500.com

www.kotura.com



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Oclaro's quarterly earnings slip further into red

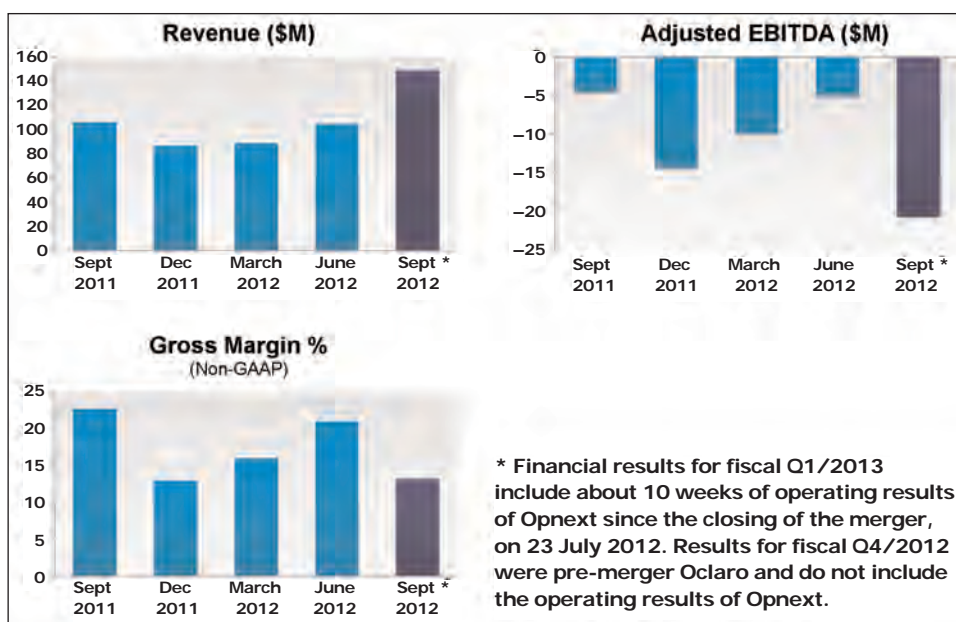
Opnext acquisition and soft market hurting; earnings to stay negative

Optical components, modules and subsystems developer Oclaro of San Jose, CA, USA has reported financial results for its fiscal first-quarter 2013 (ended 29 September 2012), including about ten weeks of operating results of Opnext Inc of Fremont, CA (acquired for \$177m on 23 July). Oclaro's results for fiscal Q4/2012 were pre-merger Oclaro and did not include the operating results of Opnext.

Revenue was \$148.8m for Q1/2013, compared to \$104.4m in Q4/2012, and below the \$154–168m guidance (issued on 31 July). Pro forma combined revenue, including Opnext's business for the full quarter, was \$160.2m. On a non-GAAP basis, gross margin was 13%, compared with 21% in Q4/2012. Operating loss was \$29.4m, up from \$9.9m.

Despite the quarter-on-quarter revenue growth, Oclaro's adjusted EBITDA (earnings before interest, taxes, depreciation and amortization) was –\$20.6m, compared with –\$5m last quarter. Excluding a 'gain on bargain' purchase of \$39.5m related to the Opnext acquisition, net loss was \$31.1m, compared with \$10.5m last quarter, which excluded an \$11.7m gain on the sale of assets and \$3.4m of net flood-related income from insurance advances (net of additional write-offs and expenses) due to October 2011's flooding at Thailand-based primary contract manufacturer Fabrinet Co Ltd.

During the quarter, cash, equivalents and restricted cash rose from \$62.4m to \$94.4m. Subsequently, on 2 November, Oclaro closed an extension of its line of credit with Wells Fargo Capital Finance, which also raised the line to \$50m with a \$50m 'accordion provision' to allow the potential for additional banks to participate as syndication partners in the future. The credit has a five-year term and the firm expects in excess of \$10m additional short-term availability on top of the \$37m outstanding (as of 29 September).



"While our financial results for the fiscal first-quarter 2013 were disappointing, our integration is on track," said chairman & CEO Alain Couder. "As the new Oclaro, we were immersed in integration activities, and therefore did not fully contemplate all potential execution risks in our forecast. With the difficult market conditions facing the industry, we focused on short-term synergies and expense reduction, which will reduce our combined expenses by \$9m per quarter in the December 2012 quarter compared to pre-merger levels," he added.

"In the meantime, our new organization is firmly in place and we are fully operating as the new Oclaro. With the continuing soft telecom market, our focus is to execute on synergies that are expected to improve margins over the next few quarters," continued Couder. "In addition, we are also focused on ramping new products, including 100G, that we expect will position Oclaro well for a positive turn of the telecoms market."

For its fiscal Q2/2013 (ending 29 December), Oclaro expects revenue of \$145–162m; gross margin of 12–18%; and adjusted EBITDA of between –\$20m and –\$9m.

"Most integration actions are now behind us," said Couder about the OpNext acquisition. "Our transfers are also on track with Shenzhen moving to Venture in Malaysia and our Japan facility moving to Sagami-hara, which is an earthquake-proof building.

"The primary focus has been to execute new product introduction with the combined company, completing our integration and plant synergy to strongly position us for the telecom business rebound. So, as a result of this we expect to reach \$9m in quarterly cost saving in the December quarter [fiscal Q2/2013]. This could mean a bottom-line improvement of five points."

Considering the situation of both Oclaro's markets and customers, Couder added, "The telecom market right now is slow: North America is kind of flat; Europe is weak and China is slowing down; Japan is also slow and therefore there is lower demand for our products right now. It's also causing a delay in recovering from the loss of business caused by the floods earlier this year, because the customers who gave the business to our competition during the flood don't have a need for a new supplier right now," he noted.

► “Customer feedback on the merger continues to be extremely positive. We are now considered as a preferred partner. We expect that this is going to increase a number of design wins and we believe that we are well positioned to regain the market share that we lost,” Couder commented.

“The new product pipeline of the new Oclaro post-merger is very robust and we expect those new products to have a positive impact on revenue as we run production. We expect 100G to be a speed that is going to be there for a long time and very important to the future of optical technology in the telecommunication market.

“The old Oclaro had mostly the line side, but not the client side, [so] the combination of the two companies now makes ours a full offering. We are already shipping the 100G coherent transponder, we have samplings of 4x28 tunable CFP transceivers, we are sampling also a 4x28 fixed-wavelength CFP transceiver, we are working on

short-distance VCSEL-based products, we are delivering components to customers who are building 100G solutions themselves. We are delivering initial samples of a line laser that provides a more effective solution and a more reliable solution than the current external-cavity laser that our competition offers right now,” Couder claimed.

Chief financial officer Jerry Turin added, “Gross margin was 13%, compared to the guidance range of 17–21%. The shortfall was primarily due to lost contribution dollars from lower revenues; however, we also had unabsorbed overhead from running lower volumes through our fabs.

“We continue to expect in excess of \$45m in annualized synergies [from the Opnext acquisition] and we are targeting to achieve them within the next 12 months... Certain of these synergies, in particular vertical integration of components into modules and subsystem product, will continue to deliver incremental benefit over a longer period of time. We expect to exit the cur-

rent December 2012 quarter with our breakeven EBITDA level at \$175m of revenues,” Turin added.

He continued, “We have also filed Oclaro formal insurance claims associated with the Thailand flood in amounts totaling \$35m. We expect to file incremental claims beyond this amount in calendar 2013, so at this time do not expect those additional claims to be material relative to the \$35m levels. We have previously received \$11m in advances on these claims, so we now have an additional \$24m in play.”

Turin concluded, “Our next-quarter guidance reflects soft December 2012 expectations discussed by many of our peers and in many parallel technology spaces. This guidance reflects softer market conditions for December than we expected approximately four weeks ago when we announced our preliminary revenues for the September quarter and the expectation of revenue growth in December.”

www.oclaro.com

Matthew Peach, Contributing Editor

Oclaro selling thin-film filter business and interleaver product line to II-VI's Photop for \$27m as it focuses on core competencies

Oclaro has agreed to sell the assets of its Santa Rosa thin-film filter business to Photop Technologies Inc of FuZhou, China, a subsidiary of II-VI Inc of Saxonburg, PA, USA. Oclaro will also sell its interleaver product line to II-VI subsidiary Photop Koncent Inc (FuZhou). Both transactions are expected to close 3 December.

The thin-film filter business and interleaver product line will both report within II-VI's Photop Technologies Inc business unit (and hence included in the firm's Near-Infrared Optics operating segment for financial reporting purposes). Established in 2003 and acquired by II-VI in December 2009, Photop makes crystal materials, optics, microchip lasers and opto-electronic modules for use in optical communication networks and other diverse consumer and com-

mercial applications.

Total consideration to Oclaro will be in the form of cash proceeds of \$27m (\$23m to be paid upon closing, \$3m payable on or before 28 December, and \$1m to be held in escrow until 31 December 2013).

“Divesting our thin film filter business and the interleaver product line is consistent with our strategy to focus our resources on our core competencies,” says Oclaro's chairman & CEO Alain Couder.

“The proceeds from these deals improve our balance sheet and give us additional operating flexibility to serve our global customer base,” he adds. “The agreements also strengthen our existing relationships with II-VI and Photop, and will ensure customers in the telecom, life-sciences and industrial markets continued access to these products as part of an even

broader portfolio.”

“This acquisition will enhance Photop's core business while expanding their global footprint and diversification into the growing life-sciences market,” comments II-VI's president & CEO Francis J. Kramer.

Divesting the product lines is expected to reduce Oclaro's revenue for its fiscal second-quarter 2013 (ending 29 December 2012) by about \$2m compared to the guidance issued on 5 November. Revenues for these product lines in the full fiscal Q1/2013 were \$3.6m.

For both the December quarter and its fiscal year ending 30 June 2013, II-VI does not expect the acquisition to have a material impact on its previously issued guidance for revenue and earnings per share.

www.ii-vi.com/photop-technologies

IN BRIEF

GigOptix ranks on Deloitte's 2012 Technology Fast 500

GigOptix Inc of San Jose, CA, USA (a fabless supplier of analog semiconductor and optical components enabling high-speed end-to-end information streaming over optical fiber and wireless networks) has ranked 125th on Deloitte's Technology Fast 500 (conducted by Deloitte & Touche LLP), a ranking of the 500 fastest growing technology, media, telecoms, life sciences and clean technology companies in North America. Technology Fast 500 award winners are selected based on percentage fiscal year revenue growth from 2007 to 2011. GigOptix grew 916% during the period.

"Upon inception in 2007, we created a business strategy based upon three pillars: 1. Innovation; 2. Execution; and 3. Financial Growth Engine," says GigOptix's chairman & CEO Dr Avi Katz. "These core ideals still hold true and strong today and have helped us become the leader in 100G semiconductor and optical components that enable high-speed information streaming," he adds.

"The companies on the Fast 500 list are among those that have demonstrated remarkable innovation, creativity and business savvy," says Bill Ribauda partner, Deloitte & Touche LLP and national TMT leader for audit and enterprise risk services (AERS). "As a result, these companies have continued to successfully forge ahead in a challenging economic environment. We applaud the leadership and employees of GigOptix for this impressive accomplishment."

GigOptix previously ranked 95th as a Technology Fast 500 award winner for 2011.

www.gigoptix.com

GigOptix reports quarterly revenue up 5% to record \$10.1m 100G and optical interconnects lead growth

For third-quarter 2012, GigOptix has reported a 12th consecutive quarter of sequential growth in product revenue, to a record \$10.1m. This is up 5% on \$9.6m last quarter and up 20% on \$8.4m a year ago.

On a non-GAAP basis (excluding \$253,000 in amortization of intangible assets, \$1.2m in stock-based compensation and \$576,000 in special litigation-related expenses), gross margin was 54%, level with last quarter but down on 60% a year ago. However, net income was \$563,000, compared with \$385,000 last quarter and a net loss of \$712,000 a year ago. Adjusted EBITDA (earnings before interest, taxes, depreciation and amortization) has risen from \$289,000 a year ago and \$1.2m last quarter to \$1.3m. However, during the quarter, cash and cash equivalents fell further, from \$12.9m to \$12.3m.

"The strong third quarter financial results, which included record quarterly revenue, continuing improvement in non-GAAP earnings and adjusted EBITDA, and most importantly generating positive cashflow from operations,

reflect our continued growth in several key areas of our business," says chairman & CEO Dr Avi Katz. "Leading the sequential gains was the ongoing growth in our optics product line, particularly with our high-speed 100Gbps and optical interconnect offerings," he adds. "We also experienced a nice uptick in our RF/MMIC business over the prior quarter due to an increase in market interest for our recently introduced E-band offering."

"While we are very satisfied with our market penetration and customer's adoption of new products, there is a higher level of uncertainty in the macroeconomic environment, increasing lack of visibility, and exceptionally short lead-times, mainly in the high-speed optical communications markets, than what we have seen in previous quarters," says senior VP & chief financial officer Curt Sacks. "Therefore, we currently believe our revenue in the fourth quarter will be roughly in-line with the third quarter, as there are enough data-points in the market that require us to be cautious with our near-term outlook," he adds.

Update on litigation against M/A-Com Tech

GigOptix says that it continues to actively prosecute the lawsuit for misappropriation of confidential information and trade secrets against its former employees, Optomai Inc (a fabless semiconductor firm that develops ICs and modules for 40Gbps and 100Gbps fiber-optic networks), and parent firm M/A-COM Technology Solutions Inc of Lowell, MA, USA (which makes semiconductors, components, and subassemblies for RF, microwave and millimeter-wave applications). GigOptix says it has been engaged in discovery (including forensic work), which

has produced evidence that the individuals copied GigOptix files when they left and then used them to develop products of the corporate defendants. GigOptix is continuing to move the case towards a trial on its claims against the defendants.

"We look forward to putting the evidence regarding the conduct and actions of the defendants before a jury and judge in 'an adjudication of the merits' at trial," says Katz. "A trial date has not been set and we have no estimate as of today when the court will set a trial date," he adds.

Molex QSFP+ active optical cable achieves aggregated data rates up to 56G over 4km

At Super Computing 2012 (SC12) in Salt Lake City (10–16 November), high-speed fiber-optic interconnect firm Molex Inc of Lisle, IL, USA has announced the availability of its QSFP+ low-power 56Gbps Fourteen Data Rate active optical cable (AOC), which delivers what is claimed to be a reliable and less costly solution for aggregated data rates up to 56Gbps over reaches up to 4km.

The QSFP+ 56Gbps AOC integrated cable requires less than 1W per cable, and provides the flexibility of traditional optical modules by interfacing to systems via a standard multiple-source agreement QSFP (quad small-form-factor pluggable) connector.

“As data centers and scalable HPC clusters become larger and more distributed, Molex’s single-mode solution provides customers with a lower-cost alternative that can interconnect at medium-range

distances at a fraction of long-range optics costs,” says product manager Brent Hatfield. “This also provides customers with a clear path to speed upgrades without having to continuously upgrade their structured cabling, and the standard QSFP+ port is an economical, readily available interconnect to support those requirements,” he adds.

Featuring four bi-directional optical data links per end, each operating at data rates from 1.0 to 14.0Gbps, Molex’s Fourteen Data Rate (FDR) AOC cables are compatible with multiple protocols including

The single-mode fiber technology provides a longer reach than copper and multi-mode fiber solutions in data-center and campus environments

InfiniBand FDR, 10Gb Ethernet, SAS 2.0 and 3.0 (6 and 12Gbps), and Fibre Channel (8 and 10Gbps). A low bit-error rate of 10^{-18} errors provides increased data reliability and a robust link compared to standard transceivers with 10^{-15} errors per link. The cables are also available in a low-loss pigtail version, which allows users to install the single-mode fiber separately and connect to the pigtail version to avoid constant high-cost cable upgrades as bandwidth increases.

The 56Gbps AOC cables are available in lengths up to 4km (2.49 miles) for optimal design flexibility. The single-mode fiber technology provides a longer reach than copper and multi-mode fiber solutions in data-center and campus environments. The firmware is field flashable via a I2C bus so cables can be reflashed while in the host system.

www.molex.com/link/fdraoc.html

Molex showcases high-performance interconnect technology at SC12

At Super Computing 2012 (SC12) in Salt Lake City (12–15 November), high-speed fiber-optic interconnect firm Molex Inc of Lisle, IL, USA conducted product demonstrations to showcase its expertise in high-speed, high-density and high-signal integrity interconnect technology.

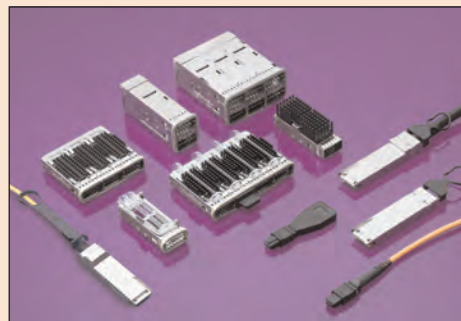
Molex displayed the following high-speed interconnect products and solutions:

- **25Gbps QSFP+ silicon-photonics-based AOCs:**

Molex recently demonstrated a 100Gbps QSFP+ active optical cable (AOC) based on silicon photonics single-chip transceiver technology enabling next-generation 100Gbps optical interconnect applications.

- **Quad small-form-factor pluggable (QSFP+) 40Gbps QDR and 56Gbps AOC assemblies:**

Providing what is claimed to be the longest link distance and lowest



Molex’s high-speed interconnect products on show at SC12.

power consumption on the market, the assemblies achieve 40 and 56Gbps data rates over long reaches of up to 4km (2.49 miles) using only 0.78 and 1W per cable end, respectively.

- **zQSFP+ interconnect solution:** Designed for next-generation high-density applications found in high-performance computing, telecoms, data networking, test & measurement, and medical diag-

nostic equipment.

- **iPass+ (HSC) CXP copper and optical systems:**

Enables 12 channels of 10Gbps data for up to 120Gbps of total bandwidth; with the enhanced-footprint integrated connectors enabling ten channels of 10Gbps data, for up to 100Gbps of total bandwidth.

- **zSFP+ connector solutions:**

Supports 25Gbps applications, with backward compatibility for 10Gbps Ethernet and 16Gbps Fibre Channel applications.

At SC12, Molex demonstrated zQSFP+ stacked thermal management technologies. Wind tunnel testing has been found to offer the most accurate, repeatable test method, says the firm. Data is generated that will support the design of NEBS-rated applications with current- and next-generation pluggable I/O modules.

Firecomms launches fiber-optic transceivers for industrial automation, transportation, medical, power generation, smart grid and home-networking markets

Firecomms Ltd of Cork, Ireland, a manufacturer of fiber-optic solutions and optical transceivers (including its OptoLock technology, licensed worldwide) for consumer plastic optical fiber (POF), has announced an expanded product line that includes DC-capable devices targeted at industrial applications, as well as the first range of LC connectors designed specifically for plastic optical fiber (POF) and hard-clad silica (HCS, also called plastic clad silica, or PCS).

"Our innovative technology enables us to readily answer our customers demand for LC transceivers for POF, and for an additional supplier of DC-capable industrial transmitters and receivers," says VP of sales & marketing Hugh Hennessy.

Responding to demand for a second source for the Versatile Link from Avago Technologies, Firecomms is introducing its RedLink series of DC-capable transmitters and receivers for industrial applications.

Drop-in compatible with the Versatile Link range, the RedLink product line extends Firecomms' capabilities for high-speed POF transceivers and interfaces into the high-reliability industrial requirements of the DC-capable realm. The firm reckons that its entrance into the Industrial transceiver market will provide assurance for customers concerned about continuity of supply.

Initially, the RedLink product line will include DC-1Mb, DC-5Mb, DC-10Mb and DC-50Mb transmitters and receivers. All RedLink products will be rated at the extended industrial temperature range of $-40^{\circ}\text{C} \sim +85^{\circ}\text{C}$.

"The introduction of Firecomms RedLink transmitters and receivers will provide existing users of Versatile Link devices with an additional source for these products, thus expanding the usage of this innovative and versatile product range," reckons Hennessy.

Firecomms also claims to be first to launch LC connectors designed

for use with POF and other large-core glass fibers such as HCS. This follows the release by the IEC of the second edition of standard IEC 61754-20, which broadens the use of LC connectors beyond glass fiber. Known for its compact form factor, the LC connector is widely used in optical networking.

Firecomms will offer several new LC fiber-optic products as cost-effective alternatives to using LC-terminated glass-fiber transceivers in SFP formats. Firecomms' LC 650nm transceivers will be available for 125Mbps, 250Mbps and 1.25Gbps data rates.

All Firecomms transmitters (including RedLink, LC and OptoLock) leverage the firm's resonant-cavity LED (RC-LED) technology to provide long-term reliability in lifetime performance.

Firecomms showcased the new LC and RedLink products at the MEV booth at the Electronica 2012 trade fair in Munich, Germany (13–16 November).

www.firecomms.com

Huawei 'Excellent Supplier Award' for NeoPhotonics

For the second consecutive year, NeoPhotonics Corp of San Jose, CA, USA, a vertically integrated designer and manufacturer of both indium phosphide (InP) and silica-on-silicon photonic integrated circuit (PIC)-based modules and subsystems, has received the Excellent Supplier Award as a Core Partner of China-based Huawei Technologies Co Ltd (one of the world's largest telecom network equipment providers, serving more than 310 carrier customers worldwide).

Huawei held its annual Core Partners Convention near its corporate headquarters in Shenzhen, China, to recognize companies that have

delivered high-performance and high-quality products meeting Huawei's specialized requirements.

In the optical networking sector of more than 30 major suppliers, NeoPhotonics was one of only five firms to receive an award for supplier excellence. NeoPhotonics supplies Huawei with access

We have expanded our technology, quality and manufacturing capabilities to support Huawei's growth

products designed for its Broadband FTTx systems, as well as advanced WDM transport products, such as

integrated coherent receivers and narrow linewidth tunable lasers designed for 40G and 100G coherent transport systems.

"Consistency and continuous improvement are hallmarks of our quality program at NeoPhotonics," says chairman, president & CEO Tim Jenks. "We have collaborated on high-speed and access products for several years, and we have expanded our technology, quality and manufacturing capabilities to support Huawei's growth during this period." Huawei was one of the earliest customers of NeoPhotonics, which has supported Huawei for the last decade.

www.neophotonics.com

IPtronics sues Avago for violating standards and for misuse of trade secrets

IPtronics A/S of Roskilde, Denmark, which designs optical interconnect products for the computer communications market, has filed claims against subsidiaries of Avago Technologies Ltd, asserting that the Singapore-based firm violated commitments made to standards-setting organizations and failed to protect IPtronics' confidential information. The claims were filed as counterclaims in ongoing litigation in the US District Court in San Jose.

IPtronics alleges that Avago ignored legally binding commitments to standards-setting organizations to disclose patented technology and to make that technology available for licensing, and

challenges the firm's conduct of concealing its patents from the standards organizations and then using those patents to stifle competition. Furthermore, IPtronics states that Avago induced IPtronics to disclose its confidential information through a series of misrepresentations and that Avago then failed to protect that information.

The standards in question relate to short-range, 40G and 100G multi-mode VCSEL-based fiber-optic modules used for communications in cloud, Web 2.0, and high-performance computing applications.

IPtronics alleges that Avago's conduct threatens not only IPtronics

but also other manufacturers and distributors of optical interconnect equipment, all of whom were the intended beneficiaries of commitments Avago is now disregarding. IPtronics strongly believes that these illegal actions on behalf of Avago will stifle the innovation needed in this market and adversely affect the entire industry.

Avago recently asked the US International Trade Commission (ITC) to initiate an investigation against IPtronics and two other companies. IPtronics believes these claims are without merit and says it will defend itself in the ITC.

www.iptronics.com

www.avagotech.com

Avago enhances Versatile Link plastic optical fiber product family, integrating digital driver and receiver logic

Avago Technologies has announced the latest product enhancements to its Versatile Link plastic optical fiber (POF) product family. This product platform has become a widely adopted solution for industrial communications and control links for industrial applications.

Avago says that its POF products offer infinite voltage isolation and electromagnetic interference (EMI) immunity performance that far exceeds what can be achieved with traditional copper cable standards. POF cable solutions can weigh up to 75% less than copper cables, while providing similar or greater performance with a 50% tighter bend radius at comparable cost.

"The enhanced Versatile Link POF product family is already an industry-standard for robust industrial communications," says Bernd Luecke, director of marketing for Avago Industrial Fiber Optic Products in Regensburg, Germany. "The enhancements Avago has released now give designers more capability to integrate their designs and achieve lower cost without compro-



mising on performance or circuit isolation," he adds.

Designed for robust industrial networking applications, communication over POF offers benefits versus copper-based implementations. Since optical fiber has no metal in its construction, the communication link has infinite isolation between nodes at the same time and, since light is used to transmit the signals, there are no effects from or creation of EMI on the transmission line.

The firm says that there are additional challenges of copper cables caused by the longer assembly time and labor costs due to the steps needed for cable prep (stripping multiple layers of insulation, tinning the strands, multiple wires to solder and terminate the foil shield).

Testing an assembled copper cable is also slightly more complex than POF, as copper requires tests for continuity, shorts, opens and breakdown voltage.

The new Versatile Link products deliver a durable low-cost solution while providing increased performance and easier design solutions, says Avago. The product family offers system designers integrated digital logic (TTL) interfaces for both transmitter and receivers.

Integrated circuits within the Versatile Link components manage the translation from electrical-optical signals on both ends. The new products are the first Versatile Link parts to offer 3.3V and 5V power supply options.

All the horizontal packaged devices are available now, and the two tilted packaged devices will be available within the next quarter.

The white paper 'Fiber versus Copper Links: Making the Right Chose for Industrial Environments' is available on Avago's website (publication #: AV02-3500EN).

www.avagotech.com/pof

Avago launches family of 10GbE SFP+, 40GbE QSFP+ and 150G CXP active optical cables

Avago Technologies has announced its new active optical cable (AOC) family, high-density SFP+, QSFP+ and CXP solutions for high-performance computing (HPC) and data-center applications. The firm says that the active optical cable assemblies use proprietary technology yielding a lower cost per 10G link than active copper cables. Combined with performance increases, lower weight and easier cable management, they enable high-data-throughput interconnects up to 100m.

Avago's portfolio includes 10GbE SFP+, 40GbE QSFP+ and 150G CXP AOCs, collectively providing an alternative to copper cable while offering the benefits of optical fiber. The firm says that AOCs use a cabling technology that accepts the same electrical inputs as a traditional copper cable, but use optical fiber 'between the connectors' with electrical-to-optical conversion on the cable ends that improves speed and the link distance of the cables without sacrificing compatibility with standard electrical interfaces.

"Applying our proven design technology and volume manufacturing expertise is expanding access to a broader variety of previously copper-only market segments," says Sharon Hall, product line manager for Avago fiber-optic products.

Driven by the ever-increasing need for more bandwidth and applications in cloud computing environments, AOCs are the newest solutions for communications within data centers, server farms, network switches, telecom switching centers and other high-performance embedded applications requiring high-speed data transfers. System applications include data aggregation, backplane communications, proprietary protocol data transfers, and other high-density/high-bandwidth applications.

The AOC market is forecasted to grow to just under \$100m by 2015,



Avago's SFP+ active optical cable.

according to market research firm LightCounting. "The main market continues to be in HPC or super-computers with the InfiniBand protocol," says Brad Smith, senior VP & industry analyst for data center interconnects at LightCounting. "Over the last couple of years AOC adoption in data centers using the Ethernet protocol to connect switch layers together and also in telecom applications, interconnecting long-haul DWDM and routers in central offices, has grown."

The SFP+ and QSFP+ AOC products are the first to be released using Avago's new Atlas 75X embedded optical engine. This optical technology makes it possible to realize significantly higher performance and reach at a lower cost compared to copper cables, the firm says. The CXP AOC offerings use the proven Atlas 77X optical engines (also known as MicroPOD modules), which deliver all the performance, link distance and features such as DMI available in discrete transceiver solutions at a cost savings, it adds.

AOCs have advantages over direct attach copper (DAC) as used in previous generation applications, which cannot provide the features required by current performance-enhanced applications. The bit

error rates (BER) for Avago's AOCs are 10^{-15} , compared with 10^{-12} for DAC, it is reckoned. Statistically, this translates to less than one bit error per day for the Avago AOC compared to a bit error every 1–2 minutes for a copper cable. Also, electro-magnetic interference (EMI) immunity is better than DAC, as the high-frequency EMI signal is confined within the pluggable modules while only the optical signal is transmitted along the cable. The reach of these AOCs is up to 20m for the SFP+ and QSFP+ versions, compared with DAC's reach of slightly over 5m maximum at 10G. Additionally, compared with DAC, AOC has about a quarter of the weight and a smaller cable diameter, and offers a minimum cable bending radius of only 30mm (much better than DAC).

Product features are as follows:

- **SFP+ AOCs with Atlas 75X Embedded Optical Engines** have a cable length of up to 20m, typical power of 275mW per end (less than half that of SFP+ MSA transceivers), and suit 10 Gigabit Ethernet, 8 Gigabit Fibre Channel, and Fibre Channel Over Ethernet protocols.

- **QSFP+ AOCs with Atlas 75X Embedded Optical Engines** have a cable length of up to 20m, typical power consumption of 1.1W per QSFP+ end, and suit 40 Gigabit Ethernet, Infiniband 40G-IB-QDR, 20G-IB-DDR, and 10G-IB-SDR (as well as a breakout version supporting high-density 10G Ethernet applications).

- **CXP AOCs with Atlas 77X MicroPOD Embedded Optical Engines** (with 10.3125Gbps and 12.5Gbps versions up to 12 lanes) have a cable length of up to 100m, a full transceiver feature set (including DMI), and suit 100 Gigabit Ethernet, Infiniband QDRx12, PCIe Gen3, and proprietary protocols.

Samples of the Avago AOC cables are available now.

www.avagotech.com/fiber

Vitesse and Avago demonstrate CXP reference design for 100G/120G connectivity in routers, data centers, and high-performance computing

At Supercomputing 2012 (SC12) in Salt Lake City (12–15 November), Vitesse Semiconductor Corp of Camarillo, CA, USA (which designs ICs for carrier and enterprise networks) and Ltd of San Jose, CA, USA and Singapore (a supplier of III-V-based analog interface components) have announced availability of what is claimed to be the industry's first CXP host joint reference design delivering 100G/120G connectivity for high-speed routers, enterprise data centers and high-performance cloud computing applications. Based on Vitesse's VSC7227 12-channel signal conditioner and Avago's AFBR-83PDZ 12-channel, pluggable, parallel, fiber-optic 100G CXP transceiver module, the joint reference design enables users to leverage Vitesse and Avago interoperability and expedite time-to-market with solutions for 100G/120G connectivity.

Sustained growth in cloud computing, mobile networking and video, remote storage and other bandwidth-intensive services is driving demand for high-density 100G/120G connectivity, say the firms. Recent surveys show that network bandwidth demand is one of the most critical issues facing data centers, driven by increases in virtualization, cloud computing, big data, and convergence. To meet these needs, both carrier and equipment providers are upgrading existing systems with higher-density 10G ports that are expected to grow 68% in 2012 alone, according to market research firm Infonetics. The reference design supports both these higher-density 10G ports, along with the migration to true 100G links and beyond.

"The Vitesse reference design demonstrates the combined superior performance of the Avago CXP transceivers with the Vitesse signal

conditioning ICs," says Sharon Hall, Avago's product manager for parallel fiber-optic products. "With this combined solution, system designers can design 100G/120G optically connected systems with confidence and improved signal integrity," she adds. "This reference design gives our customers a proven way to solve higher-bandwidth demands in optical networks," says Vitesse product marketing manager Gary Paules.

Specific devices on the reference design include:

- Avago's AFBR-83PDZ CXP module, which supports 100G Ethernet and Infiniband IB-QDR/IB-DDR/IB-SDR applications. Exceeding the electrical requirements of IEEE 802.3ba 100G (100 GBASE-SR10 and CPPI) and optical specifications for the 100G-SR standard of 100m or a more aggressive 150m on OM4 fiber, the module supports the highest-density data communications and interconnection applications with an aggregate bandwidth in excess of 120G.

- Vitesse's VSC7227 (claimed to be the industry's lowest-power 12-channel solution), which supports data rates from 155Mbps to 14.1Gbps and adaptive equalization on each channel with no requirement for firmware. VSC7227 combines a CTLE/DFE input receiver that can equalize more than 30dB of loss, along with a 3-tap FIR output driver with better than 18dB of de-emphasis. This combination of input equalization and output driver can close links up to 65-inches of FR4 and 20m of copper cable.

The joint reference platform was available for viewing at SC12 in Avago's booth. Along with the active hardware demonstration, a complete interoperability report is now available.

www.vitesse.com
www.avagotech.com

IN BRIEF

JDSU receives Huawei's Excellent Core Partner Award

At its recent core partner convention in Shenzhen, China, Huawei Technologies Co Ltd, one of the world's largest telecom networking equipment manufacturers, has honored optoelectronic chip and module maker JDSU of Milpitas, CA, USA with its 2012 Excellent Core Partner Award (the highest honor given by Huawei to any of its base of about 1000 suppliers).

JDSU received the award for its "innovative network technology, focus on high quality, and consistent on-time delivery". The firm provides an array of solutions to Huawei, including optical components, modules and transmission products for the development of self-aware networks that support more flexible network management and higher data rates.

"We will continue to collaborate with Huawei to keep increasing the performance of optical networks around the world," says Alan Lowe, president of Communications and Commercial Optical Products at JDSU. "This award also reflects our growing impact in Asia Pacific."

JDSU has offices throughout China (in Beijing, Chengdu, Guangzhou, Shanghai, Shenzhen and Suzhou) and across other parts of Asia Pacific (including India, Japan, Southeast Asia and South Korea).

In 2010, JDSU received the Excellent Core Partner Award from Huawei for service and solutions including reconfigurable optical add/drop multiplexor (ROADM) and tunable XFP products.

In a panel session during this year's Huawei partner convention, JDSU also presented on the topic of collaboration.

www.huawei.com
www.jdsu.com

JDSU's quarterly revenue up year-on-year

Profits & dividend down 15%; broadband-led market upturn cheering

Optoelectronic chip and module maker JDSU of Milpitas, CA, USA has reported its first-quarter 2013 (ended 29 September 2012). Non-GAAP revenue was \$420.9m and net income was \$35m. Last-quarter revenue was \$434m, with net income of \$35.4m. Revenue for Q1/2012 was \$416.1m, with net income of \$41.2m.

The latest results are "solid", reflecting the firm's ability to deliver to its commitments "even during periods of economic uncertainty", says president & CEO Tom Waechter.

"Communications service providers continue to spend cautiously due to macro-economic and geo-political concerns. Because of this uncertain climate, we are not projecting the calendar year-end budget release that frequently occurs in the Telecom industry," he adds. "Looking forward, we are encouraged by the relentless broadband demand that remains a powerful driver for JDSU's core business.

"Our ability to differentiate through product innovation, evolve our variable cost model, and maintain a robust balance sheet means that we are well positioned to capitalize on future growth opportunities as the gap closes between demand and actual spending by our core network customers."

During the quarter, JDSU generated \$43.1m of cash from operations (up from \$38m last quarter). Total cash and investments was \$730.3m.

The firm also adjusted its Consolidated Statements of Operations and segment financials to reflect the October 2012 sale of its holographic security business.

"Like our peers, JDSU is seeing conservative global carrier capital spending due to ongoing macro-economic weakness in Europe, slower growth in China and uncertainty in the USA," says Waechter. "However, the relentless increase in broadband demand remains a powerful driver for our business," he adds.

"In industry recovery cycles, customer investment technically shows up here first, and we are encouraged by trends we see in this business, which delivered strong year-over-year and sequential revenue growth. We have market-leading positions in the fastest-growing optical communications segments, including ROADMs [reconfigurable optical add-drop multiplexers] and tunable XFP.

"We are also making good progress with pluggable transceivers to support growing LAN/SAN needs and the cloud for customers building proprietary data-center networks. We expect to see robust revenue growth in this market over the next few quarters," continued Waechter.

"With respect to market adjacencies, we reported our highest revenue in five years in our commercial lasers business. Revenue from high-powered laser — fiber lasers — grew as expected from \$2.5m in fiscal Q4 2012 to \$6.7m in fiscal Q1.

"We are also pleased to announce our third gesture recognition customer, who plans to use our laser diodes and optical filters in a new personal computing application," Waechter adds.

"We also made the decision in Q1/2013 to discontinue our investment in concentrated photovoltaic (CPV) technologies as market opportunities for solar are currently

limited. We'll continue to monitor this market should conditions change," Waechter concluded.

For fiscal Q2/2013 (ending 29 December 2012), JDSU expects non-GAAP revenue of \$410–430m and operating margin of 7.5–9.5%.

"We are closely monitoring the impact of the severe storms in the East Coast of the USA at the end of October 2012 on our operations and those of our customers in the region," commented Rex S. Jackson, acting chief financial officer & senior VP Business Services. "We have not reflected any potential negative impacts in the guidance," he added.

"We continue to progress our business model and have initiatives we are working on in order to reach our target operating models in both our Communications and Commercial Optical Products [CCOP] and Communications Test & Measurement businesses," Waechter noted. "We expect to see significant benefits from these initiatives over the next several quarters," he added.

"We will continue our record of strong operational execution. We will focus on things in our control, such as a market-leading product portfolio aligned with high-growth opportunities, a variable cost structure with increasing scale and leverage and a robust balance sheet."

www.jdsu.com

Stockholders approve proposals

JDSU's Annual Meeting of Stockholders approved all five proposals presented for consideration:

- re-electing Richard Belluzzo and Harold Covert to the board for three-year terms ending in 2015;
- ratifying the appointment of PricewaterhouseCoopers LLP as JDSU's independent registered public accounting firm for the fiscal year ending 29 June 2013;
- approving, by non-binding advisory

vote, the compensation of JDSU's named executive officers;

- approving an amendment to JDSU's Certificate of Incorporation to eliminate the classified structure of the board of directors; and
- approving amendments to JDSU's Amended and Restated 2003 Equity Incentive Plan to (among other things) increase the number of shares that may be issued and extend its term.



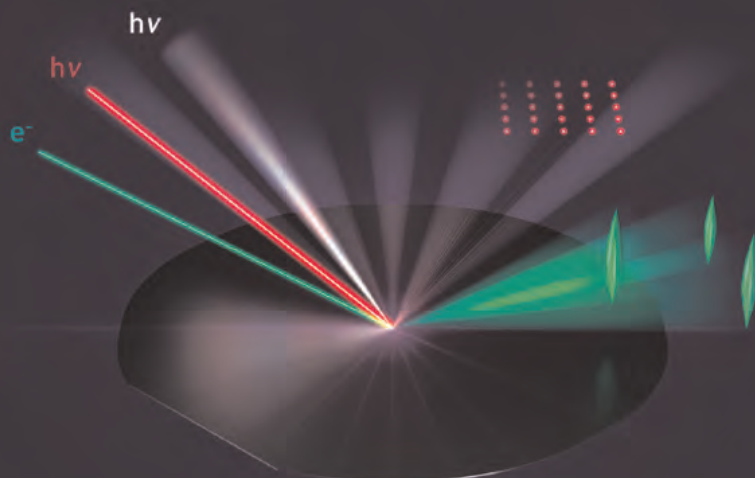
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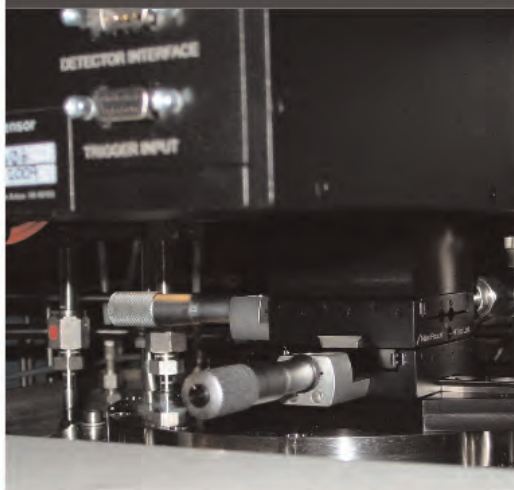
Real-Time Process Monitoring for MOCVD, MBE, Sputtering, and Thin-Film PV Deposition



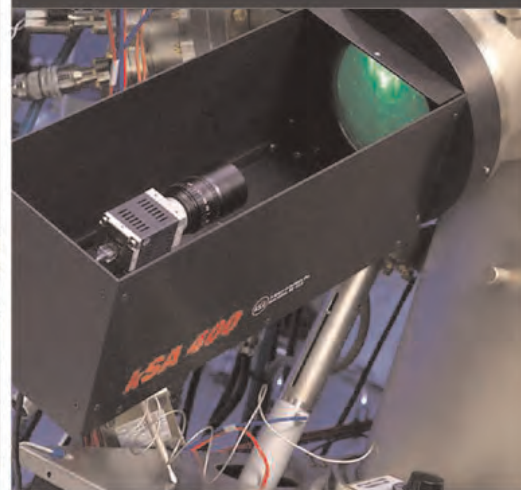
kSA BandiT Wafer Temperature



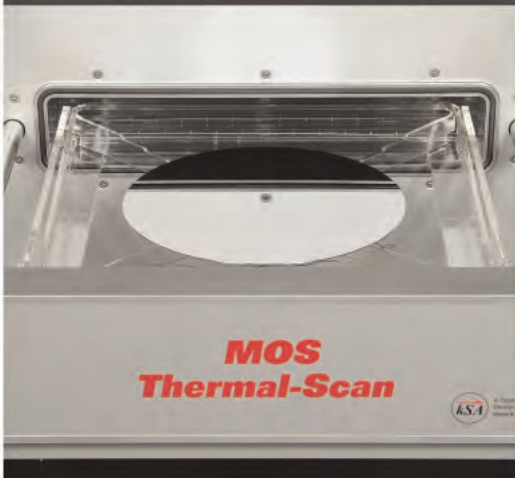
kSA MOS and kSA Mini-MOS Thin-Film Stress



kSA 400 Analytical RHEED



kSA MOS Ultra-Scan and Thermal-Scan Stress Mapping



kSA Rate Rat Pro Thickness & Deposition Rate



kSA BandiT PV Process Tuning



Amonix raises module efficiency record from 30.3% to 33.5%

Peak efficiency reaches 34.2% during NREL tests

Amonix Inc of Seal Beach, CA, USA, which makes utility-scale concentrated photovoltaic (CPV) systems using III-V multi-junction solar cells, says that its systems can now convert more than one third of direct sunlight into electricity.

In May, the US National Renewable Energy Laboratory (NREL) confirmed an outdoor operating efficiency rating of 33.5% for an Amonix module, breaking the previous record of 30.3% (also held by Amonix). Over several days of on-sun testing conducted by NREL, the module efficiency peaked at 34.2% - the highest efficiency ever reported under real-world operating conditions for a solar PV module, it is reckoned.

"CPV offers the highest efficiencies of all solar technologies in the right operating conditions with plenty of headroom," says founder & chief technology officer Vahan Garboushian. "Amonix is focused on driving CPV costs down and breaking efficiency records in the



Amonix's 7700 HCPV system.

near future," he adds.

The firm says that the record module efficiency is now internationally recognized in the most recent Solar Cell Efficiency tables publication, Version 40, released in August. Sarah Kurtz, Reliability Group Manager at NREL, also cites the efficiency rating in her 2012 annual 'state of the CPV industry' publication 'Opportunities and Challenges for Development of a Mature Concentrating Photovoltaic Power Industry'.

"While the mainstream PV industry has made critical reductions in large-scale production costs and incremental improvements in power-conversion efficiencies, much of the world is unaware of the dramatic progress that has been made by CPV companies toward achieving high power-conversion efficiencies," says Kurtz. "Achievement of >33.3% efficiency for a commercial module is an important milestone — the Department of Energy once targeted this goal ('One-third of a sun')

Much of the world is unaware of the dramatic progress that has been made by CPV

for a major initiative," she adds. "It is exciting to see this goal accomplished, especially in

light of the opportunities for further efficiency improvements and the expectation of low costs associated with large-scale manufacturing."

www.amonix.com

Semprius supplies HCPV modules for Pratt & Whitney Rocketdyne's Department of Defense project

Semprius Inc of Durham, NC, USA, which designs and makes high-concentration photovoltaic (HCPV) modules, is to supply solar modules for Pratt & Whitney Rocketdyne's (PWR's) \$2.3m award from the Environmental Security Technology Certification Program (ESTCP) office of the US Department of Defense (DoD). The project is designed to demonstrate the performance and cost effectiveness of HCPV technology for use at Department of Defense installations as well as in other commercial and utility-scale applications, says the firm.

With efficiency of 33.9%, Semprius' solar modules are reckoned to be the first to convert over one-third of the sun's energy into electricity, says the firm. In addition, Semprius-based systems can deliver up to 30% more energy than equivalent PV systems, it is claimed.

As part of the project, PWR will install a 200kW solar system, with 2400 Semprius modules mounted on dual-axis trackers, at Edwards Air Force Base in California. The system will produce over 400,000kWh of electricity annually, enough to power about 40 homes.

"Having spent several years eval-

uating emerging PV technologies, we've selected Semprius because of the potential of their technology to drive down the cost of solar electricity significantly," says Randy Parsley, Renewable Energy Program manager at PWR (which is part of United Technologies Corp).

Semprius and PWR began working together in 2011 to demonstrate Semprius' technology at the University of Alabama-Huntsville. Over the past 18 months, the firms have collaborated to scale up the technology into a cost-effective, commercial-grade system.

www.semprius.com

Soitec signs power purchase agreement for 44MWp CPV plant in South Africa

Soitec of Bernin, France has signed a power purchase agreement (PPA) covering the electricity generated at the Touwsrivier concentrating photovoltaic (CPV) solar power plant that it is to build in South Africa.

Soitec says that the agreement represents a decisive step for the project, which was submitted in connection with the first call for projects from independent power producers (IPPs) launched by the South African Ministry of Energy, for which Touwsrivier was pre-selected in December 2011. Following the signing, Soitec will now seek to refinance the project and start construction of the power plant.

Based in the Western Cape, close to the Aquila Private Game Reserve (in which Soitec has already built a

pilot facility), the Touwsrivier power plant will ultimately have a capacity of 44MWp. Construction is scheduled to be completed during 2014, but commercial operation of the first installed systems will begin in mid-2013.

"Approval of the power purchase agreement by the South African Ministry of Energy and its signature by national electricity supplier Eskom represent a major step forward in the expansion of our business in South Africa and generally worldwide," says Gaetan Borgers, executive VP of Soitec's Solar energy division. "It reflects the suitability of our concentrating photovoltaic technology for very sunny regions," he adds. "Our modules boast a yield of close to 30% and a very long service life."

According to the Integrated Resource Plan (IRP2010) launched by the South African Department of Energy, about 42% of the electricity generated in the country will come from renewable resources in 2030. The IPP program calls for 3,725MW in renewable energy capacity to be built, including 1450MW in photovoltaic power. After the IPP first bid submission, 18 solar photovoltaic projects (out of 28 renewable projects) were selected.

"Our Touwsrivier project is one of the first to have been selected by the South African Department of Energy," says Soitec's chairman & CEO André-Jacques Auberton-Hervé. "The fact we are able to take aspects of local content into account is another key point of our approach."

www.soitec.com

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Glomfjord Mono Private Treaty Sale Complete 200 MW/yr State of the Art Mono Wafer Manufacturing Facility

156mm x 156mm with 180 micron thickness

Offered in its Entirety

Located in Glomfjord, Norway

- Material Handling System: FBR IBC (2009), 3 x 2000kg Overhead Feed Points, Siemens PLC
- Crucible Weighing/Mixing and Transfer System: Tronrud HGC-Cleanroom 4-Station (2009)
- (71) Crystal Growth Pullers: (50) PVA Tepla (All 2008); (21) Kayex/Hamco
- (2) Ingot Coding Marking Labeling Machines: Goodtech Tiara-CML (2009)
- (13) CNC Horiz. Bandsaws: Meyer Burger (4) KVP 830/BS 830 (2008-2009); (9) BS 830 (2008)
- (2) Automated Block Handling Centres (2008)
- (2) Automated Gluing Centres: Artech Lime-Robot-Senter (2008)
- (17) Wire Saws: Applied Materials/HTC 500SD-B/5 (All 2008)
- (3) Process Wash Plants: Edwards CME Automated 5-Station (All 2008)
- (6) Wafer Lines: Tronrud Engineering Mono (All 2008)

Heroya #4, Norway Location also includes:

- (2) Crucible Cleanroom Mixing/Weighing Systems: Tronrud Engineering HGXXB (Both 2008)

Heroya Plants #3 & #4 Private Treaty Sales "Two" Complete 325 MW/yr State of the Art Crystalline Poly Silicon Wafer Manufacturing Facilities

156mm x 156mm x w/180 micron thickness

Offered in their Entirety or Piecemeal

Located in Heroya, Norway

Both Heroya Plants #3 & #4 Include:

- (2) Crucible Coating Systems: Artech Anlegg-1 (2007-2008)
- (4) Crucible Baking Furnaces: C.H. Evenson 07-086m01 (All 2008)
- (10) Silicon Crystallization Vacuum Melting Furnaces: ALD SMC1000 1600A°C
- (6) Ingot Band Saws: Meyer Burger BS 801 (All 2008)
- (2) Automated Block Centres: Artech, Each with ABB IRB6600 Rail Mounted 7-Axis Robot (2008), (5) Abwood CNC Grinders with GE Fanuc Controls (All 2008)
- (2) Automated Gluing Cells: Artech Lime-Robot-Senter (Both 2007)
- (32) Wire Saws: Meyer Burger DS 268 (All 2008)
- (4) Process Wash Plants: Edwards CME Automated 5-Station (2007-2008)
- (6) Wafer Lines: Tronrud Engineering (All 2008)

Heroya #3, Norway Location also includes:

- Crucible Cleanroom Mixing/Weighing System: Tronrud Engineering HGXXB (2008)
- Ingot Band Saw: MB Wafertec BS 806 Large Capacity (2009)
- Wire Saw Bricking Machine: MB Wafertec BM 860 Brick Master (2011)

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First Solar reports Q3 sales down 12% to \$839m ...but drop due to timing of project completion

For third-quarter 2012, First Solar Inc of Tempe, AZ, USA — which manufactures thin-film photovoltaic modules based on cadmium telluride (CdTe) as well as providing engineering, procurement & construction (EPC) services — has reported net sales of \$839m, down 12.3% on \$957m last quarter and down 16.6% on \$1006m a year ago.

The drop from last quarter was due mainly to project-specific decreases including Silver State North (completed in the second quarter) and reduced construction activity at Agua Caliente (consistent with the planned construction schedule). This was partially offset by initial revenue recognition for the 550MW_{ac} Topaz Solar Farms project (which began construction in late 2011).

“Despite continued uncertainties and over-supply conditions in the market, First Solar delivered another strong quarterly performance,” says CEO Jim Hughes.

Net income was \$87.9m (\$1.00 per fully diluted share), down from \$111m (\$1.27 per fully diluted share) last quarter and \$196.5m

(\$2.25 per fully diluted share) a year ago.

However, this includes a charge of \$23.6m (reducing earnings per share by \$0.27) relating to restructuring actions announced in mid-April (involving closing manufacturing operations in Frankfurt (Oder), Germany in Q4/2012 and, since May, indefinitely idling four production lines at its manufacturing center in Kulim, Malaysia, collectively cutting the firm’s global staffing by about 2000, or 30%). Excluding such charges, non-GAAP net income was \$111.5m (\$1.27 per fully diluted share), down from \$144.9m (\$1.65 per fully diluted share) last quarter.

During the quarter, cash and marketable securities fell slightly from \$744m to \$717m.

First Solar also updated its guidance for full-year 2012 as follows:

- Net sales of \$3.5–3.8bn, down from prior guidance of \$3.6–3.9bn due to weather-related disruptions in the supply chain and at certain project sites that may push the expected closing of the project

sales from Q4/2012 into Q1/2013. Nevertheless, this is still up 32% on 2011’s \$2.76bn.

- Non-GAAP earnings per fully diluted share of \$4.40–4.70, compared to prior guidance of \$4.20–4.70. This excludes restructuring and impairment charges and certain costs in excess of normal warranty expense related to the previously announced manufacturing excursion that is expected, which should reduce earnings per fully diluted share by \$6.00. On a GAAP basis, earnings per fully diluted share are expected to be \$1.60–1.30.

- Operating cash flows of \$650–850m, down from prior guidance of \$850–950m, due mainly to the weather-related disruptions for certain projects.

“Our quarterly performance, coupled with our recent project wins in sustainable markets, demonstrates we are making meaningful progress in achieving our strategic plan for long-term growth,” says Hughes.

www.firstsolar.com

First Solar collaborates with Hagerstown Community College on alternative energy technology program

First Solar Inc of Tempe, AZ, USA, which makes thin-film photovoltaic (PV) modules based on cadmium telluride (CdTe), has begun a collaborative initiative with the alternative energy technology program of Hagerstown Community College (HCC) in Maryland for faculty and students to benefit from the construction and operation of the 20MW Maryland Solar facility, a First Solar project under construction in Washington County.

HCC offers an associate degree program in alternative energy technology, and certificates in solar/wind energy installation/service and geothermal energy installation/service.

Students get hands-on training using technologies offered in the alternative energy lab, housed in HCC’s new 65,000ft² STEM Building.

Maryland Solar, which is due to begin commercial operation in 2013, has agreed to provide HCC and its students with site visits, guest lectures, internships and a digital ‘dashboard’ at HCC’s STEM Building so visitors can get a first-hand view of operational data from the solar farm.

Maryland Solar has also agreed to provide HCC with solar panels, enabling the college to install and maintain a small, ground-mounted solar power plant as well as a roof-

mounted PV system on its STEM building. These panels will further enhance the educational opportunities available to HCC’s students and help offset electricity usage on the campus.

“First Solar is committed to supporting the communities near its solar projects and to providing green jobs and educational opportunities for neighboring residents and businesses,” says Roy Skinner, First Solar’s director of permitting. The collaboration will provide first-hand utility-scale solar knowledge and experience for HCC’s faculty and students, he adds.

www.hagerstowncc.edu/aet
www.firstsolar.com

Innovative production equipment key to survival in turbulent solar panel market

Global capacity utilization is at 55% for x-Si module production, 70% for CdTe and 80% for CIGS

With production overcapacity of 82%, solar panel makers need to acquire innovative production equipment in order to cut costs, increase margins and differentiate their products from less expensive Chinese rivals, says market analysis firm Lux Research. This year, global capacity utilization is at 55% for crystalline silicon (x-Si) module production, 70% for cadmium telluride (CdTe) and 80% for copper indium gallium (di)selenide (CIGS). Consequently, cell and module manufacturers are turning to core product differentiation to revamp margins and fend off low-cost Chinese competition.

"Across the industry there is recognition that innovation is

needed to survive a shakeout," said Fatima Toor, Lux Research Analyst and the lead author of the report 'Turning Lemons into Lemonade: Opportunities in the Turbulent Photovoltaic Equipment Market' (part of the firm's Solar Components Intelligence service). "Equipment suppliers have a vital role to play in enabling that innovation."

Lux Research examined the PV production equipment market to identify opportunities for innovation. These include the following:

- Reducing silicon costs: Current wafer sawing techniques waste silicon; in contrast, technologies such as direct solidification and epitaxial silicon eliminate the need for wafer sawing. Emerging quasi-monocryst-

alline silicon (qc-Si) ingot growth enables 40% cheaper c-Si wafers.

- CIGS standardization: CIGS thin-film PV currently relies on custom equipment. However, off-the-shelf tools and improved throughput will drive higher efficiencies, performance and yield, lowering capex and helping manufacturers attain scale and competitive production costs.

- New cell designs leading to equipment upgrades: Emerging cell designs, such as selective emitter (SE) and heterojunction with intrinsic thin layer (HIT) present potential for high efficiencies. However, they require new tools, and as a result, 60–70% of new equipment sales are for the cell production equipment.

www.luxresearchinc.com

Stion wins \$2m grant from DOE's Sunshot Initiative

Production scale-up of highest-efficiency thin-film module to continue in California and Mississippi

Stion Corp of San Jose, CA, USA, which makes nanostructure-based CIGS_{Se} (copper indium gallium sulphur-diselenide) thin-film photovoltaic panels, has received a \$2m award from the US Department of Energy's SunShot Initiative to continue pilot production and scale-up of its thin film modules based on proprietary tandem junction technology.

The award is a Tier 2 grant under the Sunshot's Incubator 7 Program and is designed to accelerate the transition to commercial production. Stion is expanding production at both its San Jose headquarters and its first mass-production facility, in Hattiesburg, MS (opened earlier this year). The latest grant is a follow-on to the Tier 1 award given to Stion in February 2011. As part of Tier 1, Stion advanced its technology into the commercial prototype stage

and produced tandem junction prototype modules at 18.8% aperture efficiency (the highest for any module prototype based on thin-film technology, it is claimed).

"Our progress on the tandem technology demonstrates that thin films can achieve industry-leading efficiencies on a scalable, low-cost production platform," says president & CEO Chet Farris.

Stion says that its unique approach to thin-film PV leverages proprietary materials and device expertise along with a robust,

Tandem technology demonstrates that thin films can achieve industry-leading efficiencies on a scalable, low-cost production platform

high-volume manufacturing process based on readily available, standardized equipment. In March the firm began shipments of products based on its single-junction CIGS_{Se} technology, and has produced commercial modules with aperture efficiency as high as 15.6%.

Stion says the tandem junction module would increase efficiency by enabling broader and more effective harvesting of available light using an additional thin-film device. It utilizes mechanically stacked top and bottom devices to eliminate the design and manufacturing challenges associated with traditional junction integration, and maintains the same glass/glass packaging design as Stion's current commercial modules.

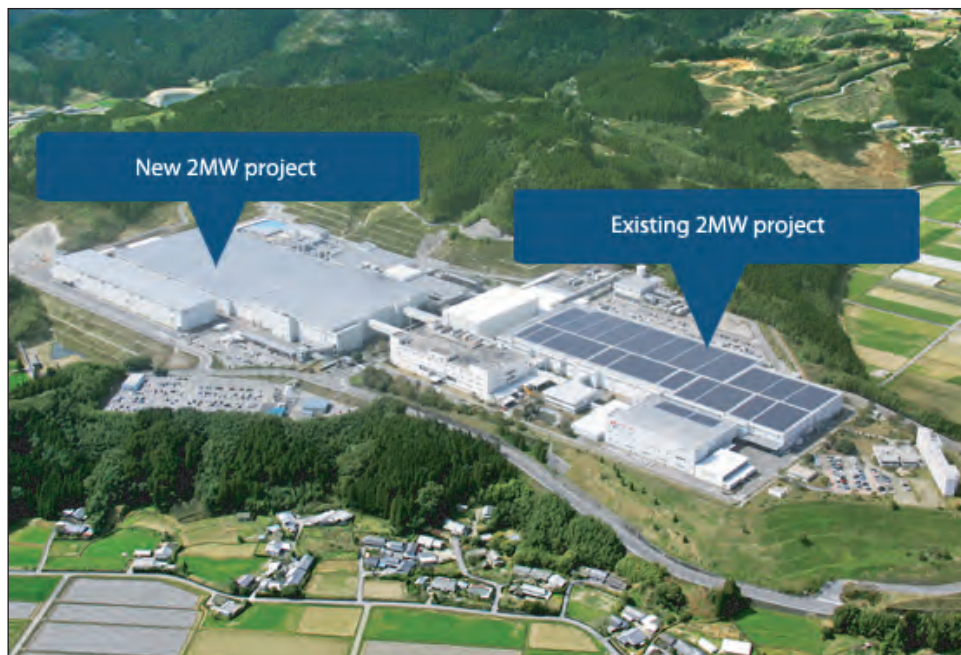
www.stion.com

Showa Shell adding 2MW power plant to roof of Solar Frontier's Kunitomi factory

Japanese energy business Showa Shell Sekiyu and its Tokyo-based subsidiary Solar Frontier — the world's largest manufacturer of CIS (copper indium selenium) thin-film photovoltaic (PV) solar modules — are cooperating on a new solar power generation project to be installed on top of what is the largest CIS thin-film solar module production facility (Solar Frontier's Kunitomi factory in Miyazaki Prefecture, which has an annual production capacity of 900MW).

Construction of the 2MW power plant is scheduled to be finished this year. Once completed, there will be 7.3MW of solar power capacity installed or planned for Kunitomi town (equivalent to about 30% of the town's residential power needs). This will be Showa Shell Sekiyu's second commercial solar power plant after the Niigata Yukigunigata Megasolar power plant in Niigata Prefecture.

The new project will add to an existing 2MW of Solar Frontier modules on top of building 2 that supply power directly to the Kunitomi plant. The power generated by the new modules on building 3 will be sold to Kyushu Electric Power Company. Solar Frontier, which owns the Kunitomi Plant, will lease the rooftop to Showa Shell Sekiyu.



Solar Frontier's Kunitomi factory.

Solar Frontier's flagship Kunitomi Plant began commercial production of CIS PV modules in February 2011, and all lines at the plant were opera-

The new project will add to an existing 2 MegaWatts of Solar Frontier modules on top of building 2 that supply power directly to the Kunitomi plant

tional by that July. The plant is Japan's largest solar module production plant (as well as being the world's largest plant producing CIS thin-film photovoltaic solar modules).

Currently, modules produced at Kunitomi have a conversion efficiency that exceeds 13%, and the amount of power generated (kWh) per installed capacity (kW) exceeds that of other solar modules, it is reckoned.

www.solar-frontier.com

Yamanashi Prefecture's first private-sector utility-scale solar power plant breaks ground

Tokyo-based Solar Frontier has been selected by Aikawa Press Industry Co Ltd to supply its CIS thin-film photovoltaic modules for the Aikawa Press Takane Plant Megasolar project. This is the first utility-scale solar project in the private sector to start construction in Yamanashi Prefecture. The ground-breaking ceremony was attended by Solar Frontier's executive officer Yukihiro Oyama and Aikawa Press' chairman &

president Takeshi Aikawa, among others.

The project is said to be one of just a few solar power plants in Japan that have been built adjacent to a factory. With 12,000 Solar Frontier modules to be installed, its generating capacity will be 1.8MW. The operator will be Aikawa Press, and the sale of electricity is scheduled to start around the end of next March.

Yamanashi Prefecture has one of

the highest annual sunshine rates in Japan, making it suited to solar energy projects. Solar Frontier has also provided modules for the Mt. Komekura Megasolar plant in Yamanashi.

The firm says that, looking ahead, it will keep working toward 'local energy generation for local consumption' using its CIS modules, as well as contributing to effective land use through similar utility-scale projects.

Ascent Solar wins USAF SBIR award for flexible lightweight PVs operating at higher temperature

Ascent Solar Technologies Inc of Thornton, CO, USA has been selected for a US Air Force (USAF) Small Business Innovative Research (SBIR) Phase 2 award to demonstrate a next-generation photovoltaic product that builds on its flexible monolithically integrated copper indium gallium diselenide (CIGS) thin-film module technology.

Subject to contract finalization, the Phase 2 program is expected to run for 24 months, with a program

value of up to \$750,000.

"Solar cells perform best at lower temperatures, but they can get hot during normal

We envision a new product that will perform over 30% better under some operating conditions that utilize process modifications that can be used in our existing manufacturing line

operation," says Ascent's president & CEO Victor Lee. "Modifying our existing technology can improve its performance at higher temperatures. This Air Force program builds upon significant work already conducted by our team in this area," he adds. "After program completion, we envision a new product that will perform over 30% better under some operating conditions that utilize process modifications that can be used in our existing manufacturing line."

Automotive battery charging products launched with CTC CarTech

Ascent Solar Technologies, which makes lightweight thin-film photovoltaic modules based on copper indium gallium diselenide (CIGS) using flexible substrate materials, has announced the initial sale of SOLab Basic and SOLab Premium products, as branded by joint development partner CTC CarTech Company of Böblingen, Germany (a development service provider for automotive electronics).

SOLab is an autonomous solar charger meant for automotive battery cycling and trickle charging. Integrating Ascent's CIGS PV modules into SOLab Basic and SOLab Premium products is claimed to be a first-of-its-kind application for automotive battery charging.

"With Ascent we found the best partner for delivering innovative products into the field of autonomous solar chargers for automotive pro-

fessionals," says Sebastian Hotz, CarTech's head of Sales Product Division. "Thin-film solar is highly innovative for our product. Not only the functionality but also the product design from Ascent makes the product very unique," he adds.

"These products are a good illustration of the multitude of applications that Ascent's unique technology can be utilized in," says Ascent's president & CEO Victor Lee.

Ascent Solar appoints Robert Roche as VP of sales, marketing & communications

Ascent Solar has appointed Robert Roche as vice president of sales, marketing and communications.

Roche has more than 25 years of sales, marketing and technical leadership experience. Prior to joining Ascent, he served two years as VP, sales & business development at United Solar (a division of Energy Conversion Devices), where he repositioned their channel sales and marketing strategies and rapidly grew their global customer network. Prior to that, he was VP, sales & business development at the Carrier Division of United Technologies Corp (UTC), responsible for growing its energy-efficiency services business in North America.

"He will be a key driver in our

continued transformation from traditional BIPV/BAPV [building-integrated/building-applied photovoltaic] solar applications to the high-premium specialty market and consumer electronics applications," says CEO Victor Lee. "With this key addition to our leadership team, Ascent is well positioned to further accelerate progress on execution of our new strategy with the EnerPlex product line," he adds.

"Ascent possesses revolutionary technology that provides a compelling solar power solution for customers in key markets such as portable consumer power, aerospace & defense, transportation and off-grid power," comments Roche.

Before joining its Carrier Division, Roche was general manager of marketing & applications engineering at the UTC Power division, and led global marketing and technical sales support efforts for its commercial fuel cell and alternative energy product lines. His career at UTC Power also included international experience in engineering management, joint venture program management, new product development and product management, and he is a named inventor on nine US Patents. Roche has a BS in Chemical and Materials Engineering from the University of Connecticut and an MBA from Rensselaer Polytechnic Institute.

www.ascentsolar.com

One-step GaN on sapphire through graphene coating

Researchers in Korea achieve internal quantum efficiency of overgrown MQWs comparable to those on conventional two-step templates.

Researchers in Korea have been studying how to simplify gallium nitride (GaN) growth on sapphire through use of an initial graphene layer [Jae-Kyung Choi et al, *Nanotechnology*, vol23, p435603, 2012]. The researchers were based at Ulsan National Institute of Science and Technology (UNIST), Seoul National University, and Sogang University.

The graphene layer improves wetting between the GaN and sapphire, allowing a one-step high-temperature process to be used instead of the more complicated sequences of low- and high-temperature growth normally implemented to initiate crystalline GaN growth (Figure 1a).

Although by some measures the quality of the GaN film is not as good as a layer grown by traditional methods, the internal quantum efficiency (IQE) of multi-quantum wells (MQWs) grown on the GaN film when subjected to photoluminescence (PL) is as high as for similar structures on conventional GaN. The researchers also believe that the method could be expanded to grow many other heteroepitaxial films on arbitrary substrates with large lattice and thermal misfits.

The researchers used their own low-temperature diffusion-assisted synthesis (DAS) process to create graphene on c-plane sapphire. DAS begins with room-temperature evaporation of polycrystalline nickel onto the sapphire. The carbon source is graphite powder that covers the substrate. The carbon-nickel/sapphire 'diffusion couple' is clamped at 1MPa pressure in a molybdenum holding stage. The assembly is put in a quartz tube with flowing argon gas and heated to temperatures between 160°C and 360°C for between 30 and 150 minutes. After the heat treatment the samples are cleaned and then

etched with iron chloride solution to remove the nickel. The result is nanocrystalline graphene on sapphire.

A commercial low-pressure reactor was used to perform metal-organic chemical vapor deposition (MOCVD) of the GaN layer at 1040°C. The low pressure of 10^{-3} Torr was used to repel residual oxygen from the substrate

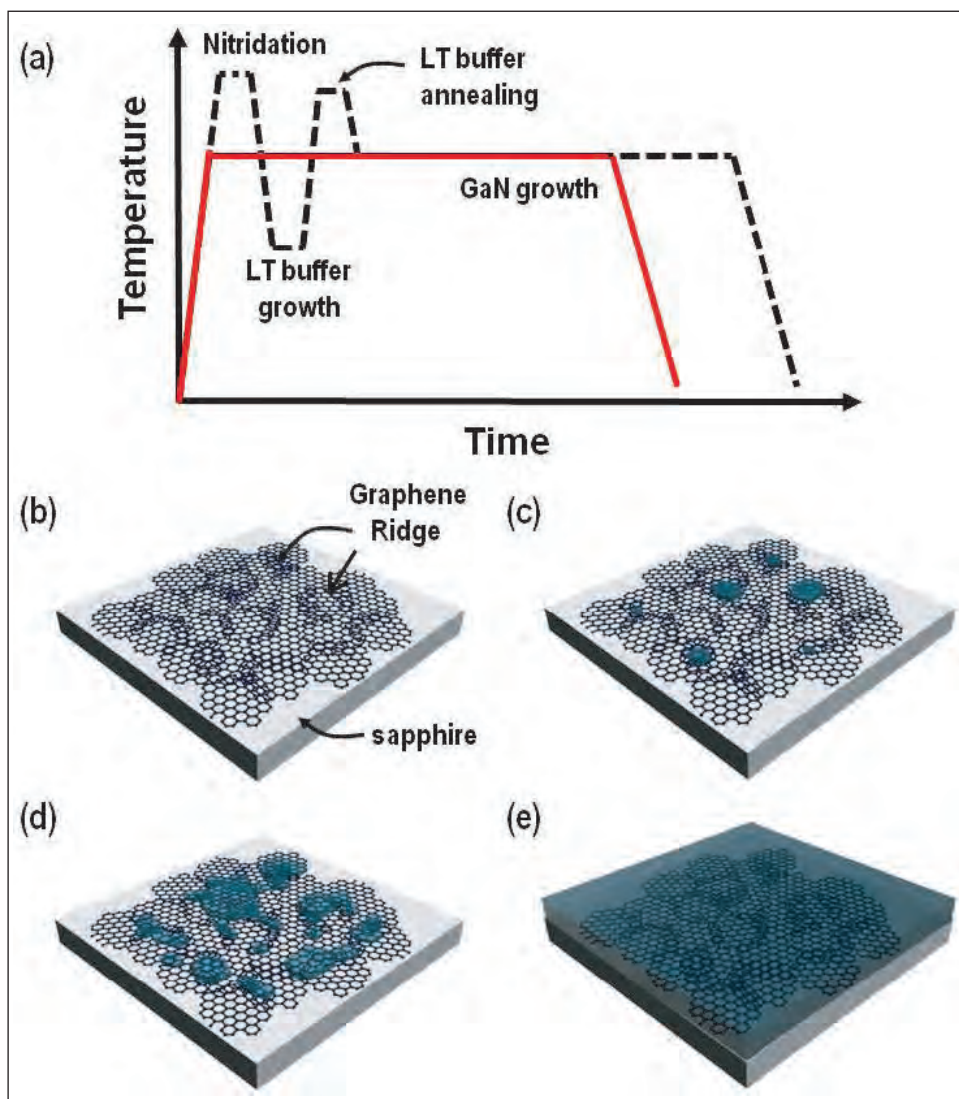


Figure 1. (a) Sketch of conventional two-step process (black dotted line) compared with one-step process using ultrathin graphene coating layers (red line), (b)–(e) scheme of one-step growth of epitaxial GaN films using ultrathin graphene coating layers: (b) graphene coating on sapphire substrate by DAS process; (c) GaN nucleation along naturally formed multilayer graphene ridges; (d) lateral growth of GaN on graphene coating layer; (e) full coalescence of GaN on graphene/sapphire template.

and graphene layer. The substrate was then ramped to the GaN growth temperature in a nitrogen atmosphere. Once at the growth temperature, the substrate was annealed in the same atmosphere for 5 minutes.

The source gases for the GaN MOCVD were tri-methyl-gallium (TMG) and ammonia (NH_3) in hydrogen carrier. The growth pressure was 25Torr.

The researchers see the irregularity of the graphene film that results from their process as being important for GaN nucleation (Figure 1). The DAS process results in ridges of multi-layer graphene with the spacing determined by the growth conditions.

"It is known that epitaxial GaN films could not be grown on pristine graphene layers due to their chemical stability," the researchers write. Other groups attempting to grow GaN and zinc oxide semiconductor films on graphene have introduced special protrusions, such as titanium droplets, to nucleate growth.

The researchers see their technique as having the advantage of not needing such extra processing: "We find that GaN nucleation can readily occur along the naturally formed graphene ridges, not on the basal plane of graphene, presumably because the side walls at graphene ridges contain many step-edges, which can act as nucleation sites. The next stage of GaN growth involves the lateral overgrowth on pristine graphene, taking advantage of high adatom mobility on a functional coating layer."

The hexagonal structure of graphene has a lattice misfit with GaN of 10.8%. The researchers see the graphene as improving the 'wetting' between the sapphire and GaN. The nanocrystalline graphene encourages overgrowth of GaN in a continuous, flat layer, rather than the more usual islands in the early phase of growth on sapphire.

The researchers found that increasing the graphene layer thickness enabled them to achieve a nearly surface-pit-free, mirror-like GaN layer. The dislocation density of $1.2 \times 10^9/\text{cm}^2$ was less than an order of magnitude higher than that for conventional GaN layers grown on a low-temperature (Al, Ga)N buffer/sapphire template ($3 \times 10^8/\text{cm}^2$). Since the crystal quality is very sensitive to MOCVD conditions, it is hoped that improvements could come from process optimization.

The researchers analyzed the GaN film using x-ray diffraction and electron micrography. Also, they carried out photoluminescence experiments using a mercury-cadmium laser excitation (Figure 2). With a view to optoelectronics (LED and LDs), the researchers also created 3-period multi-quantum wells (MQWs) of indium gallium nitride in GaN barriers on the GaN/graphene/sapphire structures. By varying the measurement temperature, the researchers determined an internal quantum efficiency value of about 0.3 (30%). The same MQW structure grown on conventional two-step growth templates gave similar performance of ~0.3 IQE. ■

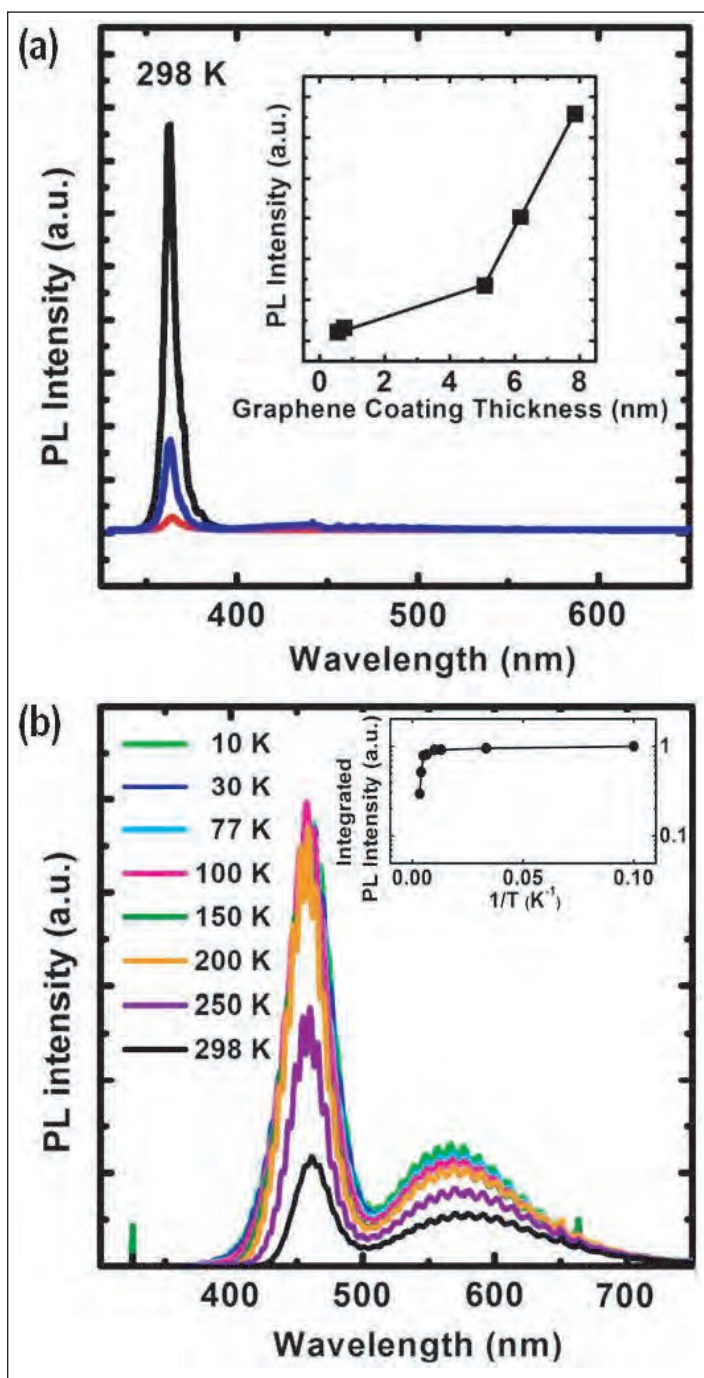


Figure 2. (a) Room-temperature PL spectra of GaN films grown on a sapphire substrate with 0.6nm-thick (red), 5.1nm-thick (blue), and 7.9nm-thick (black) graphene coating layers, respectively (from bottom to top). Inset shows changes in the integrated PL emission intensity of GaN films on graphene/sapphire template as function of graphene coating thickness. (b) Temperature-dependent PL spectra of InGaN/GaN MQWs grown on GaN/graphene/sapphire heterosystem with graphene coating thickness of 7.9nm at temperatures from 10 to 300K. Inset: Arrhenius plot of PL at 2.7eV, showing high IQE of ~0.3.

<http://dx.doi.org/10.1088/0957-4484/23/43/435603>

Author: Mike Cooke

Reducing nitride LED droop with AlInN superlattice electron blocking

UCSB has achieved peak power comparable with LEDs that use an AlGaN electron-blocking layer, but with efficiency droop almost halved.

University of California, Santa Barbara has reduced efficiency droop while maintaining peak efficiency in nitride semiconductor light-emitting diodes (LEDs) through the use of an aluminium indium nitride (AlInN) superlattice (SL) for electron blocking [Roy B. Chung et al, Appl. Phys. Lett., vol101, p131113, 2012].

Nitride semiconductor LEDs suffer from large efficiency droop at high current. One

source of this effect is thought to be from electrons overshooting the active light-emitting region, ending up in the p-contact layers. These electrons generally recombine with holes non-radiatively. This both wastes the electron and reduces hole injection into the active region.

To combat this effect, aluminium gallium nitride (AlGaN) electron-blocking layers (EBLs) are often used. Unfortunately, these barriers not only keep the electrons in the active region, they also impede hole injection.

One unpleasant factor of AlGaN layers is that they are subject to tensile strain due to lattice mismatch with the underlying GaN crystal structure. Such strain tends to lead to material quality degradation and reduced performance for LEDs. By contrast, AlInN with indium content around 18% matches the GaN crystal structure parameters and could lead to better-performing EBLs. In addition, the valence band offset (or hole barrier) is smaller than with AlGaN. However, AlInN growth is relatively immature and there is still a large amount of development work needed to optimize and find the

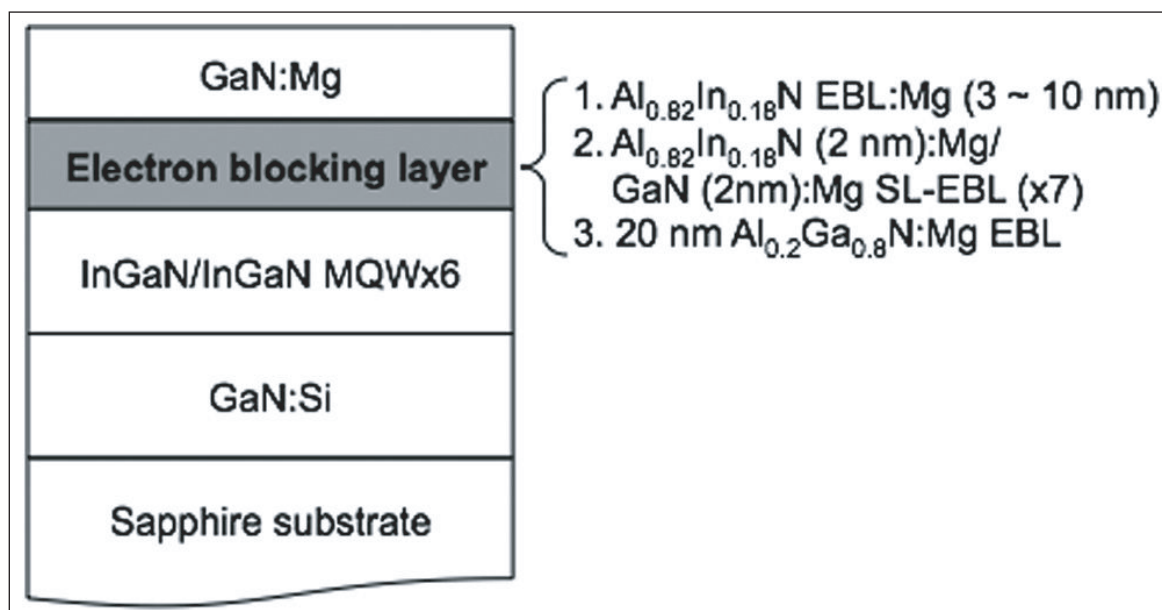


Figure 1. Schematic diagram of LED structure with various EBLs.

limitations of the material.

The researchers used metal-organic chemical vapor deposition (MOCVD) on sapphire in a Veeco P-75 vertical reactor. To create LEDs, various p-doping processes for the AlInN layers were explored. The active region consisted of six InGaN quantum wells and barriers (Figure 1). The electron-blocking layer consisted of either a single lattice-matched (18% In) AlInN layer or a sequence of AlInN/GaN layers making up a superlattice. A conventional AlGaN EBL was also produced for comparison. The magnesium (Mg) doping of the superlattice layers was heavier for AlInN than for GaN.

The material was used to make $200\mu\text{m} \times 500\mu\text{m}$ LEDs with a tin-doped indium tin oxide (ITO) transparent conducting layer p-electrode and a titanium/aluminum/nickel/gold n-electrode. The devices were mounted on silver headers and encapsulated.

One problem with a single AlInN EBL is that the layer is quite resistive, and under high Mg-doping the crystal quality deteriorates. The material also has an oxygen incorporation of around $10^{18}/\text{cm}^2$, which leads to the donation of electrons and hence could be a factor

reducing the hole carrier density through compensation. With increased thickness of AlInN EBL, the operating voltage increases and the light output power decreases at a current injection of 20mA. Neither of these effects is desirable.

The researchers believe that the structural degradation by Mg doping and the compensation effect by the unintentional donor impurity have the strongest impacts on LED performance, compared with other possibilities.

The superlattice structure, by contrast, showed similar light output power compared with the LED that had a conventional AlGaIn EBL. The power at 20mA was 23.8mW for the SL LED and 24.76mW for the AlGaIn LED. The injection current was pulsed with a 1% duty cycle to avoid self-heating effects.

The SL LED further showed improved current droop performance over the AlGaIn LED (Figure 2a). The peak external quantum efficiency (EQE) was 42% for the SL EBL and 43% for the AlGaIn EBL. While the SL EBL device continued with little change in EQE up to 100A/cm² current density, the AlGaIn EBL LED began to droop at 50A/cm². At 300A/cm², the droop from the peak was 17% with an SL EBL, but 36% with an AlGaIn EBL.

The operating voltage at 20mA was 4.4V with SL EBL and 4.6V with AlGaIn EBL. These relatively high operating voltages are attributed to “unoptimized ITO process and p-GaN, resulting in the high contact resistance”.

The measured valence-band offset between lattice-matched AlInN and GaN is 0.2–0.3eV, giving a 0.7–0.8eV conduction-band offset. In the SL structure, the conduction-band offset has an extra 0.4eV compared with the AlGaIn value. The researchers think that this could explain the delay in droop performance. Simulations (Figure 2b) suggest that the repeated thin

layers of AlInN of the SL could also minimize tunneling effects while avoiding structural degradation caused by doping. The slight reduction in the simulated hole barrier would improve hole transport into the active region. ■

<http://link.aip.org/link/doi/10.1063/1.4756791>

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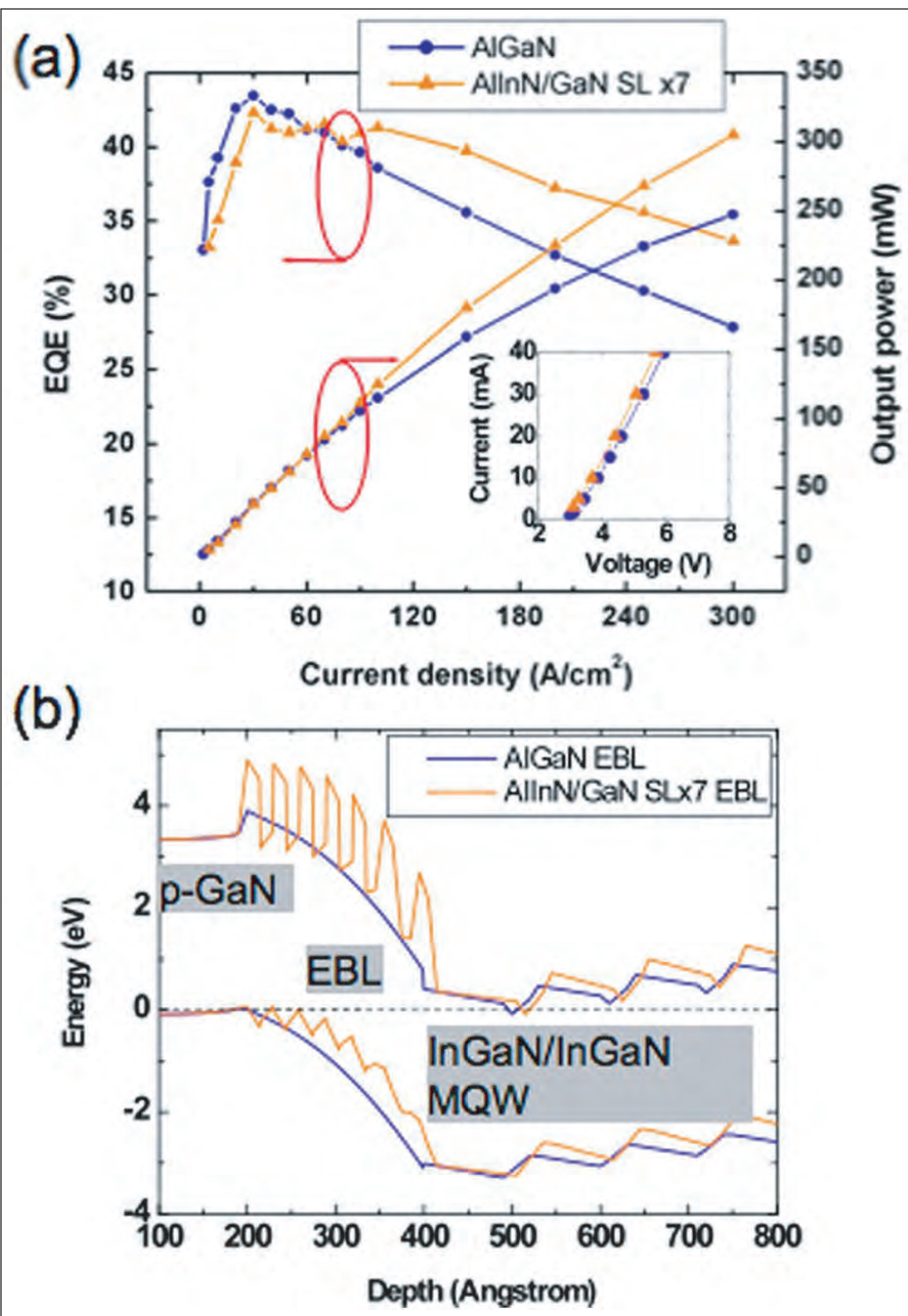


Figure 2. (a) EQE and light output power as a function of current density for LEDs with SL EBL (orange triangles) and AlGaIn EBL (blue circles), with inset showing current–voltage characteristics of LEDs (DC operation), and **(b)** calculated band diagram comparison between AlGaIn and AlInN/GaN SL EBL structures.

Quaternary electron emitter injection improves nitride LED performance

An electron-emitting layer using lattice-matched AlInGaN barriers has been used to reduce current droop while maintaining peak efficiency.

Researchers in China have improved LED power output and droop behavior in nitride semiconductor light-emitting diodes (LEDs) by including an electron-emitting layer under the active region [Jianbao Zhang et al, Appl. Phys. Express, vol5, p112101, 2012]. The electron-emitting layer included barriers of lattice-matched aluminium indium gallium nitride (AlInGaN) with a view to better controlling electrons in the structure.

The researchers were based at Wuhan National Laboratory for Optoelectronics and Huazhong University of Science and Technology.

Nitride semiconductor LEDs are of much interest for white light applications such as backlights for liquid crystal displays (LCDs) and for general illumination. Presently, these devices suffer from a fall-off (droop) in efficiency at higher currents.

Although the dominant cause of droop is not clear, carrier injection and overshoot problems are found to affect droop. In particular, achieving adequate hole injection into the active region is challenging due to the poor activation of the magnesium acceptor used to create p-type regions in nitride semiconductors. Further, electron/n-type carriers tend to overshoot the active region, recombining non-radiatively in the p-type contact.

One way to avoid overshoot is to include an electron-blocking layer (EBL) of aluminium gallium nitride (AlGaIn) before the p-contact layers. Unfortunately, EBLs also tend to reduce hole injection into the active light-emitting region of the device.

Another method to reduce overshoot could be through electron-emitting layers between the n-contact/cladding and active regions that reduce the energy of electrons entering the active region.

The epitaxial material for the Chinese research (Figure 1) was grown on 2-inch c-plane sapphire substrates using a Veeco K465i metal-organic chemical vapor deposition (MOCVD) system. The multi-quantum well (MQW) structure for the electron

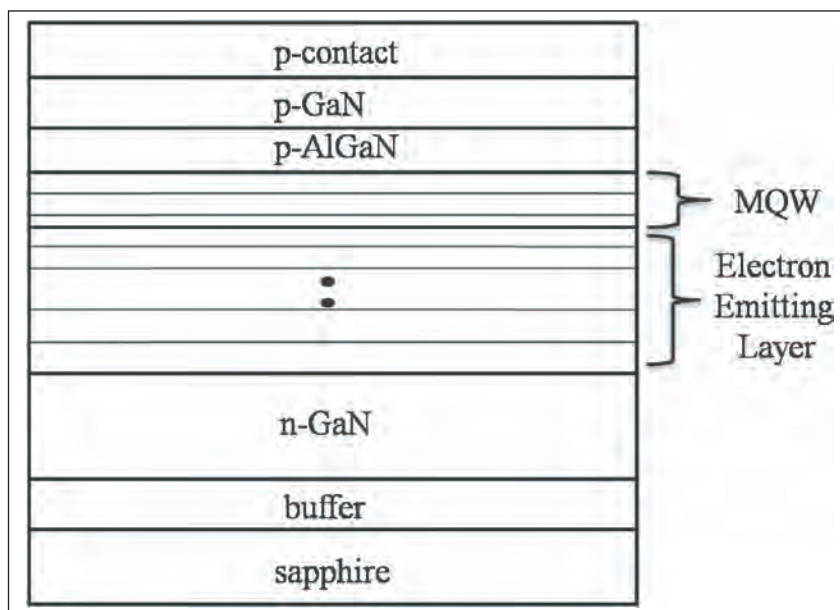


Figure 1. Schematic structure of LEDs with AlInGaN/InGaN MQW electron-emitting layer.

emitter consisted of 5 pairs of undoped 1.7nm $\text{In}_{0.08}\text{Ga}_{0.92}\text{N}$ in silicon-doped 16nm $\text{n-Al}_{0.12}\text{In}_{0.04}\text{Ga}_{0.84}\text{N}$ barriers. Comparison samples with pure GaN barriers were also produced.

At room temperature, the lattice constant of a free-standing layer of AlInGaIn (3.1878Å) with the given composition is close to that of GaN (3.1820Å). So the lattice mismatch between the barriers and wells of the emitter region is similar in the two cases. The difference is that the AlInGaIn presents a higher energy barrier with a larger bandgap offset of about 0.1eV.

The active light-emitting MQW region consisted of 12 pairs of 2.8nm undoped $\text{In}_{0.21}\text{Ga}_{0.79}\text{N}$ and 14nm silicon-doped n-GaN barriers. Further layers of p-AlGaIn for electron blocking and two layers of p-GaN for the contact region completed the structure. Also, an epitaxial structure for an LED without an electron-emitter region was also produced for a comparison with conventional LED performance.

The LEDs were produced in a standard process (contact metal, mesa isolation, etc) with thinning of

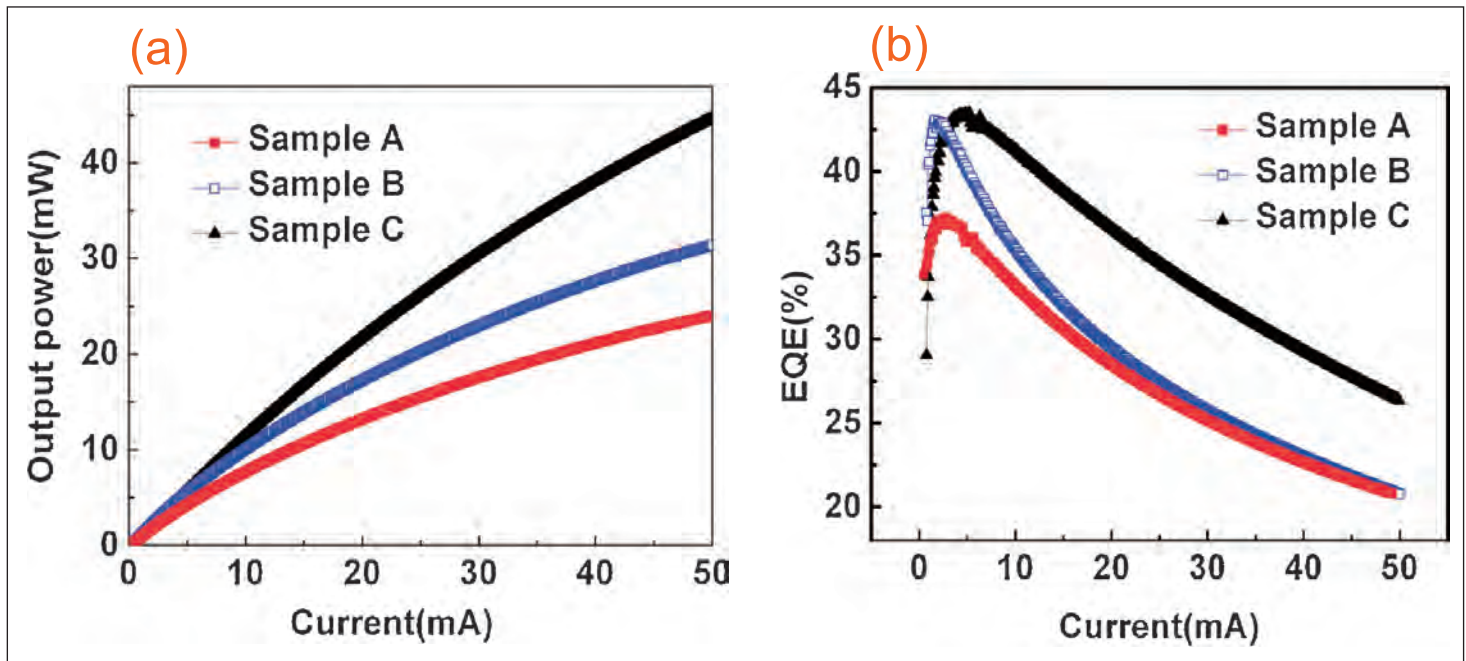


Figure 2. (a) Output power vs current (L–I) characteristics and (b) plot of EQE as a function of current for samples A, B, and C, representing LEDs without electron emitter, and with GaN- and AlInGaN-barrier electron emitters, respectively.

the sapphire substrate to about 90µm and dicing into 300µm squares. Bare chips were tested.

One effect of using AlInGaN in the electron emitter is to reduce the forward voltage, indicating smaller power loss at a given current. This effect is attributed to the better current spreading due to the MQWs trapping electrons before injection by tunneling into the active region. The barrier of AlInGaN is higher than that of pure GaN, increasing the trapping effect.

Further, the leakage under reverse bias was reduced. At –30V, the leakage without emitter layer is 21.70µA, while devices with emitter layers leak 7.82µA when the barriers are GaN and 3.24µA with AlInGaN barriers. These results suggested to the researchers that the reduced leakage for the LEDs with electron-emitter layers reflect lower dislocation densities in these samples.

Atomic force microscopy (AFM) on epitaxial samples without p-type layers confirmed this, giving pit densities of $3.22 \times 10^8/\text{cm}^2$ for samples without electron emitters, $2.62 \times 10^8/\text{cm}^2$ for material with electron emitters with GaN barriers, and $1.87 \times 10^8/\text{cm}^2$ for the new material with AlInGaN barriers in the electron emitters.

The superlattice MQW structure is thought to block/filter dislocations from threading through from the buffer to active layers. The superlattice AlInGaN is apparently better at this than SLs with GaN barriers. In addition, the diameter of the pits is smaller for AlInGaN barriers (~95nm) than for the other samples (~125nm).

The researchers comment: “It seems that the adoption of $\text{Al}_{0.12}\text{In}_{0.04}\text{Ga}_{0.84}\text{N}/\text{In}_{0.08}\text{Ga}_{0.92}\text{N}$ MQW electron-emitting layer can greatly delay the formation

of pits, leading to smaller pit sizes. More investigations are needed to understand this issue.”

The emission peak for electroluminescence was at 457.5nm at 20mA current injection. The LED with AlInGaN barrier electron emitter also had the highest output power and peak external quantum efficiency (Figure 2). Further, the fall-off of EQE for higher currents was slower.

Often, measures designed to reduce droop effects end up reducing peak efficiency as well.

The output power at 20mA was 13.2mW, 17.3mW and 21.8mW for the LEDs without electron emitter, and with GaN- and AlInGaN-barrier electron emitters, respectively. The respective peak EQEs were ~37%, ~42% (at 2mA) and 42% (at 5mA).

The researcher suggest that their results could be “mainly due to the fact that the higher bandgap of AlInGaN barrier, as compared with that of the GaN barrier, can more effectively slow down the electron velocity in the vertical direction and force more electrons to transport laterally, and thus simultaneously improve the carrier confinement in the MQW active region and the current spreading especially for the high-injection-current case.”

It was also found that the AlInGaN electron emitter gave better electrostatic discharge (ESD) endurance — while the other LEDs almost completely failed under 5000V stress, 70% of the AlInGaN devices passed the test. The researchers attribute the improved ESD performance to reduced numbers of dislocations in the active region. ■

<http://apex.jsap.jp/link?APEX/5/112101>

Author: Mike Cooke

In-situ silane treatment enhances light output from nitride LEDs

Researchers in Taiwan have used silane treatment to produce air-voids that block threading dislocations and increase light extraction.

National Chung Hsing University in Taiwan has developed a simple silane treatment to improve crystal quality/internal quantum efficiency (IQE) and light extraction in nitride semiconductor light-emitting diodes (LEDs) [Chung-Chieh Yang et al, IEEE Electron Device Letters, published online 16 October 2012].

The treatment creates air voids between the buffer and n-type contact of the LED material. The air voids block threading dislocations from the buffer from reaching the active light-emitting region. Also the air voids scatter the light produced, allowing light trapped by reflection at flat gallium nitride/air boundaries to escape.

The nitride semiconductor layers (Figure 1d) were grown on c-plane patterned sapphire substrates using metal-organic chemical vapor deposition (MOCVD). Growth began with 30nm of 550°C gallium nitride (GaN) nucleation, followed by

2µm 1150°C undoped u-GaN buffer.

Before further growth, the surface was treated with silane (SiH_4) at 950°C, producing air-voids in the subsequent 3µm n-GaN layer (Figure 1c). The silane treatment for 20 minutes created a random silicon nitride (Si_3N_4) passivation layer. The voids began as the gaps between a series of 3D islands of 950°C n-GaN grown vertically for 10 minutes on the unpassivated areas of the u-GaN buffer. The height of the islands was around 0.9µm (Figures 1a and b).

A second silane treatment was then made to prevent

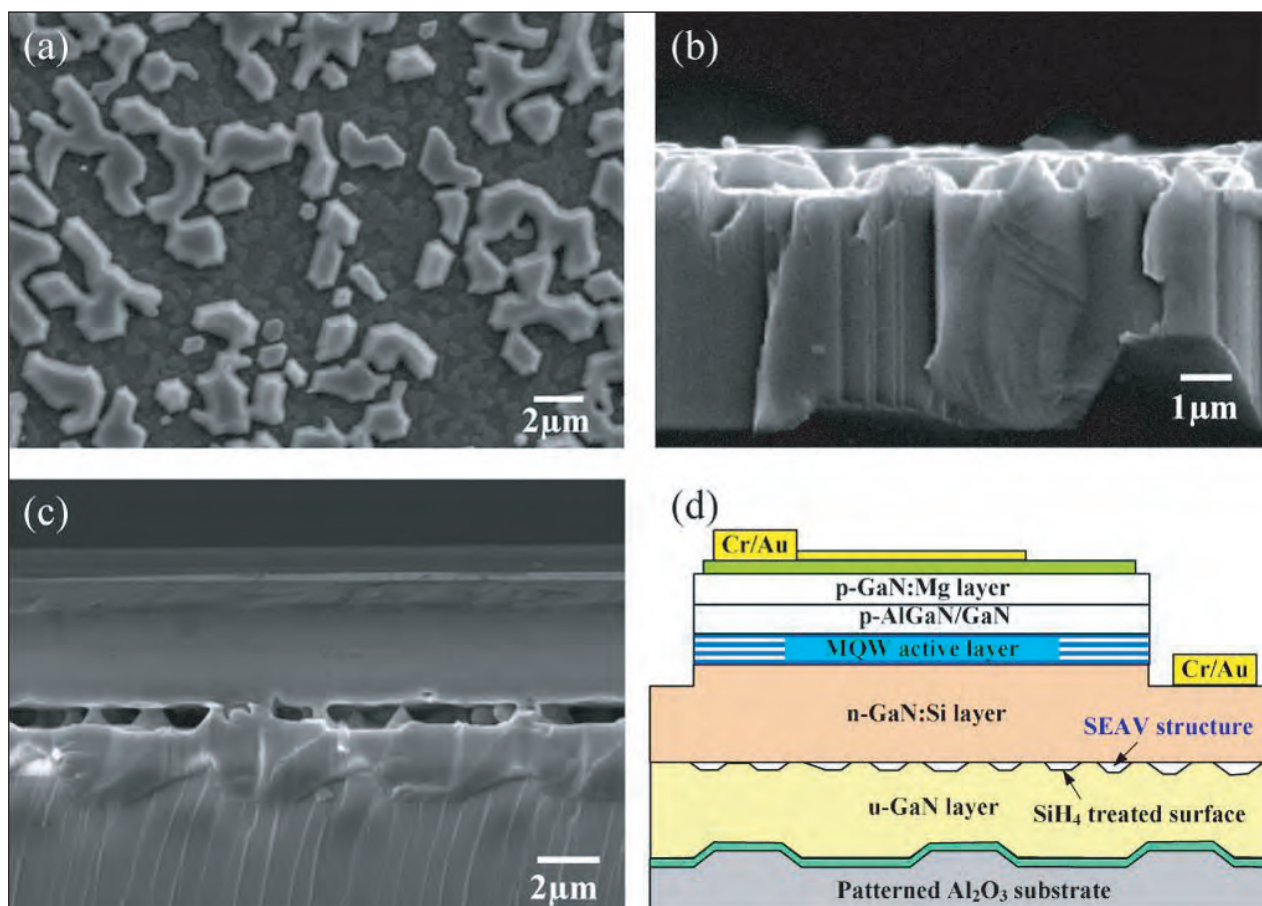


Figure 1. (a) Bird's-eye view at 45° and (b) cross-sectional SEM micrographs of u-GaN layer with random 3D island structure. (c) Series of air-voids in re-grown LED structure. (d) Schematic diagram of SA-LED.

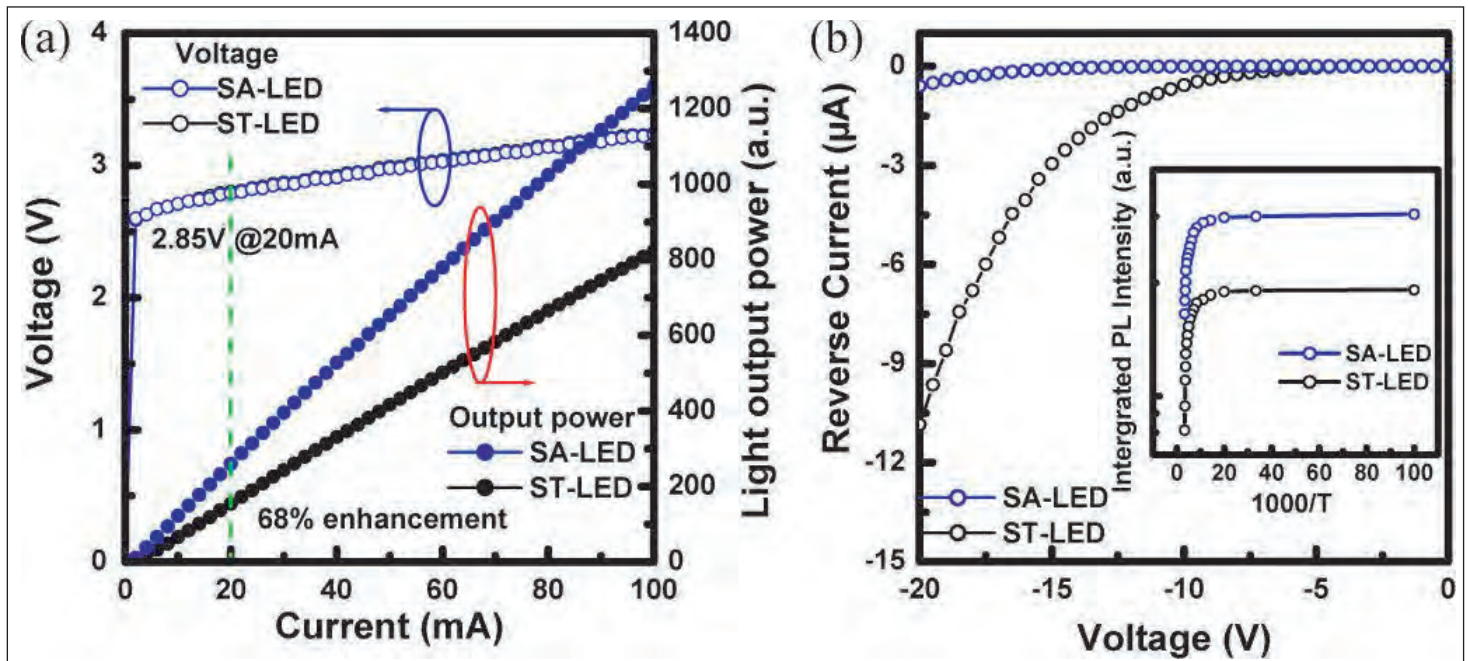


Figure 2. (a) Light output powers and operating voltages for ST-LED and SA-LED with varying injection current. (b) Reverse-bias current vs voltage (I - V) characteristics of ST-LED and SA-LED. Inset: IQEs of both LEDs measured through temperature-dependent PL.

further growth on the sidewalls of the islands. During the treatment the temperature was ramped up to 1180°C. Further n-GaN was then grown on the island base that coalesced in a manner rather similar to epitaxial lateral overgrowth (ELOG), but without using a mask. The researchers refer to their 'series-of-air-voids' (SEAV) process as being an in-situ ELOG process. The air-voids form in the spaces between the islands (Figure 1c).

X-ray diffraction and etch-pit analyses of the n-GaN material showed improved quality with silane treatment. The diffraction peaks for the (002) and (102) planes of material with silane treatment had rocking curve full-widths-at-half-maximum (FWHM) of 280 arcsec and 225 arcsec, respectively. The corresponding values for material grown without the silane treatment were 405 arcsec and 340 arcsec, indicating lower crystalline quality.

The etch-pit densities were $7.6 \times 10^7/\text{cm}^2$ with silane treatment and almost an order of magnitude larger at $6.5 \times 10^8/\text{cm}^2$ without. Low etch-pit densities are associated with lower amounts of threading dislocations (TDs) and defects that reduce LED performance.

The researchers conclude that the SEAV process "acted as a TD-stopping structure to reduce the defect density in the SA-LED structure."

The indium gallium nitride active region consisted of a 9-period $\text{In}_{0.2}\text{Ga}_{0.8}\text{N}/\text{In}_{0.01}\text{Ga}_{0.99}\text{N}$ (3nm/13nm) multi-quantum well (MQW). The electron-blocking layer was also a superlattice (of aluminium gallium nitride) with a 6-period p-type $\text{Al}_{0.3}\text{Ga}_{0.7}\text{N}/\text{GaN}$ (2nm/2nm) structure. The p-contact layer was 0.13μm of p-GaN.

Along with the SEAV LED (SA-LED), a comparison

standard nitride semiconductor LED device (ST-LED), without the silane treatment, was also produced.

The epitaxial material was processed into LEDs with 250nm of indium tin oxide (ITO) transparent conductor on the p-contact, and chromium/gold (Cr/Au) n- and p-type metal contacts.

The SEAV LED showed a 68% enhancement in light output at 20mA compared with the standard LED (Figure 2). The enhancement was attributed to both improved quality of the epitaxial material and light scattering encouraged by the air-voids that increases light extraction over that obtained from flat surfaces, which suffer from light trapping due to the small escape cone of the GaN-air interface.

The peak wavelength at 20mA was 443nm and the forward voltage was 2.85V, with similar values for the standard device. The leakage current under -10V reverse bias was lower for the SEAV device at $3.6 \times 10^{-9}\text{A}$, compared with $5.7 \times 10^{-7}\text{A}$ for the standard LED. The lower reverse bias current is another indication of the lower defect densities of the SEAV epitaxial material.

Photoluminescence experiments showed an internal quantum efficiency (IQE) for the SEAV material of 54.6% at room temperature (300K), relative to the 10K value. The corresponding figure for the standard material was 42.4%.

The angular distribution of the emitted light was also affected by the presence of air-voids, giving a narrower divergence for the SEAV LED. ■

<http://ieeexplore.ieee.org/xpl/articleDetails.jsp?tp=&arnumber=6331507>

Author: Mike Cooke

Advances in ammonia purification

SAES Pure Gas outlines the role of improved ammonia gas purification systems in eliminating impurities and variability from nitride LED manufacturing, hence improving LED characteristics.

Light-emitting diodes (LEDs) have begun to gradually replace conventional lighting due to their improvement in light efficiency, superior lifetime, color quality, and the absence of mercury.

The epitaxial growth of gallium nitride (GaN) layers is one of the most challenging steps in the LED manufacturing process. Process gases of a defined quality and reliability are essential in order to continue improving the LED's characteristics. Gas purification is hence commonly used to eliminate variations generated by the gas source and the gas distribution system.

Improved ammonia (NH₃) purification systems have been developed to expand the range of impurities that can be eliminated. This article presents the results obtained with these new NH₃ purification systems using the most advanced analytical techniques.

Introduction

Worldwide energy consumption continues to increase due to the development of emerging economies. Despite the push in many countries for the adoption of renewable energy sources, fossil fuels are by far the primary sources for energy production. In addition to greater adoption of renewable energy sources, a way of decreasing the usage of fossil fuels is to reduce overall energy consumption. It is estimated that lighting consumes approximately 19% of the energy produced worldwide. Significant improvements in the conversion efficiency of electric energy into light will result in an overall reduction in energy usage and thus fossil fuel consumption. Newly developed LED light sources are a great advancement in this direction: the efficiency of LEDs continues to increase and they now exhibit energy consumption that is more than five times lower than the most common tungsten bulbs. The efficiency of LED lighting is also exceeding the efficiency of fluorescent tubes, with the additional advantage of not containing toxic components (such as mercury) that are dangerous for the environment.

For the reasons stated above, the process of replacing conventional light sources with LEDs has started and will almost certainly proceed at a much faster rate in the next 2 or 3 years. In certain applications, such as

the backlighting of displays, LEDs have already replaced virtually all traditional lighting.

The lifetime of LED light sources is predicted to be in the range 30,000–50,000 hours. In order to achieve this, the light source must be designed with the following characteristics: an efficient semiconductor material to convert electric energy into light, good thermal management to dissipate the heat and prevent dangerously high operating temperatures, and reliable electronics capable of lasting through countless on/off cycles. Any one of the above parameters can cause premature lamp failure if not properly addressed.

The growth of the epitaxial layers is the most critical step in the preparation of the semiconductor device. The presence of impurities during the deposition steps can alter the quality of the device by increasing the unwanted resistance effect, decreasing the conversion of the input energy into light, and reducing the expected lifetime. Utilizing the correct deposition conditions such as flow rate distribution, temperature, uniformity on the wafer and between wafers ensures good quality epitaxial layer growth. However, gas purity is still essential to minimize defects. In consideration of the above, gas purifiers for N₂, H₂ and NH₃ are normally used in the metal-organic chemical vapor deposition (MOCVD) process not only to minimize the impurity content but also to eliminate the variability between batches of gases, thereby improving the reliability of the final product.

Ammonia purification

NH₃ is the precursor used for the deposition of the GaN layers by MOCVD. Typical specifications for NH₃ purifiers require the removal of oxygen-containing impurities such as oxygen and moisture. Other impurities such as hydrocarbons and metal contaminants can also be present in NH₃, with detrimental effects on the final product.

Since NH₃ is not an inert gas and interacts with the purifier media, the characterization of the purification media must be performed in NH₃ and not in inert gases to avoid incorrectly estimating the capacity of the purifier to remove impurities. However, to avoid high NH₃ consumption and safety-related problems, the correct purifier functionality can be carried out in N₂ instead of

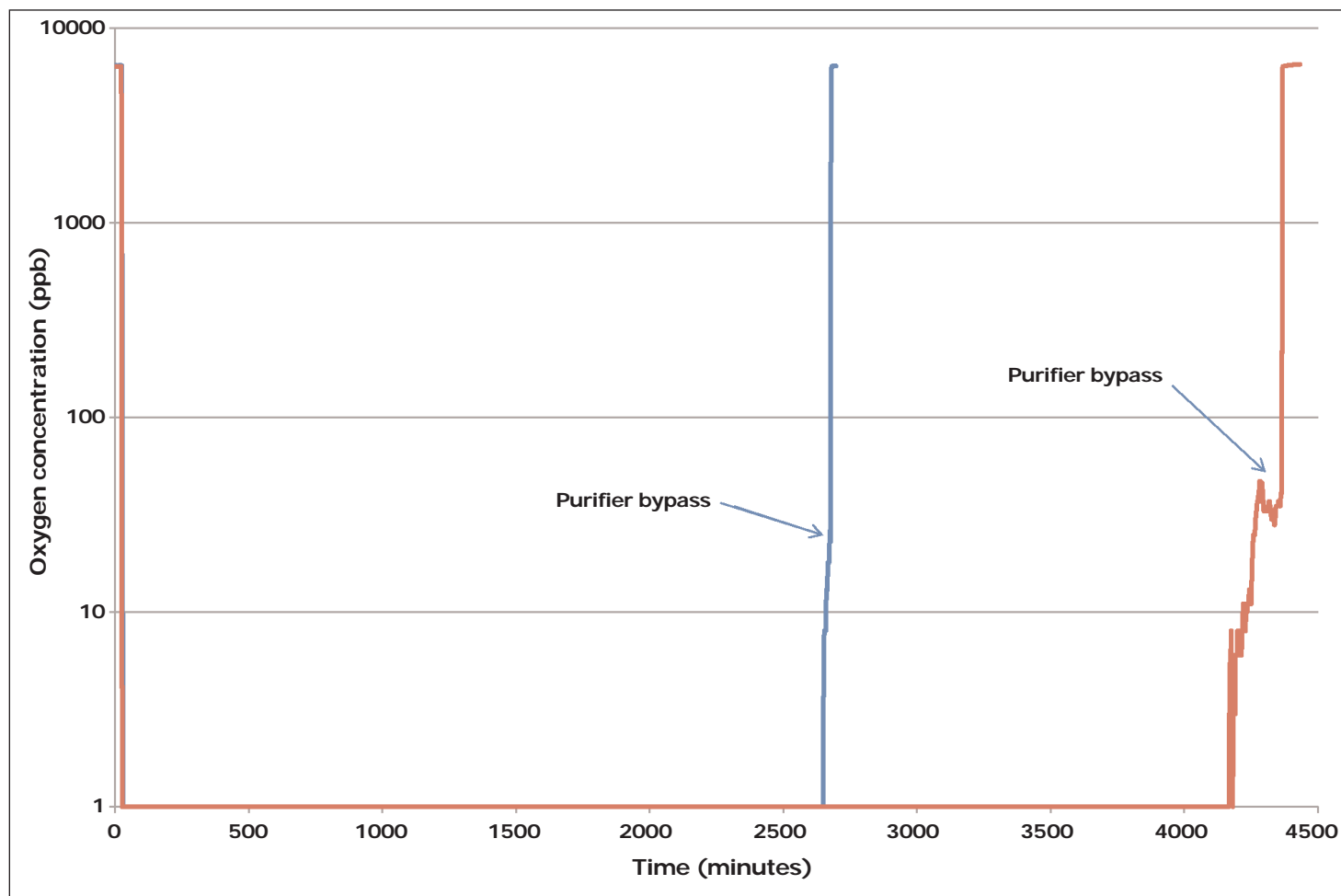


Figure 1, O₂ breakthrough curves in NH₃ for two different NH₃ flow rates and 6ppmV inlet O₂.

NH₃ while still resulting in the same kind of reliability. Testing of the gas line integrity, valve and heater operation, and system dry-down have the same value if carried out in N₂ rather than in NH₃.

This work describes the study of an NH₃ purifier focusing not only on its oxygen and moisture capacity but also on other contaminants that could potentially be present in NH₃. For oxygen and moisture analysis in NH₃, state-of-the-art analyzers like the Delta F DF-740 with a 10ppbV detection limit for water vapor in NH₃ and a Teledyne Ultra Trace 3000 Micro Fuel Cell analyzer — also with 10 part-per-billion (ppbV) detection limit for oxygen in NH₃ — allows real-time measurements of these impurities. In order to measure organic and metal contaminants it is necessary to use a sampling technique to collect and concentrate the impurities to be able to quantify them at a low concentration. Metallic impurities are detected by collecting the metallic compounds with deionized water impingers then analyzing the resulting solution by using inductively coupled plasma mass spectrometry (ICP-MS). Organic contaminants were analyzed by means of a CollectTorr sampling system, which concentrates the organic impurities onto a high surface media, which is then analyzed by thermal desorption gas chromatography mass spectrometry (TD-GC-MS).

The CollectTorr sampling system, which is based on solid sorption material, is also suitable to analyze NH₃ organic contamination in the field. The procedure for sample collection is very straightforward and does not require personnel from the analysis laboratory to be present for sample collection. Once the sample is collected it will then be analyzed in a controlled laboratory environment. The CollectTorr is a suitable and simple way to verify organic contamination in NH₃ used for LED manufacturing.

Results

To limit the amount of NH₃ required for the purifier evaluation, a scaled-down version of an actual purifier was used. The sample of the purification media was tested by flowing purified NH₃ through the unit with the addition of 6 part-per-million (ppmV) of oxygen and 2.5ppmV of moisture. The levels of the impurities used during this testing are higher than those seen in typical NH₃ to avoid carrying out excessively long tests. Figures 1 and 2 show breakthrough curves for oxygen and water vapor, respectively, at two different flow rates. As soon as the purifier is on line, the impurity levels drop down to the detection limit of the analyzers. Once the impurities progressively fill up the capacity of the purification media they start appearing at the purifier outlet. In this way it is possible to know, with a good

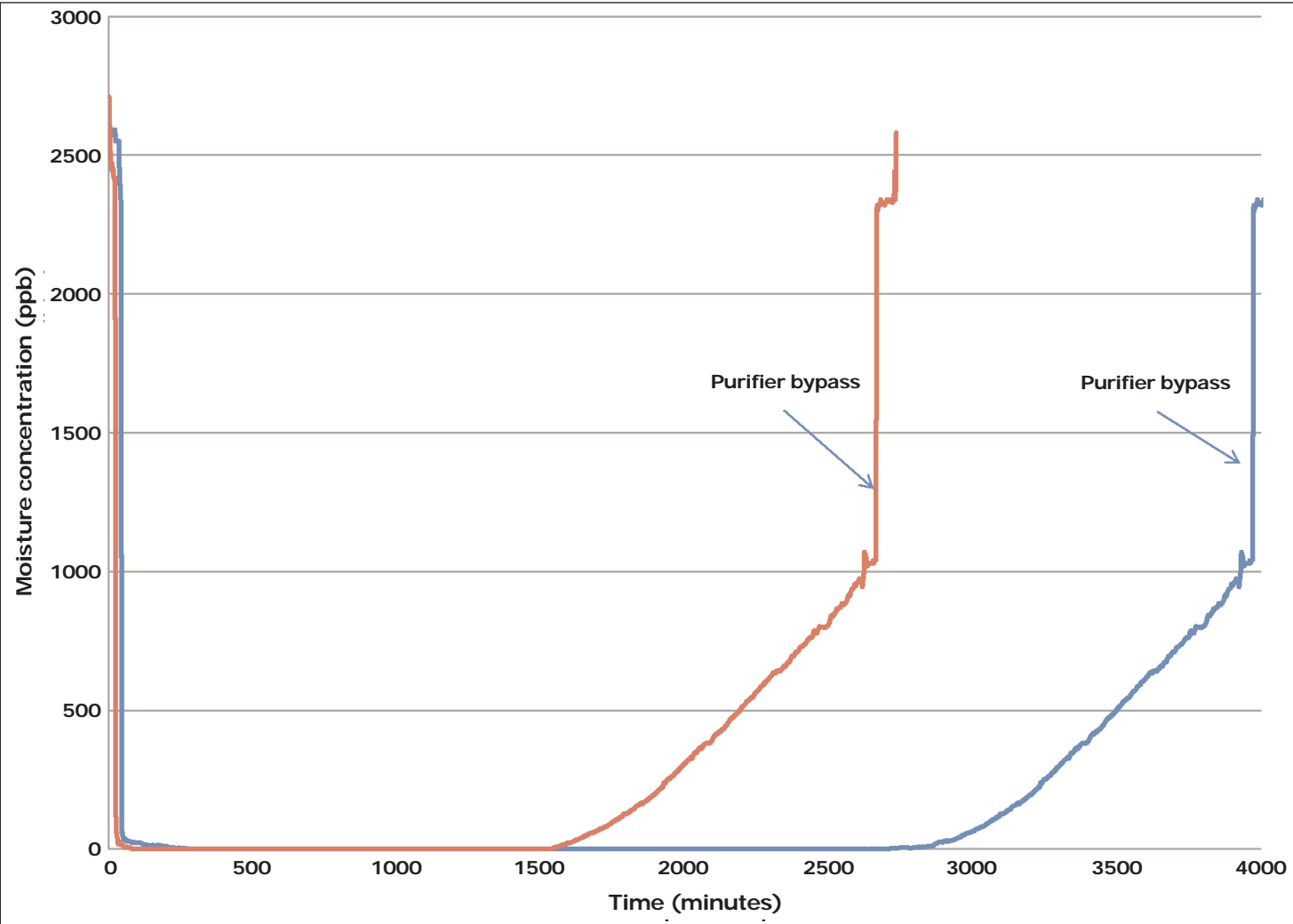


Figure 2. H₂O breakthrough curves in NH₃ for two different NH₃ flow rates and 2.5ppmV inlet H₂O.

degree of accuracy, the quantity of NH₃ that can be purified before regenerating the purification media.

Since the generation of organic compounds is not as easy as the introduction of oxygen and moisture, a sample of low-quality NH₃ was used for evaluating the removal of organic contamination. In this test the purifier was challenged with the ‘dirty’ NH₃ and the level of contamination of the organic compounds was monitored by means of the CollectTorr sampling system and subsequent TD-GC-MS analysis. Simultaneously, a second CollectTorr sampler was used to collect the organic contamination seen in the unpurified NH₃ gas. Figure 3 shows a direct comparison of the results and how efficiently the purifier can eliminate the organic contamination.

A similar test was carried out to monitor metals removal. The CollectTorr sampling system was replaced by liquid impingers containing deionized water. Table 1 compares the metal contents at the inlet and outlet of the purifier. Although the inlet concentration of

the metal contaminants was already quite low, the purifier was able to fully eliminate the measured metals. In addition, the test clearly proved that the reaction between NH₃ and the purification media does not generate any additional metallic contamination.

While it is extremely difficult to correlate the impact of the concentration of an impurity with the quality of the LED epitaxial layers due to the multiple parameters that can affect the epilayers, it is certainly true that the use of a reliable and clean gas can eliminate one of the many variables that could deplete epitaxial layer quality. The

Table 1. Metallic impurities measured in both unpurified and purified NH₃. The following metals were not detected in either sample: Sb, As, Ba, Be, B, Cd, Cr, Co, Cu, Ga, Ge, Au, Fe, Pb, Li, Mg, Mn, Mo, Ni, K, Ag, Sr, Ti, V, and Zr.

Parameter	RL	Units	Purified NH ₃ gas	Unpurified NH ₃ gas
Aluminum (Al)	0.05	ppb	*	0.42
Calcium (Ca)	0.1	ppb	*	0.3
Sodium (Na)	0.05	ppb	*	0.18
Tin (Sn)	0.01	ppb	*	0.05
Zinc (Zn)	0.05	ppb	*	0.14

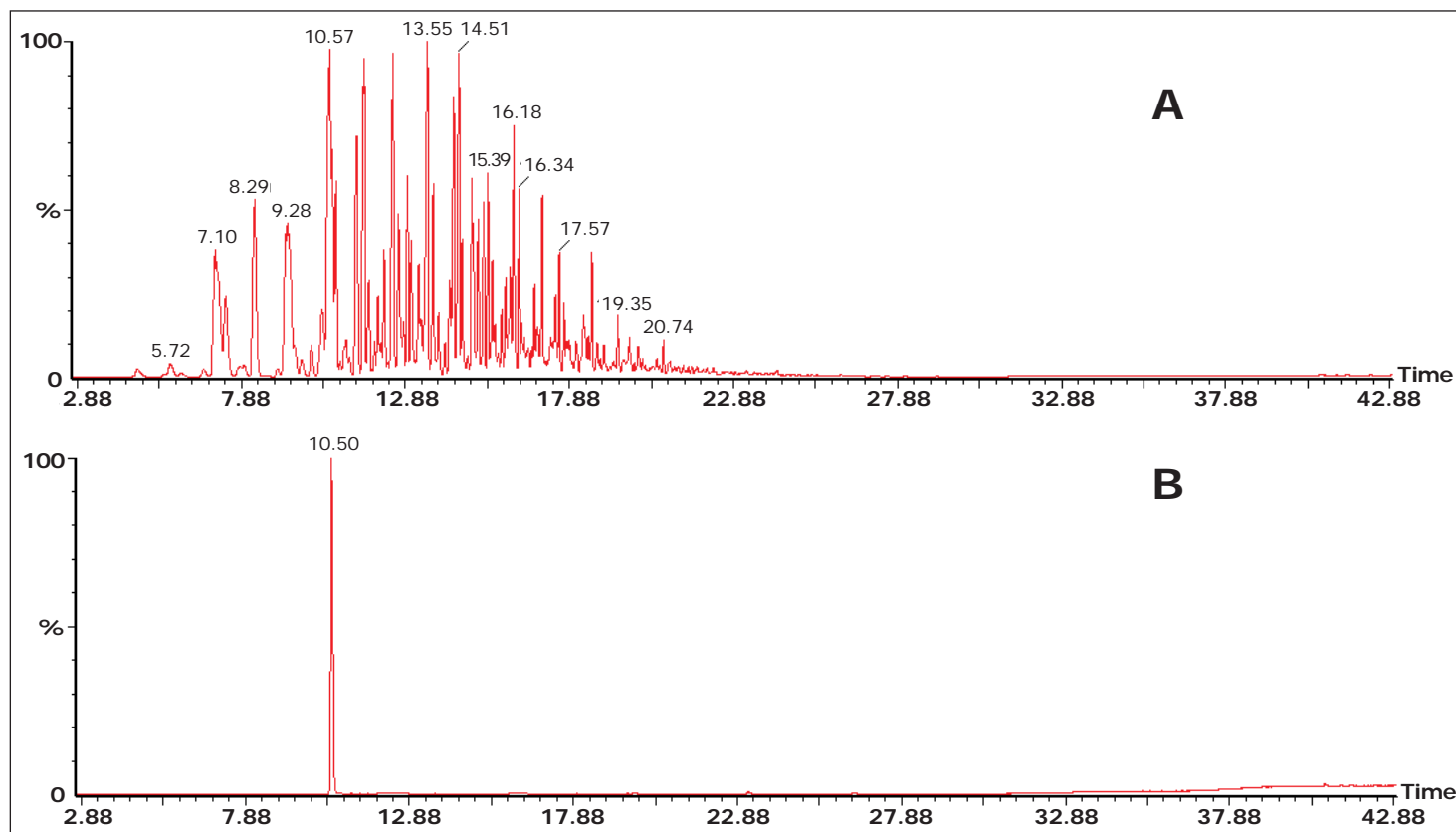


Figure 3. Hydrocarbon levels before (A) and after (B) the purifier. A total of 45ppbV hydrocarbon contamination was observed in the unpurified NH_3 . The large peak present in the chromatogram of the purified NH_3 is due to the internal standard toluene-d8.

wider the range of impurities that are removed and controlled by the purifier, the lower the risk is for introducing uncontrolled contamination into the LED process chamber.

Purifier considerations

The purification media can be packaged into point-of-use purifiers, normally used on board or at the proximity of the MOCVD tools, or into regenerable purifiers that can supply the NH_3 required for many tools. An example of a regenerable purifier is shown in Figure 4.

While the lifetime of the point-of-use purifiers depends on the impurity loading and the actual flow rate passing through the purifier, the regenerable purifier has a theoretical indefinite lifetime because the purification medium is periodically regenerated. The use of regenerable purifiers leaves open the possibility for the user to use a lower grade of NH_3 without compromising the NH_3 purity at the point of use, thus reducing the cost of ownership.

Conclusions

The introduction of LEDs is expected to dramatically change the type of light sources over the next few years, with a resulting decrease in the worldwide energy consumption used for lighting. The ramp up of LED manufacturing must also be coupled with a reduction in production cost in order to be price competitive with the present light sources. It is expected that LED manufac-

turing will follow a path similar to the one seen by the more mature silicon industry, where the adoption of large-scale gas purifiers has enhanced the reproducibility and reliability of production as well as reduced the cost. The expected growth in LED markets will further increase the need for NH_3 of high purity. Thus it is critical to provide the market with purifiers capable of removing the widest range of impurities. ■



Figure 4. Regenerable NH_3 purifier.

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First submicron AlGaN/GaN HEMTs on 8-inch silicon

Results show feasibility of device-quality structures with greater economy of scale.

Singapore researchers report “for the first time” the DC and microwave characteristics of submicron-gate aluminium gallium nitride on gallium nitride (AlGaN/GaN) high-electron-mobility transistors (HEMTs) on 8-inch (200mm) diameter Si(111) substrate [Subramaniam Arulkumaran et al, Jpn. J. Appl. Phys., vol51, p111001, 2012]. The researchers are at Nanyang Technological University, Institute of Materials Research and Engineering, and Institute of Microelectronics.

“Our results show the feasibility of achieving device-quality AlGaN/GaN HEMT structure on 8-inch diameter Si(111) for low-cost high-frequency and high-power switching applications,” the researchers write.

Nitride semiconductor devices have been recently developed for high-frequency and switching power

applications, based on these materials’ high saturation velocity at high electric field, high breakdown electric field, and high electron mobility.

The development of nitride semiconductor transistors on silicon substrates is widely seen as a way to lower production costs through using less expensive material and through economies of scale. In particular, silicon is much less expensive than silicon carbide (SiC) and, further, is available in larger-diameter substrates.

Although sapphire is lower cost than silicon carbide and is more established for growing nitride semiconductors for LEDs, it is a poor thermal conductor, making it less attractive for power applications.

AlGaN/GaN HEMTs grown on 200mm substrates are particularly attractive since there are many 200mm

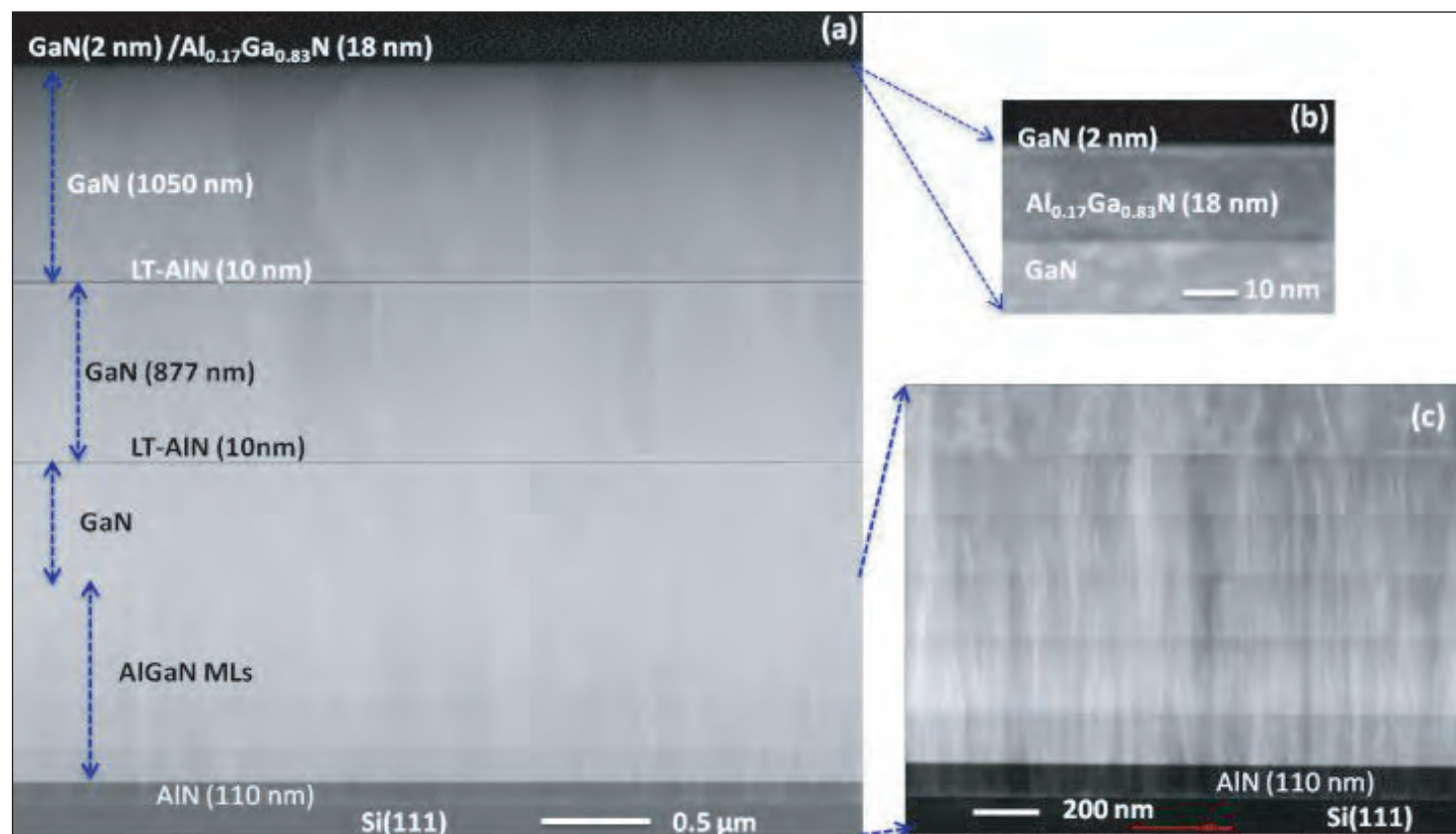


Figure 1. (a) Typical cross-sectional high-angle annular dark-field scanning transmission electron microscopy (HAADF-STEM) image of the full HEMT structure on 8-inch diameter Si(111) substrate. (b) HAADF-STEM z-contrast image of the same sample showing GaN cap layer and AlGaN barrier layer (c) HAADF-STEM z-contrast image of the same sample showing stress mitigation layers [AlGaN multi layers (MLs) on a 110nm-thick AlN nucleation layer] on 8-inch Si(111).

silicon facilities that are underutilized with the transition to 300mm production (and 450mm being actively developed for the future).

Of course, there are challenges of growing nitrides on larger-diameter wafers, such as bowing of the substrate and resulting non-uniform material qualities.

The Singapore epitaxial material (Figure 1) was grown in a Veeco TurboDisk K465i metal-organic chemical vapor deposition (MOCVD) system. The substrate resistivity was $\sim 40\Omega\cdot\text{cm}$. The epitaxial material had mobility and sheet carrier concentrations of $1550\text{cm}^2/\text{V}\cdot\text{s}$ and $0.84\times 10^{13}/\text{cm}^2$, averaged over five samples. The average sheet resistance was less than $400\Omega/\text{square}$.

The epitaxial material was diced into small pieces before transistor processing. Mesa isolation was achieved through inductively coupled plasma etch. The ohmic contacts were titanium/aluminium/nickel/gold with a contact resistance of $1.8\Omega\cdot\text{mm}$. Mushroom-shaped Schottky gates were formed using nickel/gold with a source-gate distance of $0.8\mu\text{m}$, gate width of $2\times 25\mu\text{m}$, gate length (L_g) of $0.3\mu\text{m}$, and gate-drain distance (L_{gd}) of $1.25\mu\text{m}$. The gates of separate transistors were separated by $12\mu\text{m}$.

The maximum drain current was $853\text{mA}/\text{mm}$. The peak intrinsic transconductance of $180\text{mS}/\text{mm}$ occurred at -2.3V gate potential and 10V drain bias. The threshold voltage was -3.8V .

Microwave performance was tested on $0.3\mu\text{m}$ gate-length devices with $2\mu\text{m}$ L_{gd} and $2\times 75\mu\text{m}$ gate width. The unit current gain cut-off frequency (f_T) was 28GHz and the maximum oscillation frequency (f_{max}) was 64GHz , for 10V drain and -2.4V gate. The cut-off-gate-length product ($f_T\times L_g$) was $8.4\text{GHz}\cdot\mu\text{m}$, a value comparable with that achieved on smaller-diameter silicon substrates.

The researchers comment: "The observed $f_{\text{max}}/f_T > 2$ to 2.66 is due to the occurrence of good-quality buffer GaN with low buffer leakage current ($4.8\times 10^{-3}\text{mA}/\text{mm}$ at 100V)."

At a bias of 100V , the on/off ratio was 1.36×10^5 , according to channel and buffer-leakage current measurements. Devices with $0.3\mu\text{m}$ gate length (L_g) and $2\mu\text{m}$ gate-drain separation (L_{gd}) showed gate-drain breakdown (BV_{gd}) of 60V with a $0.5\text{mA}/\text{mm}$ current. Devices with $2\mu\text{m}$ gate length and $6\mu\text{m}$ gate-drain separation had increased breakdown performance, with BV_{gd} at 188V . Buffer breakdown occurred in the long-gate device at 192V . A rough indication of the breakdown field is given by BV_{gd}/L_{gd} , which is $\sim 0.3\text{MV}/\text{cm}$ for both devices.

The researchers see the breakdown performance as being limited by GaN buffer thickness and crystalline quality. ■

<http://jjap.jsap.jp/link?JJAP/51/111001>

Author: Mike Cooke

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Growing high-mobility transistors directly on silicon

Maximum drain current of over 2A/mm achieved at drain bias of 0.6V.

Hong Kong University of Science and Technology (HKUST) has grown high-performance indium gallium arsenide (InGaAs) metal-oxide-semiconductor high-electron-mobility transistors (MOSHEMTs) directly on silicon [Xiuju Zhou et al, Appl. Phys. Express vol5, p104201, 2012]. In particular, the maximum drain current density was more than 2A/mm at a drain bias of 0.6V. The International Technology Roadmap for Semiconductors (ITRS) made such a 2A/mm specification to meet future needs for high-performance logic.

In recent years, there has been much development of III-V high-mobility-channel transistors based on InGaAs and other compound semiconductors for use as high-speed logic in mainstream electronics systems. To be a viable future technology, such devices must be incorporated in large-scale production — and that means production on large-diameter silicon wafers.

Although much progress has been made, there is still much to be done. The best performing devices tend to be grown on indium phosphide and are grown using molecular beam epitaxy (MBE). There are techniques to transfer such devices to silicon such as wafer bonding, but a preferable approach would be to grow these

devices directly on silicon. Further, manufacturers would prefer more cost-effective growth techniques such as metal-organic chemical vapor deposition (MOCVD).

HKUST device fabrication began with epitaxial growth on 4" exact-oriented (001) silicon using MOCVD in an Aixtron 200/4 system (Figure 1). The (001) silicon crystal orientation is preferred for CMOS production.

The HKUST epitaxial structure was designed to have an inverted-type InGaAs channel sandwiched between InAlAs cap and spacer layers with the peak of the electron carrier distribution nearer the channel/spacer interface. Hall measurements of the material gave a mobility of 4100cm²/V-s, carrier density of 4.02x10¹²/cm², and sheet resistance of 379Ω/square.

The source/drain regions were re-grown using a self-aligned process. Such re-growth should improve the access resistance of the connection between the source/drain metal terminals and the transistor channel.

Silicon dioxide was used as passivation and re-growth mask. The mask was patterned with a buffered oxide etch and then the source/drain recess down to the InGaAs channel layer was formed using phosphoric acid/hydrogen peroxide solution in water. The recess-

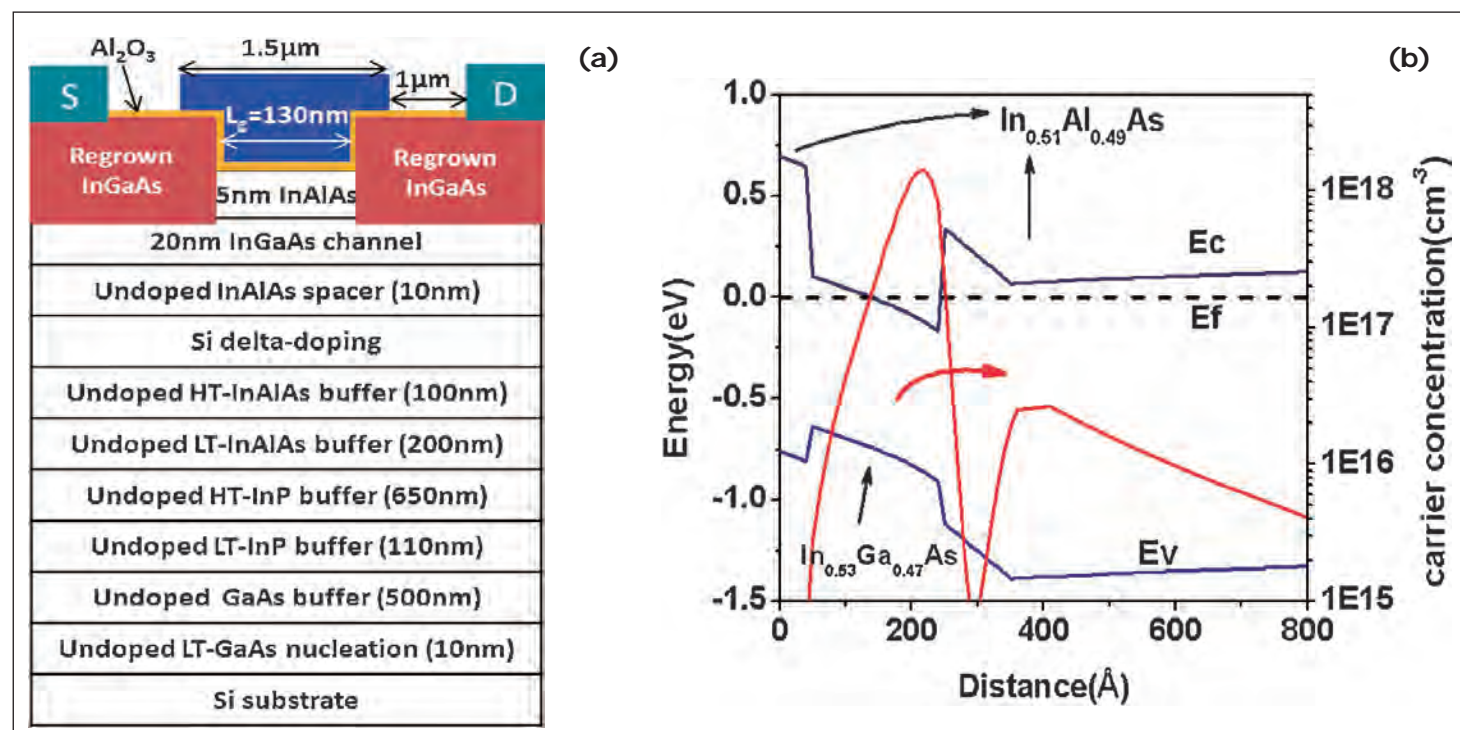


Figure 1. Schematic cross section of finished device (LT: low temperature, HT: high temperature; figure is not drawn to scale). (b) Simulation of band structure and carrier distribution of InAlAs/InGaAs heterostructure.

ing removed all the top InAlAs layer and 10nm of the InGaAs channel in the source/drain regions. The re-growth of silicon-doped n-InGaAs was by MOCVD.

The transistor fabrication began with buffered oxide etch to remove the silicon dioxide mask and wet etch down to the InAlAs layer for mesa isolation. The gate region was subjected to a pre-treatment with tri-methyl-aluminium (TMA) in an Oxford Instruments OpAL atomic layer deposition (ALD) tool. The pre-treatment was designed to provide passivation for improving the gate dielectric/III-V semiconductor interface. The gate dielectric of aluminium oxide was deposited using ALD, followed by annealing at 380°C.

The ohmic source/drain contacts were nickel/germanium/gold/nickel/germanium/gold. The gate metal stack was titanium/platinum/gold. The channel length of the resulting device was 130nm. Gate width was 9.57µm.

The maximum drain current was 2.03A/mm with a gate potential of 2V and a drain bias of 0.6V (Figure 2). Under the same bias conditions, the gate leakage was more than six orders of magnitude smaller, at 6.17×10^{-7} A/mm. A peak extrinsic transconductance of 744mS/mm was achieved at 0.5V drain. The threshold voltage was negative at -2.9V, indicating undesired 'normally-on' or 'depletion mode' behavior. The on-resistance of $163 \Omega\text{-}\mu\text{m}$ is considered 'ultra-low' and is attributed to the "raised S/D with high doping level".

These results are comparable with the best results for devices grown on InP (Table 1). The researchers comment: "Although the devices reported in this work were metamorphically grown on Si substrates, which inevitably have more dislocations in the active layers and rougher surface than lattice-matched ones on InP substrates, they still exhibit attractive current drivability and low R_{on} ."

The researchers attribute the results to the high-quality metamorphic growth of InP on silicon substrates and to the selective re-growth of the source/drain regions.

The subthreshold performance was not as low as desired for applications. The subthreshold slope of 263mV/dec at 50mV drain is more than twice that obtained by other groups developing InGaAs channel devices and far off the theoretical ideal of ~60mV/dec. "The current SS and large gate bias swing are believed to be limited by the capacitance equivalent thickness (CET) arising from the thick Al_2O_3 gate dielectric and InGaAs channel," the researchers say. "More efforts are required to improve gate electrostatic control over the channel."

The effective mobility of a 1.2µm channel device was also evaluated, showing a peak at $2975 \text{ cm}^2/\text{V}\cdot\text{s}$. ■

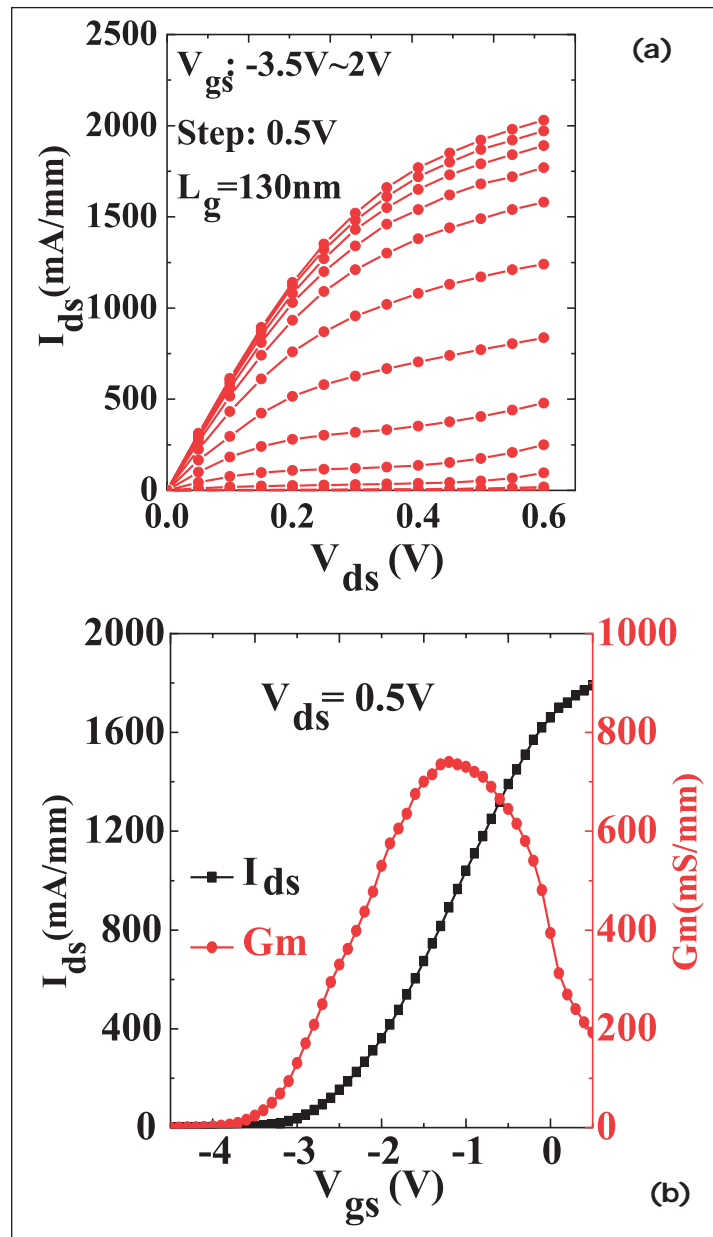


Figure 2. (a) Output characteristic of device with 130nm channel. (b) Transfer characteristics of device with 130nm channel at 0.5V drain.

Table 1. On-resistance (R_{on}) and on-current (I_{ds}) at 0.5V drain bias for InGaAs-channel FETs (D: depletion, E: enhancement, R: reference).

Ref.	Gate/channel (nm)	Substrate	Mode	Oxide	I_{ds} (mA/mm)	R_{on} ($\Omega\text{-}\mu\text{m}$)
14	160	InP	E	Al_2O_3	467	1071
15	1000	InP	E	$\text{Y}_2\text{O}_3/\text{Al}_2\text{O}_3$	555	938
16	200	InP	E	Al_2O_3	437	737
17	100	InP	D	Al_2O_3	944	496
18	50	InP	D	Al_2O_3	2400	160
19	55	InP	E	$\text{Al}_2\text{O}_3/\text{HfO}_2$	1756	199
20	60	InP	D	Al_2O_3	978	341
HKUST	130	Si	D	Al_2O_3	1920	163

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Author: Mike Cooke

Powering up with silicon carbide

Silicon carbide promises power devices with superior performance, but can it deliver commercial product at the right price? [Mike Cooke](#) reports.

A number of companies are hoping that the superior properties of silicon carbide (SiC) will make device production competitive over silicon (Table 1). However, despite significant progress in working the material, costs are still high. Not only does SiC have to compete with silicon-based devices, more recently there has been gallium nitride (GaN) to contend with. Like SiC, GaN is a wide-bandgap material.

Wide-bandgap materials tend to have high critical fields for breakdown and also can be used at higher temperatures than normal for traditional silicon-based semiconductor devices. Other attractive features of SiC-based devices, compared with silicon, include lower specific on-resistance, faster switching speeds, and higher thermal conductivity.

Use of SiC can lead to devices with reduced power losses. This, possibly combined with higher-temperature operation, reduces or even eliminates the need for cooling equipment, creating opportunities for complete system downsizing and the lightening of electronic components for automotive and industrial uses. The higher thermal conductivity allows any heat generated to be dissipated more easily.

US defense organizations, such as the Defense Advanced Research Projects Agency (DARPA), the Office of Naval Research (ONR) and the US Air Force have been particularly keen contributors to research on SiC (and GaN). The US Navy and Air Force are attracted by the prospect of reduced size for power distribution in confined spaces and in applications where there are strict weight budgets.

Table 1. Some typical material properties.				
	Si	SiC-4H	SiC-3C	GaN
Bandgap (eV)	1.1	3.2	2.4	3.4
Critical field (10 ⁶ V/cm)	.3	3	1.3	3.5
Electron mobility (cm ² /V-s)	1450	900	380	2000
Electron saturation velocity (10 ⁶ cm/s)	10	22	20	25
Thermal conductivity (Watts/cm ² -K)	1.5	5	3.6	1.3

In June, US market researcher MarketsandMarkets reported its expectations for the SiC semiconductor device market as having an expected compound annual growth rate (CAGR) of 37.67% between 2012 and 2022. This is calculated based on a 2012 revenue figure of \$218m, which is expected to reach \$5.34bn in 2022. The 2012 total power semiconductor device market is estimated at \$34bn.

Another economic analysis from IMS Research suggests that the combined SiC and GaN market could be more than \$3bn by 2021, giving it a 9% slice of the total. IMS also sees the market for next year reaching \$250m, with SiC Schottky diodes making up just over half the sales. The main use for these power devices is

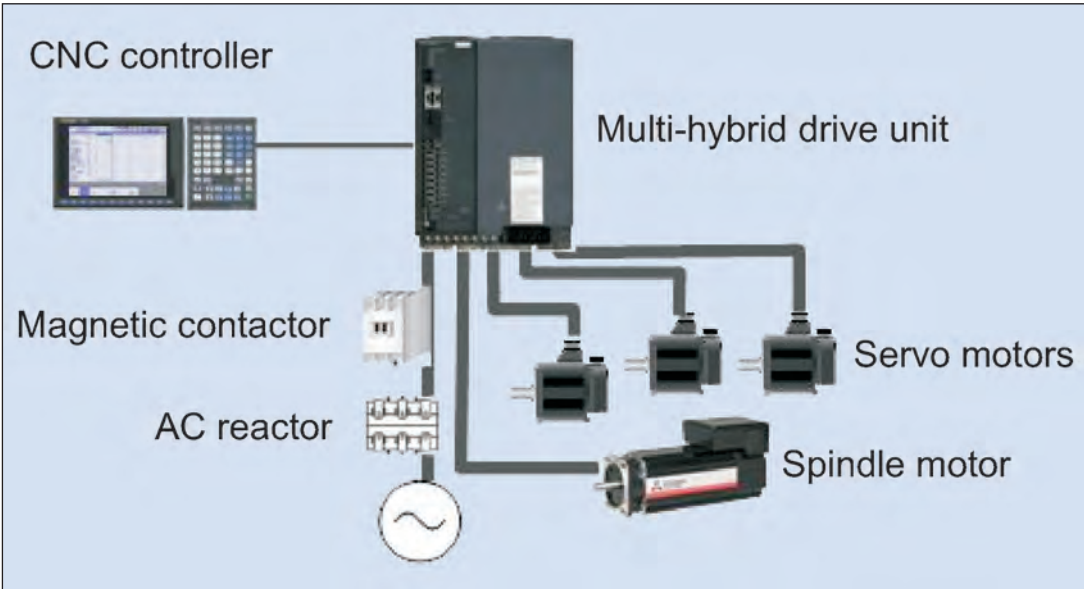


Figure 1. Numerical control system configuration with a Mitsubishi MDS-DM2-SPHV3-20080 module.

likely to be in AC–DC power supplies with power factor correction (PFC).

A more negative signal for SiC market prospects came in October 2012 with news of the probable closure of the company SemiSouth Laboratories, a spin off from the silicon carbide (SiC) R&D activities at Mississippi State University (MSU).

The news has been largely based on comment in the third quarter financial report of Power Integrations, a strategic investor in SemiSouth: in detail, Power Integrations made a pre-tax charge of \$59.2m to cover the likely closure of SemiSouth. Power Integrations made more than one capital investment in SemiSouth for the purchase of tools, etc.

MSU retains some legal rights over certain assets. At the time of writing, SemiSouth had not filed for bankruptcy.

To give an impression of what companies are doing, here we give a review of some recent announcements and SiC product portfolios and applications.

Mitsubishi Electric has made a number of announcements of SiC-based products. The latest is a drive unit for use with computerized numerical controllers (CNCs), as used in automated machine tools. Sales of the product are to begin in early December 2012.

The SiC-based Mitsubishi MDS-DM2-SPHV3-20080 module mediates between the control signals of the CNC and the varying power requirements of spindle and servo motors (Figure 1). The device is described as being “a multi-hybrid, multi-axis integrated-drive unit for drive control of spindle and servo motors”.

The module contains SiC Schottky-barrier diodes (SBDs) that allow higher-speed switching than silicon-based components. In certain conditions, the spindle motor speed can be double that of Mitsubishi’s previous drive unit. Reduced power losses allow up to 15% increase in spindle torque. The device also includes power shut-off functions with reduced size and wiring.

Mitsubishi Electric has previously commercialized SiC-based power modules for inverters in air conditioners, hybrid electric vehicles, and railcars. Such devices could also find use in more general domestic appliance and industrial applications. The SiC modules on offer from Mitsubishi are either ‘hybrid’, meaning that they contain a mix of component technologies — SiC SBDs, silicon-based insulated gate bipolar transistors (IGBTs)

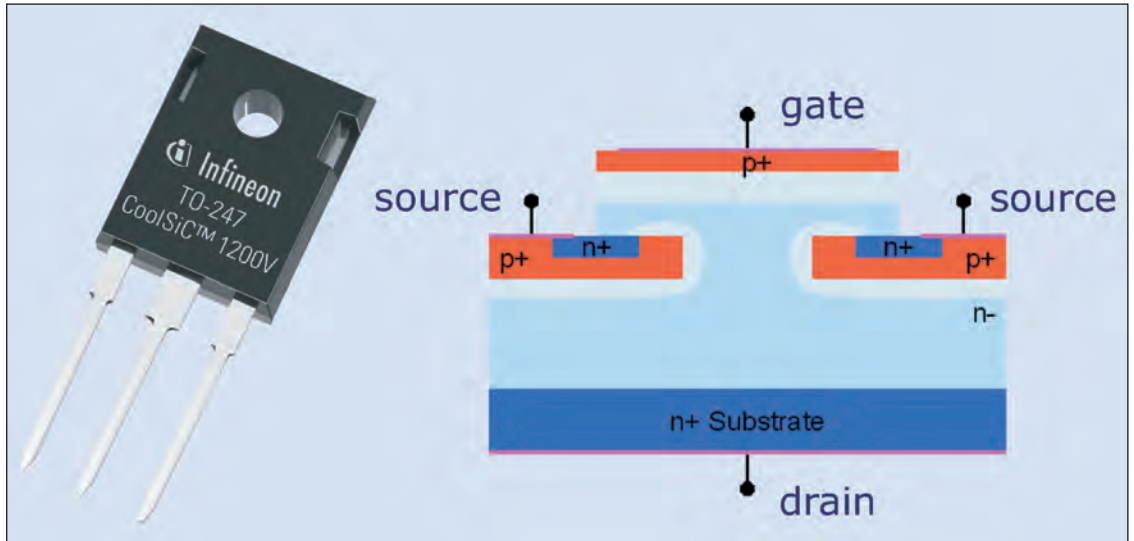


Figure 2. Infineon’s CoolSiC 1200V SiC JFET family with direct drive technology, and schematic of JFET.

etc, or ‘full’, meaning that the module contains only SiC-based components.

An example of a ‘full’ module is the prototype forced-air-cooled three-phase 400V output inverter with all-silicon carbide (SiC) power modules announced by Mitsubishi in May 2012 that boasts a power density of 50kVA per liter with 156kVA output. The aim of the prototype was to meet the needs for smaller and lighter power-electronics equipment in automotive, industrial, and other applications.

The module is rated at 1200V/300A. This was achieved by lowering the electrical resistance of the module with low-resistance wiring connecting the power semiconductor chips directly to the main terminals. The power chips also needed to be low loss, and high-speed protection circuits were used to protect the module from large destructive currents during short circuits.

Infineon markets SiC junction FET (JFET) and diode devices. The latest JFETs from Infineon form a family of 1200V-rated devices distributed under the CoolSiC trademark (Figure 2) that are aimed at replacing IGBTs in solar power inverters (DC–AC converters).

The devices use the lower switching losses of SiC-based technology to operate at high switching frequency. SiC parts allow the use of smaller passive components, resulting in overall size reduction, lower weight and reduced system cost.

The components use normally-on JFETs, so Infineon has developed what it calls ‘direct drive technology’, where the JFET is combined with an external low-voltage MOSFET and a dedicated driver IC, which ensures safe system start-up conditions as well as fast and controlled switching.

The CoolSiC JFET also includes a monolithic body diode with a switching performance comparable to that possible with external SiC Schottky devices. The



Figure 3. Cree's CAS100H12AM1 1200V, 100A SiC half-bridge module, which uses the firm's Z-FET MOSFET and Z-Rec diode parts.

company is expecting production ramp-up in first-half 2013.

The company began marketing SiC products in 2001. Infineon has also developed its fifth generation of SiC Schottky barrier diodes under the thinQ! trademark. The device is rated at 650V. These devices are designed for use in power factor correction (PFC) and boost stages for high-end server and telecom switched-mode power supply (SMPS), PC Silverbox and lighting applications, solar inverters and uninterruptible power supply (UPS) systems.

The company believes that its SiC SBDs would enable improved efficiency, along with reduced electromagnetic interference (EMI), increased system reliability and cost/size savings due to reduced cooling requirements. The company also produces IGBT power modules for various applications such as photovoltaic inverters that include SiC Schottky diodes.

Cree produces a range of MOSFETs and Schottky diodes. The company boasts that its MOSFETs are the first fully qualified, commercially available SiC power MOSFETs.

In May, the company announced a range of 50A devices, including the industry's first 1700V-rated MOSFET. The devices are available in die and packaged form for use in power modules (Figure 3) such as inverters, UPS, and motor drive units. The company believes its devices offer cost-of-ownership savings through reduced size, lower-cost bill of materials (BOM), and improved efficiency.

The higher current rating of 50A is enabled through the use of larger dies. The previous generation of Cree products was rated at 20A. Cree believes its new products will make it possible to replace conventional silicon IGBTs in high-power, high-voltage applications. Cree also produces SiC substrates and was the first to develop 75mm, 100mm and, most recently, 150mm wafers.

Raytheon has facilities in the UK (Glenrothes, Scotland) that are capable of processing 40,000 100mm SiC wafers per year. The capability is offered on a foundry basis. The company is also developing the high-temperature capabilities of SiC in a UK government research project, announced in July 2012. The aim is to overcome the present limitation of SiC devices where driver-ICs have a lower temperature rating than the high-temperature SiC components.

The new work will be based on lower-cost 3C-SiC epitaxial layers on silicon wafers. The researchers plan to develop 3C-SiC on Si hetero-epitaxy, IC processes, and the design and development of a demonstrator driver IC. However, the 3C crystal structure is not as high performance as the more common 4H material. In particular, the critical field is smaller due to the narrower bandgap. In theory, the higher cubic symmetry of 3C-SiC over the hexagonal symmetry of 4H-SiC should give it an edge in terms of mobility and saturation velocity. Such higher electron transport performance may be achieved with higher-quality material growth.

Even before the recent UK funding, the company had developed 400°C SiC transistors and 300°C SiC CMOS-based integrated circuits (Figure 4).

Microsemi offers a variety of products incorporating SiC devices including SiC Schottky diodes in industry-standard discrete packages, SiC transistors (MOSFETs and JFETs) in multi-chip power module packages, and SiC RF static induction transistor (SIT) devices aimed at UHF and L-band frequencies.

The company's most recent announcement was a range of 1200V SiC Schottky diodes for solar inverters, welding, plasma cutters, fast vehicle charging, oil exploration, and other high-power, high-voltage applications needing high power density, high performance and reliability. The devices are in production now. Microsemi adds that it is the only manufacturer to offer SiC Schottky diodes in large surface-mount backside-solderable D³ packages, enabling increased power density and lower manufacturing costs.

In 2010, the company announced RF power SiC transistors rated at up to 2200W aimed at weather radar and over-the-horizon radar using UHF pulses for military and aerospace markets. For RF power at higher frequencies (such as S-band and above) the company recently announced a GaN-on-SiC RF transistor.

Rohm claims the first mass-produced 'full SiC' power modules with the industry's most compact format and switching losses reduced by 85% compared with IGBT-based modules (Figure 5). The intended applications include industrial equipment, EVs/HVs, and solar power.

The company also offers a range of Schottky diodes and MOSFETs. The company has also worked with Kyoto University and the University of Arkansas to create an intelligent, high-temperature power module (with a junction temperature of 250°C, 150A-class).

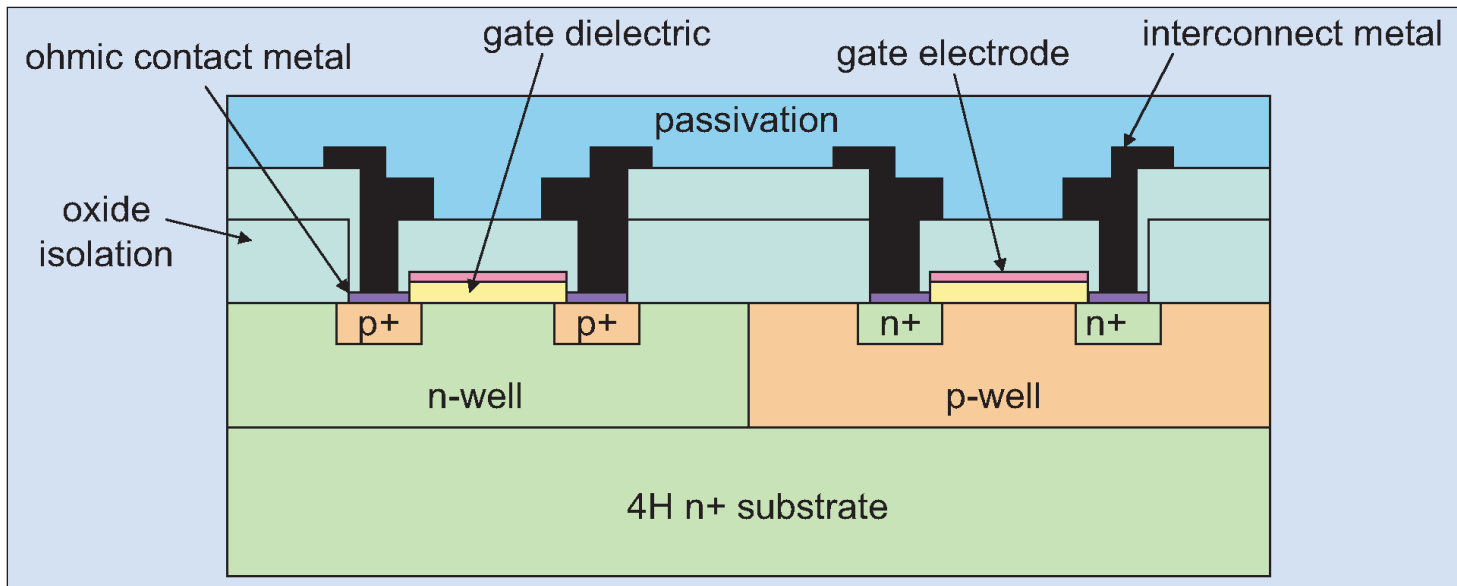


Figure 4 Raytheon's schematic cross-section for SiC CMOS.

Another product under development is a 300A trench MOSFET.

Rohm bought the SiC wafer producer SiCrystal of Germany in 2010.

Another company that is buying SiC capabilities is Fairchild, which acquired Sweden's TranSiC in April 2011. TranSiC produces bipolar junction transistors under the BitSiC tradename. TranSiC sees the advantages of its technology as being high-temperature performance up to 250°C, high efficiency, and compact size. BitSiC devices are normally-off and provide low conduction losses, low switching losses, high blocking voltage,

high operating temperatures, and high surge current capability. Among applications that TranSiC sees as advantageous for them are down-hole drilling, PV inverters, switched power, and hybrid electric vehicles.

GE Aviation and GE Global Research are developing and expanding SiC device production and GE has announced SiC-based power conversion products for air-, land- and sea-based platforms. The line includes AC-DC, DC-DC and DC-AC converters and special-purpose power supplies such as battery chargers and frequency converters. Since the company is working with US defense, some of the information about its

products can be rather sketchy. However, GE Aviation estimates that the use of SiC devices could reduce aircraft weight by more than 400 pounds (about 180kg).

Finally, STMicroelectronics has developed 1200V SiC diodes that increase inverter yields by 2%. The company is also developing MOSFETs with the aim of 50% energy savings compared with IGBT-based power systems. ■

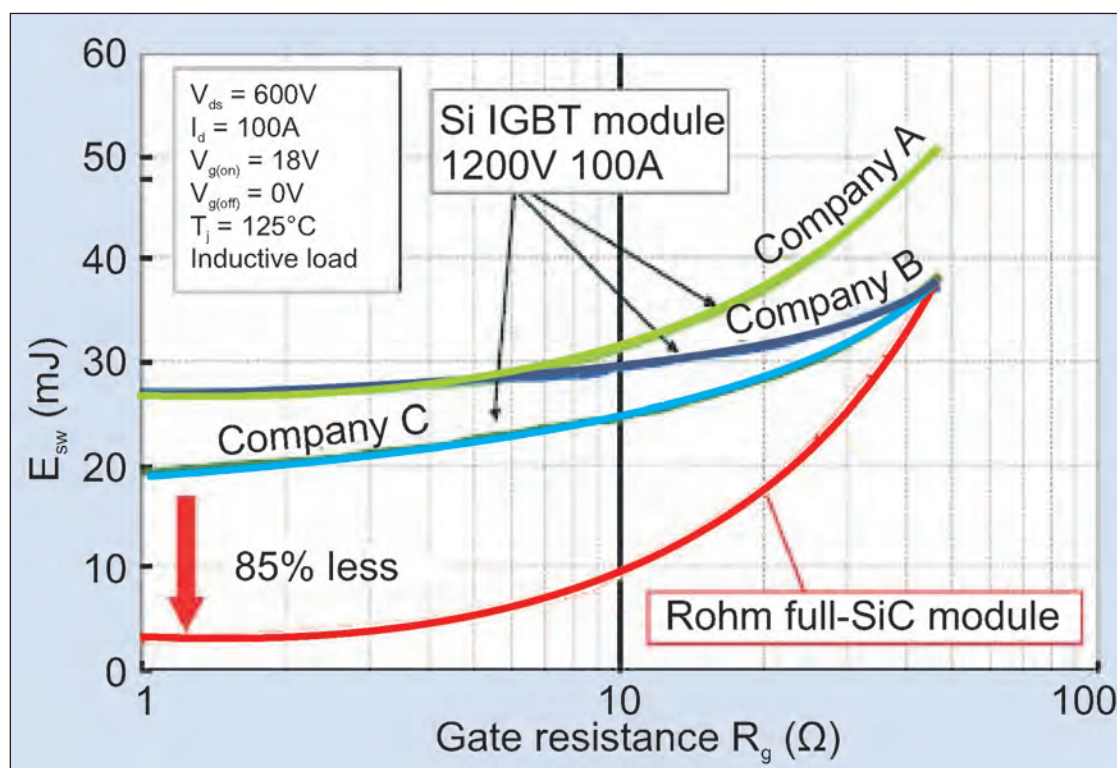


Figure 5. Comparison of Rohm full-SiC power module switching energy vs gate resistance with IGBT-based products.

Mike Cooke is a freelance technology journalist who has worked in semiconductor and advanced technology sectors since 1997.

Low noise and low power consumption with pseudomorphic HEMTs

Researchers in China show how an AlGaAs/GaAs pHEMT-based low-noise amplifier circuit has achieved the lowest power consumption while maintaining high performance.

Researchers in China have designed and constructed a two-stage 2.5–5GHz low-noise amplifier (LNA) using enhancement-mode (normally-off) aluminium gallium arsenide (AlGaAs) pseudomorphic high-electron-mobility transistors (pHEMTs) [Peng Yangyang et al, J. Semicond., vol33, p105001, 2012]. The researchers comment: “According to the author’s knowledge, this is the lowest-power-consumption LNA fabricated in 0.5μm AlGaAs/GaAs pHEMT [technology] with comparable performance.”

LNAs have many wireless applications such as radar (S-band 2–4GHz; C-band 4–8GHz), ultra-wideband data communications, and software-defined radios.

Gallium arsenide monolithic microwave integrated circuit (MMIC) technology competes against silicon technology and may soon have to seriously contend with gallium nitride (GaN) devices. Although silicon-based components can achieve cut-off frequencies up to 300GHz, GaAs technology is widely used in critical components for microwave and millimeter-wave application due to its greater reliability and high yield. GaN devices can

achieve higher gain, but at higher cost and with higher power consumption.

Zhejiang–California Nanosystems Institute and Zhejiang University jointly developed the circuit that included on-chip capacitors and inductors, and measured 1.5mm x 1mm (Figure 1). The design aimed at flat gain over a frequency range and standard 50Ω impedance matching for the input and output. A wideband matching network and a negative feedback were used to achieve the researchers’ aims of wide operation bandwidth and low noise figure.

The average small-signal gain of the circuit was 17dB with flatness of 1.6dB over the frequency range 2.5–5GHz. The input and return losses over this band

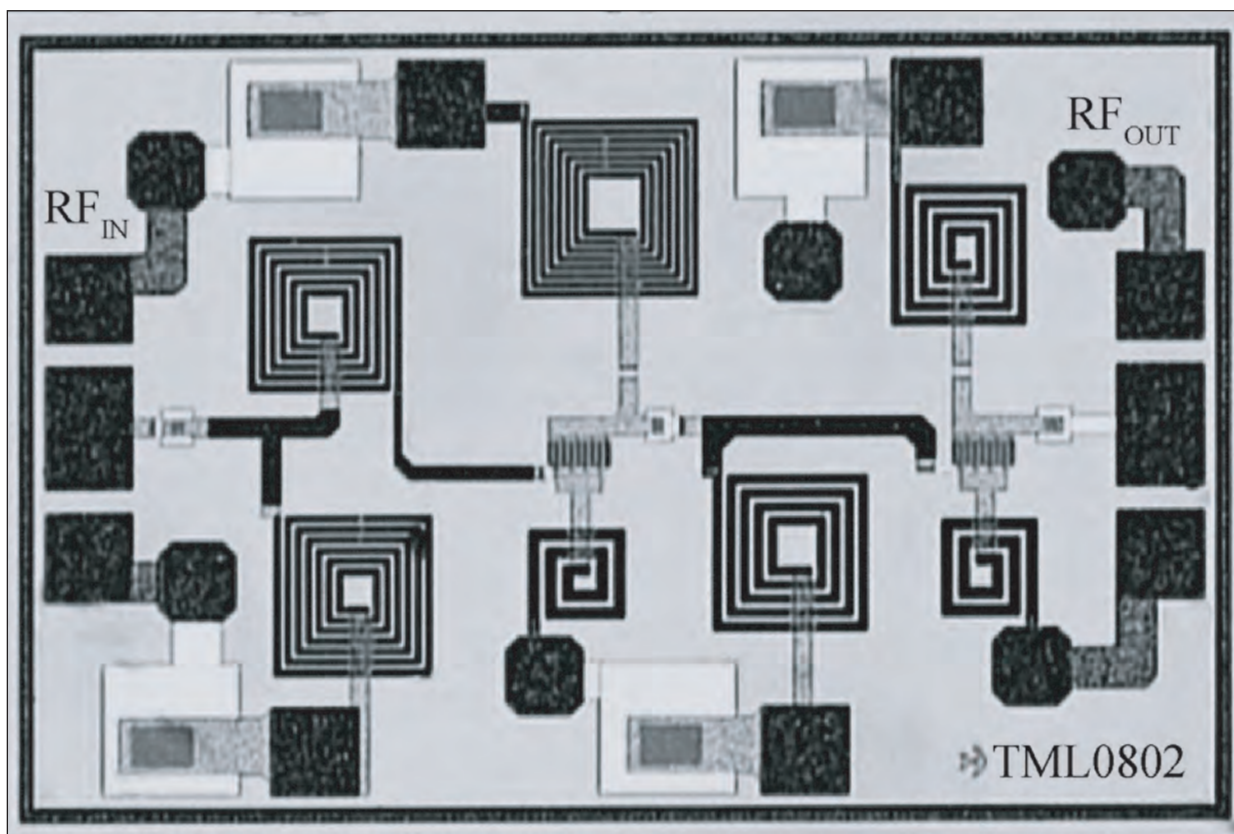


Figure 1. Chip photograph of low-noise amplifier.

were less than 10dB. The bias conditions were achieved with 1.5V power supply (V_{DD}), giving a gate bias of 0.7V and drawing a total current of 22mA (I_{DD}).

The noise figure was 2.4dB to 3dB for frequencies from 2.5GHz to 5GHz at a current bias of 33mA. From power performance measurements (Figure 2), the 1dB compression point (P_{1dB} , the power level that causes the gain to drop by 1dB from its small-signal value) was found to be 2.3dBm with total power consumption of 33mW. Another measure of non-linearity/gain compression, the third-order intercept point (IIP3), was -2dBm. ■

<http://iopscience.iop.org/1674-4926/33/10/105001>

Author: Mike Cooke

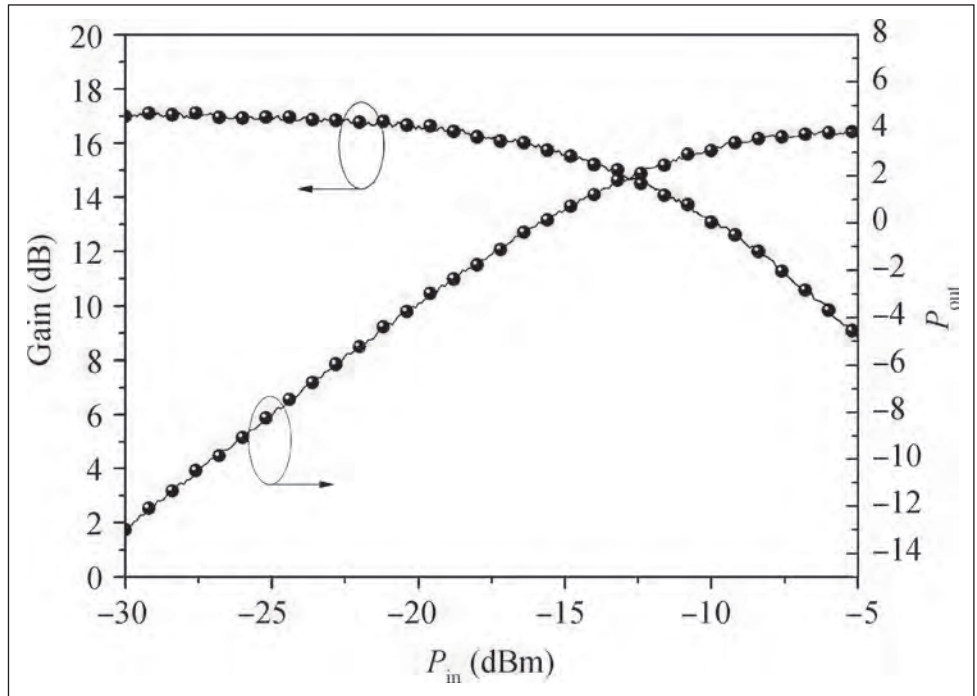


Figure 2. Power performance of the LNA at 4GHz.

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22 Used equipment

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www.ClassOneEquipment.com

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www.mw-zander.com

24 Consulting

Fishbone Consulting SARL

8 Rue de la Grange aux Moines,
78460 Choisel,
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Tel: + 33 (0)1 30 47 29 03

E-mail: jean-luc.ledys@neuf.fr

25 Resources

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Fax: +1 408 428 9600

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IEEE International Electron Devices Meeting (IEDM 2012)

Hilton San Francisco, CA, USA

E-mail: iedm@his.com

www.ieee-iedm.org

2–7 January 2013

SPIE Photonics West 2013

Moscone Center San Francisco, CA, USA

E-mail: customerservice@spie.org

<http://spie.org/photonics-west.xml>

30 January 2013 – 1 February 2013

LED Korea 2013

COEX Seoul, South Korea

E-mail: semiconkorea@semi.org

www.led-korea.org/en

30 January 2013 – 1 February 2013

SEMICON Korea 2013

COEX Seoul, South Korea

E-mail: semiconkorea@semi.org

www.semiconkorea.org/en

31 January – 2 February 2013

Second International Symposium on Semiconductor Materials and Devices (ISSMD-2)

University of Jammu, India

E-mail: convener@issmd.com

www.issmd.com

12–14 February 2013

Strategies in Light 2013 Conference & Expo

Santa Clara Convention Center, CA, USA

E-mail: Tcarli@pennwell.com

www.strategiesinlight.com

24–28 February 2013

SPIE Advanced Lithography 2013

San Jose Convention Center and Marriott, CA, USA

E-mail: customerservice@spie.org

<http://spie.org/advanced-lithography.xml>

17–23 March 2013

Optical Fiber Communication Conference & Exposition (OFC 2013)

Anaheim, CA, USA

E-mail: info@ofcconference.org

www.ofcnfoec.org

17–18 March 2013

China Semiconductor Technology International Conference (CSTIC 2013)

Kerry Hotel Pudong, Shanghai, China

E-mail: kwu@semi.org

<http://semiconchina.semi.org/cstic>

19–21 March 2013

SEMICON China 2013

Shanghai New International Expo Centre (SNIEC), China

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19–21 March 2013

LASER World of PHOTONICS CHINA

Shanghai New International Expo Centre (SNIEC), China

E-mail: laser@mimi-shanghai.com

www.world-of-photonics.net/en/laser-china/start

15–17 April 2013

9th International Conference on Concentrator Photovoltaic Systems (CPV-9)

Phoenix Seagaia Resort, Miyazaki, Japan

E-mail: info@cpv-9.org

www.cpv-9.org

29 April – 3 May 2013

SPIE Defense, Security, and Sensing 2013

Baltimore Convention Center, Maryland, USA

E-mail: customerservice@spie.org

<http://spie.org/defense-security-sensing.xml>

12–17 May 2013

223rd Electrochemical Society (ECS) Meeting

Toronto, Ontario, Canada

E-mail: meetings@electrochem.org

www.electrochem.org/meetings/biannual/fut_mtgs.htm

12–16 May 2013

World of Photonics Congress, incorporating European Conference on Lasers and Electro-Optics and International Quantum Electronics Conference (CLEO/Europe-IQEC 2013)

International Congress Centre Munich (ICM), Germany

E-mail: info@photonics-congress.com

www.world-of-photonics.net/en/photonics-congress/start

13–16 May 2013

21st LASER World of Photonics

Messe München, Munich, Germany

E-mail: info@world-of-photonics.net

www.world-of-photonics.net

13 May 2013

JEDEC's 28th Annual ROCS (Reliability of Compound Semiconductors) Workshop

Hilton New Orleans Riverside, New Orleans, LA, USA

E-mail: ptanner@jedec.org

www.jedec.org/home/gaas

13 May 2013

2013 CS MANTECH: International Conference on Compound Semiconductor Manufacturing Technology

Hilton New Orleans Riverside, New Orleans, LA, USA

E-mail: csmantech@csmantech.org

www.csmantech.org

2–5 June 2013

15th European Workshop on Metalorganic Vapour Phase Epitaxy (EWMOVPE 2013)

Technology Centre in Aachen, Germany

E-mail: ewmovpe2013@jara.org

www.jara.org/index.php?id=606

5–6 June 2013

SEMI CON Russia 2013

Moscow, Russia

E-mail: eweller@semi.org

www.semiconrussia.org/en

17–20 June 2013

LASER World of PHOTONICS 2013

Munich, Germany

E-mail: info@world-of-photonics.net

www.world-of-photonics.net/en

24–25 June 2013

euroLED 2013

The ICC, Birmingham, UK

E-mail: info@euroled

www.euroLED.org.uk

9–11 July 2013

SEMI CON West 2013

San Francisco, CA, USA

E-mail: semiconwest@xpressreg.net

<http://semiconwest.org>

4–10 August 2013

15th Summer School on Crystal Growth (ISSCG-15)

Gdansk, Poland

www.ptwk.org.pl/pol/documents/ISSCG-15-1.pdf

11–16 August 2013

17th International Conference on Crystal Growth and Epitaxy (ICCGE-17)

Warsaw, Poland

E-mail: sarzyn@unipress.waw.pl

www.ptwk.org.pl/pol/documents/ICCGE-17-1.pdf

25–29 August 2013

SPIE Optics + Photonics 2013

San Diego Convention Center, CA, USA

E-mail: customerservice@spie.org

<http://spie.org/optics-photonics.xml>

23–26 September 2013

5th International Conference on One dimensionnal Nanomaterials (ICON 2013)

Annecy, France

E-mail: icon2013@grenoble.cnrs.fr

www.icon2013.fr

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