

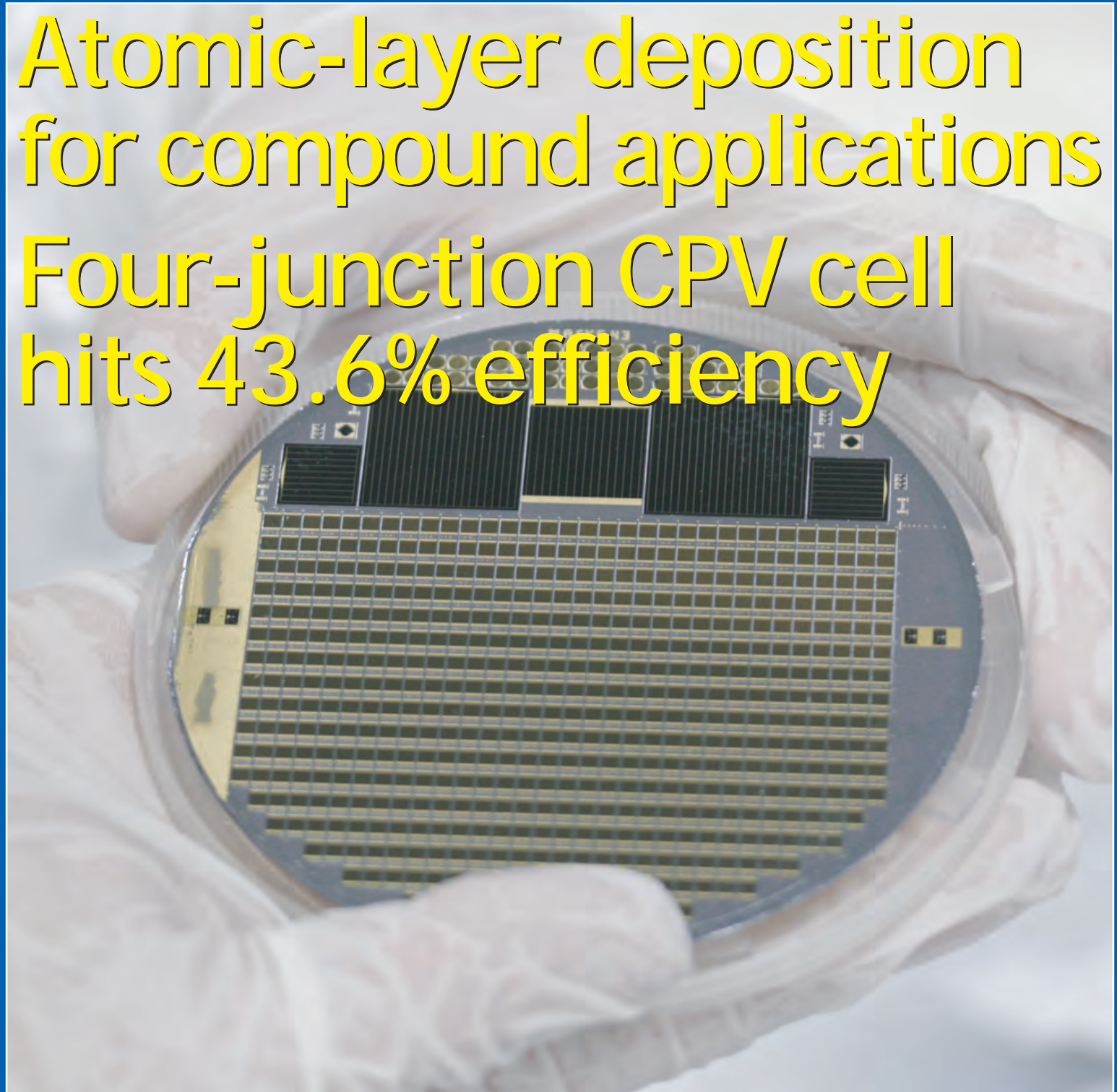
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COMPOUNDS & ADVANCED SILICON

Vol. 8 • Issue 4 • May/June 2013

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Atomic-layer deposition for compound applications Four-junction CPV cell hits 43.6% efficiency



Element Six acquires Group4 • Air Liquide to buy Voltaix
IQE launches IR & wireless divisions • San'an buys Luminus

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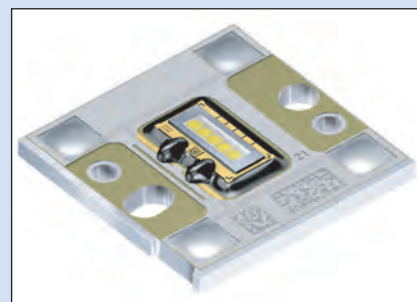
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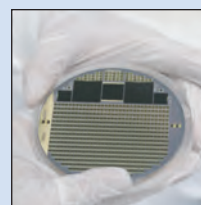
p54 CrystAl-N is transitioning its bulk AlN substrate production from 1-inch to 2-inch diameter.



p56 Verticle has extended its Honeycomb hexagonal-shaped vertically structured InGaIn-based LED chips from blue to UV.



p70 Osram's Ostar Headlamp multi-chip LED. A German research project aims to develop LED headlamps with adaptive forward lighting.



Cover: Soitec and Fraunhofer ISE have produced a four-junction solar cell with efficiency of 43.6% at a concentration of 319 suns (the first time that such a high efficiency has been obtained for a solar cell with four pn-junctions in series). **p96**

Technical developments and commercial integration

In this issue, on pages 120–124, we focus on atomic-layer deposition (ALD) and its application to compound semiconductor device processing. In addition, on page 125 we report the development by North Carolina State University of a new technique for wafer-scale atomic-layer growth, applicable to not only LEDs and lasers but also field-effect transistors.

From pages 108–119 we focus on developments in light-emitting diodes, covering various methods to increase luminous efficiency and light output in LEDs emitting at ultraviolet, blue, green and yellow wavelengths, using various techniques involving methods such as gold-doped graphene, strain engineering, and silicon dioxide-coated nanorod arrays.

Regarding LED production, news emerged in mid-June of the acquisition of the US 'photonic lattice'-based solid-state lighting LED maker Luminus Devices by the US subsidiary Lightera of Taiwanese LED maker San'an Optoelectronics (see page 60). Another of the many examples of the acquisition of US-originated assets or technology by Asian firms is the completion of the transfer of Silicon Valley-based LED chip and lighting array maker Bridgelux's gallium nitride-on-silicon technology assets to Tokyo-based semiconductor manufacturer Toshiba (see page 64).

Other acquisitions reported this issue include France-based gas supplier Air Liquide acquiring US-based materials manufacturer Voltaix, which specializes in silicon, germanium and boron materials, to complement its CVD and ALD precursor materials (see page 43). Also, to expand its semiconductor portfolio, Luxembourg-based synthetic diamond materials firm Element Six has acquired the assets and intellectual property of Silicon Valley-based Group4 Labs, which provides GaN-on-diamond wafer materials for RF and high-power devices (see page 31). Group4 is already a partner with TriQuint Semiconductor, Lockheed Martin and the UK's University of Bristol in demonstrating what are reckoned to be the first high-electron-mobility transistors using GaN-on-diamond wafers, as part of DARPA's 'Near Junction Thermal Transport' (NJTT) program (page 33). Meanwhile, US-Israeli high-performance interconnect maker Mellanox Technologies is acquiring LA-based Kotura, which designs silicon photonics application-specific integrated circuits — see page 34. With such a photonics integrated circuit firm becoming captive to a user of its technology, it will be interesting to see what impact this has on the already small pool of merchant PIC suppliers (such as silicon photonics firm Luxtera and silica-on-silicon/InP-based firm NeoPhotonics and InP-based firm OneChip).

Other commercial developments include North America-based materials maker 5N Plus announcing that it is to establish a new gallium chemicals facility in South Korea, in order to meet demand from LED makers in north-east Asia (see page 42). Meanwhile, epiwafer foundry and substrate maker IQE has launched separate divisions for both wireless products and infrared products (see pages 40–41).

IQE has also launched GaN HEMT epiwafers on 150mm semi-insulating silicon carbide substrates (supplied by II-VI Inc). This was announced during May's CS MANTECH event, which will be covered in our next issue, along with announcements from June's International Microwave Symposium (IMS).

Mark Telford, Editor

mark@semiconductor-today.com



semiconductorTODAY
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Editor

Mark Telford

Tel: +44 (0)1869 811 577

Cell: +44 (0)7944 455 602

Fax: +44 (0)1242 291 482

E-mail: mark@semiconductor-today.com

Commercial Director/Assistant Editor

Darren Cummings

Tel: +44 (0)121 288 0779

Cell: +44 (0)7990 623 395

Fax: +44 (0)1242 291 482

E-mail: darren@semiconductor-today.com

Advertisement Manager

Jon Craxford

Tel: +44 (0)207 193 9749

Cell: +44 (0)7989 558 168

Fax: +44 (0)1242 291 482

E-mail: jon@semiconductor-today.com

Original design Paul Johnson
www.higgs-boson.com

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

Regular issues contain:

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

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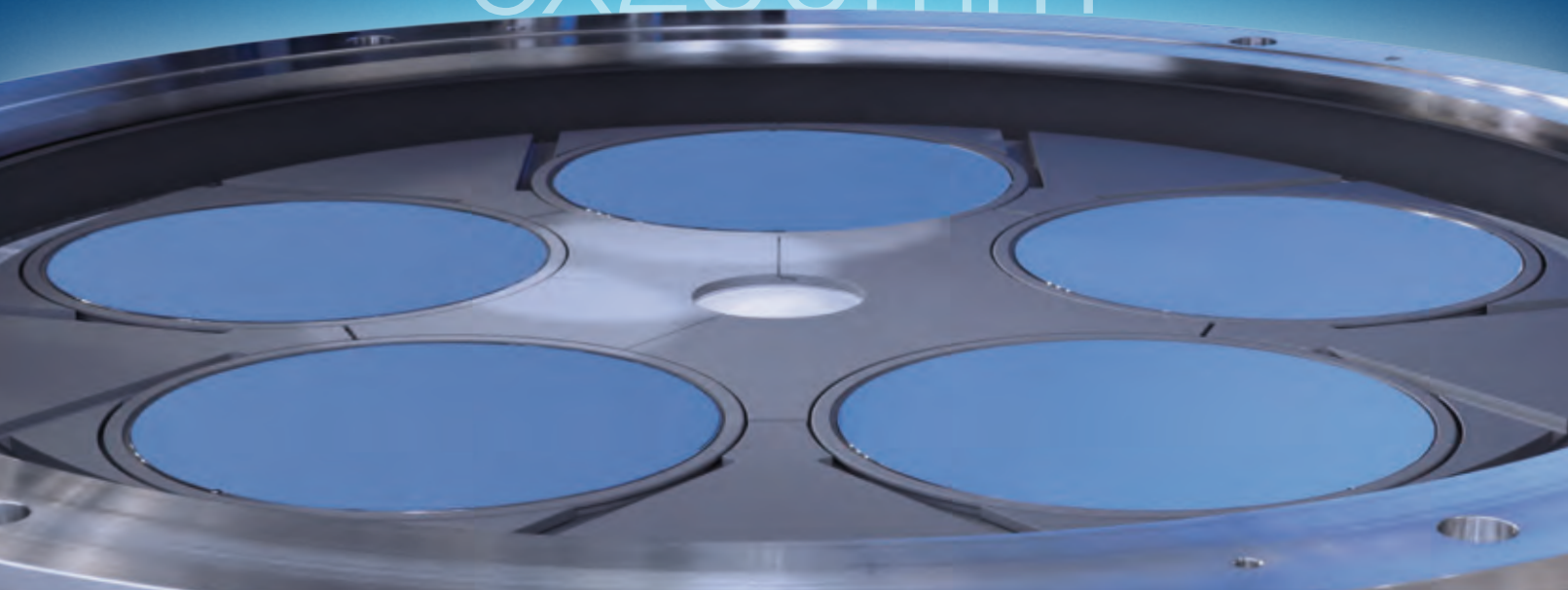
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5x200mm



AIX G5+



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Sapphire substrate oversupply signals difficult times for second-tier manufacturers

Only first-tier sapphire ingot makers continue with production expansion; non-LED applications now target of all manufacturers

Sapphire ingot manufacturers are in a state of "the big gets bigger", says LEDinside, a research department of TrendForce. According to the firm's 2013 Global Sapphire Substrate Market Report, cost-competitive, first-tier sapphire ingot manufacturers (the top ten) account for 80% of market share.

LEDinside says that the main reason for the current situation is oversupply in the sapphire substrate market, which has led to a continuous price decline over the last two years, such that current prices of sapphire substrate for LED applications have been lower than the production costs for many manufacturers. This has led to many second-tier manufacturers halting ingot production, and instead purchasing low-cost ingots from first-tier manufacturers to be processed into sapphire substrates. At present, only cost-competitive, first-tier manufacturers, such as Monocrystal, Rubicon, and STC

(Korea's Sapphire Technology Co Ltd), have production expansion plans.

In addition to LED market applications, first-tier manufacturers are also exploring non-LED application fields.

With sapphire ingot prices staying low, only sapphire substrate manufacturers with cost-management advantages, production capacities meeting economies of scale, and stable sales channels will survive, concludes the report.

The sapphire substrate industry for LED applications can generally be divided into three segments: ingot growth, cutting and grinding (CSS), and patterned sapphire substrates (PSS). Currently, there are many enterprises involved in the sapphire substrate industry with different business models. Some of them are based on ingot growth with downward extension to CSS or PSS, while others are focusing on their fields of specializations.

Therefore, in general there are two

business models: professional specialization and vertical integration. Each company has different core competences and target customers, which will eventually determine their positioning in the sapphire substrate industry.

In the early days the applications of sapphire substrates were mainly in the aerospace industry, such that they were mostly in Russia and USA. With the emergence of LED applications, manufacturers in Japan, Korea, Taiwan and China have begun to invest in the material field. In the next few years, the oversupply in the sapphire substrate industry will remain difficult to solve, with prices dropping below the production costs of most manufacturers. This is why currently there are only several major manufacturers with cost competitiveness sticking to their mass-production plans, leading to the situation of "the big gets bigger".

www.LEDinside.com

Packaged LEDs for signage/professional displays to grow from 57bn to 143bn units over 2012–2018

Asia Pacific region to grow fastest

The volume of packaged LEDs used in signage & professional displays worldwide will grow from 57 billion units in 2012 and will reach 143 billion in 2018, according to a report from market research firm Elec-troniCast Consultants. The value of the LEDs consumed will rise, but the unit growth will largely be offset by declining average prices.

This 2012-2018 market review and forecast is presented for component-level bulbs using standard-

type LEDs (with a lumen/Watt rating of less than 30lm/W) and high-brightness (HB) LEDs (more than 30lm/W).

Applications in signs & displays include building facades, large outdoor video screens, digital billboards, sport/stadium displays, small indoor retail displays, food displays (restaurants/ supermarkets), signs on taxis and destination signs on mass-transit vehicles, channel-lettering/light-boxes, and

LED/LCD TV screens (used exclusively for professional purposes).

The Americas (South, Central and North America) and Asia Pacific (APAC) regions are nearly equal in market share. However, consumption in APAC is forecast to grow the fastest (22.8% per year). The Europe, Middle East and African region (EMEA) has a much smaller share of global consumption versus the other regions in 2013.

www.electronicast.com

Electric vehicle go-slow hits SiC power devices

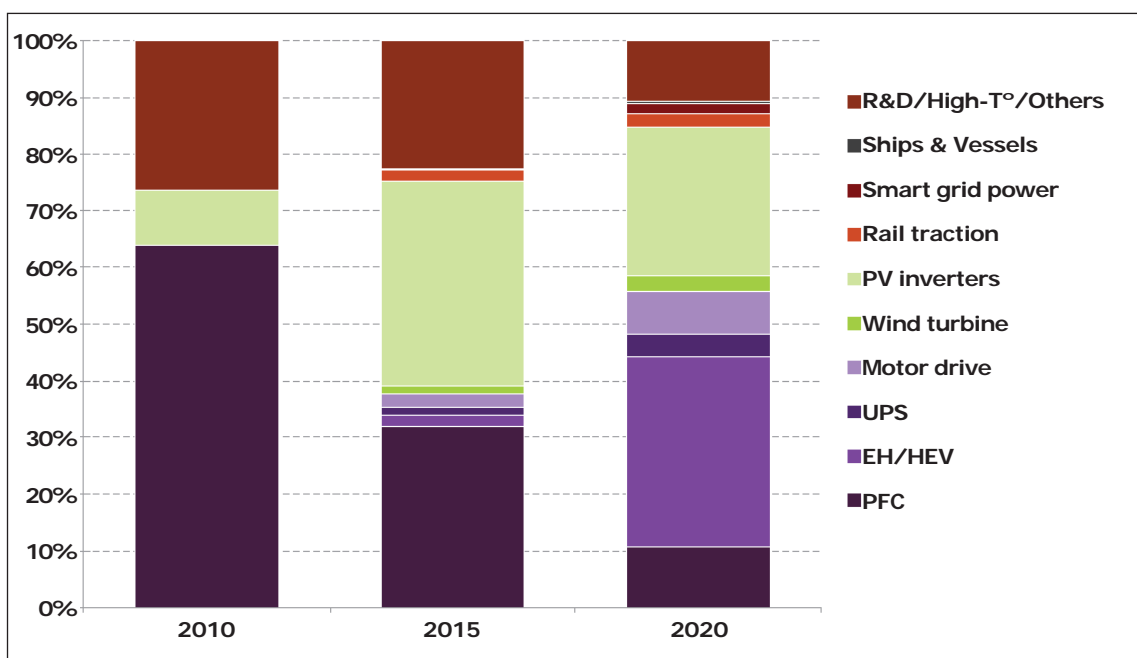
Growth potential obscured by automotive qualification, though PV inverter growth is a bright spot

Uncertainty hangs over the market for power devices made with the wide-bandgap semiconductor silicon carbide (SiC), due to a lack of clarity over whether and when electric vehicles will adopt them, according to the latest study on the SiC industry released by market analyst firm Yole Développement. "We have no firm estimate of when it will come," says Philippe Roussel, business unit manager compound semiconductors, power electronics, LED & photovoltaics.

"It's still questionable," he adds.

Automotive qualification can take up to five years, Roussel notes. So, even if qualification for use in electric and hybrid electric vehicles (EV/HEV) is on-going, it most likely will not be clear if SiC has been successful until 2015. Also, although qualification for EV/HEV charger inverters would be quicker, SiC faces a greater challenge there from silicon superjunction metal-oxide-semiconductor field-effect transistors (MOSFETs), insulated-gate bipolar transistors (IGBTs), and also wide-bandgap gallium nitride (GaN) devices.

As a result, in its latest analysis on the SiC industry Yole describes two scenarios for the evolution of the SiC industry. Its more optimistic scenario sees SiC devices (transistors and diodes) used commercially in EV/HEV from 2015 onwards, taking 11% of the market from silicon IGBT devices by 2020. In the pessimistic scenario, EV/HEV implementation does not start until 2017/2018, making PV inverters the number-one SiC application in 2020.



Distribution of SiC device market for main applications: PV inverters will dominate by 2015.

Currently, there remains much room for increasing SiC device usage in PV inverter applications, Roussel underlines. "Each inverter manufacturer's product line-up has just one or two models with SiC in them, among dozens," he says. "But it's a very positive starting point." That has helped SiC power device industry revenue to reach \$76m in 2012 (including R&D but excluding military use). PV inverter producers are the second industry to broadly adopt SiC devices, after manufacturers using SiC for power factor correction (PFC) in high-end server power supplies.

Some PV inverter manufacturers use a SiC diode and a silicon IGBT or MOSFET, and some offer full SiC inverters. "They're just the first attempt, as inverter makers have limited their SiC development investment," Roussel says. "They are doing a simple replacement for silicon devices, taking the minimum extra work." But that means that inverter producers are selling more expensive SiC products on their efficiency, without fully exploiting the material's

benefits. "The next step will definitely be a full re-design within the inverter that should fit with SiC's high-frequency and -temperature capabilities, reducing the number of capacitors and inductors needed," Roussel says.

Working with reverse costing specialist System Plus Consulting, Yole has modelled the benefits of increasing the standard PV inverter switching frequency from 12kHz to 32kHz. That shortens the payback time on the SiC investment, and would make large 50kW SiC inverters cheaper than their silicon equivalents by 2020, it is reckoned. Such benefits will help to boost annual revenue for SiC devices sold into PV inverters to \$200m by 2020, Yole predicts.

However, even though PV inverters are currently better established, EV/HEV inverter producers could still be more advanced in making full use of SiC. "Efficiency drives adoption, but putting SiC in any system could also make it smaller and lighter," Roussel stresses. "For EV/HEV, that is just fantastic."

www.yole.fr

RFMD grows more-than-expected 49% year-on-year

Diversified growth and market share gains offset industry seasonality

For its fiscal fourth-quarter 2013 (to end-March), RF Micro Devices Inc of Greensboro, NC, USA has reported revenue of \$280.6m, up 3.5% on \$271.2m the prior quarter and up 49% on \$187.9m a year ago (and much better than the expected 6–8% quarter-to-quarter drop to \$250–255m).

"Results reflect market share gains and an above-seasonal revenue performance," commented president & CEO Bob Bruggeworth. "We have won share across a broad customer set and outpaced our industries' underlying growth rates." The increase in sequential revenue reflected increased demand for RFMD's cellular RF solutions and broad-based growth in high-performance Wi-Fi, broadband/CATV and standard products applications.

RFMD's Cellular Products Group (CPG) grew 1.4% sequentially and 59% year-on-year to \$225.7m. During the quarter, RFMD began production shipments in support of a high-volume flagship smart-phone using multiple RFMD components, including multi-mode multi-band (MMMB) power amplifiers (PAs), single-band PAs, and antenna control solutions.

The firm also benefited in the entry-level segment from "leadership on major reference designs" and the expansion of RFMD's entry solutions product portfolio to include industry-leading CMOS PAs. "We are accelerating the adoption of our RF CMOS technology into new markets and new customers, and we anticipate this will provide a path to lower costs and improve margins in our 2G product portfolio," said Bruggeworth, commenting that this is "especially significant in China", where the company holds a leadership position.

The Multi-Market Products Group (MPG) grew 13% sequentially and 20% year-on-year to \$54.9m, with sequential growth in all three business units. In particular, high-performance Wi-Fi activities achieved

double-digit quarter-to-quarter growth, and doubled year-on-year.

"We supported multiple reference designs for both mobile Wi-Fi and CPE, with particular interest in our high-band front-end modules," noted Bruggeworth. "We expect continued growth in 802.11n applications and also at 802.11ac, which is beginning to ramp," he added. "While 802.11ac activity for mobile applications has been strong for a while, CPE's activities strengthened."

On a non-GAAP basis, gross margin was 34.4%, up from 32.4% a year ago although down from 35.5% last quarter. Net income was \$17.1m (\$0.06 per diluted share), down from \$21.3m (\$0.08 per share) last quarter but a big improvement on a loss of \$5.4m (\$0.02 per share) a year ago. Operating cash flow was \$10m. However, after capital expenditure of \$20.4m (up from \$13.7m last quarter), cash, cash equivalents and short-term investments fell from \$189.7m to \$179.6m.

During the quarter, RFMD announced a flexible GaAs sourcing strategy, including the intent to exit its pHEMT fabrication facility in Newton Aycliffe in the UK, to expand gross margin, and to support aggressive growth. Also, RFMD made a \$10m investment to secure duplexer capacity to support product ramps in fiscal second-half 2014.

"We expect to drive substantial margin improvement through multiple activities, including the migration of our 2G product portfolio to our lower-cost, best-in-class RF CMOS technology, the addition of internal assembly capacity to increase the share that we in-source, completing exiting our UK facility, and the resulting improvement in capacity utilization in our Greensboro GaAs fab," said Dean Priddy, chief financial officer & VP of administration.

"We believe these activities will drive three to four points of margin expansion in the second half of this fiscal year," he added.

During the quarter, operating

expenses were \$76m, including \$12.6m on general & administrative (G&A), \$16.7m on sales & marketing and \$46.8m on R&D. RFMD says its emphasis on R&D in particular is resulting in content gains and category expansion across a broad set of smartphone makers and chipset providers. The acquisition of RF CMOS firm Amalfi Semiconductor last November added about \$2.3m in operating expenses.

"If you look from a high level at our long-term strategy, a few quarters ago, you would have seen that we began making incremental investments in R&D to drive growth and diversification through product and technology leadership," said Bruggeworth. "Now, you're seeing continued above-industry growth and an additional layer of diversification across products and product categories."

"Those same investments are shaping our current year; helping us to further expand our dollar content on flagship platforms and to diversify our product offerings. To expand these customer relationships, we're leveraging our R&D and capital expenditure investments to expand our product offerings."

"To drive growth, we are engaged at a very high level with the leading carriers, smartphone manufacturers and chipset providers, and we expect these technologies to play an increasing role in differentiating our product offerings," said Bruggeworth.

"Our strong growth continues to reflect our sharp focus on diversification, category expansion and content gain in the large market supporting data mobility," Priddy commented. "RFMD's financial outlook reflects the company's current expectations for the timing of key customer program ramps and continued strength in 2G and high-performance Wi-Fi."

For the June quarter, RFMD expects rises in revenue to \$285–290m, and in earnings per share to \$0.07–0.08.

www.rfmd.com

Matthew Peach, Contributing Editor



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TriQuint's revenue dives 21% in first-quarter as Mobile Device revenue falls 30% ...but above-market growth by filters to drive return to profit for 2013

For first-quarter 2013, RF front-end component maker and foundry services provider TriQuint Semiconductor Inc of Hillsboro, OR, USA has reported revenue of \$184.2m, down 15% on \$216.7m on a year ago and 21% on \$233.6m last quarter.

End-market revenue split was 57% Mobile Devices, 28% Network Infrastructure, and 15% Defense & Aerospace.

Foxconn Technology Group was the only customer that exceeded 10% of total revenue (specifically 25%).

Network Infrastructure revenue was up 2% sequentially and 8% year-on-year, primarily due to increased optical revenue (up 8% sequentially). Defense & Aerospace revenue was up 32% year-on-year but down 16% sequentially after a very strong last quarter (noting that quarter-to-quarter variations are dependent on program timing, driven mainly by radar applications). Mobile Device revenue fell 30% sequentially to \$105.5m (as expected, through the seasonally low demand from the firm's largest customer, although all other top-five mobile customers grew).

On a non-GAAP basis, gross margin was 22.8%, down on 31.7% last quarter and 30.4% a year ago, due to lower revenue and about \$5m in charges from a now-resolved quality issue. Excluding this one-time cost, results were in line with guidance.

Driven by increased R&D spending, operating expenses were \$68m, up by \$1.4m on last quarter and by \$6.6m on a year ago.

Net loss was \$27.2m (\$0.17 per share), compared with net income of \$6.2m (\$0.04 per share) last quarter and \$4.1m (\$0.02 per share) a year ago. Despite this, cash and investments rose during the quarter from \$139m to \$141.1m, due to a lower accounts receivable balance. Capital expen-

diture was \$29.4m, primarily related to capacity expansion for premium filters.

"Our Q1 results, while disappointing, should be our low quarter for 2013," commented president & CEO Ralph Quinsey. "We are well positioned in each of our markets to regain growth and margin momentum."

In RFICs, TriQuint says it experienced healthy design-win traction with its highly efficient MMPAs (multi-band, multi-mode power amplifiers) at several major OEMs (including Samsung, Blackberry and various Chinese manufacturers). "Customers have told us they are migrating to our new TRIUMF MMPA because these modules deliver longer battery life and enable steady operating times versus competitive products," Quinsey commented.

"Besides the MMPA developments, our second focus area is TriConnect Wi-Fi solutions," noted Quinsey. "We have introduced two new 5GHz modules that deliver superior performance in the 802.11ac applications: these new TriConnect modules are shipping at high volume today," he added.

"Third, and frequently underestimated, is the rapidly expanding demand for premium filters," said Quinsey. "These filters are essential in resolving challenges brought on by more bands per phone in crowded RF spectrum. Our premium BAW [bulk acoustic wave] and advanced TC-SAW [temperature-compensated surface acoustic wave] filters [launched during Q1, to support 4G and Wi-Fi coexistence] are designed to meet the toughest filtering requirements for the new LTE bands being deployed... TriQuint is one of a limited number of suppliers worldwide who can solve these tough filtering challenges effectively," Quinsey claimed.

Regarding the Networks infrastructure market, "We have benefited from the 40 gigabit expansion over the last three years, but I expect 40 gigabit demand to peak in 2013 as we begin to ramp our 100 gigabit products," said Quinsey. Also during the quarter, TriQuint launched five new transimpedance amplifiers (TIAs) for the optical market - a new product category for TriQuint that enables the firm to now serve both transmit and receive portions of high-performance optical networks. In addition, TriQuint has secured design wins that should drive solid demand over the next three years at most major OEMs such as Ericsson, Huawei and ZTE. "We also see strong interest from customers in gallium nitride (GaN)," noted Quinsey.

Outlook for Q2 and full-year 2013

For Q2/2013, TriQuint believes that revenue will rise to \$185-190m, adding that it is 92% booked to the midpoint of this guidance. On a non-GAAP basis, gross margin is expected to rise to 27-29%, driven by higher factory utilization (as the firm builds inventory in advance of an expected strong second half) and the absence of costs from the Q1 quality issue. Operating expenses are expected to rise slightly to \$69m. Net loss is expected to be cut to \$0.10-0.12 per share.

"Investors have not yet recognized the value I believe TriQuint represents," Quinsey concluded. "We have a mobile product line built on a foundation of high-performance low-current solutions that now includes premium filters during a time that filter demand is beginning to outpace the overall market growth rates," he added. "I expect strong second-half revenue will improve utilization and push us back into profitability for the full year."

www.triquint.com

Matthew Peach, Contributing Editor

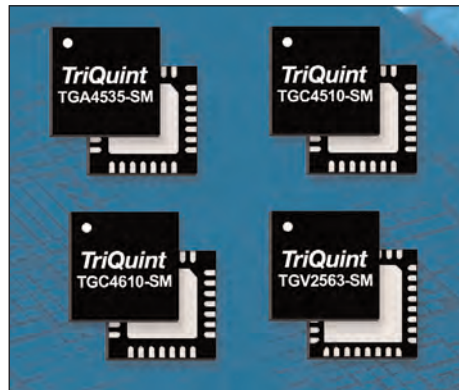
TriQuint launches RF chipsets for wireless backhaul microwave radios

TriQuint Semiconductor has introduced 12 new products and highlighted two complete RF chipset families for 15GHz and 23GHz point-to-point (PtP) radios serving 3G/4G cellular backhaul and related applications.

Released in conjunction with the 2013 IEEE MTT-S International Microwave Symposium (IMS) in Seattle, WA, USA (4–6 June), the new products include high-performance packaged amplifiers, up-converters/down-converters and voltage-controlled oscillators (VCOs) as well as additional devices to support PtP RF requirements at 10–27GHz, all in 5mm x 5mm QFN packages.

Mobile network traffic generated by smartphones, tablets and other devices is increasing exponentially, says TriQuint, making high-speed solutions that 'backhaul' data across wireless networks essential to seamless connectivity. Cisco's Virtual Networking Index notes that in 2012 global mobile data traffic grew by more than 70% compared to 2011 and predicts that it will grow at an annual rate of 66% through 2017.

"Point-to-point radio plays a vital role in sustained mobile network growth," says James L. Klein, VP & general manager for Infrastructure and Defense Products. "TriQuint's leadership in high-frequency solu-



TriQuint's new family of RF chipsets for 23GHz PtP radio.

tions now includes complete RF chipsets that simplify design and improve performance," he adds.

Microwave radios linking base-stations and central switching hubs provide an excellent backhaul solution, says TriQuint, adding that the radios are comparatively easy to install and inexpensive to maintain. Especially at higher microwave and millimeter-wave frequencies, they have broad channel bandwidths to enable very-high-speed data throughput.

TriQuint says that its new 15GHz and 23GHz chipsets provide OEMs with a single-source, surface-mount RF solution. The products are offered alongside TriQuint's larger family of PtP solutions, which cover 10–16GHz and 17–27GHz.

www.triquint.com
<http://ims2012.org>

IN BRIEF

TriQuint announces \$75m stock buyback program

RF front-end component maker and foundry services provider TriQuint Semiconductor Inc of Hillsboro, OR, USA has announced a program authorizing the repurchase of up to \$75m of the firm's common stock.

Under the program, stock repurchases may be made from time to time in the open market at prevailing market prices or through privately negotiated transactions at the discretion of company management. The timing of open market and privately negotiated purchases will be dependent on market conditions and other corporate considerations, including price, corporate and regulatory requirements and alternative investment opportunities. The firm is not obligated to repurchase any particular amount of common stock during any period and may choose to suspend or discontinue the repurchase program at any time.

Shares of common stock repurchased by TriQuint through the program will become authorized but unissued shares. As of 14 May, the firm had about 163.3 million shares of common stock outstanding.

www.triquint.com

TriQuint named finalist for American Technology Awards

RF front-end component maker and foundry services provider TriQuint Semiconductor Inc of Hillsboro, OR, USA has been selected as a finalist for the 2013 American Technology Awards in the Semiconductors & Electronic Components category for its industry-first 802.11ac Wi-Fi RF module for mobile devices. The awards are known as the 'Termans' after Frederick Terman (considered to be the father of Silicon Valley).

The TriConnect TQP6M9017 is a full WLAN/BT front-end module in an ultra-small 4mm x 4mm footprint package for 802.11a/b/g/n/ac and Bluetooth applications. TriQuint says the module is powering next-generation mobile devices such as smartphones, tablets and e-readers by supporting faster download speeds for video streaming and other demanding broadband applications. In addition, the TriConnect

module enables connectivity from greater distances, due to advances in output power technology.

The 2013 American Technology Awards were presented on 20 June at the 11th Annual Technology and Government Dinner, hosted by the TechAmerica Foundation at the Ronald Reagan Building in Washington DC.

www.techamerica.org/the-termans
www.triquint.com

Anadigics' revenue falls 13.4% in Q1 to \$26.4m

Seasonal cellular decline offset by quadrupling in WiFi revenue; staff cuts limit drop in margins

For first-quarter 2013, GaAs-based broadband wireless and wireline communications component maker Anadigics Inc of Warren, NJ, USA has reported revenue of \$26.4m, down 7.2% on \$28.4m a year ago and 13.4% on \$30.5m last quarter. The firm had three greater-than-10% customers (Samsung, Murata and Huawei) and another four at 5–10% (Cisco, ZTE, World Peace, and Richardson Electronics).

The drop in total revenue was driven by a seasonal decline of 31.6% in Cellular revenue, from \$23.7m last quarter to \$16.3m. Revenue for Infrastructure (formerly termed broadband) fell by 5.7% from \$5.6m last quarter to \$5.3m, due to lower CATV subscriber revenue. However, some of this seasonality was offset by strong market demand for 802.11 front-end ICs that led to WiFi revenue growth of more than 300%, from \$1.1m to \$4.8m (18% of total revenue).

Selling & administrative expenses increased 6% to \$5.2m as Anadigics invested in its WiFi sales efforts. R&D expenses were flat at \$9.9m, maintaining the cost improvements put in place in 2012. "We continued to improve our cost efficiency via select cost reductions while retaining a sharp focus on new product development," says VP & chief financial officer Terry Gallagher.

"During the first quarter, we repositioned the company to grow revenues with an improved cost structure," continues Gallagher. "We implemented further workforce reduction, resulting in a \$1.9m restructuring charge in the quarter. While this required some upfront cash, it improves our cost structure and business leverage," he adds. "We remain diligent in capturing efficiencies, but we'll also continue to act decisively to capitalize on growth opportunities."

Despite the sequential decline in revenue, capacity utilization has

risen again, from 55% last quarter to 65%, and non-GAAP gross margin remained positive, falling only slightly from 2.5% last quarter to 1% due to a more favorable product mix.

Non-GAAP net loss was \$14.8m, compared to \$14.9m a year ago and \$13.9m last quarter. Earnings before interest, taxes, depreciation and amortization (EBITDA) loss has risen from \$10.1m last quarter to \$11.1m.

During the quarter, cash was used to fund the EBITDA loss and restructuring payments of \$1.5m.

"At the same time, we grew current assets by \$3.3m through increased accounts receivable, inventory, and the prepayment of our annual insurance," says Gallagher. Also, capital expenditure (CapEx) rose from \$0.4m last quarter to \$1.5m.

"These investments support our WiFi and Cellular product ramps and position the company for growth [including incrementing fab capacity]."

During the quarter, cash, cash equivalents and short- and long-term marketable securities fell only slightly, from \$51.5m to \$50.9m. In Q1, Anadigics raised \$18.4m in equity by issuing 10 million shares. After quarter-end, the firm realized an additional \$1.3m in proceeds as the underwriters exercised just over 700,000 shares of their overall allotment. "Solidifying our cash and equity base allows us to capitalize on growth opportunities, add the inventories fueling Q2 growth, and expand capacity for our unique ILD [inter-level dielectric] process," says Gallagher. Anadigics is investing about \$1m each quarter to be more or less 100% ILD by the end of 2013.

Anadigics is investing about \$1m each quarter to be more or less 100% ILD [inter-level dielectric] by the end of 2013

"For the second quarter, we are seeing strong bookings to date, driven by design wins of our Cellular and WiFi products," says Gallagher. "We attribute the increase in customer demand to our aggressive growth strategy, which leverages innovative new products in high-growth markets and strong industry relationships," adds chairman, president & CEO Ron Michels.

"To provide a strong foundation for both short- and long-term growth, we remain sharply focused on three drivers that expand our served available market and are capable of driving significant product ramps. The first driver is the rapid adoption of WiFi connectivity across an expanding array of applications. The second driver is the acceleration of data consumption and adoption of 3G and 4G connectivity in wireless mobile devices. And the third driver is the expansion of infrastructure networks to support greater bandwidth and wireless data use," says Michels. "Our solid execution on addressing these three market drivers has placed our business on a growth trajectory as we capture design wins by getting superior products into customer's hands quickly for feedback and refinement. This is exemplified by the significant traction in our new WiFi and Cellular products, including our strong position at Samsung, where we have more content on the Galaxy S4 than we did on the S3," he adds.

"The WiFi group continues to secure design wins and is ramping production of our 802.11n and -11ac front-end ICs," says Michels. "These front-end ICs (FEICs) are specified on several reference designs by leading WiFi chipset manufacturers. This is creating significant end-customer demand and we are now shipping production volumes for smartphones such as the Samsung Galaxy S4 as well as

► tablets, access points and other devices." WiFi is expected to rise from 18% to more than 30% of total revenue in Q2.

"Regarding the Cellular product group, we are also making solid progress as we continue to build momentum for our ProEfficient Plus and Penta-Band products," says Michels. "The production ramp of these solutions as a replacement for our legacy portfolio is enriching our product mix and positioning the cellular group to contribute to the profitable growth," he adds.

During the quarter, Anadigics continued to roll out new cellular solutions, including the expansion of its dual-band ProEfficient Plus power amplifier family in February.

The Infrastructure group remains focused on developing new CATV, wired network and small-cell solutions to support the acceleration of data consumption. "We continue to expand our CATV infrastructure product offering although our GaN

surface-mount line amplifiers and our new eco power doublers are gaining design and traction," says Michels. "We plan to ramp all of these product families into production during the second half of 2013," he adds. "Our CATV infrastructure product development pipeline is robust, as we prepare to launch DOCSIS 3.1 solutions that we expect will provide revenue later this year and into 2014." However, the small-cell market ramp has been delayed due to a lower-than-expected carrier adoption and is now expected to occur

Aggressive ramp of our WiFi products to meet accelerating customer demand, coupled with design-win momentum of our new Cellular and Infrastructure products, should drive higher factory utilization

later in the year. "Our manufacturers wait for carriers to place orders as we continue to work closely with leading chipset developers," notes Michels. "We are specified on a number of leading reference designs that we anticipate will drive revenue when the market expands."

"The aggressive ramp of our WiFi products to meet accelerating customer demand, coupled with design-win momentum of our new Cellular and Infrastructure products, should drive higher factory utilization and significantly improve our financial performance," believes Michels.

"For 2013, we expect revenue growth to be the prime driver of margin improvement," comments Gallagher. EBITDA loss is expected to improve as revenue and margins rise. The firm is hence still targeting EBITDA breakeven at quarterly revenue of \$40–45m by the end of 2013, with gross margin in the low to mid 20s, aided by cuts in operating expenditure.

Anadigics promotes WiFi Products unit head Cresci to president and appoints John van Sadlers as chief operations officer

GaAs-based broadband wireless and wireline communications component maker Anadigics Inc of Warren, NJ, USA has announced executive management changes that aim to enhance execution of a coordinated growth strategy across its three business groups and further enable increased manufacturing scale across its process technologies, including inter-layer dielectric (ILD).

Dave Cresci, previously VP of the WiFi Products business unit, has been appointed president, and a corporate officer. The newly created role encompasses responsibility for all of Anadigics' business groups, including design and product marketing, as well as its worldwide sales organization. The firm says that Cresci has a strong sales, marketing and engineering background, and has served in a variety of leadership positions at Anadigics since 2003.



Dave Cresci.

growth into 2014," says chairman & CEO Ron Michels. "As we scale our manufacturing capabilities to meet the growing demand for our new RF solutions, we believe that it is critical to coordinate our strategy across all businesses and customer touch points," he adds.

"Dave will assume this new leadership role to help align our businesses to the overall corporate strategy, ensure that we scale efficiently, and position Anadigics for continued profitable growth into the future."

"In 2012, we organized Anadigics into three business groups to drive product innovation and improve customer traction, positioning the company for



John van Sadlers.

John van Sadlers, a business and engineering leader with over 30 years of RF semiconductor experience, has been appointed executive VP & chief operations officer.

"John will lead the company's efforts to align our process technologies and systems with the product roadmaps of our business groups, and continue to improve the way we introduce and manage innovation across our manufacturing operations and supply chain," says Michels.

"These appointments, both well deserved, will allow me to focus on the company's overall strategy, forging business alliances, and further strengthening our business development activities," he adds.

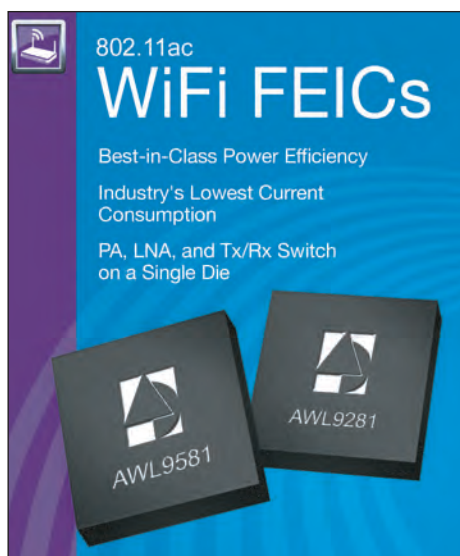
www.anadigics.com

Industry's first 802.11ac 4x4 reference design specifies Anadigics' WiFi front-end integrated circuits

GaAs-based broadband wireless and wireline communications component maker Anadigics Inc of Warren, NJ, USA says that its AWL9281 and AWL9581 WiFi front-end integrated circuits (FEICs) have been selected for use with the industry's first 802.11ac 4x4 wireless solution.

With multiple input, multiple output (MIMO) 802.11ac connectivity and beam-forming technology, devices using this reference design will utilize up to four FEICs simultaneously to achieve seamless wireless throughput of high-bandwidth data. The 4x4 system on chip (SoC) solution, coupled with Anadigics' 802.11ac FEICs, is optimized for infrastructure and multimedia applications, including gateways, routers, access points, gaming platforms, set-top boxes, and media servers.

"Our FEICs continue to set the standard with industry-leading linearity, noise figure, and thermal characteristics," claims Dave Cresci,



Anadigics' VP of WiFi Products.

"This level of performance ensures maximum throughput at extended range and excellent thermal management in MIMO implementations with multiple amplification paths," he adds. "With Anadigics' WiFi FEICs, manufacturers are able to develop next-generation devices for the most demanding wireless networking and multimedia applications."

Anadigics' 802.11ac FEICs leverage the firm's exclusive InGaP-Plus technology and patented design architectures to combine a high-performance power amplifier (PA), low-noise amplifier (LNA), and Tx/Rx RF switch on a single die. This level of integration greatly improves manufacturability and reliability, it is claimed. Also, the compact 2.5mm x 2.5mm x 0.4mm QFN package (incorporating a high-accuracy integrated power detector and RF ports internally matched to 50Ω) reduces PCB space requirements and simplifies RF front-end design (speeding time-to-market).

Anadigics' WiFi solutions also deliver thermal performance that ensures proper thermal management in MIMO applications that use multiple FEICs, the firm says. The complete family of FEICs provides error vector magnitude (EVM) and noise figure performance enables ultra-high data throughput, it adds.

www.anadigics.com

Anadigics' 802.11ac WiFi front-end IC and cellular power amplifiers selected by Samsung for Galaxy S 4 smartphone

Anadigics says that its AWL9581 802.11ac front-end IC (FEIC), AWT6651 ProEfficient power amplifier (PA), AWT6624 HELP4 PA, and AWC6323 HELP3E dual-band PA are enabling wireless connectivity in the Galaxy S 4 by Samsung Electronics.

"The selection of ANADIGICS' differentiated, battery-saving solutions for this flagship device not only exemplifies the tremendous performance advantages offered by our products, but also the strength of our relationship with Samsung," says chairman, president & CEO Ron Michels. "Our goal is to continue to support Samsung through each successive generation of mobile connectivity."

Anadigics' 802.11ac FEICs lever-

age the firm's exclusive InGaP-Plus technology and patented design architectures to combine a high-performance power amplifier (PA), low-noise amplifier (LNA), and RF switch on a single die. This level of integration on a single die greatly improves manufacturability and reliability, as well as reducing PCB space requirements and simplifying RF front-end design to speed time-to-market. The AWL9581 5GHz FEIC uses InGaP-Plus to deliver what is claimed to be the industry's lowest current consumption, extending battery life in mobile applications. The complete family of FEICs provides what is claimed to be outstanding error vector magnitude (EVM) and noise figure performance, enabling

ultra-high data throughput. The AWL9581 is featured in the Galaxy S 4 across multiple regions and carriers.

Anadigics' ProEfficient, HELP4, and HELP3E power amplifiers also use InGaP-Plus and unique design architectures to provide greater efficiency in low-power mode and to extend talk-time. Additionally, ProEfficient PAs offer exceptional performance in high-power mode to minimize current consumption when using 3G and 4G data services and maximize overall battery-life.

The AWT6651 is featured in the Galaxy S 4 for China Mobile, the AWT6624 is being used in the Galaxy S 4 for U+ in Korea, and the AWC6323 is being used in the Galaxy S 4 for China Unicom.

Anadigics launches 802.11ac WiFi power amplifiers for infrastructure and multimedia applications

GaAs-based broadband wireless and wireline communications component maker Anadigics Inc of Warren, NJ, USA has launched a new family of 802.11ac power amplifiers (PAs) optimized for WiFi infrastructure and multimedia applications, including access points, routers, media gateways, set-top boxes, and smart TVs.

The power amplifiers deliver a combination of high gain and output power (to ensure optimal performance in infrastructure and multimedia applications) as well as high linearity, to maximize data throughput and ensure reliable transmission of high-definition (HD) video at extended ranges. Ultra-low error vector magnitude (EVM) in the toughest 802.11ac modulation formats also enables extremely high transmission data rates. The new 802.11ac solutions also feature greater integration compared with a typical power amplifier, reducing external component

requirements and saving valuable PCB space.

Acting as "critical enablers" in the expanding use of 802.11ac MIMO technology for WiFi infrastructure in both commercial and residential applications, the firm's latest power amplifiers "complement and build upon the success of our highly integrated front-end ICs by offering exceptional gain, output power and linearity to deliver higher data rates at greater ranges for an enhanced computing and multimedia user experience," says Dave Cresci, VP of WiFi Products.

Anadigics' new family of WiFi power amplifiers leverage the firm's exclusive InGaP-Plus technology and patented design architectures to offer high performance and integration.

The first product in the family is the AWL5905 power amplifier, which offers 29dB of gain and is optimized for 5GHz WLAN standards, including 802.11a/n/ac.

The AWL5905 has an integrated power detector that facilitates accurate power control over varying load conditions (3:1 VSWR), as well as a CMOS-compatible digital PA enable interface that improves ease of use and eliminates the requirement for an external buffer amplifier. This level of integration includes internal RF matching and is provided in a compact, low-profile 4mm x 4mm x 0.8mm QFN surface-mount package with RF ports internally matched to 50Ω and DC blocked to reduce PCB space requirements.

The AWL5905 also combines high power efficiency and improved thermal performance, enabling manufacturers to develop multiple-input multiple-output (MIMO) solutions that consume less power and are more thermally efficient.

Engineering samples of the AWL5905 are available now for qualified programs.

www.anadigics.com

Huawei selects pentaband PA for new CPE and hotspot devices

Anadigics is shipping production volumes of its ALT6526 pentaband power amplifier to China's Huawei for the E5172 consumer premises equipment (CPE) and E5776 WiFi hotspot.

Huawei's E5172 and E5776 solutions allow multiple WiFi-enabled devices to simultaneously share a single high-speed 3G and 4G cellular data account. The E5172 also provides Ethernet connectivity to support additional users. Both the E5172 and E5776 leverage Anadigics' pentaband power amplifier to enable 3G and 4G connectivity, achieving speeds up to 150Mbps with LTE Cat4.

The ALT6526 pentaband PA is optimized for 3G and 4G computer modules, datacards and hotspots, as well as automotive and machine-to-machine (M2M) applications, operating in CDMA/EVDO,



WCDMA/HSPA, and LTE modes.

The compact, low-profile 5mm by 7mm by 0.9mm module incorporates amplification chains to deliver high linearity and efficiency in each of the 21 bands and band classes that it supports for higher

throughput and greater battery life. It also includes an integrated voltage regulator, built-in directional coupler, and internal DC blocks on all RF ports to help reduce RF space requirements.

"Anadigics' pentaband power amplifier provides a compelling path for multi-band and multi-mode cellular connectivity and M2M devices by delivering exceptional efficiency across all modes and frequency bands," says Michael Canonico, senior VP of worldwide sales. "By combining this level of performance and integration in a single module, we can help achieve higher data throughput, extend battery life, and save valuable PCB space," he adds. "We look forward to working closely with Huawei on future connectivity solutions."

IN BRIEF

Northrop Grumman launches 71–76GHz and 81–86GHz GaAs E-band high-power MMICs

Northrop Grumman Corp of Redondo Beach, CA, USA has developed two new 0.1µm gallium arsenide (GaAs) high-electron-mobility transistor (HEMT) monolithic microwave integrated circuit (MMIC) broadband three-stage high-power amplifiers operating in the E-band communication frequency spectrum.

The APH667 operates at 81–86GHz, and provides 17dB of linear gain and +25.5dBm (0.35W) of saturated output power (typical).

The APH668 operates at 71–76GHz, and provides 19dB of linear gain and +28dBm (0.63W) of saturated output power (typical).

“Customers typically combine several MMIC products in this frequency band to achieve higher output power,” says Frank Kropschot, general manager, Microelectronics Products and Services, Northrop Grumman Aerospace Systems. “The APH667 and APH668 will allow them to dramatically reduce the number of components required to reach those goals, simplifying the product’s architecture and enhancing the performance,” he adds.

Limited engineering prototype samples of the APH667 and APH668 are available from stock to qualified customers by e-mailing Microelectronic Products and Services at as-mps.sales@ngc.com.

Pre-production quantities will be available in third-quarter 2013, with production quantities available in fourth-quarter 2013.

www.as.northropgrumman.com/mps

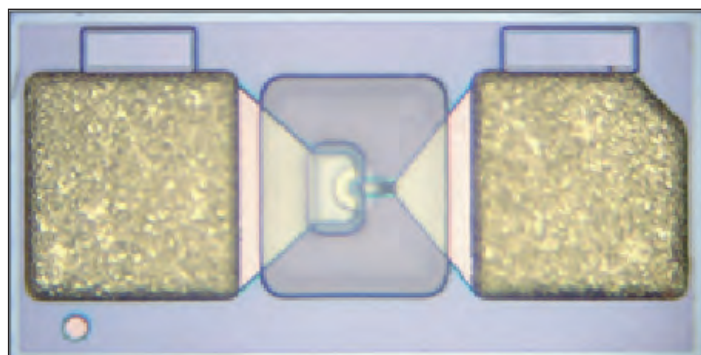
MACOM Tech launches solderable flip-chip low-capacitance GaAs Schottky, AlGaAs PIN diode and high-Q-constant gamma GaAs varactor

M/A-COM Technology Solutions Inc of Lowell, MA, USA (which makes analog semiconductors, components and subassemblies for RF, microwave and millimeter-wave applications) has launched three broadband solderable flip-chip

devices, namely a Schottky diode, a general-purpose amplifier and a general-purpose varactor diode, for multi-market applications including for police radar, point-to-point, electronic warfare and aerospace & defense applications. Designed to be versatile, low-cost and ultra-small, the package-less devices have contacts that allow for standard solder reflow manufacturing processes.

The MADS-001317-1500 Schottky has a high cutoff frequency, allowing use through millimeter-wave frequencies. Its performance makes it suitable for single and double balanced mixers in PCN transceivers and radios, police radar detectors, and automotive radar detectors. Fabricated using a gallium arsenide (GaAs) process that features full passivation for increased performance and reliability, the low parasitic capacitance and inductance allow operation up to 80GHz. “Due to wafer scale reduction, the device minimizes unwanted parasitic and allows for exceptional performance beyond 80GHz,” says product manager Paul Wade.

The MADP-000907-14020 PIN diode — unlike its nearest alternatives — is fabricated using an AlGaAs process that provides full passivation for increased performance and



Chip layout for the new solderable flip-chip devices,

reliability, the firm says. “The MADP-000907-14020 is a high-frequency [70GHz] AlGaAs PIN diode well suited for operation at millimeter-wave frequencies for RF switches and phase-shifter applications,” says Wade. “The low capacitance [0.025pF] makes it ideal for use in many microwave multi-throw switch assemblies, where the series capacitance of each ‘off’ port adversely loads the input and affects VSWR,” he adds.

The MAVR-000120-1411 varactor — unlike its nearest alternatives — is fabricated using a GaAs process that likewise provides full passivation for increased performance and reliability, the firm says. The constant gamma (0.9–1.1) varactor is designed for tuning capacitance in the 2–12V range. The low parasitic capacitance and inductance allow for operation up to 30GHz. “This flip-chip is a high-frequency GaAs varactor suitable for VCO [voltage-controlled oscillator] applications where high-Q operation is critical to design performance,” says Wade. The Q-factor of the device is 3000 (minimum).

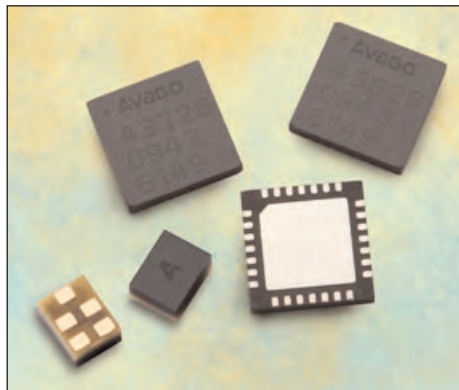
Production quantities and samples of the MADS-001317-1500, MADP-000907-14020 and MAVR-000120-1411 are available from stock.

www.macomtech.com

Avago expands portfolio of RF front-ends for small-cell base transceiver stations

Avago Technologies Ltd of San Jose, CA, USA and Singapore, a supplier of analog interface components for wireless, wireline and industrial applications, has announced two RF power amplifiers (PAs), the MGA-43728 and MGA-43828, and a WiFi FBAR (film bulk acoustic resonator) filter, the ACFF-1024, designed specifically for small-cell base transceiver station (BTS) applications.

Expanding on Avago's MGA-43x28 PA family (launched in June 2012 with the MGA43428, 43528 and 43628), the MGA-43728 and MGA-43828 are, respectively, new UMTS/LTE band 7 and band 8 PAs featuring high linearity, gain and power-added efficiency (PAE) with integrated power detector and shutdown function. The ACFF-1024 is a miniature band-pass filter optimized for use in the 2.4GHz ISM (industrial, scientific & medical) band. Designed with Avago's FBAR technology, the ACFF-1024 enables concurrent operation of WiFi and Bluetooth applications that coexist



Avago's new devices for small-cell base transceiver station applications.

with other wireless standards such as PCS and LTE bands 7, 38, and 40 without performance degradation due to interference.

"Avago is committed to serving small-cell customers with an expanded portfolio of highly differentiated products and cost-effective solutions," says Ron Ruebusch, VP & general manager of Avago's Wireless Semiconductor Division. "Leveraging proven mobile handset technology, Avago shall continue to invest in developing new products

catering to the growing small-cell market segment," he adds.

Performance details of the new products are as follows:

- MGA-43728: linear P_{out} of 27.3dBm at 48dBc ACLR (LTE, 10MHz/50RB); gain of 38.3dB; PAE of 13.7%.

- MGA-43828: linear P_{out} of 27dBm at 50dBc ACLR (UMTS, 5MHz); gain of 33.0dB; PAE of 15.0%.

- ACFF-1024: WiFi and Bluetooth coexistence with LTE bands 7, 38 and 40; 57dB minimum attenuation in LTE band 7; 55dB minimum attenuation in LTE band 38; 50dB minimum attenuation in LTE band 40.

Avago showcased its portfolio of RF front-end solutions (including the new MGA-43728, MGA-43828 and ACFF-1024) at the IEEE MTT-S International Microwave Symposium (IMS 2013) in Seattle, WA, USA (4–6 June).

The MGA-43728 and MGA-43828 are priced at \$9.24 each in 1000-unit quantities, and the ACFF-1024 is priced at \$2.13 each in 1000-unit quantities.

www.avagotech.com

MwT launches AlGaAs/InGaAs pHEMT-based ultra-broadband driver MMIC amplifier up to 50GHz

MicroWave Technology Inc (MwT) of Fremont, CA, USA, the RF division of IXYS Corp that makes microwave devices, MMICs, hybrid modules and connectorized amplifiers for wireless communication infrastructure, military/aerospace, industrial and medical applications, has launched an AlGaAs/InGaAs pHEMT-based monolithic microwave integrated circuit (MMIC) ultra-broadband driver amplifier product up to 50GHz. The product is targeted at applications including fiber-optics communications, microwave/mm-wave communications systems, microwave/mm-wave testing equipment, and military applications.

The MMA-005022 is an ultra-broadband travelling-wave amplifier MMIC with medium output power and high gain over a full range of nearly DC 30kHz to 50GHz. It offers a typical +22dBm saturated power and +20dBm output power at a 1dB gain compression point at 30GHz. The MMIC chip typically has 16dB gain across the band with ± 1 dB gain flatness. The typical input/output return loss for the chip is 15dB. The DC bias is 200mA drain current with 7V drain voltage.

"The excellent performance of the MMA-005022 ultra-broadband MMIC amplifier up to mm-wave frequency range, together with its high reliability and competitive

cost, make this part an excellent choice for wide range applications including modulator driver for fiber-optics communication, wireless communication infrastructure, microwave and mm-wave frequency testing equipment, military/EW, and high-rel/space etc," reckons MwT's general manager Dr Greg Zhou.

The MMA-005022 is fully matched for both input and output terminals for easy cascade and is also available in the low-cost R4 (4mm x 4mm) surface-mount package. The mean time before failure (MTBF) is over 100 years at 85°C ambient temperature. An evaluation board for the packaged version is also available.

www.mwtinc.com

Skyworks reports better-than-expected rise in quarterly revenue and earnings

Firm gaining margin-rich content and share across mobile applications while capitalizing on adjacent vertical markets

For its fiscal second-quarter 2013 (to 29 March), analog semiconductor maker Skyworks Solutions Inc of Woburn, MA, USA (which manufactures analog and mixed-signal semiconductors) has reported revenue of \$425.2m (split 40% in linear products and 60% in handsets). This is up 17% on the \$364.7m a year ago and exceeding the guidance of \$420m.

On a non-GAAP basis, gross margin was 42.2%, down from 43.2% a year ago. However, operating income has risen from \$83.9m (an operating margin of 23.0%) to \$99.7m (operating margin of 23.4%). Net income has risen from \$79.8m (\$0.42 per diluted share) to \$91.9m (\$0.48 per diluted share, \$0.01 better than guidance).

Cash flow from operations was \$130.2m. Capital expenditure was \$25.6m, while depreciation was \$18.5m. During the quarter, Skyworks repurchased 1.4m shares of its common stock, representing an investment of over \$30m. Nevertheless, cash and cash equivalents grew from \$378m to \$458.8m.

"Leveraging our product innovation, scale and strong customer relationships, we are solidifying our position as a highly diversified analog semiconductor market leader," said president & CEO David J. Aldrich. "Further to that end, we are increasingly migrating our product portfolio to differentiated, system-level solutions that provide greater value to our customers and command higher margins," he added.

Skyworks said its March-quarter highlights included ramping advanced infrastructure solutions for Aclara's smart gas meters, and enabling vehicle infotainment systems for Ford, Lincoln and Kia with its silicon-on-insulator (SOI) switching technology. The firm also introduced several new backlight

LED drivers for next-generation smartphones and tablets with display panels ranging in size from 4-inches to 12-inches. In addition, Skyworks recently partnered with Texas Instruments on utility metering, street lighting, telematics and tracking system solutions and expanded its customer engagements with SkyOne, a highly customizable, fully optimized front-end platform.

Skyworks has started volume production of antenna tuning solutions to increase data throughput in multi-band LTE applications. The firm secured an innovative power management design-win enabling photovoltaic battery charging of smartphones. Skyworks also announced support for Samsung's Galaxy S4 platforms with 802.11ac devices, DC/DC converters, antenna switch modules and multi-mode multi-band (MMMB) power amplifiers.

"Overall, our addressable markets are expanding, and we are capitalizing on the following opportunities: first, end-market diversification; second, the connected home; third, smartphone adoption in emerging

Overall, our addressable markets are expanding, and we are capitalizing on the following opportunities: first, end-market diversification; second, the connected home; third, smartphone adoption in emerging markets; and fourth, increasing content in high-end mobile devices

markets; and fourth, increasing content in high-end mobile devices," said Aldrich.

"Based on current demand forecast and order visibility, we expect Q3 revenue to be \$435m [representing 15% growth through the first three quarters of fiscal 2013], providing a solid baseline heading into the stronger second half of the calendar year," said VP & chief financial officer Donald W. Palette during the shareholders and analysts meeting. "Our third-quarter outlook factors in the transition of our product portfolio toward more differentiated performance-based system solutions."

"As our better-than-seasonal results and growth outlook demonstrate, Skyworks is gaining margin-rich content and share across mobile applications while capitalizing on adjacent home automation, networking, medical, smart-grid and machine-to-machine vertical markets," commented Aldrich. Gross margin should rise by 130–180 basis point sequentially to 43.5–44.0%, driven primarily by a more diversified, margin-accretive product mix.

Using the guidance of \$435m in revenue with gross margin at the midpoint of 43.7% and \$80m in operating expenses (roughly flat on fiscal Q2), Skyworks expects operating margin of more than 25% and diluted earnings per share of \$0.53.

"We see a path to continue to drive further margin expansion in the second half and beyond," said Palette. "All of the underlying drivers are in place for Skyworks to continue to outperform, putting us on a path to achieving our mid-term business model of 30% operating margin, which, as a reminder, would generate around \$3 in annualized earnings per share," he added.

www.skyworksinc.com

Matthew Peach, Contributing Editor

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- Secondary Equipment
- MEMS

Country Pavilions

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- USA
- Korea
- Moscow
- Kyushu

International Forums

	AM	PM
Wed. Sept.4	<ul style="list-style-type: none">• Market Trends Forum• IMEC Technology Forum	<ul style="list-style-type: none">• Executive Summit
	<ul style="list-style-type: none">• Advanced Packaging Technology Symposium• LED Forum• Green Manufacturing Forum	
Thru. Sept.5		<ul style="list-style-type: none">• LED Workshop
	<ul style="list-style-type: none">• MEMS Forum• IC Design Forum	
Fri. Sept.6	<ul style="list-style-type: none">• CMP Forum• MEMORY System Executive Forum	<ul style="list-style-type: none">• 450mm Supply Chain Forum
	<ul style="list-style-type: none">• Litho/Mask Technology Symposium	

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Skyworks and SMC partner on wireless solutions for security, monitoring & automation in the connected home

Skyworks Solutions is partnering with SMC Networks Inc, a customer premise equipment (CPE) manufacturer for multi-service operators (MSOs), to develop wireless connectivity solutions for security, monitoring and automation (SMA) applications in the emerging connected home market. SMC is using Skyworks' wireless networking and ZigBee front-end solutions for security sensors, smoke alarms, motion detectors and touch pads.

"With MSOs in the United States and Canada making full-scale deployments this year, SMC sought to collaborate with the industry leader in analog solutions to deliver best-in-class, energy-efficient

products," says Max Brogi, VP of product management at SMC Networks. "Together with Skyworks' front-end modules, SMC is creating platforms that integrate effortlessly with existing security systems and devices, operate and back up wirelessly, are easy to install, and give MSOs a great opportunity to present revenue-generating services to their customers," he adds.

"As more and more devices within the home become connected, we look forward to a long and successful partnership with SMC to supply a wide range of wireless solutions and next-generation technologies addressing this enormous market opportunity," says Liam K. Griffin,

executive VP & corporate general manager at Skyworks.

As cited in the GSMA's report 'Vision of Smart Home: The Role of Mobile in the Home of the Future', the combined revenue from the smart metering, home automation and home energy management segment is forecasted to be more than \$44bn in 2016, according to market analyst firms ABI Research and Berg Insight. The overall revenue potential of the smart home is expected to be even higher as devices from the entertainment, health and home security sectors also become connected.

www.smc.com

www.skyworksinc.com

Skyworks launches 0.7–3.8GHz GaAs pHEMT LNAs with 25dB noise figure supporting consumer, military and industrial applications

Analog semiconductor maker Skyworks Solutions Inc of Woburn, MA, USA has unveiled a portfolio of low-noise amplifiers (LNAs) that provide what is claimed to be best-in-class noise figure (a critical component to boosting weak incoming signals for 4G wireless infrastructure as well as diverse broad market systems including GPS, broadband, military and satellite communications).

OEMs can now leverage a single Skyworks LNA to address all cellular, ISM (industrial, scientific & medical) and military bands, enabling unconditional stability and simple band-specific external matching across a wide voltage range, says the firm.

"Skyworks' newest LNAs are achieving unprecedented performance levels, while enabling a multitude of high-performance base-station, cellular repeater and remote radio head [RRH] platforms," says David Stasey, VP & general manager of analog solutions. "Leveraging our analog design expertise, IP and scale,



Skyworks' SKY67151-396LF GaAs pHEMT low-noise amplifier.

Skyworks is delivering highly differentiated solutions."

The SKY67151-396LF is a gallium arsenide, pseudomorphic high-electron-mobility transistor (GaAs pHEMT) LNA with integrated active bias and a very low noise figure (as low as 0.25dB). The 0.25µm enhancement-mode process provides broadband return loss, high gain, very low noise and high amplifier linearity. The internal active bias circuitry provides stable performance over temperature and process variation. The device allows users to externally adjust the supply current to opti-

mize linearity.

Operating over a broad frequency range of 0.7–3.8GHz, the new LNA has four band-specific external tuning networks with common printed circuit board (PCB) layouts available to cover the full 3000MHz bandwidth. The device is suited to both macro and micro cellular base-stations, repeaters, remote radio heads, tower-mounted amplifiers, L-band and S-band military communications, global positioning transceivers and proprietary radio networks. The LNA is manufactured in a compact 2mm x 2mm, 8-pin, dual flat no-lead (DFN) Skyworks Green package, and four band-specific evaluation boards are available for customer testing.

The new LNAs are currently available for both sampling and production. Skyworks exhibited the products, as well as other RF solutions, at the 2013 IEEE MTT-S International Microwave Symposium (IMS) in Seattle, WA, USA (4–6 June).

www.skyworksinc.com

Skyworks launches family of antenna switches supporting carrier aggregation

Analog semiconductor maker Skyworks Solutions Inc of Woburn, MA, USA has launched RF switching technology that aims to enable early adopters to implement carrier aggregation solutions.

Carrier aggregation allows mobile service providers to combine spectrum and increase data rate throughput by utilizing two or more bands simultaneously instead of the single-band method used currently, regardless of location. Skyworks' devices support standardized inputs to popular industry chipsets (MIPI RFFE compatible) and address both transmit (Tx) and receive (Rx) switching paths.

"Skyworks' carrier aggregation switching solutions, which are compliant to tier-one, carrier-driven specifications, offer dedicated receive diversity functionality to accompany the primary antenna-switch path," says David Stasey, VP & general manager of analog solutions.

Skyworks says that mobile operators are driving carrier aggregation to help increase the efficiency and speed of saturated mobile net-

works, particularly as consumers download an ever increasing amount of mobile content via smartphones. With the limited availability in the wireless spectrum, carriers are seeking innovative RF solutions as a means to fully utilize their allocated spectrum.

Skyworks offers a broad selection of RF switching solutions based on silicon on insulator (SOI) and pseudomorphic high-electron-mobility transistor (pHEMT) wafer process technologies, complementing its silicon and gallium arsenide (GaAs) power amplifiers and front-end solutions. The firm's switches are available in many different configurations including ultra-high linearity, low insertion loss, high isolation, broadband, reflective and non-reflective. In particular:

- The SKY13456-11 is a double-pole, 14-throw (SP7T/SP7T) antenna switch module for primary antenna transmit. The switch features low insertion loss, high isolation, exhibits what is claimed to be excellent IMD performance and is designed to meet stringent requirements of B17 third harmonic.

Switching is controlled with an integrated mobile industry processor interface (MIPI) decoder allowing the low-band and high-band sections to be independently controlled by two separate registers. No external direct current (DC) blocking capacitors are required. The switch is manufactured in a small, 2.8mm x 3.2mm, 26-pin multi-chip module (MCM) package.

- The SKY13484 is a dual-pole, 12T (SP7T/SP5T), MIPI-controlled antenna switch designed specifically for Rx diversity in carrier aggregation applications. The SP5T switch is optimized for the low band, while the SP7T is for high band. Using advanced switching technologies, the device maintains low insertion loss and high isolation for all switching paths. The switch also exhibits what is claimed to be excellent IMD2/IMD3 performance. Packaged in a small 2.5mm x 2.9mm x 1.0mm, 22-lead MCM package, switching is controlled by a MIPI decoder and requires no DC blocking capacitors on the RF paths.

www.skyworksinc.com

Skyworks' RF and analog devices being used in multiple design wins in Novero's automotive on-board communication systems

Skyworks Solutions Inc of Woburn, MA, USA says that an increasing number of its products are enabling telematics and infotainment systems in the automotive market. Telematics describes the integrated use of computers and electronic technology in automobiles for wireless communication applications such as cell phones, the Internet and GPS receivers.

Skyworks' silicon-on-insulator (SOI) switching technology is already being used by car makers for low-noise and broadband handoffs between audio, Blu-ray/DVD, navigation, cell phone and vehicle security display inputs.

Skyworks has now secured multiple RF and analog design wins with automotive supplier Novero GmbH of Düsseldorf, Germany. Skyworks' devices are enabling Novero's on-board communication systems being deployed by several car makers, including a large, tier-one German company.

Skyworks is capitalizing on the increasing number of addressable semiconductor opportunities in the telematics and infotainment segments of the automotive market, says John O'Neill, VP of broad markets marketing. "Our high-performance, turn-key solutions are ideal for in-vehicle applications,

particularly as mobile phone integration, navigation and data access become mainstream."

Telematics and monitoring services in automobiles are rapidly growing markets as safety and security concerns become more prevalent. According to consulting and market research firm Lucintel, the global automotive semiconductor market is expected to reach \$36bn by 2018. Growth is being driven by innovations in hybrid vehicles as well as advanced safety features in infotainment systems.

www.novero-automotive.com
www.skyworksinc.com

IBM launches fifth-generation silicon germanium process, compatible with 90nm CMOS

9HP to boost data flow in network backbones for Wi-Fi, LTE cellular, wireless backhaul and high-speed optical communications

IBM has introduced the fifth generation of its semiconductor technology specialized for high-performance communications. The firm's latest silicon-germanium (SiGe) chip-making process is designed to enable increasing amounts of data to flow through network backbones in applications such as Wi-Fi, LTE cellular, wireless backhaul and high-speed optical communications.

IBM claims that, since its introduction in 1995, SiGe technology has helped to spur a revolution in radio frequency (RF) performance, enabling the development of devices such as satellite global positioning systems, WiFi radios and high-speed optical links.

IBM's new 9HP SiGe technology targets the design of chips for LTE cellular base-stations, millimeter-wave wireless communication links, and next-generation short- and long-haul optical communications. In addition to communications, the performance of the 9HP process can benefit other applications such as high-performance test equipment, automotive radar and security imaging, reckons IBM.

"Silicon-germanium is one of the key technologies that have enabled wireless operators to keep up with the explosive growth in data traffic generated from mobile handsets," says IBM fellow David Hame.

"Before SiGe, the high-performance chips used in base-stations and optical links were built using expensive, esoteric processes," he adds. "SiGe provides the necessary performance as well as integration and cost savings via its CMOS base."

Open collaboration key to success IBM says that, over the years, technology firms have worked closely with it to develop and refine new versions of the chip-making process. IBM believes that open

collaboration between companies will drive future innovation in semiconductors.

"As early adopters of IBM's SiGe technology, Semtech has consistently pushed the envelope on what can be achieved in high-speed wired and wireless communications systems and in high-performance analog devices," says Charles Harper, senior VP of the Systems Innovation Group at Semtech Corp of Camarillo, CA, USA, which supplies analog and mixed-signal semiconductors for high-end consumer, computing, communications and industrial equipment. "Semtech is a leader in 40Gbps and 100Gbps communications systems, and with IBM's latest SiGe technology we believe we can emerge as a leader in several new analog segments where performance, integration and power are critical requirements," he adds.

"Our long collaboration with IBM on SiGe technology has enabled Tektronix to break new barriers on what can be achieved in high-fidelity, high-bandwidth oscilloscopes," comments Kevin Ilcisin, chief technology officer of test, measurement and monitoring equipment supplier Tektronix of Beaverton,

The performance of the 9HP process can benefit other applications such as high-performance test equipment, automotive radar and security imaging.

SiGe is one of the key technologies that have enabled wireless operators to keep up with the explosive growth in data traffic generated from mobile handsets

OR, USA. "We utilized IBM's SiGe 9HP for our patent-pending asynchronous interleaving approach, and expect to break new ground by providing customers bandwidth capabilities of 70GHz and beyond while significantly improving our signal-to-noise ratio."

Technology details and specifications

IBM claims that 9HP will be the first SiGe technology featuring the density of 90nm CMOS, enabling the highest level of integration in a fully production-qualified SiGe BiCMOS technology. IBM adds that its new SiGe BiCMOS technology delivers higher performance, lower power and higher levels of integration than current 180nm or 130nm SiGe offerings.

The technology maintains compatibility with the firm's 90nm low-power CMOS technology platform, enabling foundry clients to port a wide range of intellectual property circuit blocks and standard cell library elements. The 90nm foundry platform also includes an RF CMOS technology option, giving foundry customers a broad range of technology choices for RF and mixed-signal applications, says IBM.

Specific technical details include: SiGe heterojunction bipolar transistor (HBT) NPNs with a current-gain cut-off frequency (f_T) of 300GHz and power-gain cut-off frequency (or maximum oscillation frequency, f_{max}) of more than 350GHz; 90nm CMOS FETs (1.5V, 2.5V/3.3V); thick dielectric add-on modules (low-K, Cu, Al); a full suite of passives (resistors, varactors, MOS and MIM capacitors, high-Q inductors, millimeter-wave elements); PIN and THz Schottky barrier diodes; and process design kits (PDKs) featuring precision RF device models.

www.ibm.com/us/en

www.tektronix.com

IBM unveils highly integrated SiGe-based mm-wave transceiver for mobile communications & radar imaging

Four phased-array ICs enable 90–94GHz operation in compact, scalable module

IBM claims to have achieved a milestone in creating a phased-array transceiver that contains all of the millimeter-wave components necessary for both high data-rate communications and advanced-resolution radar imaging applications. The newly demonstrated integrated circuits tackle data bottleneck issues for mobile communications applications and allow radar-imaging technology to be scaled down to the size of a computer laptop.

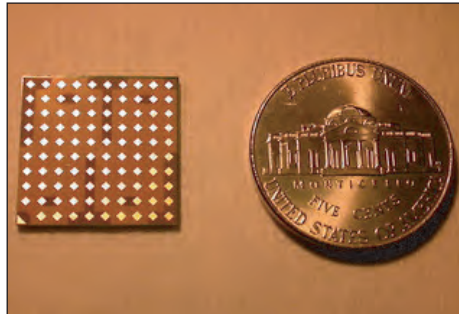
Advanced radio-frequency integration has been a key driver in the growth of mobile device capability and sophistication, says IBM. Millimeter-wave bandwidth has the ability to support Gb/s wireless communications, dramatically expanding opportunities for mobile backhaul, small-cell infrastructure, and data-center overlay network deployment.

The frequency range of the ICs is well suited to high-resolution radar imaging applications due to its short wavelength, relatively low atmospheric attenuation, and ability to penetrate debris. The ICs enable radar technology to be scaled down, giving pilots the ability to penetrate fog, dust and other vision-impairing obstructions.

"This transceiver presents the highest level of integration achieved so far in a silicon-based solution for millimeter-wave frequency applications," says Dr Alberto Valdes-Garcia, IBM Research, Communications and Computation Subsystem Group. "It is a key step toward phased-array systems of the future that are scalable, low-volume, light-weight, and low-cost."

IC and scalable array assembly technology

The packaged transceiver operates at frequencies of 90–94GHz and is implemented as a unit tile, integ-



Packaged chip. Each of the 64 diamond shaped objects is an antenna.

rating four phased-array ICs and 64 dual-polarized antennas. By tiling packages next to each other on a circuit board, scalable phased arrays of large aperture can be created while maintaining uniform antenna element spacing. The beam-forming capabilities enabled by hundreds of antenna elements will allow for communications and radar imaging applications that will extend over a range of kilometers, says IBM.

Each of the four phased-array integrated circuits in a tile integrates 32 receive and 16 transmit elements with dual outputs to support 16 dual-polarized antennas. Multiple operating modes are supported, including the simultaneous reception of horizontal and vertical polarizations. Fabricated using an IBM silicon germanium (SiGe) semiconductor process, the ICs also integrate frequency synthesis and conversion as well as digital control functions.

The complete scalable solution (including antennas, packaging and transceiver ICs) transforms signals between millimeter-wave and baseband, all in a form factor smaller than an American nickel coin.

Mobile back-haul technology

Mobile service providers have started to alleviate backhaul congestion issues by using E-band

wireless links. E-band spectrum, allocated by the US Federal Communications Commission (FCC) for point-to-point communications, covers frequencies of 71–76GHz, 81–86GHz and 92–95GHz, and enables wireless data transfer at very high rates. The atmospheric attenuation in this band is relatively low, making it well suited to supporting long-range communications links.

Existing E-band solutions consist of multi-chip modules and bulky mechanically aligned antennas. The newly developed compact scalable phased array solution provides electronic beam steering and the bandwidth to support Gb/s wireless communications.

Millimeter-wave radar and imaging capabilities

The millimeter-wave range spans 30–300GHz on the electromagnetic spectrum (10–100 times higher than the frequencies used for mobile phones and Wi-Fi).

Frequencies of 90–94GHz are well suited for short- and long-range, high-resolution radar imaging.

Weather, debris and other vision-impairing obstructions often leave aircraft pilots helpless, but 94GHz radar imaging technology could alleviate this problem, says IBM. Moreover, the design's support for two antenna polarizations — with minimal increase in footprint — provides a further advantage while navigating through fog and rain.

IBM debuted the phased-array transceiver design at the IEEE Radio Frequency Integrated Circuit Symposium (RFIC 2013) in Seattle, WA, USA on 4 June. The work was partially funded by the Defense Advanced Research Projects Agency (DARPA) Strategic Technology Office (STO).

www.ibm.com/us/en

www.rfic-ieee.org

Freescale's RF business creates aerospace & defense unit

Multi-technology approach to leverage LDMOS, GaAs and GaN lines

Freescale Semiconductor of Austin, TX, USA, which provides RF power technology for cellular markets, has announced a major initiative focused on demonstrating how its new and existing commercial RF power and microwave RF devices can meet the requirements of the US aerospace and defense (A&D) market.

The firm plans to support a broad range of A&D applications with entirely new gallium nitride (GaN) RF power transistor products, as well as its proven portfolio of more than 400 LDMOS RF power transistor and gallium arsenide (GaAs) monolithic microwave integrated circuit (MMIC) products. These products will be supported by a dedicated team focused exclusively on A&D markets and customers.

"Freescale has more than 60 years of RF power innovation and experience, and we look forward to extending our focus beyond our leading position in RF power transistors to growing A&D markets," says Ritu Favre, senior VP & general manager of Freescale's RF business. "A&D equipment manufacturers will benefit from Freescale's long track record of working closely with customers to create cost-effective solutions that combine superb performance, proven reliability and extreme ruggedness."

According to analyst firm ABI Research, global sales for RF power devices targeting the defense market (under 4GHz and above 4W output) will total \$144m by 2018.

"Freescale has been the market leader in RF power devices for wireless infrastructure for many years," comments Lance Wilson, research director, RF Devices, at ABI Research. "That experience and expertise should serve them well as they branch out into other RF power market segments, including A&D."

Freescale's RF business (formerly part of Motorola's Semiconductor Products Sector) has more than six decades of history and expertise in RF power transistor development, introducing its first device in 1952. Since then it has predominated in silicon-based LDMOS RF power transistors for wireless infrastructure, delivering more than 30 million annually. The firm maintains the RF power market's only US-based LDMOS device fabrication facility, as well as in-house final manufacturing facilities. Its Airfast LDMOS products that have been 'ruggedized' for commercial applications are suited to A&D requirements, with the ability to operate into extreme load mismatches (VSWR) greater than 65:1 and enhanced protection from electrostatic discharge (ESD). The LDMOS devices span frequency ranges to

more than 3GHz with RF power outputs up to 1250W.

In addition, Freescale's GaAs MMIC devices cover applications to over 5GHz and include gain block amplifiers, power amplifiers (up to 4W), and low-noise amplifiers with noise figures as low as 0.35dB. Also, the firm's first GaN RF power transistors are planned for availability in late 2013.

Freescale says that this experience and technology will be complemented by a team of RF experts dedicated to the A&D market, including technical and applications support. The RF A&D team is led by a senior member of Freescale's technical staff who has more than 30 years of RF power transistor experience, from design engineering to executive management. He is joined by a former marketing director for Freescale's RF power business, who has 40 years of experience in marketing, sales and distribution. The products will also be supported by a dedicated team of marketing, program management, applications, regulatory compliance and other professionals focused exclusively on A&D markets and customers.

New products bought for use in A&D applications are planned for inclusion in the Freescale Longevity Program, with assured supply for 15 years.

www.freescale.com/rfmilitary

pHEMT-based broadband LNA to optimize receiver performance

Freescale has launched a GaAs-based enhancement-mode pHEMT low-noise amplifier (LNA), designed to optimize receiver performance for a broad array of wireless systems operating at 700–1400MHz. Typical applications include small-cell and macrocell transceivers, as well as a range of applications requiring extremely low noise figures, high linearity, and high RF output power.

The noise figure of the new MML09231H is 0.36dB at 900MHz (claimed to be one of the lowest noise figures of any small-signal device), suiting receiver design because it can boost product sensitivity to very low-level signals. The MML09231H also has an output third-order intercept point (OIP3) of 37.4dBm at 900MHz, delivering the high linearity required by wireless systems.

The LNA can tolerate a maximum input signal of +20dBm, has an RF output peak power of +24.5dBm (280mW), high reverse isolation of –21dB, small-signal gain of 17.2dB (externally adjustable), and current consumption of 55mA from a single 5V_{dc} supply. Also included: a power-down pin, active bias control for maintaining constant current, unconditional stability over temperature, and low external component count.

TowerJazz wins Manufacturing Leadership 100 Award for Operational Excellence category

At the 9th annual Manufacturing Leadership Summit in Palm Beach, FL, USA on 15 May, specialty foundry TowerJazz (which has fabrication plants at Tower Semiconductor Ltd in Migdal Haemek, Israel, and at its subsidiaries Jazz Semiconductor Inc in Newport Beach, CA, USA and TowerJazz Japan Ltd) was honored by Frost & Sullivan as a winner of the Manufacturing Leadership 100 (ML100) award. TowerJazz was recognized for implementing radio-frequency identification (RFID) in its production line to improve operational efficiency.

TowerJazz was a winner in the Operational Excellence category, which celebrates outstanding projects undertaken and completed by a manufacturing company. Winners in this category have undertaken projects that transform production processes and systems with a view towards reducing costs and enhancing agility, says the firm.

"Integrating RFID into our Fab 3 semiconductor manufacturing dispatch process has enabled us to substantially increase operating efficiency," says CEO Ephie Koltin. "This was accomplished by automating tracking steps into the existing Real Time Dispatch (RTD) system and enabling visual location through the integrated LED lights which reduced cycle time and cost," he adds.

Judging criteria for the projects examined how the project transformed key processes and allowed the manufacturing company to add value in new ways, the bottom-line business benefit which resulted from the project, how the project enabled the company's overall business strategy, to what extent the use of technology was key to enabling the project and how it was deployed in a way that delivered maximum value to the business.

www.towerjazz.com.

Custom MMIC launches 4–8GHz LNA

Monolithic microwave integrated circuit developer Custom MMIC of Westford, MA, USA has added the CMD185P3 low-noise amplifier to its expanding line of standard amplifier products.

The CMD185P3 has a low noise figure of 1.9dB and associated gain of +15dB across the 4–8GHz bandwidth, while only requiring a single positive supply voltage (+4.0V @ 75mA). With an output 1dB compression point of +15dBm,

the CMD185P3 suits converter chains in communications systems where small size and low DC power consumption are required, the firm says.

The CMD185P3 is housed in a Pb-free, RoHS-compliant, 3mm x 3mm plastic surface-mount package and is 50Ω matched on the input and output ports, eliminating the need for external DC blocks and matching components.

www.CustomMMIC.com



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Peregrine launches highest-isolation SPDT RF switch for wireless infrastructure market

Peregrine Semiconductor Corp of San Diego, CA, USA, a fabless provider of radio-frequency integrated circuits (RFICs) based on silicon-on-sapphire (SOS), has announced availability of what it claims is the industry's highest-isolation SPDT (single-pole double-throw) RF switch for the wireless infrastructure market.

The UltraCMOS-based PE42420 RF switch has high isolation of 64dB @ 4GHz (an increase of about 20% over competing devices on the market, it is reckoned). Also, the switch features HaRP technology enhancements to deliver high linearity, with an IIP3 of 65dBm. By providing high linearity and isolation in a single, small package, the PE42420 simplifies digital pre-distortion (DPD) loop design, which reduces cost and shortens time to market.

Peregrine says that the high-performance switch enables increased network capacity and higher data rates in infrastructure applications such as base-station transceiver systems (BTSSs), remote radio heads (RRHs), and wireless back-haul, as well as industrial, scientific & medical (ISM)-band devices that operate in the 2.4GHz and 5.8GHz frequencies.

"As we enter a period of major mobile broadband capacity upgrades, network equipment vendors are challenged to provide mobile operators with flexible,



Peregrine's UltraCMOS-based PE42420 SPDT RF switch.

backward-compatible solutions to replace 2G and 3G network products with LTE-ready systems that are capable of supporting multiple standards," says Mark Schrepferman, director of the communications and industrial product line for Peregrine's High-Performance Solutions business unit. "At the same time, the demand for higher data rates is requiring improved network performance, which we believe is driving market needs for high-isolation and high-linearity RF components," he adds. "The PE42420 switch enables equipment vendors to meet these network modernization challenges."

In order to maximize network performance in next-generation wireless communication systems, high port-to-port isolation is

required to prevent the output signal from spilling into adjacent radio channels or bands, says Peregrine.

Also, because the DPD receiver is shared by multiple power amplifiers (PAs) in these systems, high isolation between the multiple paths ensures that the power amplifier that is being sampled is not contaminated

by other signals.

The 0.1–6GHz PE42420 switch supports 1.8V control logic, enabling the use of lower-voltage and lower-power microcontrollers. ESD tolerance of 2kV HBM on all pins eases manufacturing and results in higher reliability of the end-product, says Peregrine.

The PE42420 switch is available in a 20-pin 4mm x 4mm LGA package, and is priced starting at \$1.25 each. Samples and volume-production quantities can be ordered through Peregrine's global direct sales representatives and worldwide distribution partners. The PE42420 Evaluation Kit (part number EK42420-02, \$95) is also available, enabling designers to evaluate the PE42420 switch in their applications.

www.psemi.com

Judge consolidates cases in patent infringement actions vs RFMD

Peregrine Semiconductor Corp of San Diego, CA, USA, a fabless provider of radio-frequency integrated circuits (RFICs) based on silicon-on-sapphire (SOS), says that Judge Irma Gonzalez has consolidated its two lawsuits pending in US District Court that allege the infringement by RF Micro Devices Inc of Greensboro, NC, USA of

Peregrine's patented intellectual property relating to RFICs and switching technology.

The two lawsuits — filed in the US District Court for the Southern District of California in February 2012 and March 2013 — claim that certain RFMD products infringe Peregrine patents relating to silicon-on-insulator (SOI) tech-

nology for RFICs. In addition to damages, Peregrine seeks to permanently enjoin RFMD from further infringement.

Peregrine expects that consolidation of the cases will allow its infringement claims to move more efficiently towards trial and appropriate legal remedy.

www.psemi.com

Peregrine completes collaborative sourcing and UltraCMOS license agreement with Murata

License covers RFSOI-based design, process and third-party sourcing

Peregrine Semiconductor Corp of San Diego, CA, USA, a fabless provider of radio-frequency integrated circuits (RFICs) based on silicon-on-sapphire (SOS), has signed a collaborative agreement with Japan's Murata Manufacturing Company on a multi-sourcing arrangement for RF switches based on Peregrine's proprietary UltraCMOS technology.

Peregrine pioneered RF CMOS-based devices with its UltraCMOS technology, an advanced form of silicon-on-insulator (SOI) process, and more than 20 years of R&D have resulted in 150 patents issued and pending. Aided by its IP portfolio, Peregrine has established its position in the RF front-end section of mobile devices for RF switches and tunable RF components.

Murata is a supplier of RF front-end (RFFE) modules (incorporating

RF switches and tuning devices with SAW filters, passive components, and advanced packaging techniques) for the global mobile wireless market.

Murata will source a majority of its RF switching requirements from Peregrine in exchange for being granted a license to purchase or manufacture RF CMOS switches using Peregrine's technology and intellectual property (IP). The parties expect the agreement to result in an expanded source of supply for these critical RF components and to assure global OEMs broad access to RF CMOS products.

"Global OEM customers of both Peregrine and Murata have for some time requested that the companies implement an independent source of supply for the critical switching elements that are widely utilized in today's smart phones

and other wireless-communications products," says Peregrine's president & CEO Jim Cable. "This agreement marks the first license of Peregrine's switch-based intellectual property to a third party; we look forward to working collaboratively with Murata to expand the deployment of UltraCMOS technology," he adds.

"Peregrine has fundamental IP in CMOS-based switches and tuning products," says Norio Nakajima, Murata's VP, Communication business unit. "This IP licensing arrangement solidifies our existing relationship and future collaboration with Peregrine," he adds. "We believe that the combination of Murata's filter and packaging technology with Peregrine's UltraCMOS switch and tuning technology is a formidable RFFE solution."

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IN BRIEF

Digi-Key to distribute GeneSiC's 3300V Schottkys

Global Internet-based electronic components distributor Digi-Key Corp of Thief River Falls, MN, USA has agreed to act as exclusive distributor of the latest low-capacitance silicon carbide (SiC) Schottky rectifiers (launched earlier this year) from GeneSiC Semiconductor Inc of Dulles, VA, USA, which develops silicon carbide and silicon-based devices for high-temperature, radiation and power grid applications. The rectifiers are specifically targeted at voltage multiplier circuits and high-voltage assemblies used in a range of x-ray, laser and particle-generator power supplies.

GeneSiC's GAP3SLT33-220FP 3300V/0.3A Schottky rectifiers feature zero reverse recovery current that does not change with temperature. This relatively high voltage in a single device allows a reduction in voltage multiplication stages required in typical high-voltage generator circuits, through the use of higher AC input voltages. The near-ideal switching characteristics allow the elimination or dramatic reduction of voltage balancing networks and snubber circuits.

"The 3300V rating is a key differentiator for the high-voltage generator market," believes GeneSiC's president Dr Ranbir Singh.

"GeneSiC's low- V_F , low-capacitance SiC Schottky rectifiers enable this breakthrough product," he adds. The on-state forward voltage drop (V_F) is 1.7V at 0.3A. The capacitance is 42pF at a reverse bias (V_R) of 1V and a frequency of 1MHz.

All devices are 100% tested to full voltage/current ratings and housed in halogen-free, RoHS-compliant, industry-standard TO-220FP (Full Pack) packages.

www.digikey.com
www.genesicsemi.com

SPTS and QMF grow 3C-SiC epitaxy on 300mm silicon

Joint development of reactor to extend epi growth to commercial-scale SiC-coated silicon wafers for GaN devices

The Queensland Micro and Nanotechnology Facility (QMF) of Griffith University in Brisbane, Australia and its industry partner, plasma etch, deposition and thermal processing equipment maker SPTS Technologies Ltd of Newport, Wales, UK, have announced the epitaxial growth of 3C silicon carbide (SiC) films on 300mm silicon wafers. The achievement is the result of over 10 years of research at QMF on low-temperature SiC deposition on silicon and the joint development by QMF and SPTS of a commercial reactor to extend the epitaxial growth process to commercial-scale production of SiC-coated silicon wafers.

The ultimate target of the joint project is to provide a cost-effective buffer material to enable the fabrication of gallium nitride (GaN) devices on silicon substrates. Fabricating GaN light-emitting diodes (LEDs) and power devices on large-diameter silicon wafers is viewed as a path to improve performance and reduce cost, hence increasing commercial acceptance of these devices. However, existing buffer layers used to bridge the large thermal and lattice mismatches between silicon and GaN are costly and not completely effective for large-scale production.

A 3C-SiC film provides an effective buffer layer lattice-matched for GaN growth on silicon, as well as an impervious barrier to prevent silicon from diffusing into GaN, which is of particular concern for power devices. Initial estimates are that the new SiC-on-silicon coating process in volume production would add no more than \$25–35 to the cost of a silicon wafer, increasing the appeal of silicon as a substrate for LEDs and GaN power devices.

"We are the first in the world to grow 3C-SiC epitaxially on 300mm silicon wafers, which means following the same crystal structure as the silicon crystal substrate," says Alan Iacopi, QMF director of operations. "The reactor development project with SPTS has allowed the QMF R&D process to be extended from small wafers up to 300mm wafers with semiconductor industry specifications; in fact, we have already achieved SiC film thickness uniformities of around 1% on 300mm wafers using the new reactor," he adds.

"We see the QMF SiC technology as a potential breakthrough in reducing the cost of LEDs and improving the performance of GaN power devices," says SPTS' president & CEO William Johnson. "Based on our extensive background in vertical furnace technology, the new reactor has been designed for high-temperature vacuum processing of batch loads of 150mm to 300mm wafers, with process automation suitable for commercial application. There are a number of buffer and template wafer suppliers offering alternative solutions; however, we see a strong business case for device manufacturers adopting the QMF/SPTS SiC solution to optimize process and control substrate costs," he adds.

"The partnership has far-reaching implications in terms of demonstrating how Australian research entities (like QMF) can collaborate with international industry to advance frontier technologies," says Iacopi. "We have all the ingredients to develop a high-tech economy in Queensland, including technically leading Universities, the Australian National Fabrication Facility infrastructure, entrepreneurial spirit, and start-up company investment."

www.griffith.edu.au/qmnc
www.spts.com

Cree launches first commercially available SiC six-pack power module in industry-standard 45mm package

Cree Inc of Durham, NC, USA has launched what it says is the first commercially available silicon carbide (SiC) six-pack power module in an industry-standard 45mm package.

When replacing a silicon module with equivalent ratings, Cree's six-pack module can reduce power losses by 75%, leading to a 70% reduction in the size of the heat sink or a 50% increase in power density, says the firm. Compared with state-of-the-art silicon modules, the SiC 1.2kV, 50A modules deliver performance equivalent to silicon modules rated at 150A.

"The efficient switching of the SiC module allows us to use them with significantly less derating than

silicon IGBTs," says Dr Jun Kang, research and applications manager at Yaskawa America Inc. "This feature enables significantly higher-frequency operation, which both increases fundamental output frequency and reduces passive component size in the motor drive."

"Cree's SiC power module family can also provide significant benefits to applications such as solar inverters, uninterruptible power supplies (UPS) and industrial power supplies," says Mrinal Das, product marketing manager, Cree Power and RF. "Even when designers simply substitute Si modules with SiC in motor drive applications, the improved performance of SiC reduces power

losses, leading to reduced cooling requirements and, in turn, to a reduction in size, weight, complexity and the overall cost of the power electronics system."

The CCS050M12CM2 six-pack modules from Cree are available for immediate shipping through Digi-Key and Mouser Electronics. Gate-driver ICs suitable for SiC MOSFETs are available from IXYS and Texas Instruments. Complete gate driver boards (CRD-001) are available as samples from Cree upon request.

Cree exhibited the new six-pack module at the PCIM 2013 event in Nuremberg, Germany (14–16 May).

www.cree.com/SiC-modules

Mitsubishi Electric launches SiC power modules for home appliances, industrial equipment, railcar traction

Tokyo-based Mitsubishi Electric Corp has begun shipping three types of silicon carbide (SiC) power module for home appliances, industrial equipment and railcar traction systems. The modules, which use SiC Schottky barrier diodes (SBDs), are expected to reduce the size, lower the weight and raise the efficiency of inverters in power electronics.

The hybrid SiC DIPFPC (dual-in-line package power-factor correction) — a transfer-mold-type IPM (intelligent power module) with for PFC circuits — for home appliances, together with a hybrid SiC-IPM for general industry applications and a hybrid SiC module for railcar traction systems, are being exhibited at Power Conversion Intelligent Motion Europe (PCIM Europe 2013) in Nuremberg, Germany (14–16 May).

Mitsubishi Electric says that, in recent years, inverters have come to be used in a variety of applications, including home appliances (e.g. air conditioners and refrigerators) as well as industrial equipment and railcar traction systems. Power

semiconductors using SiC can greatly decrease power loss and enable high-speed switching, which is raising expectations regarding energy efficiency, the firm adds.

In the PSH20L91B6-A hybrid SiC DIPFPC for home appliances, SiC-SBDs reduce the recovery current and decrease electromagnetic interference (EMI) noise. Rated for a voltage of 600V and current of 20A_{rms}, the module realizes high-frequency switching of up to 30kHz. With under-voltage, over-current and over-temperature protection, the PFC circuit and built-in drive IC reduce the footprint and simplify the wiring pattern (using interleave connection). The package size (24mm x 38mm) is compatible with Mitsubishi Electric's supermini DIPFPC products.

The PMH200CS1D060 hybrid SiC-IPM for general industry reduces power loss by about 20% compared to Mitsubishi Electric's PM200CS1D060 (Si-IPM) device and enables smaller, more efficient equipment. With 6in1 connection,

the 50mm x 120mm package and control terminals are compatible with Mitsubishi Electric's PM200CS1D060 (S1-IPM) module. Rated for 600V and 200A_{rms}, under-voltage, over-current and over-temperature protection (including an on-chip temperature sensor) are the same as those in Mitsubishi Electric's PM200CS1D060 (S1-IPM) module.

The CMH1200DC-34S hybrid SiC module for traction systems (which is rated for 1700V and 1200A) reduces power loss by about 30% compared with Mitsubishi Electric's silicon-based CM1200DC-34N (N-series IGBT) device and enables more efficient devices. With 2in1 connection, the 140mm x 130mm package and terminals are compatible with the CM1200DC-34N (N-series IGBT). High reliability makes the module suitable for use in traction systems, says the firm.

The modules comply with RoHS (European Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment).

www.MitsubishiElectric.com

European project LAST POWER summarizes results on SiC and GaN power electronics developments

Three-year program develops 150mm 4H-SiC junction barrier Schottkys, JFETs and MOSFETs as well as gold-free normally-off AlGaIn/GaN-on-silicon HEMTs

LAST POWER (Large Area silicon-carbide Substrates and heteroepitaxial GaN for POWER devices), the European Union-sponsored program aimed at developing a cost-effective and reliable technology for power electronics, has announced its three-year program achievements, targeted at placing Europe at the forefront of research and the commercialization of energy-efficient devices for industrial and automotive applications, consumer electronics, renewable-energy conversion systems, and telecoms.

Launched in April 2010 by the European Nanoelectronics Initiative Advisory Council (ENIAC) Joint Undertaking (JU), a public-private partnership in nanoelectronics, LAST POWER links private firms, universities and public research centers working in the field of wide-bandgap semiconductors based on silicon carbide (SiC) and gallium nitride (GaN). The consortium members are project coordinator STMicroelectronics (Italy), LPE/ETC (Italy), Institute for Microelectronics and Microsystems of the National Research Council – IMM-CNR (Italy), Foundation for Research & Technology-Hellas - FORTH (Greece), NOVASiC (France), Consorzio Catania Ricerche -CCR (Italy), Institute of High Pressure Physics – Unipress (Poland), Università della Calabria (Italy), SiCrystal (Germany), SEPS Technologies, SenSiC and Acreo (all Sweden), Aristotle University of Thessaloniki – AUTH (Greece).

The main achievements in SiC-related efforts were based on the demonstration by SiCrystal of large-area 4H-SiC substrates, 150mm in diameter, with a cut-off angle of 2°-off-axis. The material quality, both in crystal structure and surface roughness, is comparable with the standard 100mm 4°-off-axis material available at the beginning of the project. At LPE/ETC, the substrates have been used for epitaxial growth of moderately doped epi-layers suitable for the fabrication of 600–1200V junction barrier Schottky (JBS) diodes and MOSFETs, owing to the development of a novel chemical vapor deposition (CVD) reactor for growth on large-area (150mm) 4H-SiC.

The epilayer quality enabled the fabrication of junction barrier Schottky diodes in the industrial production line at STMicroelectronics. Characterization of the first lots showed electrical performance comparable with state-of-the-art 4°-off-axis material. In this context, the fundamental technological step was the chemical mechanical polishing (CMP) process — StepSiC reclamation and planarization — implemented at NOVASiC, which is a key issue both for the preparation of the substrates before epi growth and for the sub-nanometric control of the surface roughness of the device's active layers. Within the project, the same firm also developed epitaxial growth capability for both MOSFET and JFET devices.

Additional research activities on SiO₂/SiC interfaces have been carried out in collaboration with ST and IMM-CNR to improve the channel mobility in 4H-SiC MOSFETs.

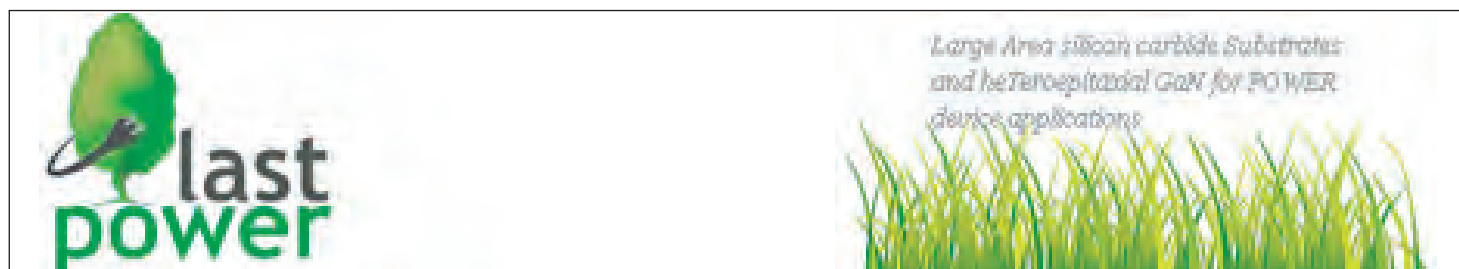
Finally, novel technological modules for high-temperature 4H-SiC JFETs and MOSFETs have been developed in collaboration between Acreo and FORTH, with the support of CCR for the study of molding compounds and 'lead-free' die-attach materials for reliable packaging solutions.

The LAST POWER project also researched the use of GaN-based devices in power-electronics applications. In particular, ST developed AlGaIn/GaN HEMTs epi structures grown on 150mm silicon substrates, reaching a target of 3μm thickness and 200V breakdown voltage. LAST POWER worked with IMM-CNR, Unipress and ST to develop the technological steps for normally-off AlGaIn/GaN HEMTs with a 'gold-free' approach. The process modules are fully compatible with the device fabrication flow-chart set in the ST production line and are being integrated for HEMT fabrication.

The interaction between the project partners working on material growth and device technology has enabled key steps towards the monolithic integration of GaN-based and SiC-based devices, it is reckoned, as both technologies have been proven on 2°-off-axis 4H-SiC substrates.

www.eniac-lastpower.org

www.st.com/web/en/press/t3427



Element Six acquires Group4 Labs to expand portfolio of synthetic diamond materials

Element Six to boost scale-up of Group4's GaN-on-diamond wafer manufacturing

Luxembourg-registered synthetic diamond materials firm Element Six (part of the De Beers Family of Companies, and co-owned by Belgian materials group Umicore) has acquired the assets and intellectual property of Group4 Labs Inc of Menlo Park, CA, USA, which provides gallium nitride (GaN)-on-diamond wafer materials for RF and high-power devices. The asset acquisition will expand Element Six's semiconductor portfolio for defense and commercial applications.

Founded as a startup in 2003, Group4 has partnered with Element Six since 2008. Group4 developed what was claimed to be the first commercially available composite semiconductor wafer that includes GaN and diamond. Designed for manufacturers of transistor-based circuits with high-power, high-temperature and high-frequency characteristics, the first-ever GaN-on-diamond system enables rapid, efficient and cost-effective heat extraction. This process can reduce the operating temperatures of packaged devices, addressing heat issues that account for more than 50% of all electronic failures. Synthetic diamond dissipates heat up to five times better than existing materials, such as copper and silicon carbide, enabling device makers to produce smaller, faster and higher-power electronic devices with longer lifespans and improved reliability.

When implemented within power amplifiers, microwave and millimeter-wave circuits, GaN-on-diamond systems can provide benefits for defense and commercial applications including cellular base-stations, radar sensing equipment, weather and communications satellite equipment, and inverters and converters typically used in hybrid and

electronic vehicles, it is claimed.

In April, RF front-end component maker and foundry services provider TriQuint Semiconductor Inc of Hillsboro, OR, USA said that it had demonstrated its new GaN-on-diamond high-electron-mobility transistors (HEMT) in conjunction with partners at the University of Bristol, Group4 and Lockheed Martin under the Defense Advanced Research Projects Agency's (DARPA) Near Junction Thermal Transport (NJTT) program. TriQuint has designed devices using this technology to achieve up to a three-fold improvement in heat dissipation (NJTT's the primary goal) while preserving RF functionality. This would translate into a potential three-fold reduction in power amplifier size or increase in output power.

"GaN-on-diamond wafers are poised to take a center seat in many of our customers technology roadmaps, as new developments demonstrate its ability to dramatically reduce device temperatures, while maintaining output performance," says Element Six's head of technologies Adrian Wilson. "With the acquisition of the GaN-on-diamond process developed by Group4, we plan to continue to support the market's growth trajectory, ramping up manufacturing capabilities to deliver innovative synthetic diamond solutions to meet emerging market demands," he adds.

"The scaling up of GaN-on-diamond wafer manufacturing volumes will need the unique heft, skill, and synergy of Element Six to make it possible," says Group4's chairman & CEO Felix Ejeckam. "Our customers will benefit enormously from this GaN-on-diamond process acquisition," he believes.

www.e6.com/electronics

<http://group4labs.com>

IN BRIEF

Integra launches GaN-on-SiC devices for L-band avionics

Integra Technologies Inc (ITI) of El Segundo, CA, USA, which makes high-power pulsed RF transistors, has developed two gallium nitride on silicon carbide (GaN-on-SiC) devices — the IGN1011M675 and the IGN1011M1200. Both operate over the instantaneous bandwidth covering 1030MHz in the L-band frequency range, targeted at the avionics market.

Intended for commercial avionics including IFF Mode S applications, the IGN1011M675 typically supplies a minimum of 750W of peak output power.



The PN IGN1011M1200 supplies over 1200W of output power.



Both single-ended devices are characterized under a pulse train of 2.4ms with 6.4% LTDC., and provide over 12dB of gain and 50% efficiency.

Both devices are housed in a ceramic flanged package, providing thermal advantages over plastic-packaged devices.

The IGN1011M675 and IGN1011M1200 will be available for sampling in third-quarter 2013.

www.integrattech.com

TriQuint accelerates GaN offerings, releasing new products, processes and foundry services

48V variant added to 0.25 μ m process; 0.15 μ m GaN-on-SiC process pushed to 40GHz

At the 2013 IEEE MTT-S International Microwave Symposium (IMS) in Seattle, WA, USA (4–6 June), RF front-end component maker and foundry services provider TriQuint Semiconductor Inc of Hillsboro, OR, USA displayed 15 new gallium nitride amplifiers and transistors along with two new GaN processes. The firm says that the new products offer performance, size and durability advantages for communications, radar and defense RF systems.

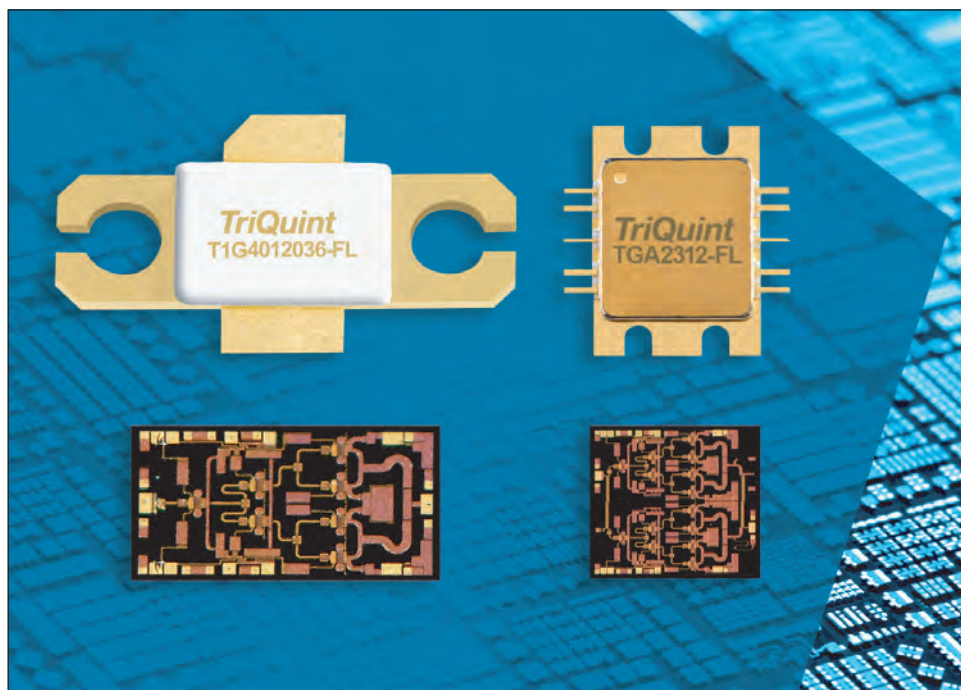
James L. Klein, VP & general manager for Infrastructure and Defense Products, remarks that, due to TriQuint's expansion of process and product solutions, GaN's performance advantages are now more accessible to RF manufacturers.

"This announcement shows the accelerated pace of TriQuint innovation. Customers have access to more world-class products in addition to three GaN processes supported by packaging, assembly and test services," he adds.

"TriQuint is comprehensively addressing the most demanding RF requirements with the flexibility to engage customers of all sizes."

Market research firm Strategy Analytics foresees significant GaN growth. "While defense remains the largest GaN revenue source, infrastructure is growing fast. Sat-Com, power and CATV are ramping to higher revenues," notes Eric Higham, director of Semiconductor Practice. "Strategy Analytics forecasts that the market for GaN microelectronic devices will grow with a CAAGR [compounded average annual growth rate] of over 34% to approximately \$186m by 2015."

TriQuint's original quarter-micron process is now complemented by a high-voltage variant, TQGaN25HV. The new process extends the drain operating voltage of 0.25 μ m GaN to 48V while delivering higher break-



TriQuint's new T1G4012036-FL 120W discrete packaged RF power transistor and TGA2312-FL X-band power amplifier.

down voltage, greater power density and high gain for DC–10GHz applications. This enables more rugged devices that can withstand VSWR (voltage standing wave ratio) mismatches that might destroy other circuits while delivering more RF output power. A new product designed with this process is T1G4012036-FS/FL, a 120W packaged transistor for radar and infrastructure that is nearly two-thirds smaller than similar LDMOS devices. Additional products built using TQGaN25HV are now available.

The firm's third GaN process, TQGaN15, pushes the frequency range of GaN to 40GHz while delivering high power density and low-noise performance. The 0.15 μ m gallium nitride on silicon carbide (GaN-on-SiC) process was used to create the new TGA2594 (4W) and TGA2595 (10W) Ka-band VSAT ground terminal amplifiers, which have power-added efficiency (PAE) up to 35% and are three times

smaller than comparable gallium arsenide (GaAs) solutions. Additional products built using TQGaN15 are now available.

TriQuint's product portfolio of new GaN solutions also includes the TAT9988 direct-to-board MMIC amplifier for CATV and fiber-to-the-home (FTTH) optic networks, created using the second-generation of TriQuint's original TQGaN25 process. It is claimed that the TAT9988 leads the industry in gain, composite distortion performance and surface-mount convenience.

TriQuint's expanded GaN range is complemented by its integrated assembly services, which include die-level device packaging, x-ray and testing. TriQuint is also a US Department of Defense (DoD)-accredited 'Trusted Source' for GaN and GaAs, which includes post-processing test & packaging services.

www.ims2012.org

www.triquint.com

TriQuint produces first GaN-on-diamond HEMT results

Three-fold boost in heat dissipation while preserving RF functionality supports reducing amplifier size or raising output power three-fold

RF front-end component maker and foundry services provider TriQuint Semiconductor Inc of Hillsboro, OR, USA has produced what are reckoned to be the industry's first gallium nitride (GaN) transistors using GaN-on-diamond wafers, which substantially reduce semiconductor temperatures while maintaining high RF performance. The technology could enable new generations of RF amplifiers up to three times smaller or up to three times the power of existing GaN solutions, the firm adds.

Unlocking the true potential of high-efficiency GaN circuits will depend on achievements like those of TriQuint's advanced research and development program, believes James L. Klein, TriQuint's VP & general manager for Infrastructure and Defense Products.

Operating temperature largely determines high-performance semiconductor reliability. It is especially critical for GaN devices that are capable of very high power densities. "By increasing the thermal conductivity and reducing device temperature, we are enabling new generations of GaN devices that may be much smaller than today's products," Klein says. "This gives significant RF design and operational benefits for our commercial and defense customers."

TriQuint demonstrated its new GaN-on-diamond high-electron-mobility transistors (HEMTs) in conjunction with partners at the UK's University of Bristol, Group4 Labs and Lockheed Martin under the US Defense Advanced Research Projects Agency's (DARPA) 'Near Junction Thermal Transport' (NJTT) program.

NJTT is the first initiative in DARPA's new 'Embedded Cooling' program, which includes the ICECool Fundamentals and ICECool Applications R&D engagements. NJTT focuses on device thermal resistance 'near the junction' of the transistor. Thermal resistance inside device structures can be responsible for more than 50% of normal operational temperature increases, says TriQuint. The firm's research has shown that GaN RF devices can operate at a much higher power density and in smaller sizes, through its highly effective thermal management techniques.

TriQuint says that its latest development involves the transfer of a semiconductor epitaxial overlay onto a synthetic diamond substrate, providing a high thermal conductivity and low thermal boundary resistance, while preserving critical GaN crystalline layers. This is reckoned to be the first demonstration of the feasibility of GaN-on-diamond

Fabrication improvements and extensive device testing are underway

HEMT devices. Results to date indicate that TriQuint has achieved the primary NJTT goal of a three-fold improvement in heat dissipation while preserving RF functionality; this supports reducing power amplifier size or increasing output power by a factor of three. Additional fabrication improvements and extensive device testing are underway to optimize the epitaxial layer transfer process and fully characterize the enhancements that can be achieved in the new HEMT devices.

www.triquint.com/defense

www.darpa.mil/Our_Work/MTO

IN BRIEF

High-output power doublers for CATV infrastructure

At the ANGA-COM 2013 broadband trade fair in Cologne, Germany in June, TriQuint launched the TAT9988 GaN integrated power doubler for fast-growing CATV infrastructure applications.

The GaN MMIC amplifier offers high gain (24dB) and good composite distortion performance (CTB=-69dBc/CSO=-75dBc), which is critical for multi-carrier CATV environments.

TriQuint also launched the TAT8804 GaAs power doubler, with what is claimed to be the highest gain (21dB) and output power among 'green' 12V CATV amplifiers. The MMIC amplifier provides RF output of +58dBmV/ch while consuming less than 8W, making it the highest-output 12V GaAs solution for CATV (replacing the equivalent of two legacy devices).

The growth of CATV technologies is important to delivering sought-after content, says Jeff Heynen, directing analyst for Broadband Access and Video at Infonetics Research in a March 2013 report. "Cable operators are gaining significant traction with DOCSIS 3.0 in North America, Europe, Korea and Japan; they're in the early stages of rolling out video gateways that combine DOCSIS CPE with video transcoding capabilities to deliver whole-home, multi-screen service," he adds. "We anticipate hearty growth for the devices over the next few years."

TriQuint says its CATV/FTTH products deliver improved system-level performance and are offered as surface-mount, 40-pin 5mm x 7mm QFN packages, driving cost-effective direct-to-board assembly. Samples and evaluation boards are available; both devices are production-ready.

www.triquint.com

Transphorm appoints Humi Esaka as CEO; co-founder Umesh Mishra to be chairman & CTO

Transphorm Inc of Goleta, near Santa Barbara, CA, USA (which designs and delivers power conversion devices and modules) says that Fumihide 'Humi' Esaka will join the firm as its new CEO, starting 1 July.

Transphorm reckons that Esaka will play a pivotal role in its expansion in providing gallium nitride (GaN)-based power conversion in power supplies and adapters, motor drives, solar panels, and electric vehicles.

Esaka is currently CEO of Tokyo Stock Exchange-listed firm Nihon Inter Electronics Corp (NIEC), and is also former VP - Japan sales of NYSE-listed power semiconductor device maker International Rectifier Corp (IR) of El Segundo, CA, USA. He has leadership experience in both US and international businesses and markets, having contributed to IR's significant revenue expansion in Asia, and revitalizing

NIEC, a Japanese-based power solutions manufacturer with more than \$300m in revenues.

"When launching in 2007, we started with a breakthrough technology and ambitions to redefine energy efficiency," says Transphorm's co-founder & CEO Umesh Mishra. "Since then, we've eliminated every daunting technical obstacle that's stood in our way and just released the world's first qualified GaN-on-silicon product," he adds. "I'm proud to hand over the reins to someone as accomplished as Humi, and continue to work with him and Primit Parikh (co-founder & president) in my capacity as chairman and chief technology officer to help make GaN the industry standard in electric power conversion," Mishra concludes.

"Transphorm has assembled the most impressive GaN technical and engineering talent on the planet

and produced solutions that satisfy customer demands for better form factor and efficiency," believes Esaka. "The mission is meaningful: use Transphorm's technology to cut total world electrical energy waste by more than 50%," he adds.

"After solving technical problems that have confounded the industry to qualify the world's most energy efficient power conversion products, Transphorm is ready to move its business to another level," says Randy Komisar, general partner at investor Kleiner Perkins Caufield & Byers.

Transphorm says that its power conversion solutions, through its proprietary EZ-GaN platform, reduce power system size, increase energy density and deliver high efficiencies across the grid, providing a cost-effective, customizable and easy-to-use solution ready for commercial scale.

www.transphormusa.com

Cree ships its 2 millionth GaN HEMT device for cellular telecommunications infrastructure

Cree Inc of Durham, NC, USA has surpassed the milestone of shipping more than 2 million gallium nitride high-electron-mobility transistors (HEMTs) for cellular telecommunications, providing benefits over traditional silicon-based technologies including higher power, higher efficiency and wider bandwidth.

As mobile devices such as smartphones are becoming more widespread, telecom firms are seeking innovative technologies to improve channel capacity and speed of wireless systems, while simultaneously lowering power consumption of transmission amplifiers. The use of GaN HEMT in transmitter amplifiers is gaining attention for cellular telecoms, says Cree, due to the ability to decrease power consumption and size, and increase bandwidth.

The world's mobile networks are reported to consume about 120TWh of electricity per year (for an average cost of \$14.4bn), and 50% of the networks power is consumed by power amplifiers and associated components. Consequently, improved power amplifier efficiency can result in considerable energy savings.

"GaN HEMT prices have greatly improved and are now a viable alternative to Si LDMOS transistors for cellular telecom amplifiers," says Tom Dekker, director sales and marketing, Cree RF business unit. "We target continued growth of our telecommunication volumes."

Cree says that the performance enabled by its GaN HEMT are required to support existing 4G LTE cellular networks, as well as to help

drive LTE release 10 and advanced LTE networks currently being developed. The superior efficiency and bandwidth advantages of GaN HEMTs help LTE cellular network transmitters to achieve smaller size, lower weight and improved thermal management compared with incumbent technologies, says the firm. GaN HEMT power amplifiers allow for data channel bandwidths over 100MHz and wide instantaneous RF bandwidths, helping operators to aggregate multiple, non-adjacent frequencies to maximize the benefits of their licensed spectrum, says Cree. Another advantage is improved transmitter efficiency, which offers energy savings for operating budgets, adds the firm.

www.cree.com/rf

NXP granted £2m by UK Government to develop GaN power semiconductors in Hazel Grove

Funding supports £7.5m private sector investment, creating 100 jobs

The UK Government's Chief Secretary to the Treasury, Danny Alexander, has announced a £2m boost for research into the development of gallium nitride (GaN) power semiconductors by Netherlands-based electronics firm NXP Semiconductors at its research facility in Hazel Grove, Stockport, near Manchester, UK.

The funding, which comes from the government's Regional Growth Fund (RGF), will support a private sector investment of over £7.5m. The investment is expected to safeguard over 400 existing jobs, create up to 100 new positions in Stockport, and establish the UK as a global research hub for NXP.

Since it is more efficient than conventional silicon, GaN is expected to become a vital resource for the power industry and future electron-

ics market. The material could eventually replace traditional silicon components in power electronic systems such as used in car systems, mobile phones and communications infrastructure as well as cloud computing, it is reckoned.

The funding has been awarded as part of the third round of the Regional Growth Fund and will be used to recruit extra R&D staff, make prototype models, consult the UK's leading academics, and provide equipment for the development phase. It will support NXP's investment to create a centre for power semiconductors in its Manchester facility, as well as local businesses and suppliers.

Speaking to the Manchester Chamber of Commerce, Alexander described the funding as "a real

boost for the local area, supporting a huge private sector investment and local jobs... The Regional Growth Fund gives us the opportunity to support innovative projects like this."

The Regional Growth Fund is a £2.6bn fund operating across England from 2011 to 2016. It supports projects and programs that leverage private sector investment to create economic growth and sustainable employment. The first three rounds will generate over £13bn of private sector investment and are expected to create or safeguard over 500,000 jobs. The fourth round (which closed on 20 March, with over 300 bids received) will make a further £350m available.

www.nxp.com

www.gov.uk/understanding-the-regional-growth-fund

Northrop Grumman samples GaN flange-packaged power amplifier for Ka-band communications

Northrop Grumman Corp of Redondo Beach, CA, USA has developed a new gallium nitride flange-packaged power amplifier targeting military and commercial Ka-band communication applications. The APN180FP represents the first commercial availability of a packaged, GaN-based component from the firm.

"The APN180FP provides customers with a powerful, easy-to-use, high-frequency product that greatly expands the accessibility of monolithic microwave integrated circuits [MMICs]," says Frank Kropschot, general manager of the Microelectronics Products and Services business unit of Northrop Grumman Aerospace Systems.

The new amplifier is produced in Northrop Grumman's advanced microelectronics wafer fabrication facility in Manhattan Beach, CA, which has provided large volumes of compound semiconductor products

to both military and commercial customers for more than 20 years. "We are targeting the APN180FP for the growing Ka-band satellite communication terminal and the commercial wireless infrastructure markets," Kropschot says.

The APN180FP is a 0.2mm GaN high-electron-mobility transistor (HEMT) MMIC power amplifier chip mounted in a flange mount package. It operates at 27–31GHz, and is optimized for 29–31GHz.

The power amplifier operates with a drain voltage of +28V and provides 21dB of linear gain, +37dBm (5.0W) of output power at 1dB gain compression, and +39dBm (8W) in saturation with power-added efficiency of 26% at mid-band. For less-demanding applications, the APN180FP can be operated from a drain voltage as low as +20V while still producing +37dBm (5W) of saturated output power.

Limited engineering prototype samples are available from stock to qualified customers by e-mailing as-mps.sales@ngc.com. Pre-production quantities will be available in July, and production quantities in fourth-quarter 2013.

"This new product is a follow-on to the GaN MMICs we released in November 2012, and is the first of several package and module products we plan to introduce during the next few months," Kropschot says.

The new power amplifier is based on MMICs using Northrop Grumman's 0.2µm GaN HEMT process developed partially under the US Defense Advanced Research Projects Agency's Wide Band Gap Semiconductors for Radio Frequency program (the first of several GaN technology development contracts awarded to Northrop since 2002).

www.as.northropgrumman.com/mps

Anadigics launches GaN power doubler line amplifier for 1.2GHz CATV systems

GaAs-based broadband wireless and wireline communications component maker Anadigics Inc of Warren, NJ, USA has launched the ACA2429 gallium nitride (GaN) power doubler surface-mount IC supporting operation up to 1.2GHz. Samples are available now for qualified programs.

The firm's GaN line amplifiers combine Anadigics' MESFET technology with a GaN output stage in a proven 16-lead SOIC surface-mount package to deliver what is claimed to be exceptional performance and reliability in CATV infrastructure applications. With a combination of high gain, output power and linearity coupled with low current consumption (420mA at 24V operation) and bit error rate (BER), the GaN line amplifiers can be used as output power doublers for system amplifiers and deep fiber nodes. Anadigics says that this level of performance provides a power-efficient solution that saves energy and ensures



distortion-free video and audio in an advanced fully loaded spectrum.

"New high-speed HFC [hybrid fiber coax] networks are demanding higher gain, output power and operating frequencies to provide additional video capabilities and increased data speeds," says Tim Laverick, VP of Infrastructure Products. "These systems continue to require exceptionally linear amplifi-

cation at greater gain and output power levels than 1GHz systems to ensure quality and reliability," he adds. "Anadigics has responded to this challenge by developing GaN line amplifier solutions that combines our field-proven, highly linear GaAs technology with a high power GaN output stage in our reliable surface-mount package platform."

The ACA2429 GaN power doubler provides 25dB gain with +60dBmV output power and 1.2GHz bandwidth. It delivers this performance with 10W of power consumption in a standard surface-mount package. The firm claims that its GaN surface-mount line amplifiers offer exceptional composite triple beat (CTB), composite second-order (CSO), cross modulation, and carrier-to-intermodulation noise (CIN) characteristics for optimal performance in a fully loaded spectrum.

Anadigics exhibited at ANGA COM in Cologne, Germany (4–6 June).

www.anadigics.com

Nitronex fully qualifies NPT1015 28V GaN-on-silicon RF power transistor

Nitronex LLC of Durham, NC, USA, which designs and makes gallium nitride on silicon (GaN-on-Si)-based RF power transistors for the defense, communications, cable TV and industrial & scientific markets, has fully qualified its NPT1015 transistor.

The NPT1015 is a 28V, DC–2.5GHz, 50W power transistor with 12dB saturated gain and 60% peak drain efficiency at 2.5GHz. Its thermal resistance is 2.1°C/W, which is reckoned to be among the lowest in the industry in this power class. Also, the GaN technology is claimed to be capable of surviving the industry's most severe robustness tests without significant device degradation.

Developed under an entirely new design process that incorporates

thermal management improvements to lower thermal impedance, the NPT1015 leverages Nitronex's existing 28V NRF1 process platform, which has been in volume production since 2009. Devices from multiple wafers were mounted in a 50Ω test circuit tuned for CW operation at 2.5GHz, and operated at rated output power and subjected to a 15:1 VSWR (voltage standing wave ratio) at all phase angles. The devices showed 100% survivability with no measurable change in saturated output power.

"The NPT1015 is a robust next-generation product, as it incorporates significant design improvements that increase breakdown voltage and lowers thermal impedance," says president & CEO Greg Baker.

"We are using these same techniques in our new 48V product line." The advances in product robustness and reliability put Nitronex's GaN-on-Si devices on a par with, or ahead of, competitive products that primarily use GaN-on-SiC, he adds.

Nitronex's patented SIGANTIC GaN-on-Si process is claimed to be the only production-qualified GaN process using an industry-standard 4" silicon substrate. This results in a robust, scalable supply chain, positioning Nitronex well for the growth expected from emerging GaN markets such as military communications, broadband, radar, commercial wireless, satellite communications and point-to-point microwave, the firm reckons.

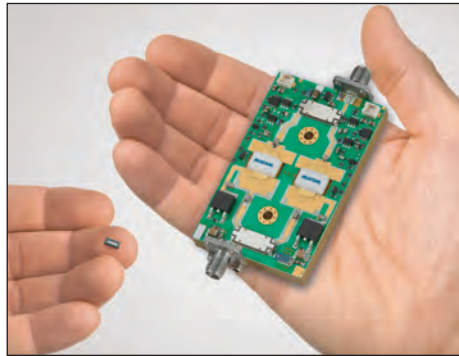
www.nitronex.com

MACOM launches 90W, 50W and 15W GaN in plastic packaged power transistors

M/A-COM Technology Solutions Inc of Lowell, MA, USA (which makes analog semiconductors, components and subassemblies for RF, microwave and millimeter-wave applications) has introduced its series of GaN in Plastic packaged power transistors for high-performance civilian and military radar and communications systems.

Scaling to peak pulse power levels of 100W — claimed to be the highest among competing components in this product category — MACOM says its GaN in Plastic transistors defy the power, size and weight limitations of competing ceramic-packaged offerings to enable a new generation of high-performance, ultra-compact military and civilian radar systems. Customers can hence use the products to provide new capabilities and take advantage of the total system cost reductions associated with size, weight and cooling requirements, the firm adds.

Packaged in 3mm x 6mm dual-flat no leads (DFN) and standard small-outline transistor (SOT-89) packages, MACOM's GaN in Plastic transistors operate at 50V drain bias, resulting in what is claimed to be outstanding power density and performance, higher efficiency, and smaller



MACOM's GaN in Plastic transistor.

impedance matching circuits due to improved device parasitics. The high-voltage operation also benefits overall system design with smaller energy storage capacitors and lower current draw, the firm adds.

The power transistors leverage thermal management techniques to ensure reliability in surface-mount applications. The 90W power transistor demonstrates less than 115°C junction temperature (80°C base-plate) for a pulsed power output of 93W, using a 1mS pulse and 10% duty cycle on standard Rogers board material. The devices can operate at higher temperatures, as the calculated mean-time-to-failure (MTTF) at 200°C is about 600 years.

The first entries in MACOM's GaN in Plastic power transistor product

portfolio include 90W (MAGX-000035-0900P), 50W (MAGX-000035-05000P) and 15W (MAGX-000035-01500P) transistors, all of which are available in standard 3mm x 6mm DFN packaging. The devices can be mounted on PCBs via ground/thermal arrays. Internal stress buffers allow the devices to be reliably operated at up to 200°C channel temperature. The GaN in Plastic series also includes a 5W (MAGX-000040-5000P) device in an even smaller SOT-89 package, measuring 2.5mm x 4.5mm. All of these transistors are capable of operating at frequencies up to at least 3.5GHz.

"Radar system designers are challenged to reduce the size, weight and cost of next-generation system designs, while meeting new requirements of higher power, efficiency and reliability," says product manager Paul Beasley. "MACOM's GaN in Plastic packaging innovation and rich heritage of expert engineer-to-engineer customer support ensure that radar system designers are best equipped to harness the highest power in the smallest possible size," he adds.

GaN in Plastic test fixtures are available upon request.

M/A-COM Tech launches internally matched 500W GaN-on-SiC HEMT pulsed power transistor

M/A-COM Technology Solutions has launched a gallium nitride on silicon carbide (GaN-on-SiC) high-electron-mobility transistor (HEMT) power transistor for L-band pulsed radar applications.

The MAGX-001214-500L00 is a gold-metalized pre-matched GaN-on-SiC transistor optimized for pulsed L-band radar applications. Providing 500W of output power with 19.2dB of gain and 55% efficiency, the device also has very high breakdown voltage, allowing operation at 50V under



MACOM's new MAGX-001214-500L00 flanged packaged GaN-on-SiC HEMT.

more extreme load mismatch conditions.

"The device is an ideal candidate for customers looking to upgrade L-band radar systems to the next level of pulsed power performance," says product manager Paul Beasley.

Operating in the 1200–1400MHz frequency range, the MAGX-001214-500L00 is highly robust, with a mean time to failure (MTTF) of 5.3×10^6 hours, and is available as both flanged and flangeless packaged devices.

Samples of the MAGX-001214-500L00 are available from stock.

www.macomtech.com

IN BRIEF

IR starts commercial shipments of GaN-on-Si devices

Power semiconductor device maker International Rectifier Corp (IR) of El Segundo, CA, USA has qualified and shipped product built on its GaN-based power device technology platform for a home theater system made by a 'leading consumer electronics company'.

"Commencing commercial shipments based on our leading-edge GaN-based technology platform and IP portfolio extends IR's leadership in power semiconductor devices," claims president & CEO Oleg Khaykin. "We fully anticipate the potential impact of GaN-based technology on the power conversion market to be at least as large as the introduction of the power HEXFET by IR over 30 years ago."

IR says that the achievement underlines its strategic advantage in the power management market, providing a capital-efficient manufacturing model that enables improvements in key application-specific figures of merit (FOM) of up to a factor of ten compared to state-of-the-art silicon technology.

"GaN has the potential to be infused into every business unit and product line within IR over the long-term," says Khaykin. "We see it as one of the major drivers for our long-term revenue growth, and market share expansion."

The GaN-based power device technology platform is the result of ten years of R&D by IR based on its proprietary GaN-on-silicon epitaxial technology. The high-throughput 150mm GaN-on-Si epi, together with subsequent device fabrication processes that are fully compatible with IR's existing cost-effective silicon manufacturing facilities, offers a commercially viable manufacturing platform for GaN-based power devices, the firm reckons.

www.irf.com

Modelithics' COMPLETE Library v10.1 of simulation models available for AWR's Microwave Office EDA software

AWR Corp of El Segundo, CA, USA, which supplies electronic design automation (EDA) software for designing RF and high-frequency components and systems, and Modelithics Inc of Tampa, FL, USA, which provides simulation models for RF, microwave and millimeter-wave devices, have announced the availability of Version 10.1 of the Modelithics COMPLETE Library of passive and active device models for AWR's Microwave Office high-frequency design software.

The COMPLETE Library offers simulation models for passive components, transistors and diodes etc, which are completely integrated within Microwave Office. The firms say that their joint offering enables designers to accurately complete a design with highly scalable models that take pad parasitic effects, substrate effects etc into account.

"Modelithics develops the industry's highest-quality, scalable measurement-based models that are designed to work seamlessly within AWR's popular circuit design software," says Modelithics' co-founder Larry Dunleavy. "With this new release, the Modelithics COMPLETE Library now represents over 8600 individual components, providing the RF and microwave design community with more extremely accurate models and improved features," he adds.

"As a global reseller of the Modelithics COMPLETE library, AWR customers worldwide benefit from easier and more convenient access to and installation of Modelithics' highly accurate, well documented model libraries," says Sherry Hess, AWR's VP of marketing. "The new Version 10.1 release provides an even greater breadth of choices within Microwave Office that enable designers to improve product performance and cut design cycles."

Version 10.1 introduces 28 new Global Models for popular surface-mount RLC component families from vendors such as Passive Plus, AVX, Aeroflex, and Chilis. The Passive Component (CLR) Library within Modelithics COMPLETE now contains the first Modelithics Global Model for conical inductors from Piconics, validated up to 65GHz and in multiple mounting configurations. The v10.1 System Level Component (SLC) Library includes new broadband Global Models for Aeroflex attenuator families. The free SELECT Plus library, included with Modelithics COMPLETE, now has Global Models for two Mini-Circuits attenuator families, with validations through 30GHz.

Additionally, upon customer request, Modelithics has added access points to internal voltage and current probes on select power transistor models, including a 10W Nitronex gallium nitride (GaN) model that is part of the SELECT Plus Library. A number of models have also been updated for improved solder pad de-embedding accuracy and a new flexible 'pad mode' features has been added to some models, especially of interest to designers interested in performing EM co-simulations with Modelithics models.

Designers can download Modelithics SELECT from the firm's web-site. To request a free full-version trial of the Modelithics COMPLETE Library, either click on the free trial link or e-mail Sales@Modelithics.com.

For AWR customers, the Modelithics COMPLETE library can be licensed directly through AWR either as an add-on module to or as part of an AWR Microwave Office bundled configuration.

www.awrcorp.com

www.modelithics.com

Mesuro launches Rapid Load Pull solution for device characterization test

Mesuro Ltd of Pencoed Technology Park, UK, a spin-off from Cardiff University's Centre for High Frequency Engineering, has launched a new device characterization test solution that uses an 'envelope load pull technique', along with the latest generation of commercial off-the-shelf PXI hardware and LabVIEW system design software from National Instruments, to provide extremely rapid test scenarios to be run on the device under test.

The new 'Rapid Load Pull' product can replace traditional passive tuning networks within load pull test systems, offering the customer significant improvements in speed of test, says the firm. The way in which the Rapid Load Pull solution fits into the test environment allows for the existing measurement hardware to be re-used within the improved test station. The system can be supplied as a turnkey project to include the NI

portion with Mesuro Software/Coupler/Amplifier, or it can be customer assembled, providing a cost-effective way of improving throughput on a test station. The system is currently available covering frequency ranges up to 4.4GHz.

Device output is measured on the receiver elements via the coupler, with the output then being down-converted to baseband. The loop algorithm, implemented in the LabVIEW FPGA Module, then calculates the required settings to form the reflected signal that is then presented to the device under test, based upon the requested impedance. The loop amplifier provides the active element to ensure that the loop can tune the impedance to any desired point on the Smith Chart. The NI PXI solution contains an embedded controller, on which the main Mesuro test software resides and operates. The system can perform all the required load

pull tests and the data can be viewed within the measurement software or exported for use within EDA or other tools by the user.

National Instruments' support of the project continues its expansion into the RF marketplace, specifically in the nonlinear area. "Finally, load pull goes digital! By using National Instruments PXI vector signal transceiver software-designed technology, which uses hardware programmable with the LabVIEW FPGA Module, Mesuro is redefining active load pull by combining the advantages of open- and closed-loop active load pull," says Marc Vanden Bossche, Technical Market Development manager of the National Instruments Network Analysis Center of Excellence.

Mesuro exhibited at the International Microwave Symposium 2013 (2–7 June) and at the ARFTG 2013 conference (7 June), both in Seattle, WA.

Mesuro delivers measurements needed for non-linear devices

Mesuro has announced the capability for its RF measurement services to deliver whatever measurements are needed for non-linear devices.

Whatever measurement set or application is needed from non-linear device data, Mesuro's laboratory allows for device testing up to 100W CW packaged devices to 6GHz fundamental; up to 20W CW packaged devices at X-band; fundamental test up to 67GHz; and fixture design and manufacture.

Device characterization allows customers to evaluate their device performance using Mesuro's test platforms for immediate use within designs and to gain experience of the WaveForm Engineering process that can aid in business case justification and provide confidence through verified data sets. All parameters available

in the test platforms can be measured, including DCIV, S-parameters, P_{in}/P_{out} , power and efficiency contours.

With device modeling, non-linear measurement data has been exploited in various ways to create behavioral models for high-frequency transistors. These include frequency-domain descriptive behavioral models, including poly harmonic distortion (PHD) models, S-functions and X-Parameters. Formulations of these models have been developed in the travelling-wave domain with a desire to represent non-linear behavior of high-frequency transistors. Work demonstrated using the Cardiff Model formulations, based on PHD models, has shown that, by considering higher-order mixing terms in the PHD formulation, a better fit

can be achieved around a more compact file size, without sacrificing accuracy.

When considering the performance of RF power amplifiers (PAs) or other non-linear devices, it is the terminal RF I–V waveforms that are the unifying theoretical link between transistor technology, circuit design, and system performance, says Mesuro. From a non-linear PA design perspective, the integration of RF waveform engineering capability, whether passive or active, with RF waveform measurement capability, is essential, the firm adds. With such systems, the practical design of PAs achieved by directly employing the theoretically based waveform engineering approach is now experimentally possible, the firm adds.

www.mesuro.com

IQE launches dedicated wireless products division

Epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK has launched the new division IQE Wireless, which will provide a complete 'one-stop shop' for radio frequency (RF) wireless epitaxial wafer materials.

The new brand was launched at the start of the International Conference on Compound Semiconductor Manufacturing Technology (CS MANTECH 2013) in New Orleans, LA, USA (13–16 May). The launch is part of an overall branding exercise to enable in each of IQE's key markets. Earlier in May, IQE launched the new division IQE Infrared to provide a one-stop shop for infrared sub-

strate and epiwafer materials covering the short- to very-long-wavelength (SWIR to VLWIR) regimes.

IQE says it is already established as the leading supplier of epiwafers for wireless products (including pHEMTs, HBTs and BiFETs), providing the key enabling technology for wireless communications for smartphones, tablets, PCs, WiFi, base-stations and other wireless devices and equipment. Also, in January, IQE acquired the Kopin Wireless MOCVD-based heterojunction bipolar transistor (HBT) epiwafer manufacturing business of Kopin Corp of Taunton, MA, USA — plus its 90.2% controlling interest in subsidiary

Kopin Taiwan Corp (KTC) in Hsinchu — for \$75m (with \$15m payable in January 2016), extending IQE's global manufacturing footprint and providing access to growing Asian semiconductor markets.

"The establishment of a dedicated wireless brand within the group allows the new division to further focus on enhancing its product offerings and customers' experiences as we continue to grow both our existing business and enter new and emerging markets," says vice president Russ Wagner, who has been appointed to head the new wireless division.

www.iqep.com

IQE and II-VI launch 150mm GaN-on-SiC HEMT epi

Epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK has launched gallium nitride (GaN)-based high-electron-mobility transistor (HEMT) epitaxial wafers on 150mm-diameter semi-insulating silicon carbide (SiC) substrates supplied by the WBG Materials subsidiary in Pine Brook, NJ, USA of II-VI Inc, a provider of engineering materials and optoelectronic components.

GaN power amplifiers offer superior power capability, efficiency, bandwidth and linearity compared with silicon (Si) or gallium arsenide (GaAs)-based technologies commonly used, providing benefits in terms of both higher performance and lower overall system costs.

GaN-based low-noise amplifiers (LNAs) exhibit improved robustness, noise figure and dynamic range compared with incumbent solutions, the firms say. In addition, GaN-based transistors can operate at high temperatures, reducing system cost, size and weight. They are hence now established as a new technology for a wide range of defence applications, the firms add.

The introduction of 150mm GaN HEMT epiwafer products also

enables cost reduction, customers' production capacity and yield improvement, as well as the potential for insertion into a wider range of chip fabrication facilities, it is reckoned. To date, the commercial market penetration of GaN HEMTs has been limited by the higher cost of epitaxial material grown on 100mm SiC substrates.

GaN HEMT fabrication using LDMOS (laterally diffused metal oxide semiconductor) process lines has been demonstrated by IQE's customers, and the firm's 150mm products are compatible with existing LDMOS processing lines that have been made available as a result of the silicon industry's transition to 200mm technology.

"Scaling up to 150mm wafer diameter is a critical milestone on the path to technological maturity and wide market acceptance of GaN HEMTs on SiC," says Russ Wagner, VP of IQE's Wireless business unit. "IQE has established an industry-leading position by offering a full range of GaN-based high-power RF transistor wafers in formats that enable the most cost-effective processing and system designs," he adds. "We are very pleased with the quality of sub-

strates supplied by II-VI Inc and look forward to continuing our partnership as we execute volume production ramp and expand IQE's range of advanced high-power high-frequency transistor products for defense and wireless infrastructure applications," Wagner comments.

"The WBG Materials subsidiary of II-VI Inc has developed high-quality 4H - 150mm SiC substrates, for both the RF and power markets," says Dr Tom Anderson, general manager of II-VI subsidiary WBG Materials. "These 150mm SiC substrates will greatly reduce device costs by increasing the number of devices produced per wafer, enabling 150mm wafers to be processed using modern, high-volume semiconductor tools designed for large wafers and by providing competitive sourcing and leveraging of high volumes into commercial markets," he adds. "Our partnership with IQE in this 150mm product development has enabled rapid technology advances for both groups and we are looking forward to continuing our work together to deliver this state-of-the-art product to our joint end users."

www.iivibwg.com

IQE launches dedicated infrared products division

IQE Infrared offering one-stop shop for substrates and epiwafers spanning SWIR to VLWIR

Epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK has announced the launch of the new division IQE Infrared, which aims to provide customers with a complete 'one-stop shop' for infrared substrate and epitaxial wafer materials covering the short- to very-long-wavelength (SWIR to VLWIR) regimes.

The move is part of an overall rebranding exercise to enable the group to enhance its customers' experiences in its key markets.

IQE is reckoned to be the leading supplier of substrates and epi-wafers for infrared sensing applications ranging from night-vision and thermal imaging devices to energy conversion solutions for both military and consumer products.

The new IQE Infrared division will bring together similar product

groups from across IQE's multiple operations to provide a unique focus on IR detector materials based on gallium antimonide and indium antimonide (GaSb and InSb) and indium phosphide (InP).

IQE notes that it is already active in a number of government and industrial research programs for next-generation applications which include the development of larger wafer diameters to meet the expected growth in demand for GaSb, InSb and InP-based wafer products.

The new division will bring together similar product groups from across IQE's multiple operations to provide a unique focus on IR detector materials

Dr Mark J. Furlong, currently general manager of IQE's substrate divisions, will be vice president IQE Infrared as head of the new division, which will offer products from across the IQE Group of companies.

"IQE is the only supplier offering a complete range of substrate and epitaxial wafer supply solutions spanning SWIR to VLWIR regimes," claims Furlong.

"The opportunity to establish a new business unit with an exclusive focus on infrared materials will give IQE better opportunities to combine its substrate and epitaxial wafer products for serving a broader range of customers and even broader range of infrared device applications," Furlong believes.

www.iqep.com



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5N Plus to open new gallium chemicals facility in South Korea by end 2013

Materials supplier expands Asian footprint, supplementing plants in USA and UK

To meet the growing demand for gallium in LED manufacturing in North-East Asia, specialty metal and chemical products firm 5N Plus Inc of Montreal, Quebec, Canada is to invest in a new gallium chemicals facility to be located in South Korea, one of the world's fastest-growing regions for electronics manufacturing.

5N Plus provides specialty purified metals such as bismuth, gallium, germanium, indium, antimony, cadmium, selenium and tellurium, and also produces related II-VI semiconducting compounds such as cadmium telluride (CdTe), cadmium sulphide (CdS) and indium antimonide (InSb) as precursors for the growth of crystals for solar, LED and eco-friendly materials applications.

5N Plus has existing gallium chemicals manufacturing facilities in Madison, WI, USA and Wellingborough, UK. The new plant will be

located within an industrial park nearby a number of electronic manufacturing facilities, and should be operational by the end of 2013. 5N has entered into an agreement with a local chemical distributor for the supply of operating services and logistics for the new facility.

North-East Asia represents the majority of the world's LED production, and more than 70% of electronic tablet display supply. The LED market is expected to grow at a 15–20% annually in the near to medium term, with

The new plant will be located within an industrial park nearby a number of electronic manufacturing facilities, and should be operational by the end of 2013.

growth driven mainly by increasing market penetration for lighting applications.

High-purity gallium metal and chemicals are also essential for manufacturing products such as gallium arsenide (GaAs) electronic components for 3/4G wireless applications, indium gallium zinc oxide (IGZO) transparent semiconductor for next-generation displays, copper indium gallium diselenide (CIGS) thin-film solar panels, and gallium antimonide (GaSb) wafers for infrared (IR) detection and imagery systems.

As a group, these applications are expected to drive significant growth in gallium demand in the coming years. 5N Plus adds that its new investment in South Korea should serve as a platform in future for the manufacture of other high-purity materials for the Asian market.

www.5nplus.com

5N Plus settles dispute with vendors of MCP Group

Specialty metal and chemical products firm 5N Plus Inc of Montreal, Quebec, Canada has entered into a full and final settlement agreement with Florinvest SA, Heresford Ltd, Metals Corp SCRL and S.R.I.W. SA, which are all former shareholders of MCP Group SA, in relation to the dispute announced on 21 December 2012.

Formed in September 2007 from the merger of specialty metal firms MCP Aramayo Ltd and Sidech SA, MCP produced and distributed bismuth and bismuth chemicals as well as other specialty metals (including gallium, indium, selenium and tellurium), used in products mainly related to industrial and electronic applications.

Founded in 2000, 5N Plus now provides specialty purified metals

including bismuth, gallium, germanium, indium, antimony, cadmium, selenium and tellurium, and it also produces related II-VI semiconducting compounds such as cadmium telluride (CdTe), cadmium sulphide (CdS) and indium antimonide (InSb) as precursors for the growth of crystals for solar, LED and eco-friendly materials applications.

5N Plus acquired MCP from the vendors on 11 April 2011, from which there remained a balance of the purchase price and accrued interest of about €54m. 5N Plus filed a counterclaim in arbitration proceedings against the vendors as it estimated that they had breached the representations and warranties of the acquisition agreement. Following that, other

civil proceedings were begun.

The full and final settlement entails: (a) a final adjustment to the purchase price through the final payment by 5N of an all-inclusive lump sum of €17.5m to the vendors (of which €15m was paid at closing, with the balance to be paid on 9 April 2014); (b) the withdrawal and cancellation of all arbitration and civil proceedings; and (c) the granting of mutual releases and discharges.

"We are pleased with the outcome and the complete settlement of this dispute as it will allow our management to solely focus on the corporation's main objective of increasing shareholder value," comments 5N Plus' president & CEO Jacques L'Écuyer.

Air Liquide to acquire electronics materials firm Voltaix Voltaix to complement ALOHA precursors and bring synergies in molecule discovery and scale up

Gas supplier Air Liquide of Paris, France, which supplies precursors for semiconductor manufacturing, has agreed to acquire Voltaix Inc of Branchburg, NJ, USA, a manufacturer of materials used in the production of semiconductor devices and advanced solar cells. The acquisition is expected to close later this summer, pending applicable regulatory approvals.

Founded in 1986, Voltaix has expertise in silicon, germanium, and boron chemistries. It operates manufacturing facilities in the USA in Branchburg (New Jersey), High Springs (Florida) and Portland (Pennsylvania) and in South Korea in Sejong-si (South Chungcheong Province), and employs 185 staff.

Air Liquide says that it uses a comprehensive process for designing, screening and industrializing precursors in close cooperation with semiconductor manufacturers and process tool makers. In particular, as well as chemical vapour deposition (CVD) and atomic layer

deposition (ALD) precursors for sub-130nm technology (with capabilities ranging from ton-level of low-k materials down to few grams of sub-45nm R&D products), the ALOHA product line includes proprietary process solutions, such as AHEAD or TSA for the deposition of low-temperature silicon nitride, TDEAA as a non-pyrophoric

The acquisition of Voltaix complements Air Liquide's ALOHA product line and brings synergies in molecule discovery and scale up. Air Liquide reckons that this should help to accelerate the introduction of a broader portfolio of new semiconductor manufacturing materials

TMA (trimethyl aluminium) substitute, or ToRuS for carbon-free, high-adhesion ruthenium ALD.

The acquisition of Voltaix complements Air Liquide's ALOHA product line and brings synergies in molecule discovery and scale up. Air Liquide reckons that this should help to accelerate the introduction of a broader portfolio of new semiconductor manufacturing materials that will enable increases in computing power and connectivity.

"Joining the resources and expertise of our two companies will expand our product offering for semiconductor manufacturers around the world," says Michael J. Graff, senior VP Americas and a member of Air Liquide's executive committee. "Our continuous innovation on new molecules allows us to timely meet the growing consumer demand for increasingly powerful flat screens, tablets and smart phones," he adds.

www.voltaix.com

www.airliquide.com

Riber's revenue impacted by pause in system sales in Q1 ...but order research system orders continue unabated

For first-quarter 2013, Riber S.A. of Bezons, France, which manufactures molecular beam epitaxy (MBE) systems plus evaporation sources and effusion cells, has reported revenue of €2.7m, down on €6.2m a year ago and €10.7m last quarter.

During Q1/2013, Riber delivered just one research system, compared with three research systems and one production system a year ago. Systems revenue was hence just €0.9m, down 89% on €4.6m a year ago. However, revenue is dependent on the production cycle for systems that have been ordered and are not an indication of the firm's performance over the full year, Riber notes.

In contrast, following work to strengthen its commercial and

technical organization, says Riber, the Services & Accessories business has confirmed its turnaround, with revenue rising 35% from €1m a year ago to €1.4m.

Sales of Evaporation sources & Cells are not particularly significant (€0.4m, versus €0.6m a year ago), says Riber, in view of the low level of investment in the organic light-emitting diode (OLED) and photovoltaic sectors. However, to prepare for the next waves of investment, Riber is maintaining a major research effort related to these markets, which the firm describes as 'structurally buoyant'.

In Q1/2013, Riber booked three MBE system orders for research laboratories in China, Russia and

India. Although still down 25% on €19.5m a year ago, the order book hence rose during the quarter from €12.1m to €14.6m. This includes Systems orders worth €13.4m (down 25% on €17.9m a year ago but up from €10.1m last quarter), comprising 14 research systems to be delivered in 2013 (in comparison, the total number of systems delivered in full-year 2012 amounted to 17, including a record 15 research systems). Orders for Services & Accessories were €1.1m, down on €1.7m last quarter and €1.5m a year ago. Orders for Evaporation sources & Cells are level on a year ago, at €0.1m, although down on €0.2m last quarter.

www.riber.com

Aixtron outlines 5-Point Program to return to profitability

20% of jobs in Germany to go as firm aims to reduce breakeven point

At its annual general meeting (AGM), Martin Goetzeler, CEO of deposition equipment maker Aixtron SE of Aachen, Germany since March, set out measures that the firm's executive board intends to implement together with Aixtron's team to return it to sustainable profitability.

"We have to focus more closely than ever on our core competence — optimally supporting our customers to reach their targets by offering efficient high-tech equipment for use in complex material deposition," Goetzeler. "We aim to regain our position of leadership, and on a sustainably profitable basis," he adds, as he sets out a clear direction for the company in the 5-Point Program. "The challenges currently faced by Aixtron resulted from both internal and external factors.

"Processes and responsibilities are two particular areas where we have to do our homework."

The first measures have already been initiated. These include a project to enhance efficiency in product development. Also, the executive board has decided to cut more than 20% of jobs in Germany. Further measures aim to contribute towards sustainable profitability.

Although weakness is still apparent on the demand side, the executive board stresses that the positive

medium- and long-term outlook is still intact for the MOCVD, silicon and organic deposition technologies provided by Aixtron.

Key aspects of the 5-Point Aixtron Program include the following:

1. Customer — focusing on customer benefit. To optimally address customer needs, such as product quality and productivity, Aixtron compiles roadmaps together with its customers that are then factored into the relevant development programs. The business model is being reviewed to boost the service business.
2. Technology and products — putting a unique product portfolio to more effective use, strengthening future products. To be sustainably profitable, Aixtron is building on technological leadership in complex material deposition and aims to regain market leadership in MOCVD technology for LED production.
3. Efficiency — systematically optimizing process and project structures. A cross-functional project aims to optimize the timing and use of resources in product development and thus make it possible to achieve development results at lower expense. The firm will also step up its partnership-based cooperation with suppliers.
4. Finance — value-oriented financial targets. Aixtron's executive board

sees management by clear financial targets as the basis for achieving sustainable profitability. It will focus on four key financial figures: revenue, EBIT (earnings before interest and taxes), free cash flow, and return on capital employed exceeding the cost of capital over a business cycle ($ROCE > WACC$). The current priority has been to rapidly adjust costs to present circumstances. For this year, the executive board has already decided in March to cut operating expenses — excluding restructuring and transformation expenses — by 20% compared with last year, and thus to reduce the breakeven point.

5. Employees — strengthening Aixtron culture, taking individual responsibility, fortifying communication. Following some tough quarters, Aixtron aims to reinforce its employees' sense of identification with the company. Moreover, the executive board wants to further develop its management culture and to adapt it to new challenges. To accomplish this, the firm is agreeing clear goals and closely monitoring their achievement.

Aixtron adds that, in its future financial reporting, the executive board will regularly report both internally and externally on the status of this company program.

Aixtron's shareholders approve all resolutions at AGM

At Aixtron's 16th AGM at the Eurogress convention center in Aachen, Germany, shareholders voted in favor of the resolutions presented by the executive board and the supervisory board.

Following the resignations by previous supervisory board members Dr Holger Jürgensen and Karl-Hermann Kuklies in January, shareholders elected two new members.

Dr Andreas Biagosch worked for 28 years as an engineer for international consulting firm McKinsey

& Co on international projects for high-tech and other industries, and was part of McKinsey's global shareholder council. He now works as an independent entrepreneur.

Dr Martin Komischke (also an engineer) is chairman of the executive board at Swiss firm Hoerbiger Holding AG, a manufacturer of performance-defining components for mechanical engineering.

The following resolutions were also approved:

- Approval of activities of members of the executive board and the

supervisory board during 2012;

- Approval of the system for remuneration of members of the executive board;
- Election of the auditors and group auditors for 2013; and
- Authorization to purchase and use own shares and to exclude pre-emptive rights.

All resolutions were approved with an approval rate of up to 99.4%. About 37% of Aixtron's share capital was represented at the shareholder meeting.

www.aixtron.com/agm

LayTec signs OEM deal with Evatec

LayTec AG of Berlin, Germany (which makes in-situ metrology systems for thin-film processes, focusing on compound semiconductor and photovoltaic applications) has signed a strategic OEM agreement with thin-film deposition system maker Evatec Ltd of Flums, Switzerland. LayTec will equip Evatec with high-precision in-situ metrology tools for versatile process control.

Evatec's evaporation, sputter and PECVD systems have applications in the MEMS, optoelectronics, precision optics as well as semiconductor markets. The OEM partnership enables an ongoing close cooperation for the integration of in-situ metrology in Evatec's reactors.

LayTec's EpiCurve TT metrology tool is already used with Evatec sputter systems for stress management of metal multi-layers for

optoelectronics. EpiCurve TT enables strain-engineering of the multi-layer structures by real-time tuning of the sputter parameters.

"With LayTec's state-of-the-art in-situ metrology we are able to meet the growing demands on precise process control and optimization, which is the key to high yields and low costs," says Evatec's senior process engineer Silvia Schwyn Thöny.

"An OEM cooperation with Evatec is of strategic importance," says LayTec's CEO Dr Thomas Zettler. "It will enable implementation of our metrology into processes beyond LayTec's established applications. And when Swiss precision meets German quality standards, the expectations can never be too high."

www.evatecnet.com

www.laytec.de

LayTec expands customer service team

LayTec has appointed Markus Wendt as new member of its service team, responsible for installations and customer support.

Prior to joining LayTec, Wendt worked on implementing in-line process control at a German thin film solar cell manufacturer. From 2007 to 2009 he worked at Helmholtz-Zentrum in Berlin as a development engineer on implementing white light scattering and laser light scattering in physical vapor deposition processes (PVDs).

Wendt studied mechanical and energy engineering in Leipzig and devoted his diploma theses to

"Space-resolved characterization of thin film solar cells".

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LayTec appoints Bergen as new sales a service partner in India

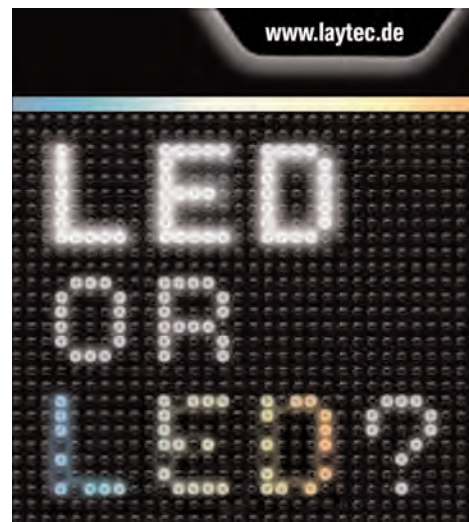
LayTec in-line GmbH, which is part of LayTec AG of Berlin, Germany, has signed a distribution agreement with Bergen, a service and sales company for photovoltaic (PV) and electronic manufacturing industries in India.

Bergen has 20 years of experience

representing leading international technology companies in India. LayTec adds that Bergen is the ideal partner to introduce LayTec's in-line metrology for PV manufacturing and other large-area thin-film applications in India.

www.baplindia.com

www.laytec.de



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IN BRIEF

Aixtron receives Aurora Award for AIX G5+ GaN-on-Si MOCVD system

Deposition equipment maker Aixtron SE of Herzogenrath, Germany has been awarded the 2013 LEDinside Aurora Award in the category 'Most efficient MOCVD Equipment' for its AIX G5+ system for the growth of gallium nitride-on-silicon (GaN-on-Si). The system was chosen for its production efficiency and technological advancement, says Aixtron.

"Producing gallium nitride based LEDs on 200mm silicon substrates is a promising route towards a much lower chip manufacturing cost," says Aixtron's chief technology officer Andreas Tönnis.

With the AIX G5+, Aixtron has created a 5x200mm technology package for the existing AIX G5 HT for GaN-on-Si device production, offering what is claimed to be the industry's largest multi-200mm MOCVD reactor.

Manufacturers such as US firm Transphorm will build on Aixtron's GaN-on-Si technology, expanding productivity from 150mm to 200mm diameter wafers, with the aim of fully exploiting the economies of scale offered by the AIX G5+.

The challenges of GaN-on-Si MOCVD processes are met by the novel features of the G5+ reactor, including modified temperature management, a new gas inlet and a chamber re-set procedure. This results in the minimization of wafer bow and the elimination of melt-back effects, maximum process stability and highest uniformity due to a specifically designed rotational symmetry pattern, says the firm.

www.aixtron.com

EpiCurveTriple TT used for 200mm GaN-on-Si at Singapore's IMRE

In his invited talk at the LED Technology Forum in Singapore in May, Dr Sudhiranjan Tripathy of IMRE (Institute of Materials and Research Engineering) — part of Singapore's Agency for Science, Technology and Research (A*STAR) — revealed the latest results of growing gallium nitride on 200mm silicon. His team uses an EpiCurveTriple TT in-situ monitoring system

from LayTec in the development of epiwafers for InGaN/GaN LEDs and GaN power electronic devices.

LayTec says the EpiCurveTriple TT is suited to 200mm real-time wafer characterization due to its three sensor heads for radial analysis of growth conditions. It provides wafer bow and temperature measurements, as well as simultaneous detection of growth rate and surface morphology.

Figure 1 shows reflectance profiles at three wavelengths: 950nm for emissivity correction of pyrometry, 633nm for analysis of thick layers (e.g. GaN buffer) and 405nm for thin layers. Figure 2 demonstrates how the 405nm reflectance is used for individual in-situ tuning of each well and barrier within the MQW (multi-quantum-well) stack. The in-situ signal (Figure 2 — left) corresponds with the MQWs, as seen in

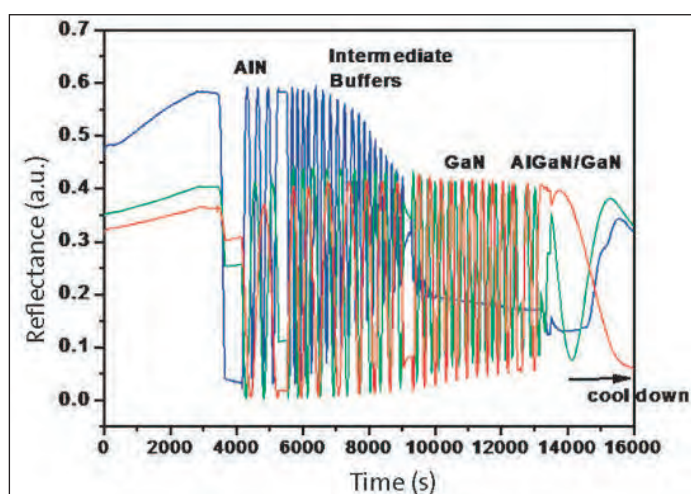


Figure 1: Reflectance monitoring of AlGaIn/GaN HEMT structure grown on 1mm-thick 200mm Si(111) at IMRE: blue — 405nm, green — 633nm, red — 950nm.

the scanning transmission electron microscopy (STEM, Figure 2 — right).

According to Tripathy's team, LayTec's in-situ metrology is a key element for identifying the epitaxial process optimization potentials. In comparison to the time-consuming, destructive ex-situ cross-section transmission electron microscopy (TEM) analysis, the in-situ tool provides real-time information on growth thickness and homogeneity during growth. LayTec says that its system has significantly reduced IMRE's R&D cycles for epitaxial growth optimization and enables faster industrialization of GaN-on-silicon (GaN-on-Si) technology.

www.laytec.de

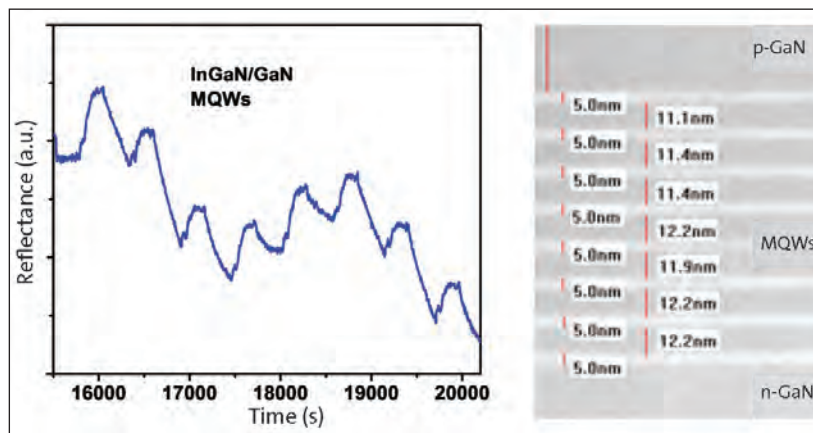


Figure 2: 405nm reflectance (left) of InGaIn/GaN MQW stacks and corresponding STEM image of the MQWs (right).

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Advanced Vacuum launches Apex small-footprint ICP system based on Plasma-Therm Shuttlelock SLR platform

Advanced Vacuum of Lomma, Sweden, which supplies vacuum solutions ranging from plasma etch and deposition systems through chemical pump systems to thermal/vacuum environmental test chambers, has launched the Apex SLR, a robust ICP system based on parent firm Plasma-Therm's proven Shuttlelock (SLR) platform but with a much smaller footprint and benefitting from years of proven SLR technology and an extensive process library. With over 50,000 cycles of testing, the Apex will provide the reliability and availability that researchers need, the firm reckons.

"This tool expands and complements our product portfolio with a logical extension into high-density ICP plasma processing," says Advanced Vacuum's CEO Thomas

Engstedt. "This ICP system is a perfect fit for R&D and pilot production," he adds.

With a small footprint, high reliability, ease of use and ergonomic design, the Apex SLR suits a wide range of uniform, high-quality ICP etch applications. It is a load-lock ICP system with an easy four-button control for processing in a <1.0m² footprint. The Apex SLR was designed incorporating Plasma-Therm's Shuttlelock SLR technology, repackaged with updated, tier-one components. Built and controlled with trusted programmable logic control (PLC) DeviceNet software on a Windows-based operating system, the Apex SLR achieves high uptime with low, simple maintenance, it is claimed. The Apex SLR is backed by

Plasma-Therm's 15 continuous years of VLSI awards for customer satisfaction, and the global service network is ready to install and support the Apex SLR anywhere worldwide.

"The introduction of the Apex SLR will enhance Advanced Vacuum's positioning in served markets and will make high-value technology accessible to researchers at an affordable price," says Jim Pollock, executive VP of sales for Plasma-Therm. "The SLR ICP has long been a respected tool in the industry for its reliability, low maintenance and repeatable processing," he adds. "Reintroduced by Advanced Vacuum in a smaller footprint, the Apex SLR will continue that same legacy for years to come."

www.Advanced-Vacuum.com

Korea Advanced Nano Fab Center hosts Plasma-Therm workshop

Plasma-Therm LLC of St Petersburg, FL, USA says that its advanced plasma processing workshop at the Korea Advanced Nano Fab Center (KANC) attracted nearly 100 engineers and researchers from 25 companies and institutes.

Topics spanned the fundamental and advanced technology used in semiconductor device fabrication, materials research, and nanotechnology. Attendees from disciplines as diverse as MEMS, LEDs, power, photonics, and nanotechnology participated in the full-day event.

KANC was established in 2003 by

the Korean government and Gyeonggi Provincial government as a national core R&D and support infrastructure to promote the development of nano and compound semiconductor technologies. The facility was completed in 2006 and the platform supports a network of over major 30 domestic and international industrial, academic, and research institutes.

"The practical aspects of semiconductor fabrication and in particular plasma processing are often omitted in curriculum in favor of device design and physics," says

Plasma-Therm principal scientist and workshop organizer Dr David Lishan. "Facility users at universities and institutes frequently rely on engineering staff to develop standard processes and as a result researchers, without the hands-on understanding of the plasma processing fundamentals, are constrained in their research efforts," he adds. "We are very pleased to support KANC, a long term customer and important, pivotal member of Korea's research network."

www.kanc.re.kr

Plasma-Therm receives repeat orders from wireless chip maker

A "leading US wireless compound semiconductor device manufacturer" has placed capacity-driven follow-on orders for Plasma-Therm's VERSALINE wafer processing etch modules, to support production of RF power amplifier and switch chips (used primarily in handsets and other RF applications) with advanced backside GaAs via formation.

The modules include Plasma-Therm's EndPointWorks technology and unique active feedback chamber temperature management to ensure maximum etch yield, reproducibility and uptime productivity. The orders complement an installed base of VERSALINE and Versalock systems at the site, used for both deposition and etch process steps.

"Follow-on orders are especially encouraging as they confirm we are continuously providing solutions that meet the expectations of our customers," says Dr David Lishan, director-technical marketing. "On-time solutions, whether for capacity or technology needs, are a result of close collaboration with our customers."

www.plasmatherm.com

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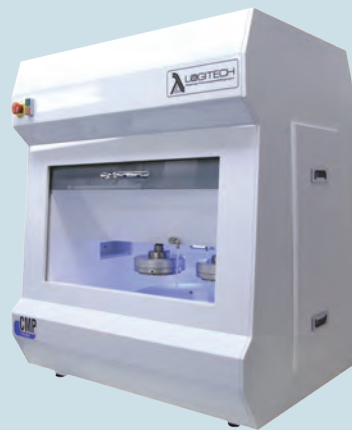
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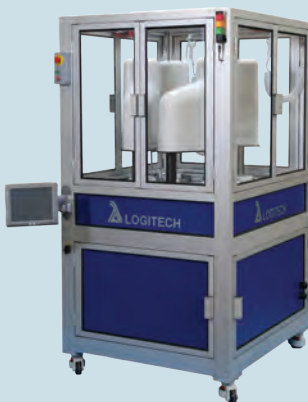
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- Gallium Nitride

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IN BRIEF

SPTS ships 1000th DRIE process module

At the SEMICON Singapore MEMS Forum, SPTS Technologies Ltd of Newport, Wales, UK said it had shipped its 1000th deep reactive ion etch (DRIE) module.

SPTS was the original licensee of the switched Bosch process, shipping its first commercial system in 1995.

"MEMS feature in every automobile, smartphone, tablet and gaming console on sale today," says Dr Dave Thomas, marketing director for Etch Products.

"For nearly 20 years, our engineers have contributed to this widespread adoption by producing more reliable, cost-effective DRIE systems with the precision and control that is required for ever more sensitive and functional devices," he adds.

www.spts.com

Oxford Instruments' seminars in China and Taiwan attract record attendance

UK-based etch, deposition and growth system maker Oxford Instruments Plasma Technology (OIPT) has completed its series of Asian seminars in Beijing, China and Hsinchu, Taiwan, attracting a record total attendance of over 250 people.

The Beijing seminar was co-hosted by the Institute of Semiconductors, Chinese Academy of Sciences (IOS-CAS) one of the most important bases for R&D on semiconductor science and technology in China. The Taiwan seminar was co-hosted by ITRI, a non-profit R&D organization with over 5800 staff.

Both featured a range of international and national speakers including professor Yang Fuhua from IOS-CAS and professor Chyi Jen-Inn, executive VP, National Applied Research Laboratories in Taiwan; with the talks covering topics including GaN-on-Si power device

development; SiC wide-bandgap semiconductors for power electronics applications; and MEMS devices, processes and trends.

"Oxford Instruments has an excellent cleanroom facility established here at ITRI, so it is fitting for us to host an event covering the wide range of applications that the Oxford Instruments systems can offer including MEMS, HBLED, ALD and III-V," says Dr Shao-Chung Hsu, executive director of ITRI South Campus, in a welcome address.

"Talks about the recent progress in their research and development and future trends in the fabrication and applications in micro and nano structures gave the audience from academia and industry much opportunity for discussion," he adds. "We hope to hold more events like this with Oxford Instruments at ITRI."

www.oxford-instruments.com

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For more information, please contact Oxford Instruments Plasma Technology:

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www.oxford-instruments.com/plasma



OIPT restructures into three groups

UK-based etch, deposition and growth system maker Oxford Instruments Plasma Technology (OIPT), part of Oxford Instruments plc, has restructured to sharpen its focus on main target customer groups and build existing strengths.

Effective 1 April, the firm has restructured into three discrete business groups, made up of multi-disciplined teams that are directly aligned to the needs of customers. The groups will encompass product management, technical review and sales support, product and process configuration and development, backed by the firm's sales and customer support teams worldwide.

"This structural change will enhance our customers' experience through the increased focus our teams will bring to bear on their areas of expertise," says managing director Dan Ayres. "Our business

has trebled in size since 2006, and building on the success of recent years, we are creating a structure and environment aligned with our strategy that supports our further growth," he adds.

"It is important that we respond to the needs of our customers, by better aligning ourselves to the markets we address, to ensure maximum product performance," Ayres continues. "In today's demanding markets, we have taken the opportunity at the start of our financial year to restructure and focus on this challenge. This, together with the confidence that our strategy and investment in product and process will drive further expansion in the near future, will enable our business to grow both efficiently and profitably," he adds.

www.oxford-instruments.com

IN BRIEF

VLSIresearch ranks Plasma-Therm first in multiple categories

Plasma-Therm LLC of St Petersburg, FL, USA has ranked number 1 in the 10 BEST of VLSIresearch's 2013 Customer Satisfaction Survey.

Plasma-Therm showed the most improvement among Focused Suppliers of Chip Making Equipment, with an 8% increase to secure its number 1 ranking.

The firm also ranked number 1 in Silicon Wafer Fab Equipment and in Etch & Clean Equipment. In addition to the number 1 rankings, Plasma-Therm received THE BEST award for Suppliers of Silicon Wafer Fab Equipment and the 10 BEST for focused Suppliers of Chip Making Equipment.

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EVG updates automated resist processing system

At the SEMICON Singapore 2013 show, wafer bonding and lithography equipment supplier EV Group of St Florian, Austria launched the latest version of its EVG120 automated resist processing system. Incorporating new features and improved productivity in an ultra-small footprint design, the system supports coating and developing applications for markets including compound semiconductors, micro-electromechanical systems (MEMS), and advanced packaging. The flexible tool can be configured with combined spin and spray coating modules — a unique feature that maximizes productivity and optimizes cost of ownership (CoO), says the firm.

“Our new EVG120 system reflects EVG’s 15 years of experience in resist coating and developing,” says Dr Thomas Glinsner, head of product management. “In independent surveys, our customers consistently attribute the highest scores to EVG’s lithography equipment, and we’ve listened to their feedback to create a more optimized system,” he adds. “Based on a proven platform, the next-generation EVG120 coater/developer offers increased functionality and reliability in a highly cus-



tomizable and economical package.”

The EVG120 automated resist processing system features a new robot with dual arms for fast wafer swapping and additional processing chambers, resulting in enhanced throughput and overall productivity. To further optimize throughput and overall productivity, the system runs the same EVG CIM Framework software as EVG’s high-end XT Frame systems and offers full software integration with SECS/GEM standards. Two customizable wet processing bowls are complemented by 10 stacked modules for vapor prime, soft and hard bake, and chill processes. Like its predecessor, the EVG120 can accommodate wafers up to 200mm in diameter.

Other new features of the system

include EVG’s CoverSpin rotating bowl cover that allows improved coating uniformity across the substrate regardless of substrate shape. A new, temperature-controlled chuck further enhances EVG’s proprietary OmniSpray coating technology, which specifically allows conformal coating of high-topography surfaces via its proprietary ultrasonic nozzle. OmniSpray coating is suited for ultra-thin, fragile or perforated wafers and can result in an 80% or greater reduction in material consumption compared to traditional spin coating, adds the firm.

Further improved serviceability and low CoO make the EVG120 system a versatile production tool for an entry-level budget, the firm reckons. EVG120 suits a wide range of markets and applications, including: high-topography coating and spray coating for MEMS; thick-film resists and bumping for advanced packaging; and passivation, dielectrics and thick-film processing for compound semiconductor devices.

The updated EVG120 automated resist processing platform is available for demonstration and evaluation.

www.EVGroup.com

Windows 8 spectroscopy & imaging software from CRAIC

CRAIC Technologies Inc of San Dimas, CA, USA has released its Lambdafire microspectroscopy and imaging software package. Written specifically for Window 8, the software is designed to collect, analyze and process both microspectra and images from CRAIC microspectrophotometers. Designed for both industrial processes and scientific research, Lambdafire contains spectroscopic, imaging and data analysis features, says the firm.

“Customers want to use our Lambdafire software with the latest generation of 64-bit processors and Windows 8 for even greater performance,” says president Dr Paul Martin. “Lambdafire software was

developed in response to customer requests for a high-performance package to control CRAIC microspectrophotometers situated on both the manufacturing floor as well as those in the R&D laboratory,” he adds. “Features are provided to address both of these functions while maintaining the powerful analytical capabilities.”

The complete solution combines 64-bit software written for CRAIC’s latest microspectrophotometers, such as the new 20/30 PV, and the latest versions of Windows. The new software allows users to control CRAIC microspectrophotometers and to acquire ultraviolet, color and near-infrared spectra and

images of microscopic samples by absorbance, reflectance, Raman and different types of luminescence and fluorescence.

The software also incorporates data analysis features that can analyze microspectra and images. Designed for the production environment as well as the lab, it has tools for analyzing UV (ultraviolet)-visible-NIR (near-infrared) data.

The software also features touchscreen control, a native Windows 8 feature, and automation control. Additional modules can be incorporated to add capabilities such as small-spot film thickness measurements and micro-colorimetry.

www.microspectra.com

Hidden launches new SIMS system family

Hidden Analytical Ltd of Warrington, UK has expanded its secondary-ion mass spectrometry (SIMS) primary system options to offer the choice of three initial equipment levels to suit a broad range of budgets.

All systems offer full UHV operation and expandability to the top-level specification.

The dual-mode MAXIM mass spectrometer features operation both in the secondary-ion mode and in the secondary-neutral (SNMS) quantification mode.

The Foundation SIMS System includes the IG20 fine-focus (50µm) oxygen/argon ion gun, multiple sample holder and primary ion beam monitor. An uplifted version, the SIMS Workstation, is configured for higher throughput rates with the addition of a sample load-lock and sample manipulator, together with charge-neutralizing electron flood gun and system bakout facility. The SIMS Workstation Plus has the most comprehensive specification, with the addition of the IG5C Caesium ion gun for electronegative species, having a spot size of just 20µm.

Hidden's MASsoft Professional SIMS PC data system provides automated measurement of positive and negative ions and of neutral species. It enables full control of



SIMS workstation.



IG20 5keV argon or oxygen ion source.

the mass spectrometer and ion gun operating parameters and ion beam raster, with acquired data presented in real time. The ESM LabVIEW SIMS Imaging program acquires, stores and displays the data for presentation in the form of elemental surface maps with both 2D and 3D view capabilities.

www.HiddenAnalytical.com

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The Business of Science®

GT acquires Thermal Technology

Complementary thermal and vacuum product portfolio to further GT's diversification into new markets

GT Advanced Technologies Inc of Nashua, NH, USA (a provider of polysilicon production technology as well as sapphire and silicon crystal growth systems and materials for the solar, LED and electronics markets) has acquired substantially all of the business of Thermal Technology LLC of Santa Rosa, CA, USA in exchange for about 3.4 million shares of GTAT common stock plus an earn out.

Thermal Technology develops high-temperature thermal and vacuum products used in the fabrication of materials that are deployed across industries including smartphones and touch screens, LED, medical devices, oil and gas and automotive. Since it was founded 60 years ago, the firm has delivered over 3000 products to customers in over 40 countries.

GT has acquired several key products and technologies that will allow it to address new markets with a range of production equipment options that can be optimized around customers' specific needs. This includes annealing technology that it believes will be important in the manufacturing of sapphire

cover screens; crystal growth technology based on the Kyropoulos (KY) growth method and edge-defined film growth (EFG) technology for large-surface-area sapphire. It has also acquired Spark Plasma Sintering (SPS) technology, which allows dense ceramics to be obtained under uniform heating at relatively low temperatures and in short processing times. The SPS technology is expected to have a wide range of applications including medical applications, sputtering targets, space applications and thermoelectric convertors for hybrid electric cars.

"The acquisition of the Thermal Technology business adds a number of innovative and important products and technologies to our rapidly diversifying portfolio that will, we believe, allow us to accelerate our entrance into new markets," says GT's president & CEO Tom Gutierrez. "The acquisition expands our served markets and complements several of our current product lines. In areas such as sapphire crystal growth, we can now offer customers a wider range of product options best suited to their specific production environments. This will enable

us to compete for incremental business in areas where we would have previously been unable to offer a product," he adds.

"The acquisition will open new opportunities for growth for our products and technology as we integrate them into GT's business operations," says Thermal Technology's president & CEO Matt Mede. "Leveraging GT's leadership in engineering and product development and their strengths in low-cost global supply chain management will accelerate the time-to-market of our technology to drive market adoption in several promising markets," he adds. "Customers will also benefit through GT's global service and support capabilities."

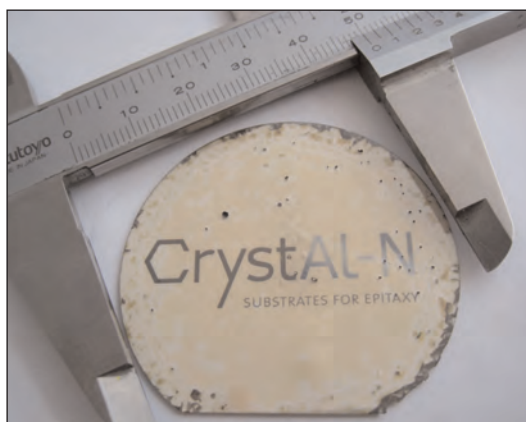
GT does not expect the acquisition to materially impact its 2013 revenue or earnings guidance range. The anticipated revenue contribution from the Thermal Technology business in the balance of 2013 is \$9–14m. GT expects minimal impact on earnings per share as expenses and the increase in share count will limit the contribution during the initial year of integration.

www.gtat.com

CrystAl-N switches from 1" to 2" bulk AlN wafer production

CrystAl-N GmbH of Fürth, Germany, which manufactures single-crystalline aluminum nitride (AlN) substrates, says it is now transitioning its production from 1-inch to 2-inch AlN and accepting pre-orders.

Founded in 2010 as spin-off of Friedrich-Alexander-University, Erlangen-Nuremberg, the firm says that using AlN will boost the efficiency of deep UV LEDs, lasers and high-power, high-frequency devices as soon as its cost-performance ratio is competitive. Shifting production to larger substrates will help to realize this, the firm says.



CrystAl-N's 2-inch AlN wafer.

"After many years of R&D we finally managed to combine high

UV transparency with suitable wafer size, enabling a real commercial product," says chief technology officer Boris Epelbaum. "Further diameter increase in our patented tungsten based furnaces is not limited as we are using SiC as initial seed."

Besides diameter enlargement, wafer polishing is also drastically improved. "The corresponding wafers feature surface roughness of less than 0.3nm and are highly UV transparent," says CrystAl-N's director of wafering Octavian Filip.

www.crystal-n.com

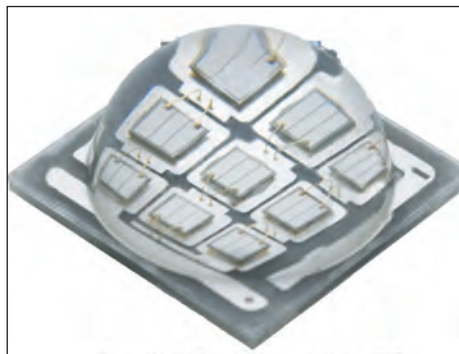
SemiLEDs adds mid- and high-power products to vertical UV-LEDs range

LED chip and component maker SemiLEDs Corp of Hsinchu Science Park, Taiwan, has released two new UV-LED product families, the 10W high-power N9 series, and the 0.17–0.50W mid-power P50N series. Based on SemiLEDs' patented vertical LED structure, both product families are designed for industrial applications, such as printing, coating and curing, and specialty applications including signage and medical or cosmetic uses.

The N9 series, housed on a 9mm x 9mm ceramic package, is offered at 385–420nm wavelengths in 5nm bins. Drive currents up to 1000mA deliver typical optical output power of 5000mW at the nominal 350mA drive current at 30V. The lambertian output distribution is compatible with secondary optics to allow precise control of the high-intensity UV light.

Compared to the standard 1000–4000-hour life of incumbent UV lamp technologies, vertical UV-LED systems support lifetimes of up to 50,000 hours under optimal thermal management conditions, decreasing system maintenance requirements in applications where even planned downtime carries substantial monetary costs. In addition, with instant on/off capabilities and a compact point-source that is compatible with a wide variety of optics, the N9 UV-LED allows solution integrators to eliminate maintenance-intensive components such as mechanical shutters or focusing windows, says the firm. High-output UV sources are commonly used in semiconductor and electronic photo-resistive etching or processing, as well as high-throughput printing systems, and larger-scale industrial bonding or curing applications, often eliminating the need for toxic solvents.

The mid-power P50N UV-LED series consists of a complete product family available for 0.17, 0.34 and 0.50W drive options, delivering up



SemiLEDs' new N9TL 10W high-power vertical UV-LED.

to 140mW of output, for wavelengths of 385–420nm in 5nm bins. The 5mm x 5mm package is suited to integration into compact arrays or for high-reliability backlight elements in UV-driven signage. The wide selection of output combinations simplifies the system integrator's task by allowing a common design platform for portable device applications, such as cosmetics or health care, where differing performance profiles are needed to address separate curing or treatment functions.

"SemiLEDs has consistently led the way in development of cost-effective UV-LED solutions that efficiently provide a wide range of output options, delivering the UV light where and how it is needed," says Ilkan Cokgor, executive VP of sales & marketing. "With the addition of the high-power N9 and mid-power P50N series, SemiLEDs has really opened up that area of the industrial market where both very high-output single UV-LED sources, and cost-effective UV-LED arrays, have not previously been available," he adds. "Given the key advantages that UV-LEDs bring to the market, including increased efficiency and lifetime, reduction of hazardous substances, and the virtual elimination of heat in the beam, we expect this advanced technology will displace the inefficient, short-lifetime incumbents over the next few years."

www.semileds.com

IN BRIEF

Water tech award for Crystal IS' UVC LEDs

Crystal IS Inc of Green Island, NY, USA, which makes UVC LEDs grown pseudomorphically (strained) on AlN substrates, has won the Disrupt-o-Meter Award at the 2013 BlueTech Forum in Amsterdam. It was selected from participants for the water sector award, honoring innovative, industry-revolutionizing technology.

"The technology presented by Crystal IS represents one of the strongest opportunities in the technical space in the next 5–10 years, and are excited about the potential for LEDs in the market, particularly within the water space," says BlueTech Research's CEO Paul O'Callaghan. "UV LEDs represent one of the top five potentially disruptive water technologies, with the global UV water disinfection market worth \$1.1bn," he adds. "UV LEDs have the potential to disrupt this market and access market share, and equally importantly, to open up new applications and markets previously inaccessible to conventional UV lamp technology."

BlueTech monitors the global water market for firms with innovative and disruptive technologies and a strong go-to-market strategy. The Disrupt-o-Meter Award is given to the firm with the highest potential to not only influence existing markets but open up new markets because of its ability to be used in various applications. The award also analyzes the firm's business model and quality of service provided with the technology.

As part of the award, Crystal IS can showcase its products in the Innovation Pavilion at the 86th Annual Water Environment Federation Technical Exhibition and Conference (WEFTEC 2013) in Chicago, IL, USA (7–9 October).

www.weftec.org

www.cisuvc.com

Verticle extends Cu-base hexagonal LED chip range to UV Copper substrate allows 1A drive current, yielding 1.025mW at 392nm

Verticle Inc of Dublin, CA, USA has extended its range of Honeycomb hexagonal-shaped vertically structured InGaN-based LED chips from blue wavelengths (in mass production since February 2012) to ultraviolet (UV). As with the firm's existing LEDs, the new UV chip uses patented chemical chip separation technology and a copper (Cu) substrate, enabling it to drive high current.

Despite its many advantages, the main drawback of a UV LED is its lower optical power due to lower internal quantum efficiency (IQE), says Verticle. Since improving the IQE of UV epitaxial wafers is a long-term prospect, an alternative way to boost output power is to drive more current into the UV-LEDs. However, heat generation is a big issue with high drive current, says the firm. Moreover, an aluminium-containing UV epiwafer is more resistive than a blue LED epiwafer, so thermal management for UV LEDs is more critical than for blue LEDs, notes Verticle. Hence, one of the main challenges of UV LEDs is lowering the junction temperature.

To operate at higher current injection and to dissipate heat more efficiently, Verticle's UV-LED chip is constructed with a copper substrate. As shown in Figure 1, the Cu-base vertical chip's thermal resistance (R_{th}) is 2K/W lower than that of a GaN/Si vertical LED chip. As a result, the junction temperature (T_j) for GaN/Cu is lower than for GaN/Si. Verticle notes that the difference in junction temperature between two chips is 2°C at an injection current of 350mA, but the difference becomes larger (6°C) at 1A current injection.

Figure 2 shows that Verticle's Cu-base UV-LED chip has higher radiant flux than a lateral UV-LED chip fabricated on the same epiwafer. Furthermore, the firm's UV-LED chip can be driven at higher current than other vertical chips fabricated

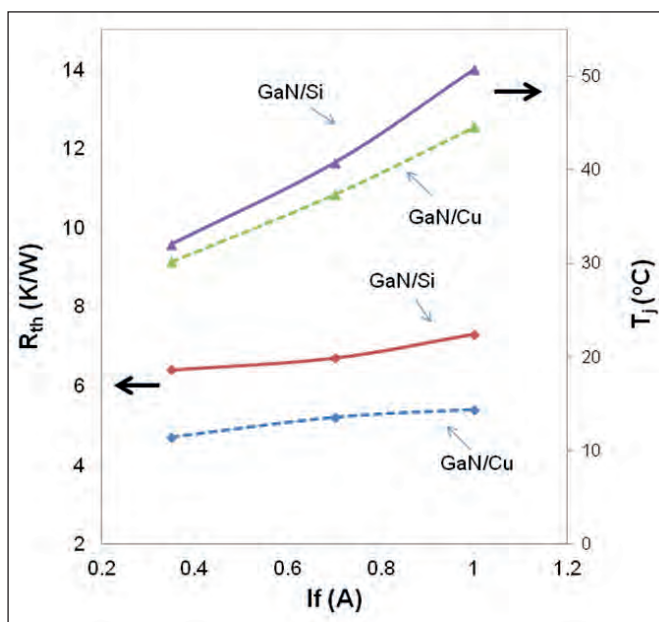


Fig. 1 Thermal resistance and junction temperature of GaN/Si and GaN/Cu vertical LEDs as a function of injection current ($T_a=25^\circ\text{C}$).

on different substrate materials, the firm claims. Verticle's GaN/Cu UV-LED chip does not saturate over 1A, while GaN/W and GaN/sapphire

and 1.025mW at 1A, respectively, for an emission wavelength of 392nm.

Verticle says that an additional benefit of its hexagonal chip is higher extraction efficiency once it is packaged with a circular lens, for which the hexagonal chip has a near-circular beam profile, meaning that there is less of a dark spot than for rectangular chips. The Honeycomb LED is hence useful for optic designs with a circular lens system, where a near-circular beam profile is required for various package and module applications.

Samples of the hexagonal UV-LED chip are available on request by e-mailing info@verticleinc.com. www.verticleinc.com

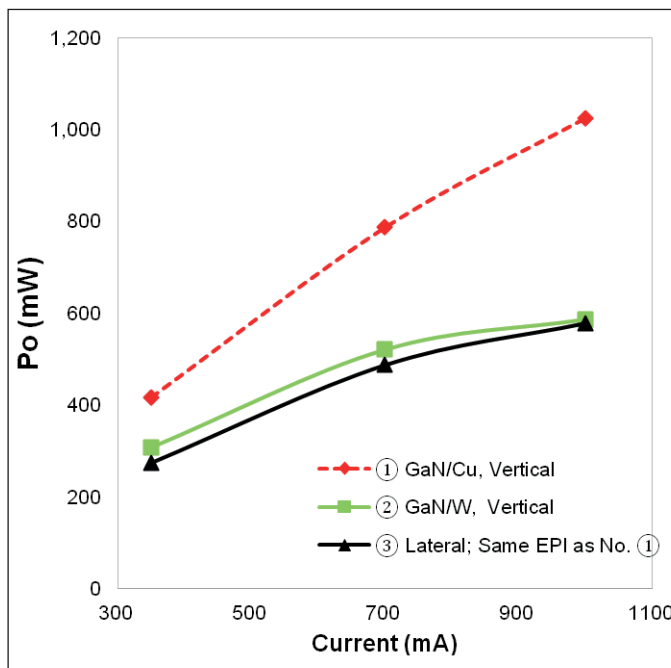


Fig. 2 Radiant flux versus current: (1) GaN/Cu vertical UV-LED, (2) GaN/W vertical UV-LED, and (3) GaN/sapphire lateral UV-LED. Bare UV-LED chips were attached on a 5050 metal lead frame without molding. To eliminate the wavelength dependency on radiant flux, 390–395nm UV-LED chips were used.

NCSU research opens door to ZnO-based UV lasers and LEDs

Defect complex creates p-type zinc oxide and enables efficient room-temperature light emission

Together with researchers at the US Army Aviation & Missile Research, Development & Engineering Center (AMRDEC) and Duke University, a team led by North Carolina State University (NCSU) claims to have solved a long-standing materials science problem, making it possible to create devices using zinc oxide (ZnO) — including efficient ultraviolet (UV) lasers and LED devices for use in sensors and drinking water treatment, as well as new ferromagnetic devices (J.G. Reynolds et al, 'Shallow acceptor complexes in p-type ZnO', Applied Physics Letters 102, 152114 (2013); <http://dx.doi.org/10.1063/1.4802753>).

"The challenge of using ZnO to make these devices has stumped researchers for a long time, and we've developed a solution that uses some very common elements: nitrogen, hydrogen and oxygen," says co-author Dr Lew Reynolds, a teaching associate professor of materials science and engineering at NCSU. "We've shown that it can be done, and how it can be done — and that opens the door to a suite of new UV laser and LED technologies," adds the lead author, NCSU research scientist Dr Judith Reynolds.

There is interest in using ZnO to create lasers and LEDs because ZnO produces UV light, and because ZnO can be used to make devices with fewer unwanted defects than other UV emitters — which means that the resulting lasers or LEDs can be more energy efficient.

However, researchers had been unable to consistently produce stable p-type materials from ZnO. Now, the NCSU-led team claims to have solved this problem by intro-

ducing a specific defect complex, via a unique set of growth and annealing procedures, into the ZnO. Compared with a normal ZnO molecule, in the defect complex the zinc atom is missing and a nitrogen (N) atom (attached to a hydrogen atom) substitutes for the oxygen atom. These defect complexes are dispersed throughout the ZnO material and serve as the electron-accepting holes in p-type materials.

Specifically, N-doped ZnO films grown by metal-organic vapor phase epitaxy (MOVPE) on a sapphire substrate have been shown to exhibit significant room-temperature p-type behavior (an acceptor concentration of $\sim 10^{18}\text{cm}^{-3}$) when sufficient nitrogen is incorporated and the material is annealed appropriately. Substitutional N on the oxygen (O) sublattice is a deep acceptor; however, shallow acceptor complexes involve N, H and zinc vacancies (VZn). By combining the use of secondary-ion mass spectrometry, Raman scattering, photoluminescence and Hall-effect data, the researchers have established the evolution of N from its initial incorporation on a Zn site to a final shallow acceptor complex VZn-NO-H⁺ with an ionization energy of about 130meV, responsible for the observed p-type behavior.

Not only does the research demonstrate how to create p-type materials from ZnO, but the defect complex also allows the ZnO p-n junction to function efficiently — and produce UV light — at room temperature, say the researchers.

The research work was supported by the US Defense Advanced Research Projects Agency (DARPA).

http://apl.aip.org/resource/1/applab/v102/i15/p152114_s1
www.ncsu.edu

IN BRIEF

SETi and USDA demonstrate increased shelf-life and improved nutritional quality of fresh using UV LEDs

Researchers from ultraviolet light-emitting diode (UV LED) maker Sensor Electronic Technology Inc (SETi) of Columbia, SC, USA and the Food Components and Health Laboratory of the US Department of Agriculture (USDA) say they have found a way to extend the shelf-life of fresh fruit and vegetables stored in home refrigerators.

The three-year program, which investigated the effects of light from certain types of UV LEDs, has led to more than double the shelf-life of fresh produce, while retaining the nutritional quality and appearance. The technology is currently being commercialized for the home appliance market.

"Findings of this exciting program are expected to have a major impact on the appliance business to extend the shelf-life and preserve nutritional value of the fresh produce," says SETi's president & CEO Dr Remis Gaska. "We look forward to the prospect of UV LEDs in residential refrigerators impacting on everyday life and reducing waste through spoilage," he adds.

"We are exploring the possibility that the UV effect involves the induction of defense mechanisms in the fruit itself in addition to inhibition of mold growth, since evidence indicates parts of the UV spectrum retards decay," notes Dr Steven Britz, a research plant physiologist at USDA's Agricultural Research Service.

www.usda.gov
www.s-et.com

Soraa requests EPA's ENERGY STAR program to address LED lighting color quality

To ensure the long-term success and widespread market adoption of LED lamps, Soraa Inc of Fremont, CA, USA, which develops solid-state lighting technology on 'GaN on GaN' (gallium nitride on gallium nitride) substrates, has urged the US Environmental Protection Agency's (EPA) ENERGY STAR program to address light quality — specifically color rendering — in its new lamp specification. Support for higher color rendering has been expressed by many individuals and industry groups, including the California Lighting Technology Center; professors Shuji Nakamura and Steven DenBaars at the University of California Santa Barbara; the International Association of Lighting Designers (IALD); Northeast Utilities Companies (NSTAR); and lighting designer Chip Israel; who all filed formal comments on EPA's Draft 3 product specification for LED lamps.

"Poor light quality ruined many consumers' confidence in compact fluorescents," says Soraa's chief technology officer Mike Krames. "The ENERGY STAR qualification must be associated with LED lamps that provide a better quality of light; otherwise, the program will start to lack credibility with end-users and the low adoption rate history of CFLs will be repeated by LED lamps," he adds.

In comments filed with the EPA on 17 May, Soraa told EPA that, while ENERGY STAR is not a mandatory standard, the Agency must recognize that it has become a de-facto standard for utility rebate dollars crit-

ical to lowering the initial cost of LED products. In the absence of a second high-color-rendering-index (CRI) tier, it is likely that, similar to the historical situation with compact fluorescent lamps (CFLs), the vast majority of lamp products will engineered to perform close to the lower boundaries of quality requirements as set in the ENERGY STAR lamp specification for cost reasons. Left unaddressed, this lack of high color quality lighting products will lead to a stalling in consumer adoption of energy efficient lighting technology, similar to what has been observed to date with CFLs, says Soraa.

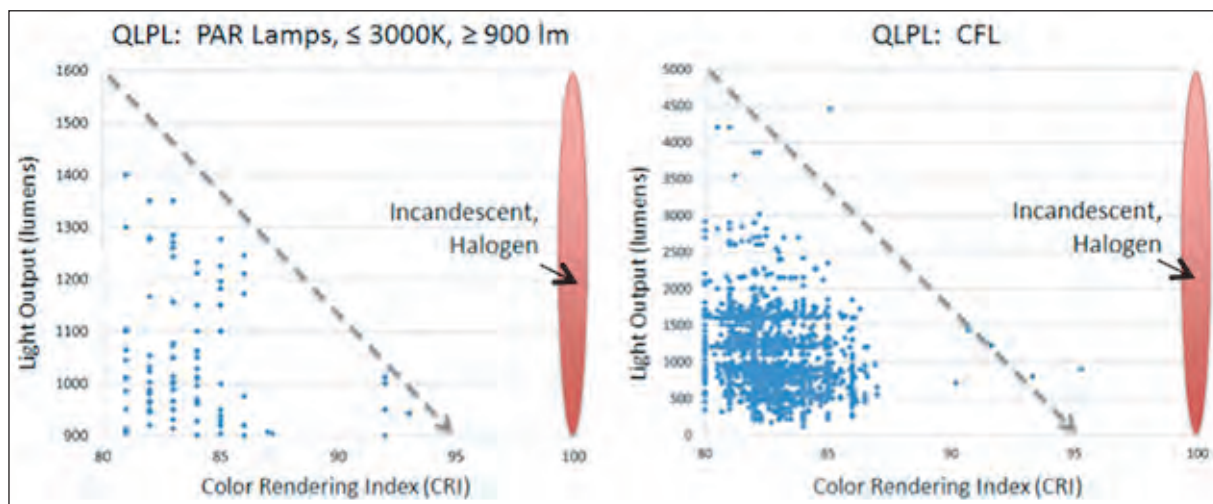
"To persuade consumers to purchase LEDs instead of incandescent lamps, LED lamps must be seen as high-quality products worth the initial higher price differential," says Ravi Parikh, Energy Services Specialist at Burlington Electric in Vermont. "Therefore, LED lamps must closely replicate the color rendering of the incandescent and halogen lamps that they replace," he adds. "The Soraa VIVID is such a product, providing superior color quality while improving energy efficiency," Parikh claims. "As a utility, we are always willing to consider higher incentives for projects utilizing

lamps such as Soraa's. We want to ensure customer satisfaction by reduced energy bills and maintained — if not, improved — quality of light. There is no need to sacrifice quality for efficiency. It is critical we understand the value in both."

To provide a more balanced portfolio of ENERGY STAR lamp products on the market and mitigate color quality as a barrier to wider adoption of energy efficient lighting products, Soraa proposed to the EPA a second high-CRI tier with differential efficacy requirements, taking into account the inherent lumen per watt trade-off as a function of CRI for phosphor converted white LEDs. Soraa proposed to keep the existing minimum efficacy requirements, but to raise the color quality to a minimum CRI of 90. For lamps with CRI of 80–90, Soraa proposes to increase the luminous efficacy requirements.

Soraa says that adoption of its proposal would increase overall energy savings through enhanced adoption of higher-light-quality lamps as well as through higher energy efficiency in lamps of modest light quality.

www.soraa.com/public/docs/Soraa-Comments-to-E-Star-draft-4



Light output versus CRI for both PAR lamps (left) and CFL (right) from the ENERGY STAR Qualified Lighting Product List (QLPL), compared to conventional light sources (red ovals). Existing standards drive the industry to produce modest color quality lamps, which do not address the color quality barrier to adoption.

Soraa launches 230V and 100V versions of VIVID 2 and PREMIUM 2 LED MR16 lamps

Soraa Inc of Fremont, CA, USA, which develops solid-state lighting technology built on 'GaN on GaN' (gallium nitride on gallium nitride) substrates, has launched 230V GU10 and 100V E11 versions of its new full-spectrum VIVID 2 and PREMIUM 2 LED MR16 lamps (replacements for 65-watt and 75-watt halogen lamps).

Enabled by Soraa's GaN-on-GaN LEDs, the new LED MR16 lamps deliver what is claimed to be the industry's highest light output while rendering vivid colors, richer reds and whiter whites. The latest launch follows the announcement of the availability of Soraa's new lamp line for the North American market.

"We now have 65–75W-equivalent lamps that produce full-visible-spectrum light and consume 80–85% less energy," says president & chief operating officer Dr Tom Caulfield. "We have just scratched the surface in terms of performance gains from our GaN-on-GaN LED technology," he believes.

Most LED lamps currently available are based on LEDs made by depositing GaN on foreign substrates such as sapphire, silicon carbide (SiC) or silicon, so they have high crystal defect densities that limit the amount of current densities they can handle, limiting the amount of light they emit per unit area. These high defect densities also constrain the LEDs to much lower temperatures in order to operate reliably, says Soraa. Both these limitations are amplified when these LEDs are used in a small form factor like an MR16 lamp, which is frequently installed in constrained or enclosed fixtures, and is used in applications that require very high light output, adds the firm. The lamps that use these LEDs have to make compensating design choices like using multiple



Soraa's LED MR16 lamp.

LED light sources to generate the required amount of light, and active cooling mechanisms to keep the LEDs within their operating temperature range.

In contrast, the VIVID 2 and PREMIUM 2 lamps' GaN-on-GaN LED technology leverages the 1000x lower crystal defect density of the native substrate, emitting substantially more light and allowing reliable operation at much higher temperatures, claims Soraa. This enables a simple and robust MR16 lamp design that uses a single LED light source and a simple heatsink, while producing 65–75W-halogen-equivalent light output and operating reliably at lamp temperatures of up to 120°C (a requirement for use in the most constrained fixtures).

"Smaller-form-factor, high-output LED MR16 lamps will now replace larger lamp types like PARs," believes Caulfield.

The VIVID 2 LED MR16 lamp has a color rendering index (CRI) of 95 and R9 of 95 and is available in a complete suite of beam angles, color temperatures and lumen outputs. The PREMIUM 2 LED MR16 lamp has a CRI of 80 and is available in multiple beam angles and color temperatures.

Soraa exhibited the LEDs in May at The ARC Show in London, UK.

www.soraa.com

IN BRIEF

Soraa adopts SAP business suite on HANA via NTT DATA

IT services provider NTT DATA Inc of Plano, TX, USA has expanded its customer agreement with Soraa.

Challenged with providing rapid real-time reporting to executives, plus better interaction with their back-end enterprise, on-demand CRM and other applications, Soraa will adopt SAP Business Suite on HANA. NTT DATA's expanded responsibilities will include identifying key opportunities aligned with technology and business strategies, building a solid roadmap, and migration implementation services to move Soraa's SAP Business All-in-One enterprise application from its existing Sybase database to SAP Business Suite on HANA powered by SAP HANA. This marks the first partner-driven sale of a Business Suite on HANA license by NTT DATA.

"We strive to be technology pioneers when doing so can lead to exponential improvements in our business, and the SAP Business Suite on HANA is one example of early adoption that fits our criteria," says Eran Ziv, VP of finance at Soraa. "The SAP HANA solution allows us to have real-time access to data in order to support rapid, more informed decisions that impact product development, delivery and customer service."

SAP Business Suite powered by SAP HANA helps customers to manage mission-critical business processes in real time such as planning, execution, reporting and analysis. It provides a flexible, real-time approach for managing large data volumes, allowing users to reduce hardware and maintenance costs, says NTT DATA.

www.nttdata.com/americas

IN BRIEF

Cree introduces LED canopy lighting

Cree has launched the CPY250 canopy and soffit lighting series. Consuming 75% less energy than MH (metal halide) systems it is designed to replace and 5–15% less energy with over 35% increased performance compared to competing higher-cost LED luminaires, the new CPY Series delivers exceptional visual environments across a range of canopy applications, including gas stations, bank drive-through ATMs and hotel/airport drop-off centers, says the firm.

"Canopy operators are under constant pressure to lower operating costs while simultaneously providing safe and visually appealing lighting," says Greg Merritt, VP, lighting at Cree. "The high-performance LED luminaires not only outperform existing LED and MH solutions but also enable the lowest total cost of ownership objectives to be achieved."

A canopy installation with CPY250 luminaires can deliver a payback period of under two years, compared with MH recessed and surface-mount solutions (based on typical commercial usage of 12 hours per day and a national average of \$0.12 per kWh costs with virtually zero maintenance).

Available in both flat and prismatic drop lens, the CPY250 provides two illumination aesthetics to meet the visual, as well as the vertical and horizontal illumination, performance needs of a typical canopy application. The CPY250 can mount to almost any canopy deck and is secured in place with self-sealing screws that provide a water-tight seal. The integrated driver in the canopy housing simplifies installation. The canopy series also features Cree's 10-year limited warranty.

www.cree.com/lighting/cpyseries

San'an's US affiliate Lightera acquires Luminus Devices Specialty lighting LED maker to gain access to increased technical and financial resources

Luminus Devices Inc of Billerica, MA, USA, which makes PhlatLight (photonic lattice) LEDs for solid-state lighting applications, has agreed to merge with Lightera Corp of Sunnyvale, CA, a US affiliate of LED maker San'an Optoelectronics Co Ltd of Xiamen, China that designs and develops LED components and system products for lighting applications.

Luminus was founded in 2002 on the basis of research at Massachusetts Institute of Technology. The firm subsequently raised more than \$150m in venture capital from Argonaut Private Equity, Braemar Energy Ventures, Paladin Capital Group, Stata Venture Partners, CMEA Ventures, Battery Ventures, DFJ, DFJNE, and Eastward Capital. Luminus focused initially on projection displays before shifting toward general illumination and high-brightness applications such as street lighting. The firm's LEDs are now used for general lighting, projection display, entertainment, ultraviolet curing, life sciences, medical, portable, transportation and digital signage lighting applications. Annual revenue in 2012 was \$17m.

Founded in 2000, publicly traded San'an produces LED epiwafers and chips, as well as compound semiconductor solar cells, solar products, and sapphire substrates. With expertise in LED epitaxial materials, chip/package design and lighting systems, the aim of San'an's subsidiary Lightera is to develop lighting technologies and products to accelerate the adoption of energy-efficient and smart LED lighting.

Luminus will now operate as an independent business unit and subsidiary of Lightera. The firm says that its business will have expanded capability, financial

backing and access to San'an's operations, coupled with a global R&D team focused on enabling lighting with LED technology. Luminus will continue to focus on specialty markets and applications for its expanding product and customer portfolios.

Luminus Devices says that it gains access to an R&D operation in California as well as the overall technical capabilities of San'an's Corporate R&D Technical Center, providing access to added global R&D operations in the USA and a large footprint for global expansion in specialty markets such as projection display, medical, transportation, ultraviolet and general lighting markets and applications.

"Luminus has been searching for the right partner that would add to our extensive intellectual property, allow for expansion of our global operations, and would be additive to our market-leading position in many segments of the worldwide specialty lighting market," says Luminus Devices' president & CEO Keith T.S. Ward. "This relationship with Lightera and San'an will allow us to expand our capabilities through new access to technical and financial resources well beyond our current position," he adds.

"As a leader in the specialty lighting market, Luminus Devices provides us with proven, state-of-the-art technology that will allow Lightera to expand both our US and international offerings," says Lightera's chairman & CEO Dr Decai Sun. "We expect Luminus to continue to focus on new technology, specialty lighting markets, applications and superior customer service."

www.luminus.com

www.lighterausa.com

www.sanan-e.com/en



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Lumileds' latest mid-power LEDs achieve 140lm/W efficacy for cool-white light at 4000K

Philips Lumileds of San Jose, CA, USA has launched the Luxeon 3535 2D, which combines two LED chips in a package to enable reduction in LED count and cost of designing retrofit lamps, consumer downlights and diffuse industrial lamps, says the firm. Best-in-class efficacy of 140lm/W is achieved for cool-white light at 4000K and minimum 80 CRI.

"Lighting designers can take advantage of a high lumen package with high efficacy while using significantly fewer chips per fixture," says Rahul Bammi, VP of product management. "For example, a 50W PAR20 lamp can be achieved using only four LEDs. Alternatively, a 40W A19 lamp that previously required 14 LEDs can now be created using only six."



Lumileds' new LUXEON 3535 LED.

The new mid-power LEDs are offered across a full spectrum of correlated color temperatures (2700–6500K) with a minimum CRI of 80. Versions with CRI 70 for outdoor applications and CRI 90 for high-end indoor applications are planned for future release.

The Luxeon 3535 2D line operates at 0.5–1W, delivering up to 130lm in the compact 3535 form factor. Rated at 100mA, the Luxeon 3535 2D can be driven up to a maximum of 200mA. Luxeon 3535 2D supports ENERGY STAR certification requirements up to 25,000 hours at 85°C and 150mA.

Lumileds has also launched its first low-power LED, the Luxeon 4014. The rectangular, high-efficiency LED was designed specifically to address linear and omnidirectional lighting applications such as under-cabinet and cove, refrigerator lighting and the retrofit LED market. Delivered in a 4.0mm x 1.4mm x 0.7mm footprint, the LUXEON 4014 line can achieve an efficacy of 160lm/W at 4000K and CRI of 80.

www.philipslumileds.com

IN BRIEF

KORE to distribute for Lumileds in India

Lumileds has signed a distribution agreement with Delhi-based Key Operation & Electrocomponents Pvt. Ltd (KORE), enabling immediate access to Lumileds' application-specific LEDs in India.

Founded in 2008 and part of LED component distributor Ramakrishna Electro Components Group, KORE is a distributor, manufacturer and supplier of LED lighting systems and accessories as well as LED lamps to India.

"LED lighting is just beginning to take off in India. But we expect remarkable growth in this market over the next several years, in both commercial and off-grid applications," says Lumileds' CEO Pierre-Yves Lesaichere. "KORE personnel will have full access to the products, services and people at Philips Lumileds," he adds.

www.indiamart.com/keyoperation

Global distribution partners appointed

Lumileds has appointed four new online and catalog distribution partners (Digi-Key, Farnell, Mouser Electronics, and RS Components).

"Solid-state lighting is one of the fastest-growing segments in today's fast-paced market," says Mark Zack, VP, Global Semiconductor Product, Digi-Key. "As a global distributor with the largest selection of electronic components, we're pleased to serve the needs of lighting designers by supplying Philips Lumileds' comprehensive line of LED products."

"Our industry-leading element14 community demonstrates a shared commitment, together with Philips Lumileds, to empower engineers with the components, service and information they need to rapidly design and deliver leading-edge products," says Mike Buffham, Global Head of Product and Pricing, Premier Farnell.

"Our customers across the globe will now have easy access to Lumileds' innovations, like their Freedom from Binning program, which simplifies the design process

to reliably select consistent color without the need for binning designations," notes Russell Rasor, Mouser's VP of Advanced Technology.

"Our strategy at RS is focused heavily on reducing design times for engineers by supporting them with free online design resources, and by providing fast, easy access to a vast selection of products direct from stock," says Jonathan Boxall, global head of Semiconductors at RS Components. "We are delighted to be partnering with Philips Lumileds, a move that will provide luminaire designers worldwide with a significant competitive advantage by combining leading-edge LED products with a time- and cost-efficient sourcing and purchasing experience."

"New distribution partners will have full access to the products, services and people at Philips Lumileds," says CEO Pierre-Yves Lesaichere.

www.digikey.com

www.farnell.co.uk

www.mouser.com

<http://uk.rs-online.com/web>

DOE selects five projects for \$10.1m fourth-round SSL Manufacturing R&D funding opportunity

Lumileds to cut cost of PSS-based InGaN LEDs; Cree to develop a scalable, low-cost, low-profile LED light module

In response to SSL Manufacturing R&D funding opportunity announcement (FOA) DE-FOA-0000792, the US Department of Energy (DOE) has announced the competitive selection of five projects for solid-state lighting (SSL), involving a total of \$10.1m in DOE funding plus \$10.1m in matching private-sector investment from five firms.

The two-year projects will focus on achieving significant manufacturing cost reductions while maintaining quality by improving manufacturing equipment, processes, or monitoring techniques.

This is Round 4 of the DOE's investments in solid-state lighting manufacturing projects since 2010. The efforts are part of the DOE's initiative to accelerate the adoption of SSL technology via improvements that reduce costs while maintaining product quality and performance. They are intended to play a key role in accelerating US-based manufacturing of SSL technologies, helping to create jobs, boost exports, and promote the USA's role as a global leader in energy efficiency.

The five projects selected include the two projects below (final details are subject to negotiations):

- \$1.8m to Philips Lumileds Lighting Company of San Jose, CA, USA for 'Development and Industrialization of InGaN/GaN LEDs on Patterned Sapphire Substrates for Low Cost Emitter Architecture', which aims to reduce LED manufacturing costs by establishing a patterned sapphire substrate (PSS) fabrication process with demonstrated epitaxial growth of indium gallium nitride (InGaN) layers capable of producing high-efficiency LEDs when combined with chip-on-board packaging techniques. The proposed cost reductions would

result from the elimination of some of the complex processes associated with current flip-chip technology, and from the enabling of lower-cost packaging methods that take advantage of the stability of the sapphire substrate, which is removed in a standard flip-chip device. This approach has the potential to reduce the cost of high-brightness LED lamps and modules targeted across a wide range of lighting and illumination applications, it is reckoned.

- \$2.3m to Cree Inc of Durham, NC, USA for 'Scalable Light Module for Low-Cost, High Efficiency LED Luminaires', which aims to develop a versatile, low-cost, low-profile LED light-module architecture that facilitates the assembly of a variety of high-efficacy, broad-area LED luminaires. The light module will be driven by a novel, compact LED package for a combination of high color rendering index (CRI) and high efficacy over a wide range of color temperatures. Cree will hence take a vertically integrated approach to developing the LED component and light module, optical, electrical and mechanical sub-systems for optimal light generation, distribution, extraction, and diffusion.

The remaining three projects include the following recipients: Eaton Corp of Menomonee Falls, WI, USA for 'Print-Based Manufacturing of Integrated, Low Cost, High Performance SSL Luminaires'; OLEDWorks LLC of Rochester, NY, USA for 'Innovative High-Performance Deposition Technology for Low-Cost Manufacturing of OLED Lighting'; and PPG Industries Inc of Pittsburgh, PA, USA for 'Manufacturing Process for OLED Integrated Substrate'.

www1.eere.energy.gov/buildings/ssl/financial.html

IN BRIEF

Wide-bandgap funding opportunities

The US Department of Energy's (DOE) Advanced Research Projects Agency (ARPA-E) has announced two funding opportunities relating to solid-state lighting.

Both seek proposals for "transformational advances in wide-bandgap materials, device fabrication, and device architectures", with the goal of enabling the development of high-voltage, high-current, single-die power semiconductor devices:

- Non-SBIR (Small Business Innovation Research) Strategies for Wide-Bandgap, Inexpensive Transistors for Controlling High Efficiency Systems (SWITCHES) [DE-FOA-0000942] offers about \$10m in total funds, with individual awards of \$250,000 to \$10m. There are two categories of investigation: Proof of Concept Seedling Project (with average award of \$500,000 and focusing on early-stage R&D efforts) and Technology Development Program (offering an average award of \$3m and focusing on early-stage prototypes of various technology concepts for which some kind of initial proof-of-concept component demonstration already exists).

- SWITCHES SBIR (DE-FOA-0000941) is similar to the first opportunity but is aimed at small business. It offers about \$15m in funding, with individual awards of \$225,000 to \$3.255m.

Both opportunities require a Notice of Intent (due by 8 July) followed by a proposal (due by 19 July).

ARPA-E's mission is to identify and fund research to translate science into breakthrough energy technologies that are too risky for the private sector and that, if successfully developed, can create the foundation for entirely new industries.

<https://arpa-e-foa.energy.gov>

IN BRIEF

Seoul Semiconductor qualifies for UL Witness Test Data Program for testing LEDs and modules

South Korean LED maker Seoul Semiconductor has achieved qualification for the UL Witness Test Data Program (WTDP), allowing it to conduct UL tests on LEDs and modules in its own laboratories, under the supervision of an engineer from Underwriters Laboratories.

Seoul Semiconductor says that this allows it to build on its foundation of manufacturing LED products such as Acrich, MJT, and nPola by adding in-house testing for the international standards that customers require. An added benefit of UL WTDP is speeding product introductions to global markets through the reduction in the time it takes to get the UL mark.

"We will continue to react quickly to the needs of the global LED lighting market as it rapidly grows by focusing on reinforcing our internal capabilities so we can quickly provide high-quality solutions for LED light sources as requested by our global customers," says Jeong Min Yeong, chief of Seoul Semiconductor's Reliability Team.

Seoul Semiconductor already holds certifications to ISO/IEC 17025 'General Requirements for the Competence of Testing and Calibration Laboratories' and ISO/TS 16949 'Quality Management Systems' as well as being part of the US Environmental Protection Agency (EPA)'s list of recognized laboratories for conducting LM-80 testing in order to meet ENERGY STAR requirements for solid-state lighting products.

www.seoulsemicon.com

Bridgelux completes transfer of GaN-on-Si technology to Toshiba

LED chip and lighting array maker Bridgelux Inc of Livermore, CA, USA has closed an agreement with Tokyo-based semiconductor manufacturer Toshiba Corp (announced on 22 April), which aims to strengthen and extend their strategic technology collaboration.

The firms have now completed the transfer of Bridgelux's gallium nitride-on-silicon (GaN-on-Si) technology assets to Toshiba and inaugurated the new phase of GaN-on-Si LED collaboration, including an expanded licensing

and manufacturing supply relationship. Bridgelux will continue to develop and market its GaN-on-sapphire LED products as a fabless solid-state lighting company.

"Bridgelux will focus on commercializing, productizing and bringing to market GaN-on-silicon technologies alongside a proven global scale semiconductor manufacturer," says Bridgelux's CEO Brad Bullington. "At the same time, we remain committed to our GaN-on-sapphire business."

www.bridgelux.com

Solid-state lighting expert Bernhard Stapp joins Aledia's board

Aledia S.A. of Grenoble, France, which is developing LEDs based on 'WireLED' three-dimensional (3D) microwire GaN-on-silicon technology that is claimed to cut manufacturing costs compared to conventional planar (2D) LEDs, says solid-state lighting (SSL) industry veteran Dr Bernhard Stapp has joined its board of directors.

Stapp has more than 12 years of executive experience in LED lighting, most recently in senior management positions at Germany-based lighting manufacturer Osram.

As general manager & senior VP of Osram AG's SSL unit, Stapp was responsible for its professional LED and organic LED (OLED) business. Earlier, as SSL VP & general manager at Osram Opto Semiconductors of Regensburg, Germany, he launched and managed the general-lighting LED business and oversaw the launch of the world's first OLED lighting products. Prior to that, he was VP & chief technology officer of the firm, where he oversaw global LED, laser and OLED R&D. Earlier in his career, he held various management positions in Siemens AG's Corporate Technology division.

"Aledia's mission is to bring funda-

mental change to the world's lighting markets by making LED technology substantially more affordable and more versatile, with better performance and fewer limitations," says Aledia's co-founder, president & CEO Giorgio Anania. "Bernhard has been a key player at the heart of the global LED industry since its inception, and also has an outstanding technical background," he adds. "His unique perspective on this industry's future will be invaluable as Aledia moves into the next stage of its evolution."

WireLED, Aledia's unique 3D microwire GaN-on-silicon technology, was developed at the CEA-Leti nanotech research institute in Grenoble. It aims to address the basic technical and economic challenges facing LED lighting by allowing production of LEDs on inexpensive industry-standard 8" (200mm) silicon wafers (or larger) using standard semiconductor processes and tools in existing CMOS foundries. "It [WireLED] can meet the industry's critical requirement for cost-reduction, while using far simpler production processes and much less material than conventional approaches," comments Stapp.

www.aledia.com

VPE reveals details of a new MOCVD System for high-volume GaN LED production

Valence Process Equipment (VPE) of Branchburg, New Jersey, has announced the commercial introduction of a high-performance MOCVD reactor for GaN LEDs.

According to founder and CEO, Frank Campanale, "The VPE GaN500 system is now available in a 59x2-inch configuration that can be upgraded to a 20x4-inch wafer configuration."

"Although a new name to many, VPE has been in R&D mode since 2007. Its core technology team has a long pedigree in the MOCVD industry" continued Campanale. "Prior to bringing the GaN500 to market, we successfully completed a number of custom epitaxial system design projects, including a continuous-flow III-V Solar MOCVD system and a dedicated AlN epitaxy system. In 2010, we decided to push forward with the design and build of a large-scale GaN system, and in 2011, we installed our first unit in a customer fab in Asia. Data from that, plus data from our in-house systems, over hundreds of process runs since 2011, clearly demonstrate the reliability and robustness of the VPE platform – so

much so, that we are fully confident to bring it to the market at this time." VPE's GaN500 design team took a radically different approach from other recent entrants to the MOCVD field. The system is built around a relatively small, multi-zone, proportional-flow injector housed in an elliptically-flared chamber producing excellent uniformity of the epitaxial layers with highly efficient use of the gases and precursor chemicals. According to Dr. Michael Begarney, founder and CTO "In side-by-side comparisons against a smaller-capacity competitive unit and, for the same process, the VPE GaN500 system can use up to 40% less Hydrides and Alkyls – with the added benefit that our injector is designed to run clean, so maintenance costs are low."

The emphasis on low cost of ownership extends to all aspects of the VPE design. "When faced with a choice between a complex and a simple solution – we chose the simple option" said Begarney. "For example, we worked closely with a manufacturer of in-situ monitoring tools to develop our own proprietary hardware and software for reflectance measurement – including the ability to monitor growth on PSS substrates. The result is a system that is affordable to acquire, efficient in operation and economical to maintain."

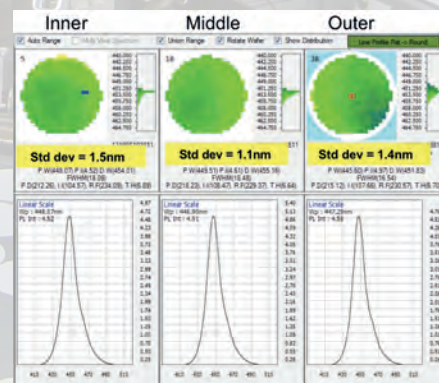
Low COO does not compromise epitaxial wafer quality. The VPE team believes that many aspects of its MOCVD system design directly translate into superior material quality. "GaN (002) and (102) XRD rocking curves are routinely in the low 200s of arc seconds" said VPE Vice President Dr. Tom Ryan "and independent third parties have been impressed by our level of control of both temperature and gas switching during

MQW growth. We believe that these attributes lead to higher IQE LEDs".

In mid-2012, VPE moved into a 24000ft² facility in Branchburg, New Jersey. The facility has a clean manufacturing area, with simultaneous production capacity of up to 12 MOCVD systems, as well as an engineering area and full characterization lab.

Campanale went on to talk about the VPE wafer capacity roadmap. "When we designed the GaN500 we deliberately used an over-sized chamber with room to accommodate a larger diameter platter. Our first system used a 52x2" wafer platter, which we have subsequently expanded to 59 wafers. We are currently testing an upgrade kit – that allows us to expand the capacity to 72x2" wafers or 20x4" wafers in the existing chamber, with the same efficient operating properties."

www.valenceprocess.com



VALENCE PROCESS EQUIPMENT

XLamp XP-E2 color LEDs made commercially available

Cree Inc of Durham, NC, USA has announced commercial availability of its new XLamp XP-E2 color LEDs, in red, red-orange, amber, green, blue and royal blue colors. Delivering up to 88% higher maximum light output compared to alternative high-power color LEDs, it is claimed, they enable lighting manufacturers to more cost-effectively address a wide range of applications, such as architectural, vehicle and display lighting.

Fabricated on Cree's SC³ Technology next-generation LED platform, the

new XP-E2 color LEDs deliver higher lumens-per-watt and -per-dollar than the original XP-E color LEDs, lowering system costs for existing XP-E color designs. The XP-E2 color LEDs leverage the same XP footprint (3.45mm x 3.45mm) and are optically compatible with the original XP-E LED, providing drop-in-ready performance enhancements to shorten design cycle and improve customer time to market.

"The brighter XP-E2 color LEDs enable Lumenpulse to continue to provide innovative, high-performance

LED lighting systems," comments Greg Campbell, executive VP & chief technology officer Lumenpulse of Montreal, Canada.

XLamp XP-E2 color LEDs deliver up to 1409mW for royal blue, 109lm for blue, 253lm for green, 203lm for amber, 193lm for red-orange and 155lm for red, all at maximum drive currents in the 3.45mm x 3.45mm footprint.

Samples are available now, and production quantities are available with standard lead times.

www.cree.com/xpe2

Cree expands CR Series LED downlights

Cree has launched its Full Definition CR4 and CR6 downlights, designed to replace incandescent 4" and 6" recessed downlights. Featuring a warm-white 2700K color temperature, dimming and better than 80 color rendering index (CRI), they target applications requiring good light quality and low initial cost.

"The new Full Definition CR downlights cost less than fluorescent alternatives and also use 20–30% less energy compared to the outdated CFLs they replace," says Greg Merritt, VP, lighting at Cree.

The new products combine Cree's latest advances in LEDs and driver design with full-system thermal and electrical integration to reduce initial cost barriers to LED adoption. Payback against incandescent downlights is under a year in many installations and the price-point is up to 25% less than Cree's comparable 90CRI products (for typical commercial usage of 9 hours per day and \$0.11 per kWh electric costs with virtually zero maintenance).

For those requiring a higher CRI, Cree is also expanding its existing

CR Series LED downlights from the existing color temperature of 2700K to 3000K, 3500K and 4000K (with a CRI of 90 or more).

The CR4 Full Definition downlight delivers up to 575lm and the CR6 Full Definition downlight delivers up to 625lm. Both are dimmable to 5% with most standard incandescent dimmers. The Full Definition downlights are qualified for both residential and commercial ENERGY STAR standards.

www.cree.com/lighting/CRSeriesDownlights

Cree introduces mid-power LEDs

Cree has launched the XLamp XH Series of mid-power ceramic LEDs. XH LEDs are optimized for fluorescent-replacement-lighting applications, such as troffers and panel lights, where high efficacy, lifetime and smooth appearance are critical, says the firm.

XH LEDs are optimized for fluorescent-replacement-lighting applications, such as troffers and panel lights, where high efficacy, lifetime and smooth appearance are critical.

The XH-G LED delivers luminous efficacy of up to 170lm/W at 65mA, a correlated color temperature (CCT) of 5000K, and a color rendering index (CRI) of 80, at 25°C. In addition, the ceramic-based XH LEDs

are designed to deliver the long L70 lifetimes at high-temperature and high-current operation of Cree's other high-power LEDs, such as XP and XT LEDs. In comparison, plastic LEDs are known for very short L70 lifetimes at high-temperature and high-current operation, says the firm.

"Cree is offering high-quality, ceramic-based, mid-power LEDs designed for real-world lighting applications," comments Roger Suen, supply chain management director at Light Engine. "The XH LED family gives us confidence in providing products that deliver stable lumen maintenance and good color consistency that cannot

be duplicated by plastic packages."

"The use of plastic packages for lighting solutions places a high degree of risk for end-customers and the industry in general," says Paul Thieken, Cree director of marketing, LED components. "The XH LEDs provide peace-of-mind to lighting manufacturers while enabling them to better differentiate their products in the marketplace."

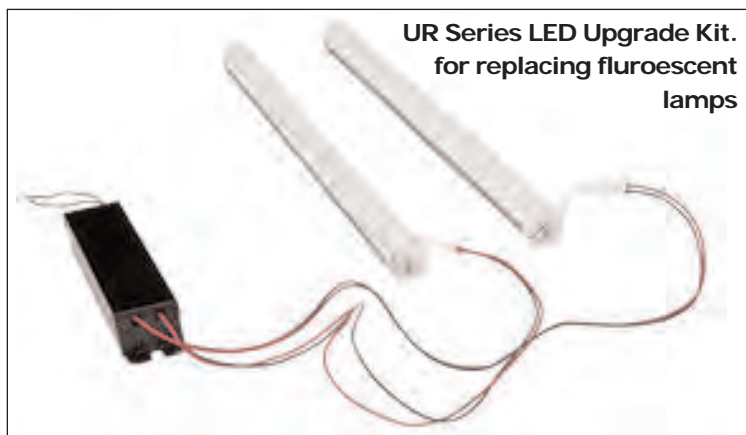
Both XH-G and XH-B LEDs share a common 3.0mm x 3.0mm footprint package with a 13% wider beam angle than most plastic mid-power LEDs. XLamp XH LEDs are offered in 2700–7000K color temperatures with high-CRI options available.

www.cree.com/xh

Cree's 102lm/W linear LED upgrade kit targets quick retrofit and payback to replace fluorescent lighting

LED chip, lamp and lighting fixture maker Cree Inc of Durham, NC, USA has introduced a 102 lumen-per-watt linear LED upgrade kit to replace fluorescent lamps. The new UR Series LED Upgrade Kit is easy to install, saves over 50% in energy, provides better light, and lasts up to twice as long as the standard 32W fluorescent lamps it replaces, Cree reckons, delivering payback in less than two years (calculated against a fluorescent three-lamp fixture — with lamp and ballast equal to 88 system watts — and based on typical commercial usage of 12 hours per day and \$0.11 per kWh electric costs).

The upgrade kit is designed to fit into existing T8/T12 linear fluorescent fixtures, allowing end-users to easily upgrade to LED. The UR Series covers both 2-and 4-feet lengths in various lamp configurations. Due to its unique



magnet design, quick connect technology and form-fitted driver, it can be installed more quickly than competitive retrofit LED tubes and complex LED conversion kits, Cree claims. Designed to be compatible with existing fluorescent fixtures, the UR Series LED lightbars and driver can fit into almost any linear fluorescent luminaire without the need to reuse existing sockets and ballasts.

"The UR Series is an ideal solution for applications where building owners prefer to retain existing lighting fixtures, including hospitals where retrofit construction can negatively impact the environment," said Greg Merritt, vice president, lighting at Cree.

The LED lightbar and driver combination makes the UR Series a versatile upgrade option for many different fluorescent lamp and length configurations, says Cree. The new kits deliver 4500 lumens for a 2x4 fixture and 3600 lumens for a 2x2 fixture. Designed to last 50,000 hours and featuring a 7-year warranty, the UR Series suits users wanting to accommodate current energy-efficiency legislation while receiving a fast payback and return on investment, reckons Cree.

www.cree.com/lighting/URseries



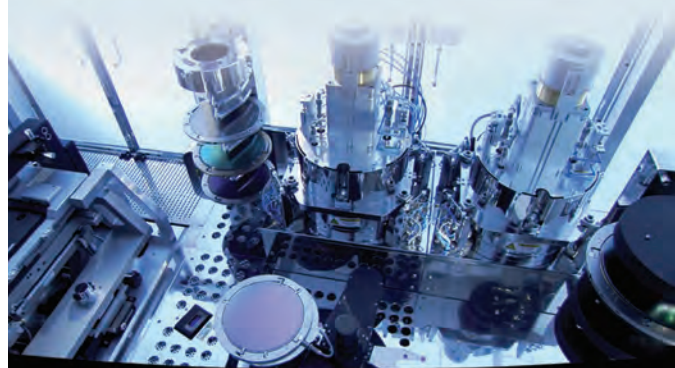
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www.EVGroup.com

Cree's quarterly revenue grows a more-than-expected 23% year-on-year to record \$349m

Margin hit by LED bulb launch, but lighting growth boosts June quarter

For its fiscal third-quarter 2013 (to end-March), LED chip, lamp and lighting maker Cree Inc of Durham, NC, USA has reported record revenue of \$348.9m, up 1% on last quarter and up 23% on \$284.8m a year ago (and at the high end of the targeted range of \$335–\$350m, which had been revised upwards from January's guidance of \$325–\$345m).

Highlights that have helped to drive Cree's improved figures include: introducing the Cree LED Bulbs, marketed at a price "that gives consumers a reason to switch to LED lighting"; launching the XLamp XQ LED family — Cree's smallest lighting-class LEDs (57% smaller than Cree's XLamp XB package); and the new CR Series LED Architectural High-Efficiency troffer, which delivers 130lm/W and 90 CRI (color rendering index).

Specifically, by product sector, Power & RF product revenue was \$22.7m (roughly level with last quarter's \$22.6m), with gross margin falling slightly from 56.6% to 53%. Lighting product revenue rose by 6% from \$122.7m to \$130.7m, as strong sales of commercial indoor fixtures and the new Cree LED bulb more than offset seasonally lower outdoor lighting sales in cold weather regions (although gross margin fell from 33.7% to 30.6% due to start-up costs from the LED bulb launch). LED product revenue fell 3% from \$201m to \$195.6m, although gross margin rose from 41.9% to 43.8% due to higher LED volumes driven by LED bulbs. Overall gross margin has fallen from 39.2% last quarter to 38.8% (although this is up on 35.6% a year ago).

On a non-GAAP basis, net income was \$40.8m (\$0.34 per diluted share), up 75% on \$23.3m (\$0.20 per share) a year ago, and on the high end of the targeted \$35–\$41m (\$0.31–\$0.36 per share, which was revised upwards from \$0.30–\$0.35).

The rise was due mainly to the strong sales of lighting products and the firm's ability to continue to reduce the cost per lumen at the LED chip, package and systems level.

"Our results continue to demonstrate the benefits of being vertically integrated from LED chips through lighting systems, which has enabled us to drive LED lighting adoption," commented chairman & CEO Chuck Swoboda.

"Cash provided by operations was \$46m and capital expenditures were \$31m, including \$6m related to patents, which resulted in free cash flow of \$15m," said Cree's newly appointed chief financial officer & executive VP Mike McDevitt. During the quarter, cash and investments rose by \$51.2m to \$937.1m, due to "solid execution and focused capital spending". Inventory rose by \$10.7m to \$195.7m (from 78 to 82 days on hand) to support new product introductions (specifically, the increase in the lighting business in the LED bulb product brand).

"Overall, the company's order backlog is ahead of this point last quarter and we are targeting solid growth for the next quarter," noted Swoboda. "We remain focused on using new product innovation to grow our growth by taking share from traditional technologies," he added. "The Cree LED bulb is the latest example of what is possible in terms of opening new markets to LED lighting, and creating opportunities for Cree to both increase revenue and build our brand."

"For fiscal 2013, our first priority in the coming quarter will be to accelerate adoption of LED lighting and increase sales of our indoor and outdoor lighting products," said Swoboda.

"Our second priority is to drive growth in our LED component product line through innovation by leveraging the SC3 LED technology

into a range of customer lighting products. We recently released the XLamp XQ family of LEDs based on our SC3 technology platform, which are 57% smaller than our XB series of power LEDs. This new LED family uses a completely new package design that enables higher-density design, novel optics and lower cost per lumen," Swoboda added.

"We expanded our CXA series of LED arrays with new higher-output versions from 5000 lumens to over 10,000 lumens," he continued. "We also set a new R&D record for LED efficacy with a prototype [white] LED that delivers 276 lumens per watt... our track record suggests that we should be able to bring this type of innovation to production LEDs over the next few years."

For fiscal fourth-quarter 2013 (to end-June), Cree expects revenue to rise to \$365–\$385m, consisting of double-digit Lighting revenue growth (driven by commercial fixtures and LED bulbs), single-digit growth in LED product revenue, and Power & RF product revenue up slightly.

On a non-GAAP basis, gross margin should rebound to 39.5%, resulting from increased volumes, cost reductions across product lines, and lower-cost new-product designs. "This builds on the momentum from the last several quarters as we target incremental improvement across product lines, led by gains in factory efficiency due to higher volumes, factory cost reductions and lower-cost new products," said Swoboda.

Operating expenses are targeted to increase by \$5m, mainly to support the media campaign for the Cree bulb launch, seasonal trade shows, and sales & marketing expenses related to the growth in business. Net income is hence expected to rise to \$41–\$47m (\$0.34–\$0.40 per diluted share).

www.cree.com

Matthew Peach, Contributing Editor



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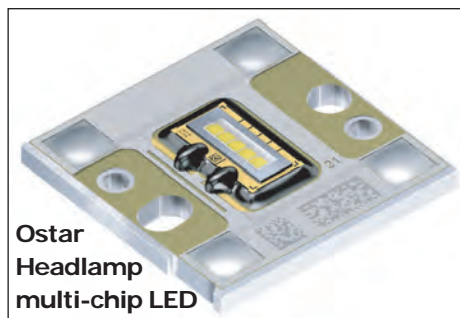
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German project focuses on intelligent LED headlamps

Osram-led consortium to increase road safety

Adaptive forward lighting (i.e. glare-free camera-controlled headlamps that react instantly to changing conditions at night) is to help keep drivers and their passengers safer, as a consortium of high-tech automotive firms design and build additional intelligent functions. The key to this complex functionality is the integration of microelectronics and optoelectronics — one of the principal aspects of a research project sponsored by the German Federal Ministry of Education and Research (FMER). As a major provider of LED lighting for the automotive sector, Osram Opto Semiconductors GmbH of Regensburg, Germany is contributing its expertise as the project coordinator.

As part of the FMER's 'Integrated microphotonics' initiative, the aim of the joint project is to develop the technical framework for a new class of energy-efficient LED headlamps with supplementary traffic safety functions. This can provide the basis for adaptive forward lighting systems (AFS) that offer drivers and pas-



sengers increased safety with functions such as glare-free high-beams and low-beams that adapt to the speed of the vehicle. At high speed, the range of the light will be automatically increased. However, in city traffic a wider distribution of the light can improve road safety by illuminating more of the sidewalk and other peripheral elements such as pedestrians and cyclists. These functions are fully electronic, so there is no need for mechanical actuators.

Osram Opto Semiconductors has expertise in chip and converter technologies, and the Specialty Lighting division of its parent firm, the light manufacturer Osram

GmbH of Munich, Germany, will develop new electronic control gear for controlling the LED headlamp system. The Fraunhofer Institute for Reliability and Microintegration (IZM) is contributing its expertise in interconnection technology and materials, and Infineon Technologies is offering its experience in automotive electronics and LED drivers. The automotive industry supplier and lighting specialist HELLA will develop the entire optical system for the LED module and the headlamps, and will build prototypes. Automotive manufacturer Daimler will carry out the vehicle tests.

"We have brought together major players in their respective sectors and have assembled a wealth of expertise for this pioneering project," says project coordinator Stefan Grötsch, responsible for LED applications in automotive lighting at Osram Opto Semiconductors.

"Together, these experts will make safer driving applications a priority for automakers worldwide."

www.osram-os.com

Osram launches five new color versions of Duris P 5 mid-power LEDs

Osram Opto Semiconductors is now offering its mid-power LED Duris P5 in color options, suitable for architecture lighting and the hospitality sector (i.e. hotels and restaurants).

With a compact form factor familiar from the white version, the five new versions are deep blue (450nm), blue (470nm), true green (528nm), yellow (590nm) and red (615–625nm) based on InGaN or InGaAlP chips, depending on wavelength. Low forward voltages and optimized light extraction result in high luminous efficacies: the deep blue version delivers output of 140mW (at 100mA and 25°C), corresponding to typical efficiency of 48%.

As mid-power LEDs, the color versions suit linear, area or omnidirectional lighting applications in

which the light must be distributed as uniformly as possible. Color mixing is also much easier in applications involving several colors.

"The color Duris P 5 versions will give our customers even greater freedom in designing luminaires," says Martin Wittmann, product manager marketing SSL. "A good example is the combination of white and colored mid-power LEDs within a luminaire," he adds. "The use of the Duris power class also reduces system costs while at the same time improving the distribution of light and simplifying thermal management."

As with the white versions, the colored versions can stand very harsh conditions, says the firm. The package technology offers greater corrosion stability compared

with conventional mid-power LEDs, it is claimed. The small component dimensions of 2.6mm x 2.2mm also allow good optical control in connection with secondary optics.

As well as architectural lighting and signage, the color Duris LEDs can be used in lamp and luminaire modules with 'remote phosphor' technology: the converters needed to generate white light are not attached directly to the chip but are illuminated by a deep blue LED from a distance, causing them to luminesce. This results in uniform distribution of light and high luminous efficacy, says Osram Opto.

The new color Duris P 5 versions were premiered at Lightfair International 2013 in Philadelphia, PA, USA (23–25 April).

www.lightfair.com/lightfair/V40

Osram supplements Duris family with higher-temperature LED for linear and area indoor lighting

Osram Opto Semiconductors has added the S 5 to its Duris LED family, suitable for indoor lighting (in retrofits, downlights or panel luminaires).

The Duris S 5's package is made from robust synthetic material that is resistant to aging caused by high temperatures and short-wave blue light. In contrast to LEDs in other package materials, the new Duris has a life-time of over 35,000 hours even at a much higher ambient temperature of 105°C. "This innovative LED package makes the component robust and cost-effective," says Janick Ihringer, product manager marketing SSL. "This is then reflected of course in luminaire manufacturing costs."

The main applications for the new Duris are retrofits and luminaires for both linear and area indoor lighting, as used in places such as offices, hotel lobbies and museums. The square footprint and the small round light-emitting surface translate into a compact arrangement in the lamp, says the firm. The light can hence be efficiently coupled into secondary optics such as lenses and reflectors.

The new Duris has three versions, all with correlated color temperatures (CCTs) of 2700–6500K but with different chip surfaces and hence three different brightness levels.

1. The GW PSLPS1.EC suits where a large amount of light must be emitted from a small surface area, e.g. in downlights and LED retrofits. At 3000K and a minimum color rendering index (CRI) of 80 it achieves brightness (luminous flux) of 97lm and luminous efficacy of 101lm/W at an operating current of 150mA. Its optimized forward voltage of about 6V means that efficient driver solutions can be used that have a beneficial effect on the cost-effectiveness of the overall system, says the firm.

2. The GW PSLMS1.EC is designed for high luminous efficacy (125lm/W at 65mA, with 24lm at 3000K), e.g.

for use in panel luminaires and linear retrofits in which individual light points should not be visible and low energy consumption is important.

3. The GW PSLLS1.EC has slightly lower efficacy (113lm/W at 80mA, with 28lm at 3000K) for optimum system costs.

"The right LED for the particular design of luminaire can be selected, depending on whether high brightness, high efficacy or a good average of the two is required," says Ihringer.

Certification to the LM-80 standard is underway via 10,000hr life tests.

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US photonics societies form National Photonics Initiative

NPI aims to boost R&D, grow economy and improve national security

The American Physical Society (APS), IEEE Photonics Society, Laser Institute of America (LIA), Optical Society of America (OSA) and SPIE have announced the launch of the National Photonics Initiative (NPI), a collaborative alliance seeking to unite industry, academia and government experts to identify and advance areas of photonics critical to maintaining US competitiveness and national security.

"The NPI will work to advance photonics in the areas that are most critical to the US, like improving the economy, creating jobs, saving lives and sparking innovation for future generations," says OSA's CEO Elizabeth Rogan.

Photonics generates, controls and detects light to advance manufacturing, robotics, medical imaging, next-generation displays, defense technologies, biometric security, image processing, communications, astronomy and much more. Photonics forms the backbone of the Internet, guides energy exploration and provides night vision and physiological feedback on the battlefield.

In 1998, the National Research Council released the report 'Harnessing Light', which presented a comprehensive overview of the potential impact of photonics on major industry sectors. Subsequently, several worldwide economies moved to advance their already strong photonics industries. The USA, however, did not develop a cohesive strategy. As a result, it lost its competitive advantage in a number of cutting-edge technologies as well as thousands of US jobs and companies to overseas markets.

"The EU, Germany, Korea, Taiwan and China all recognize the importance of photonics, and have taken action," says SPIE's CEO Eugene Arthurs. "The US Department of Defense, for example, has long supported photonics, but more photonics research is needed to maintain our national security in

the face of non-traditional threats," he adds. "The time is now for the US to make the right investments in the crucial capabilities of the future."

In 2012, the National Research Council released 'Optics and Photonics: Essential Technologies for our Nation', which called for a national photonics initiative to regain US leadership in key photonic-driven fields. In response, the NPI was established to raise awareness about photonics and the impact of photonics on everyday lives; increase collaboration and coordination among US industry, government and academia to advance photonics-driven fields; and drive US funding and investment in areas of photonics critical to maintaining US competitiveness and national security.

"The NPI offers an opportunity for us to show how critical it is for federally funded research to flourish in this country," says APS' executive officer Kate Kirby. "So many of the technologies that we use have come from the results of basic research funded by the federal government."

As part of the NPI effort, more than 100 experts from industry, academia and government collaborated to draft a white paper detailing recommendations to guide funding and investment in five key photonics-driven fields: advanced manufacturing, communications and information technology, defense and national security, health and medicine and energy. New opportunities in these fields such as 3D printing, more efficient solar power, improved nuclear threat identification and the growth of Internet speeds and capacity, offer the potential for even greater societal impact in the next few decades.

"There are thousands of companies that have sprung up in the last decade or so that produce the photonics devices and systems that we all depend on now, but there's plenty

of room for growth," comments Richard Linke, executive director of the IEEE Photonics Society.

In order to capitalize on new opportunities and regain global leadership and economic prosperity, the white paper also provides key recommendations to the US government that apply across all five of the fields:

- drive funding and investment in areas of photonics critical to maintaining US competitiveness and national security — advanced manufacturing, defense, energy, health and medicine, information technology and communications;
- develop federal programs that encourage greater collaboration between US industry and academia to better support the R&D on next-generation photonics technologies;
- increase investment in education and job training programs to reduce the shortage of technically skilled workers needed to fill the growing number of photonics-based positions;
- expand federal investments supporting university and industry collaborative research to develop new manufacturing methods that incorporate photonics such as additive manufacturing and ultra-short-pulse laser material processing; and
- collaborate with US industry to review international trade practices impeding free trade, and the current US criteria restricting the sale of certain photonic technologies overseas.

The NPI maintains that fulfillment of these recommendations will position the USA as a global leader in photonics R&D, and will grow the US economy and add jobs at home.

"Our objective is to direct funding intelligently to research, implementation and education and training, with the ultimate goal of restoring US competitiveness, thereby improving our security, our economy and our quality of life," summarizes LIA's executive director Peter Baker.

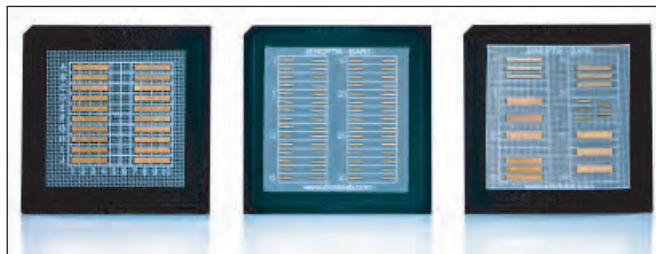
www.LightOurFuture.org

Jenoptik presents new single-emitter and mini-bar lasers

At Laser World of Photonics in Munich, Germany (13–16 May), Jenoptik's Laser & Materials Processing Division presented its new higher-efficiency semiconductor lasers (previously presented at March's LASER World of PHOTONICS CHINA show in Shanghai).

The new semiconductor lasers from Jenoptik are pumping sources for fiber lasers and disk lasers. Due to their high efficiency of over 70% with very little beam divergence, they guarantee high output power and high brilliance along with long life and low cost.

The 9xx nm single emitters have output power of 12W. The wall-plug efficiency at this output level on a passively mounted heat-sink is 64%. The highest obtainable efficiency is 74%. With an aperture of 90µm, the far-field beam divergences of 26° in the fast-axis direction and 6.5° in the slow-axis direction (full width half maximum of the peak at 12W) makes them suitable for coupling into a 105µm fiber.



Jenoptik's new mini-bar and single-emitter lasers.

The 9xx nm mini-bars combine the high brightness and coupling efficiency of single emitters with the low mounting costs of full bars. The mini-bars contain five emitters with an aperture of 90µm each, pitched at a spacing of 1000µm. With maximum output power of 55W and mounted on a passively cooled heat-sink, the maximum wall-plug efficiency is 69%. The beam divergences are the same as those of the single emitters.

The new laser bars are available for wavelengths of 915, 940 and 955nm and (with low filling factor) of 976nm. They are suitable as pumping sources for fiber and

solid-state lasers, but also provide a solution for direct-diode applications and other applications such as plastics welding or annealing.

The higher efficiency is particularly evident from the full bars for

976nm with a filling factor of 20%. Mounted on passive heat sink, these bars achieve 66% efficiency at 80W output power. Beam divergences at this output level are 23° in the fast-axis direction and 6.5° in the slow-axis direction (full width half maximum of the peak). The degree of polarization of these TE-polarized lasers is better than 97%.

The bars for 938nm wavelength and 50% filling factor have been improved for the optical pumping of disk lasers. Mounted on passive heat sink, their efficiency is 64% at 200W output power; at 250W output the efficiency is still over 60%.

www.jenoptik.com/lm

DILAS launches Compact Evolution diode laser system

Diode laser maker DILAS of Mainz, Germany has launched the Compact Evolution next-generation, fiber-coupled, CW diode laser system.

Designed in a 19" rack-mountable chassis with 3HU, the system release has major platform and interfacing enhancements, says the firm. The new standardized diode laser control unit (DLC) can be used in a cross-platform strategy for all of DILAS' industrial diode laser systems. The DLC provides external interfaces such as the common analog/digital interface, BUS interfaces and remote access option for easy analyses and parameter settings.

The Compact Evolution can be combined with DILAS' processing heads, offering camera and pyrometer options and allowing the closed-loop operation of the system in pre-defined welding temperature

ranges for quality-related applications in medical device manufacturing and automotive. The system is available with an optional fiber-input galvo-scanner featuring a field of operation in which the laser spot can be freely addressed.

The Compact Evolution is available up to 600W CW at 976nm wavelength and stable beam quality of 22mm mrad. The improved brightness allows for a variety of applications such as scanner-based plastics welding with larger working areas or reduced spot sizes, says the firm. In addition, the system suits thin metal welding, heat treatment selective soldering, brazing and scientific applications.

Based on DILAS' water-cooled tailored bar technology, the system does not require DI water.

www.DILAS-ILS.com

IN BRIEF

Daylight licenses mid-IR to Corning

Daylight Solutions Inc of San Diego, CA, USA has agreed a licensing deal for Corning Inc to access its patented mid-infrared technology. Daylight holds 19 fundamental patents, with 27 more pending.

"The licensing of our technology by Corning illustrates the significance of Daylight's patent and IP position in the mid-infrared solution space," says president & chief operating officer Paul Larson.

"We've managed more than \$85m to develop technology and deliver system-level solutions."

Daylight is currently in discussion with several other industry leaders over the licensing of its mid-IR technology.

www.daylightsolutions.com

Panasonic develops 10,000lm white light source using single near-UV semiconductor laser and new phosphors

Smaller light-emitting area and better directionality than LEDs yields compact optical configuration and higher brightness

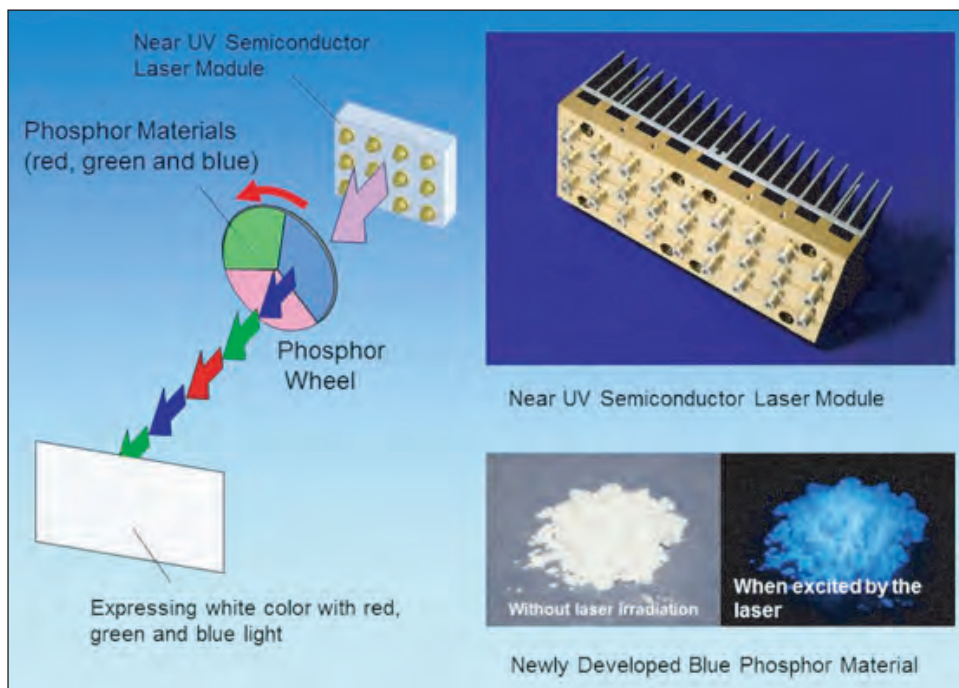
Osaka-based Panasonic Corp has developed a semiconductor white light source capable of outputting luminous flux in the 10,000-lumen class. The new technology will enable wider variation in design, higher brightness and a smaller form factor in applications such as data projectors and vehicle headlights, reckons the firm.

Conventional laser white light sources require multiple visible-light semiconductor lasers that emit blue and other colors, creating a tradeoff between small form factor and high brightness. Although some laser wavelengths are projected directly, without passing through phosphor material, conventional phosphors are not suitable for use as high-intensity light sources, as they are subject to significant luminance saturation (where optical power can decline as incident radiation intensity rises) when laser light is focused on them.

In the newly developed technology, increased light output was achieved due to the high-efficiency, low-loss design and modularization of the near-ultraviolet semiconductor laser that is used in the light source. A high luminous flux of white light was realized through the development of a phosphor material that is not subject to luminance saturation even when irradiated with high-intensity laser light. The use of a laser with a smaller light-emitting area and superior light emission directionality to LEDs has allowed a compact optical configuration with higher brightness and a smaller form factor.

The development is based on the following new technologies:

- a high-output, low-loss laser design with a wider near-UV laser optical waveguide and optimized light loss control;



Conceptual diagram of the new white-light source.

- phosphor material technology that uses the high-density crystalline structure of SMS ($\text{Sr}_3\text{MgSi}_2\text{O}_8$) phosphor to control the density of the luminescent center and thus prevent luminous saturation; and
- wavelength conversion technology that uses a rotating phosphor wheel that absorbs near-UV laser light and converts it to red, green and blue luminescent light.

The newly developed technology therefore has the following features:

- By increasing the output of the near-UV laser in the light source to ten times that of Panasonic's conventional lasers, what is claimed to be the industry's highest light output power of 60W (for a near-UV laser) has been achieved. The miniaturized laser module (containing multiple lasers) can hence be incorporated into a wider range of equipment.
- The use of a newly developed phosphor material has increased blue light emission by 40% (when

irradiated with 60W near-UV light), contributing to the realization of a 10,000lm-class high-luminous flux white light source through red, green and blue phosphors.

- The generation of red, green and blue light from just one type of laser light (using a rotating phosphor wheel) simplifies the optical system and ensures that the laser is projected directly onto the screen.

Panasonic presented the new technology at the 2013 SID International Symposium in Vancouver, Canada (21–24 May), where it received the Distinguished Paper Award from the Society for Information Display.

Panasonic reckons that the new technology opens the way to greater use of semiconductor light sources in the projection/lighting market.

The firm says that it holds 39 patents in Japan and 22 overseas patents (including pending applications) for the new development.

<http://panasonic.net>

OPEL provides update on Hurricane Sandy-hit R&D facility and development

OPEL Technologies Inc of Toronto, Ontario, Canada — which develops III-V semiconductor devices and processes through US affiliate OPEL Defense Integrated Systems (ODIS Inc) of Storrs, CT, USA — reports significant progress in rehabilitating its R&D facilities in Storrs following the extensive damage caused by Hurricane Sandy last October.

The molecular beam epitaxy (MBE) system used in gallium arsenide wafer production was the most damaged and required a virtual rebuild. The system has now been fully refitted and is completing its 'burn-in' cycle. A sample testing procedure will commence, following which it is expected to be declared operable

and ready to be placed online.

Although severely impacted by the MBE failure, this quarter's milestone still appears on track to be met. After on-line wafer production begins, producing wafers for the continuance of the BAE Systems military IR sensor proof-of-concept project, due for completion later this year, will take precedence, says OPEL.

The firm also notes that, while refitting the MBE system, virtually all of the R&D facility's build-out work was finalized, enabling the installation of additional new equipment. The first of the four new research devices arrived and was installed several weeks ago. A second unit has arrived and awaits

a factory installation team. The remaining two units were due to arrive in June, prior to installation, trial and acceptance testing.

OPEL also says that its monetization activity continues at a rapid pace. A confidential due-diligence report detailing the evolution of its Planar Optoelectronic Technology (POET) platform — with the addition of the latest trial data points from R&D — will be completed within the quarter. The business development white paper will be made available under non-disclosure agreement (NDA) to potential prospective partners and IP licensees only.

www.opeltechinc.com

www.odisinc.com

OPEL's AGM agrees name change to POET Technologies Inc

At its Annual General & Special Meeting (AGM), OPEL's shareholders approved a change of the firm's name to POET Technologies Inc. Previously, through its subsidiary OPEL Solar Inc, the firm made high-concentration photovoltaic (HCPV) panels and solar tracker systems, but last December OPEL divested its solar operations.

The core component of OPEL's strategy going forward is for ODIS to continue to develop the firm's proprietary planar-optoelectronic technology (POET) platform.

Developed by chief scientist Dr Geoff Taylor and his team over the

past 18 years in cooperation with the University of Connecticut in Storrs, the POET platform enables monolithic fabrication of GaAs ICs containing both electronic and optical elements on a single wafer. By offering components with increased speed, density, reliability, power efficiency and lower costs, POET offers the ability to push Moore's Law to the next level, claims OPEL, overcoming silicon-based bottlenecks and potentially changing the roadmap for a broad range of applications, such as servers, smartphones, tablet and wearable computers.

Shareholders also approved the 2013 Stock Option Plan and election of the following nominees to the board: Mark Benadiba, Peter Copetti, Adam Chowanec, John F. O'Donnell, Dr Samuel Peralta, Leon M. Pierhal, Dr Geoff Taylor, and Chris Tsiofas.

In a board meeting following the AGM, the board reappointed the following executive officers: Mark Benadiba (executive chairman); Leon M. Pierhal (president & CEO); Kevin Barnes (treasurer & chief financial officer); Lee Shepherd (VP of technology); Michel Lafrance (corporate secretary); and Blaine Grisel (controller).

Committee established to evaluate sale or licensing of POET platform

OPEL has established a Special Strategic Committee (SSC) of its board of directors, with a mandate to: evaluate strategic alternatives in relation to the sale or licensing of the firm's POET platform; deliver recommendations to the board; and carry out any selected transactions to completion (as confirmed by the board).

OPEL has not established a definitive timeline for the SSC review process

but will assess available alternatives over the next few months.

On recommendation of its Corporate Governance and Nominating Committee, the board has named executive director Peter Copetti as chair of the SSC. Copetti was also given the authority to assemble his own team of industry experts, to be used in concert with the OPEL personnel he deems beneficial to achieve the goal of delivering on

the mandate of the SSC.

The POET platform is currently the basis for a number of key commercial and military projects now in the delivery pipeline — including optical code division multiple access (OCDMA) devices for avionics systems, combined RF/optical phased arrays, optoelectronic directional couplers, and ultra-low-power random access memory (RAM).

Oclaro shows laser diodes at LASER World of PHOTONICS

Optical components, modules and subsystems developer Oclaro Inc of San Jose, CA, USA showcased several new laser diode products for fiber laser, direct diode, medical and consumer applications at the LASER World of PHOTONICS event (13–16 May) in Munich, Germany.

Leveraging the newest-generation 9xx chip design, the BMU80 fiber-coupled single-emitter module delivers 80W power in a 105µm fiber. The 106x nm DFB seed laser (capable of 800mW peak power at 150ps

pulses and 150kHz line-width in CW mode) enables short pulse lasers for materials processing applications with improved precision and reduced thermal effects.

Oclaro is also expanding its high-power laser diode portfolio to include 10xx and 14xx nm wavelengths. Highly reliable 10xx bars enable multi-kW direct-diode systems through wavelength multiplexing with the 9xx wavelengths. The new family of 14xx nm bar and single-emitter products can be

used for medical, cosmetics and industrial applications.

New additions to the visible laser diode family include 100mW, 633nm and 150mW, 638nm laser diodes.

● At the co-located 21st International Congress on Photonics in Europe (CLEO/Europe 2013), Mike Wale, Oclaro's director of Active Products Research, gave a presentation on 'Integrated photonic devices in III-V semiconductors for optical communications'.

www.cleoeurope.org

Oclaro unveils 80W high-brightness fiber-laser pump module

Oclaro has introduced its BMU80, a high-power fiber-coupled laser diode pump capable of delivering 80W power in a 105µm fiber.

The high-brightness pump enables fiber-laser manufacturers to generate higher pump power levels using fewer modules, allowing them to increase pump block efficiency, design more compact pump configurations, and simplify their packaging, says the firm.

The single-emitter based platform is available at output powers of 80W with a 0.15NA or 65W with <0.14NA at 1kFITchip rating, making it suitable for pumping of kilowatt and high-power pulsed fiber lasers.

The 80W pump module leverages a new generation of laser diode chip with increased efficiency above the prior generation. A proprietary optical scheme delivers light into the fiber with high coupling efficiency, and a controlled under-filled NA along with a cladding mode stripping feature, allowing users to increase reliability and reduce losses at the combiner. A compact, rugged housing offers superior thermal management. Automated alignment and manufacturing processes enable high volume with highest consistency in module-to-module performance.

The new multimode laser diode

chip has endured a 4000 hour multi-cell life-test under accelerated conditions, totalling 0.5 million accelerated device hours, and has already been integrated into an Oclaro mid-power fiber-laser pump module, allowing seamless upgrade from 25W to 30W.

"This is a significant evolution in the development of our portfolio of high-power pump modules for the fiber-laser market," says chief commercial officer Yves LeMaitre.



1060nm DFB seed laser debuted

Oclaro has introduced a distributed feedback (DFB) 1060nm laser diode module as the latest addition to its seed laser portfolio, designed for the seeding of sub-nanosecond fiber and solid-state lasers.

The 10xx nm DFB laser diode module, featuring a single-mode laser diode with an on-chip distributed feedback grating delivers high peak power for sub-nanosecond and picosecond pulse operation. Capable of peak powers up to 800mW for a pulse width as short as 150ps, and a spectral line-width

below 100pm, the 10xx seed laser enables highly efficient pulse amplification and improved frequency conversions to green and UV wavelengths, says the firm.

It allows customers to extend their current nanosecond lasers to the picosecond regime. Operating with these short pulses improves the quality of material processing and mitigates the common SBS (stimulated Brillouin scattering) problem with pulse fiber lasers that occurs above 10ns. In CW mode, the seed laser module delivers 200mW of optical power with a 3dB line-width of 150kHz and 50dB side mode suppression ratio.

"The market for picosecond material processing is growing fast as these systems enable higher precision in micromachining by reducing the affected heat zone," says Gunnar Stolze, VP of sales & marketing for Global Industrial and Consumer business. "We are partnering with our customers to leverage the exceptional performance of this DFB seed laser to drive innovation in shorter pulse generation for these applications."

The DFB seed module's standard telecom butterfly-type package includes a thermistor and back-facet monitor photodiode. Reliability of the DFB chip has been demonstrated with over 8000 hours of multi-cell life-testing at accelerated operating conditions with zero failures.

Oclaro launches high-power single-mode 633nm red laser diode for biomedical, inspection & measurement markets

Oclaro has introduced its HL63163DG 633nm wavelength red laser diode, which provides 100mW single-transverse-mode optical output power for the biomedical, inspection and measurement market. The HL63163DG is a compact alternative to existing helium-neon (He-Ne) gas lasers that exhibit lower energy efficiency, says the firm.

Leveraging existing technologies used for Oclaro lasers in the 637–642nm range, the focus in developing the HL63163DG was to enable system designers to increase measurement accuracy, stability and speed essential for biomedical and inspection applications, while reducing power consumption and footprint. These laser performance characteristics have traditionally been experienced only while using large He-Ne gas lasers.

The HL63163DG offers power consumption of only 0.4W at 100mW operation in the 633nm wavelength band, and comes in a 5.6mm-diameter TO industry-standard package.

"We expect to see the HL63163DG laser cannibalize the He-Ne gas lasers market since we've been able to shrink the laser size and lower the power consumption without compromising the performance attributes needed for the biomedical and inspection markets," says Takayuki Kanno, president, Oclaro Japan & general manager of the Modules and Devices business unit. "The industry has long been waiting on a semiconductor laser solution, and Oclaro was able to overcome the design challenges to offer a laser diode capable of delivering a high-power 633nm beam," he adds.

Oclaro customers have access to working samples of the HL63163DG immediately, with volume production expected to begin in August.

Oclaro introduces 150mW single-mode 638nm red laser diode in 3.8mm package for laser displays

Oclaro has launched the HL63153AT red laser diode, which delivers a 150mW single-transverse-mode optical output power at a wavelength of 638nm. The HL63153AT offers improved image display over previous versions, enabling high-lumen pico-projector or miniature displays for personal computers, and other mobile devices such as smartphones, gaming, and digital cameras, says the firm.

The HL63153AT offers what is claimed to be the highest single-transverse-mode optical output power at a red wavelength available on the market, with 25% more power than its predecessor. This was accomplished by developing new processes, including an optimized waveguide structure and fine-tuning the laser device structural parameters.

With low power consumption of 0.6W at 150mW optical output power, the HL63153AT operates in the 638nm wavelength range, and comes in a 3.8mm-diameter TO industry-standard package, allowing compact integration.

"This newest red laser diode product has been designed as a direct result of customer requests for a shorter wavelength diode that delivers higher power in a thin package," says Takayuki Kanno, president, Oclaro Japan and general manager of the Modules and Devices business unit. "We are able to deliver this light source with high brightness, high operating temperature range and small-form-factor package, so that system designers can develop compact RGB modules for the mobile display market which is experiencing rapid growth leading into 2014," he adds.

Oclaro customers will have access to working samples of the HL63153AT red laser in July.

Oclaro showcased its portfolio of visible and near-infrared lasers and VCSEL products at LASER World of PHOTONICS in Munich, Germany.

IN BRIEF

Oclaro claims broadest wavelength range of high-power laser diodes for multi-kilowatt direct-diode systems

Oclaro has launched what it claims is the broadest wavelength range of high-power, high-brightness laser diodes enabling multi-kilowatt direct-diode systems. Its high-power laser diodes are available at wavelengths of 800–1070nm and are shipping in volume to laser system makers targeting industrial, semiconductor, automotive and materials processing markets.

In addition to output power and brightness, another critical factor for scaling the power of kilowatt direct-diode systems is the consistency of performance and reliability across the entire available wavelength range that is used, says Oclaro. In the 910–1070nm range, Oclaro offers seven standard wavelength windows with up to 200W on a microchannel cooler and up to 120W on the passive mini-cooler, the Oclaro BLM. This family of mounted bar products enables the scaling of system power up to 15kW. Oclaro recently demonstrated output powers of up to 350W on a microchannel cooler and 250W on a passive mini-cooler, illustrating the technology reach.

"Today's announcement underscores our ability to deliver a comprehensive portfolio of solutions for direct-diode applications and highlights the extensive technology and design capabilities we have assembled in-house," says Gunnar Stolze, VP of sales for the Global Industrial and Consumer business. "By offering the industry's broadest wavelength range while consistently delivering product performance and reliability, our customers have the flexibility to scale system power as needed to better respond to their customer's needs," he adds.

www.oclaro.com

Oclaro's quarterly revenue falls 11%

Assets and product lines to be sold off to secure \$25m in bridge loans

For fiscal third-quarter 2013 (to end-March), optical component, module and subsystem maker Oclaro of San Jose, CA, USA, has reported revenue of \$141.6m, down 11% on \$159.5m the prior quarter and up 60% on \$88.7m a year ago (prior to closing the merger with Opnext on 23 July 2012).

"Our financial results were at the lower end of guidance for the third quarter [expected to be seasonally down to

\$140–155m], in the face of continued softness in the telecommunications market," commented president & CEO Alain Couder.

Revenue for 'Amplifiers, Filtering and Optical Routing' was down \$10.4m quarter-on-quarter (from \$31.2m to \$20.8m), with about \$3m of this drop due to selling the thin-film filter and interleaver product lines last quarter. Revenue for '10G and Lower Transmission Modules' was down \$5.5m quarter-on-quarter (from \$47.8m to \$42.3m). Other product categories were flat to slightly down quarter-on-quarter: '40G and 100G Transmission Modules' down from \$38.2m to \$37.6m, 'Transmission Components' flat at \$22.3m, and 'Industrial & Consumer' down from \$20.1m to \$18.6m. "Sales declined further than expected, which drove a higher loss compared with the prior quarter," noted Couder.

On a non-GAAP basis, gross margin has fallen from 15.9% a year ago and 15.7% last quarter to 10% (at the bottom of the expected 10–14% range), driven by the overall fixed

costs, higher inventory reserves (consistent with the lower demand forecast), and the impact of annual cost reductions being weighted most heavily to the March quarter.

Net loss has risen from \$15.5m a year ago and \$24.2m last quarter to \$33.8m. Adjusted EBITDA was –\$24m (near the top of the expected –\$13.5–25m), compared with –\$13.2m last quarter and –\$9.9m a year ago. During the quarter, cash, cash equivalents, short-term investments and restricted cash fell from \$96m to \$80.5m.

Compared to just \$1.6m in fiscal Q2, capital expenditure (CapEx) was \$2.6m (still significantly less than the previous \$6m per quarter, and \$10m per quarter in fiscal 2011). "We plan to continue to manage CapEx tightly while demand continues to be soft," commented chief financial officer Jerry Turin. "We expect CapEx to remain in the \$2.5–4.5m range accordingly."

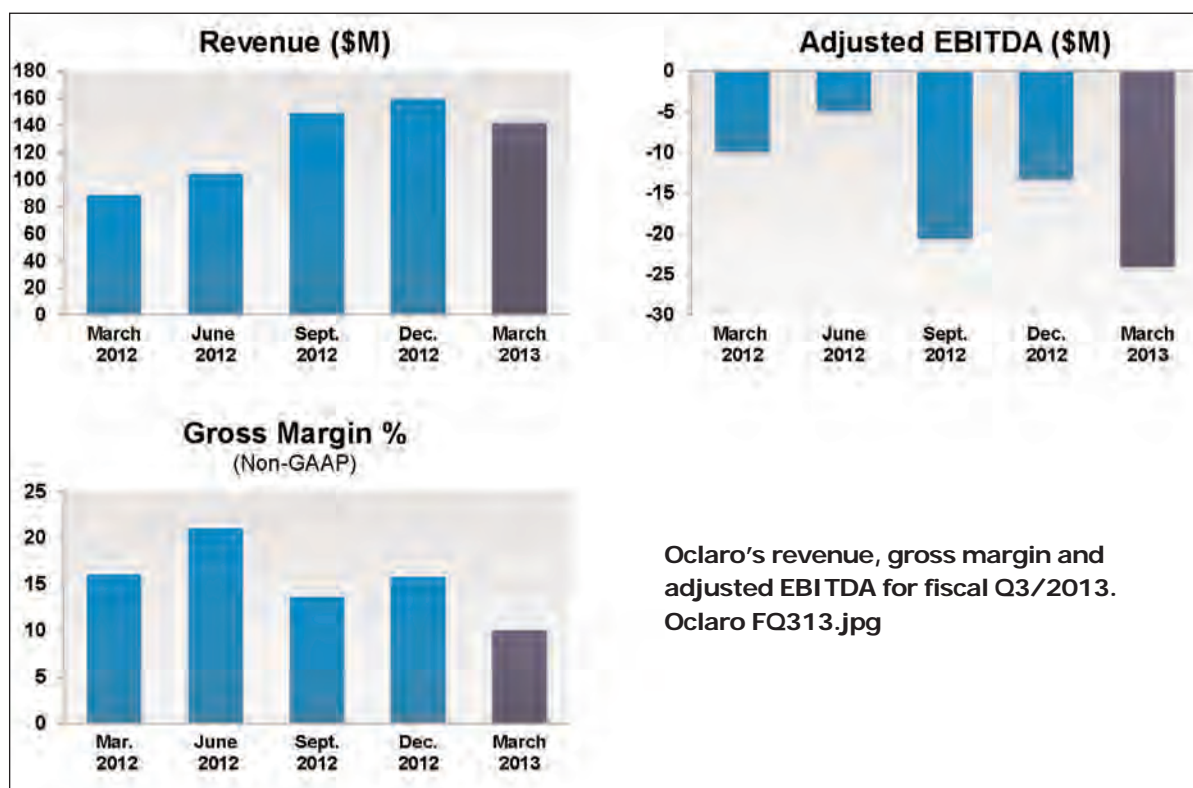
Oclaro has also secured \$25m in short-term bridge loans from Providence Equity Capital Markets, which joins Wells Fargo Bank and Silicon

Valley Bank as a lender under Oclaro's existing credit agreement (which has been revised). The term of the loan is about one year. "This financing is an initial step to simplify the company and develop a profitable operating model," Couder said.

Sell-offs expected

"In connection with the bridge financing from Providence, we amended our credit agreement with our existing lenders, in which we agreed to complete the sale of certain assets, product lines or operating segments of our business expeditiously, and we are actively engaged in a corresponding process," noted Couder. "We believe that a successful completion of such disposition of assets, product lines or operating segments is a necessary step to fund our continued operations and to complete our plans to restructure the company." Once those sell-offs have been completed, Couder is confident that Oclaro can become a profitable business:

"Even while we battle with short-term challenges, I'm very encouraged about the future of Oclaro."



Oclaro's revenue, gross margin and adjusted EBITDA for fiscal Q3/2013. Oclaro FQ313.jpg

► Outlook

During fiscal Q3, Oclaro completed the transfer in Japan from its earthquake-damaged building to a new building where the firm is now back in full production. Oclaro also started to ship the first products transferred from the firm's fab in Shenzhen, China to contract manufacturer Venture in Penang, Malaysia.

For fiscal Q4 (to 29 June), Oclaro expects revenue of \$132–144m, gross margin of 9–13%, and adjusted EBITDA of –\$30–17m.

"The optical component sector has not yet seen a tangible upside, the enterprise data-center is strengthening according to some customers, but not the telecoms side," said Couder regarding Oclaro's own forecast

and the wider markets. "As we exit March and enter the June quarter, we believe the overall demand environment is softer than in the December quarter, and this is particularly true in the telecoms market," added Turin.

www.oclaro.com

*Matthew Peach,
Contributing Editor*

Oclaro's chairman & CEO Couder retires; board members Dougherty made CEO and Peterson made chair

Oclaro's chair & CEO Alain Couder has retired. The board of directors has hence named board member Greg Dougherty as CEO, while board member Marissa Peterson has been elected chair of the board.

"Since joining the company in 2007, Alain has played an important role in transforming the company from a small optical component company called Bookham into an industry leader," says Peterson. Couder first joined predecessor firm Bookham as CEO in August 2007 and was elected chair of the board in July 2011. He led Bookham through its merger with Avanex Corp in April 2009 to create Oclaro, and also led the firm through its merger with Opnext Inc in July 2012. Prior to joining Oclaro, Couder was president & CEO of three private companies, a venture advisor to a venture capital company, the chief operating officer of Agilent Technologies, and held various positions over the years with Packard-Bell NEC, Groupe Bulle, Hewlett-Packard and IBM.

"Greg Dougherty, brings significant operational experience in the optical industry," Peterson says. "We look forward to working closely with Greg as we navigate through the current challenging financial situation."

Dougherty has been a board member since 2009, and has substantial leadership, operations, sales, marketing and general management experience in the optical and laser industries, notes Oclaro, including previous roles as

chief operating officer of JDSU and chief operating officer of SDL.

"Through its rich history of mergers and acquisitions, Oclaro has amassed an extensive technology and product portfolio," comments Dougherty. "My focus will be to harness those powerful assets to their fullest potential, by accelerating efforts to simplify the company and strengthen our execution; and by focusing on developing and implementing a profitable operating model," he adds. "My goal is to solidify our position as a leader in the optical industry and to be the preferred supplier to our customers around the world."

Prior to Oclaro, Dougherty was a director of Avanex from April 2005 to April 2009, when Avanex and Bookham merged. He has been a director of Picarro Inc, a manufacturer of ultra-sensitive gas spectroscopy equipment using laser-based technology, since October 2002., and was also its CEO from 2002 through 2003. Dougherty served on the board of directors of the Ronald McDonald House at Stanford from January 2004 until 2011. From February 2001 until September 2002, he was chief operating officer of optical technology firm JDS Uniphase Corp. Previously, he was chief operating officer of SDL Inc from March 1997 to February 2001 when it was acquired by JDS. From 1989 to 1997, Dougherty was director of product management and marketing of Lucent Technologies Microelectronics' Optoelectronics

strategic business unit. He received a B.Sc. degree in Optics in 1983 from the University of Rochester

Peterson (an Oclaro board member since 2011) has extensive knowledge in operations, strategy and customer relations, as well as experience as a senior executive of a large, complex and well-respected technology company. She was formerly executive VP, worldwide operations, services and customer advocacy of Sun Microsystems Inc, until her retirement in 2006 after 17 years with the firm.

Since August 2008, Peterson has been a director of healthcare provider Humana Inc, and is currently a member of its nominating and corporate governance and organization and compensation committees. Since August 2006, she has been a director of Ansell Ltd, a global public company listed on the Australia Stock Exchange, where she is currently a member of the audit committee and chair of the risk committee. Peterson is also a director of Quantros Inc and a member of its audit committee and chair of its technology committee. She was previously a director of Supervalu Inc and the Lucile Packard Children's Hospital at Stanford, and served on the board of trustees of Kettering University. Peterson is also a National Association of Corporate Directors Board Leadership Fellow. She has an M.B.A. from Harvard University, and an honorary doctorate of management and a B.S. in mechanical engineering from Kettering University.

IN BRIEF

Mi-Light photonics cluster launched

Mi-Light (a non-profit alliance of professionals from companies, academia and organizations to support and promote photonics-related business in Michigan) has been launched with its first annual meeting.

Board members include: chair Michelle Stock of MLStock Consulting; vice-chair & acting treasurer David Shindell of Data Optics Inc; secretary Anca Sala of Baker College; as well as Bodo Ehlers of Rigaku Innovative Technologies Inc; Sheila Jensen of diode laser firm Visotek Inc; Michael Klos, general manager of IPG Photonics Corp's Midwest operations; and Richard Kurtz, CEO of Advanced Photonix Inc of Ann Arbor, MI.

Finance for the initiative was provided by the 21st Century Jobs Fund, a Michigan Strategic Fund program designed to accelerate the growth and diversification of Michigan's economy.

In 2012, Michigan Economic Development Corporation (MEDC) awarded Mi-Light \$89,000 to kick-off activities supporting and promoting the growth of the State's photonics industry cluster. Leaders from Michigan photonics firms began meeting in 2008 to collaborate on developing Michigan's photonics industry.

Mi-Light will use the funds to:

1. promote Michigan's industry and research assets in photonics to a global audience to attract companies, talent and business;
2. increase awareness of Michigan's breadth and depth of photonics capabilities and assets;
3. develop photonics education and training programs to increase the availability of skilled technical personnel at all levels; and
4. stimulate collaboration among its members and with outside organizations.

www.mi-light.org

Firecomms' manufacturing facility in China awarded ISO 9001:2008 and ISO 14001:2004 certification

Firecomms Ltd of Cork, Ireland and Tongxiang, China, a manufacturer of fiber-optic solutions and optical transceivers, says that its manufacturing facility in China has been awarded ISO 9001:2008 and ISO 14001:2004 certification.

ISO 9001:2008 certification shows that Firecomms has implemented a quality management system that enables it to consistently provide product that meets customer and applicable statutory and regulatory requirements, and to enhance customer satisfaction through the effective application of the system, including processes for continual improvement of the system and the assurance of conformity to customer and applicable statutory and regulatory requirements.

"The ISO 9001:2008 certification demonstrates our on-going commitment to both the quality and reliability of our optical transceivers," says CEO Hsin Chia. "Having our own in-house ISO-certified production system enables us to easily adjust our product offering to meet the needs of our

global customers, for maximum flexibility with short lead times."

ISO 14001:2004 certification was awarded for Firecomms' willingness and commitment to improve its environmental impact in day-to-day operations, and to constantly improve environmental performance.

Firecomms' manufacturing facility comprises a 4000m² building with a 1000m² cleanroom facility that can

Firecomms' manufacturing facility comprises a 4000m² building with a 1000m² cleanroom

be expanded to accommodate future growth. Dedicated to the manufacture of the firm's RedLink, LC and OptoLock fiber-optic transceiver products, the manufacturing

facility has a production capacity of 2 million devices per month.

Strategically located in China where the market for POF transceivers is growing significantly, the manufacturing facility is situated in Tongxiang, Zhejiang, close to major sea ports and airports.

Firecomms demos rugged transceivers for power applications at PCIM Europe

At the Power Conversion Intelligent Motion Europe (PCIM Europe 2013) event in Nuremberg, Germany in May, Firecomms showcased its complete line of rugged industrial fiber-optic transmitters and receivers. The line includes RedLink, the firm's newest range of rugged industrial fiber-optic transmitters and receivers for controlling high-power or high-voltage semiconductors, such as IGBTs, thyristors or MOSFETs used in frequency converters, power converters/inverters or traction control applications.

Designed to be drop-in compatible with the Versatile Link range of

components from Avago Technologies, Firecomms' RedLink devices offer improvements including enhanced EMI immunity, lower power consumption, and other performance-enhancing features, says the firm.

At PCIM, Firecomms previewed its new 530nm-based RedLink transmitters, which promise extended transmission distances compared to current solutions due to the lower attenuation characteristics of plastic optical fiber (POF) at 530nm over traditional 650/660nm wavelengths.

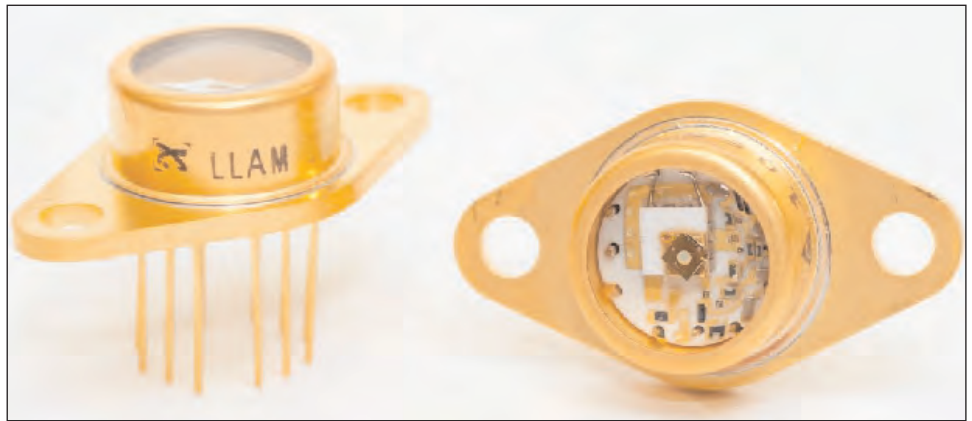
www.firecomms.com

Excelitas expands APD receiver module family for enhanced optical damage threshold and increased 1550nm peak response

Excelitas Technologies of Waltham, MA, USA has introduced two new products — the LLAM-1550E-R2AH and the LLAM-1550E-R08BH — to its LLAM line of silicon and indium gallium arsenide (InGaAs) high-speed, low-light analog avalanche photodiode (APD) receiver modules. Featuring enhanced optical damage thresholds and increased 1550nm peak response, the InGaAs-based LLAM-1550E modules offer greater resilience when exposed to higher optical power densities and increased reliability for a broad range of mission-critical applications.

The LLAM-1550E modules were developed specifically for situations requiring a wide dynamic operating range, high-frequency response, extremely low-light detection scenarios such as laser imaging detection, combat, range finding and free-space communication.

Hermetically sealed within a TO housing, the modules are capable of



Excelitas' LLAM-1550E InGaAs APD preamplifier modules.

detecting extremely low-light signals with a bandwidth up to 200MHz and have a spectral response of 900–1700nm. The LLAM series is offered as a standard, RoHS-compliant, commercial off-the-shelf product and can be customized for bandwidth and gain optimization, use of different APDs, and packages.

"We are proud of our legacy in providing mission-critical solutions to our defense and aerospace

industries," says Michael Ersoni, senior VP & general manager, global detection business. "By extending our line of APD offerings with the new LLAM-1550E modules, we continue to deliver innovative, customizable products that meet the specific needs of our customers."

Excelitas displayed the LLAM-1550E modules at the 2013 SPIE Defense, Security & Sensing show in Baltimore, MD, USA (30 April–2 May).

Excelitas launches surface-mount 905nm pulsed laser for high-volume applications

Excelitas Technologies of Waltham, MA, USA, which provides customized optoelectronics to OEMs, has launched the Surface Mount 905nm Pulsed Semiconductor Laser as the latest addition to its family of pulsed laser diodes. With high optical pulses centered at a wavelength of 905nm, the laser is designed specifically for high-volume applications such as range finders, safety light curtains and laser therapy.

The 905nm pulsed laser diode chip has monolithically grown layers that concentrate the emitting source size and create three emitting active areas. On average, the lasers produce 70W of peak optical output power when operated at

30A on a triple-cavity version, with single-, dual- and quad-cavity variants also available.

The laser chip is mounted on an FR4 substrate, a leadless laminate carrier, which offers thermal management and power stability with temperature. In addition, the chip is protected by an optically clear hard epoxy coating.

"As a cost-effective, high-volume manufacturing-ready solution,

The laser can be precisely mounted by automated equipment, reducing labor and time constraints

this product allows us to offer customers the specific solutions they need to increase productivity and automate complex manufacturing processes," says Michael Ersoni, senior VP & general manager of Excelitas' global detection business.

Intended for surface-mount application or hybrid integration, the laser can be precisely mounted by automated equipment, reducing labor and time constraints. It is also capable of emitting light in a plane that is parallel or perpendicular to the mounting surface for easy integration into various OEM designs.

Excelitas exhibited the new laser at the 21st Laser World of Photonics in Munich, Germany (13–16 May).

www.excelitas.com

Infinera raises \$144m for potential strategic projects

Infinera Corp of Sunnyvale, CA, USA, a vertically integrated manufacturer of digital optical network systems incorporating its indium phosphide-based photonic integrated circuits (PICs), has issued \$150m aggregate principal amount of 1.75% convertible senior notes due 2018.

This comprises \$135m of notes offered on 22 May in a private placement to qualified institutional buyers, plus an additional \$15m after those initial purchasers on 30 May exercised in full the 30-day overallotment option granted to them.

Interest on the notes is payable

semi-annually (at a rate of 1.75% per year) in arrears on 1 June and 1 December of each year, beginning on 1 December 2013. The notes will mature on 1 June 2018, unless repurchased or converted earlier. Infinera may not redeem the notes prior to maturity.

The initial conversion rate is 79.4834 shares of common stock per \$1000 principal amount of notes, equivalent to an initial conversion price of \$12.58 per share of common stock (subject to adjustment upon the occurrence of certain specified events but not for any accrued and unpaid interest).

This initial conversion price represents a premium of 37.5% relative to the last reported sale price of Infinera's common stock on 23 May of \$9.15 per share.

The net proceeds from the sale of the notes (including the exercise in full by the initial purchasers of their option) were about \$144.3m, after deducting the initial purchasers' discounts and commissions and the estimated offering expenses payable by the firm. Infinera intends to use the net proceeds for general corporate purposes, including working capital and potential strategic projects.

Infinera retains top spot in global long-haul 100G market

Market research firm Dell'Oro Group has ranked Infinera number one for Q1/2013 in the global long-haul 100G wavelength division multiplexing (WDM) market, as measured by the number of long-haul 100G ports sold. Infinera hence retains the number one market share position in long-haul 100G since the DTN-X entered the market in Q3/2012.

Dell'Oro reports the market leaders by the number of long-haul 100G ports recognized for revenue in the quarter. Infinera accounts for 34% of the long-haul 100G WDM ports sold in Q1/2013, and for 29% of all long-haul 100G ports sold since the long-haul 100G market emerged in 2010. Dell'Oro forecasts that 100G revenue will rise at a compound annual growth rate (CAGR) of 47% between 2012

and 2017, reaching \$5.6bn and contributing 60% of WDM capacity shipments by 2017.

Infinera reports strong traction for the DTN-X around the world, with purchase commitments from 27 customers through Q1/2013 in North America, Europe and Asia Pacific, including BICS, CenturyLink, Cable&Wireless Worldwide, KDDI, Telefonica International Wholesale Services, TeliaSonera International Carrier and DANTE for the

100G revenue will rise at a CAGR of 47% between 2012 and 2017, reaching \$5.6bn and contributing 60% of WDM capacity shipments

GÉANT pan-European Research Network.

Infinera says its DTN-X platform is designed for global network operators facing increasing bandwidth demands driven by video, high-speed data and cloud-based services. It provides a simple, scalable, and efficient solution that integrates optical transport network (OTN) switching capacity with multi-Terabit transport capacity. The DTN-X enables network operators to efficiently deploy the world's only commercially available 500G long-haul super-channels. Long-haul super-channels enable operators to scale transport capacity without scaling operational complexity, lowering total cost of ownership for multi-Terabit transport networks.

Infinera's PICs exceed 1 billion hours of failure-free operation

Infinera has surpassed 1 billion hours of failure-free operation in live networks worldwide. This figure is a cumulative total for all of the PICs that Infinera has shipped to customers since late 2004 in its DTN and DTN-X platforms. Infinera's PICs are deployed by 109 customers in 67 countries to light over 1 million kilometers of fibre and

provide over three petabits per second of transmission capacity.

"It demonstrates that photonic integration offers the same kind of benefits in reliability as silicon integration for electronics has demonstrated over the past 50 years," says Rick Talbot of Current Analysis. "This reliability is critical as operators leverage PICs for cost-effective

super-channel solutions to scale Intelligent Transport Networks."

Infinera announced last month that the Dell'Oro Group ranked the firm number one for first-quarter 2013 in the global long-haul 100G wavelength division multiplexing (WDM) market (after entering the market in Q2/2012).

www.infinera.com

NeoPhotonics' revenue falls 9.6% to \$56.1m in Q1, but 100G grows 41% 40/100G products rise to record 39% of total revenue; to drive rebound in Q2

For first-quarter 2013, NeoPhotonics Corp of San Jose, CA, a vertically integrated designer and manufacturer of both indium phosphide (InP) and silica-on-silicon photonic integrated circuit (PIC)-based modules and subsystems, has reported revenue of \$56.1m, down 9.6% on \$62m last quarter but up 3.4% on \$54.2m a year ago (and above the expected \$50–\$55m).

On a non-GAAP, gross margin was 23.1%, down from 24.5% last quarter and 23.9% a year ago. Loss from continuing operations was \$4.4m (\$0.14 per diluted share), up from just \$0.1m (\$0.00 per share) last quarter but an improvement on \$5.4m (\$0.22 per share) a year ago.

Adjusted EBITDA was a loss of \$1.7m, down from income of \$3.5m last quarter but an improvement on a loss of \$2.4m a year ago.

On 29 March, NeoPhotonics completed the acquisition of LAPIS Optical Components Unit (OCU), a designer and manufacturer of high-speed lasers, laser drivers, photodiodes and amplifiers for high-speed networks, which included the business, a portfolio of over 150 patents and patents applications, and high-speed semiconductor, laser and detector fabrication facility.

During the quarter, total cash, cash equivalents and short-term investments fell from \$101.2m to \$99.8m.

Also, bank debt almost doubled, from \$22.2m to \$40m, as the firm amended and restated its loan agreement to finance the acquisition of LAPIS OCU. NeoPhotonics also agreed to pay the seller \$11.1m in Japanese Yen for the purchase of the real estate used by the acquired business in three equal installments on the first, second and third anniversaries of the closing date.

"We are pleased with the success we are experiencing in our portfolio of 100G products for telecom and datacom applications, which grew approximately 41% quarter-on-quarter and are poised for further growth as the 100G upgrade cycle continues," says chairman, president & CEO Tim Jenks. "Our recent acquisition of the optical components unit of LAPIS Semiconductor, now called NeoPhotonics Semiconductor, is expected to further strengthen our technology leadership and market opportunity in the 100G upgrade cycle as carriers seek to satisfy growing customer demand for high-speed connectivity to drive mobile video and other bandwidth-intensive enterprise applications."

For second-quarter 2013, NeoPhotonics expects revenue to rebound to \$70–\$75m, non-GAAP gross margin to be 21–25%, and loss per diluted share to be \$0.08–\$0.18.

Moscow sales and R&D office opened

NeoPhotonics has opened a sales and R&D office in Moscow to service the Russian Federation and the broader eastern European market, building on the growing demand in the region for advanced telecoms and enterprise data solutions.

"Together with our expanded sales force serving the region, this is the next step in our local business

development activities, including a greater research presence and the potential for production of advanced PIC-based solutions," says chairman & CEO Tim Jenks.

In May last year, NeoPhotonics completed a private placement investment with the Russian sovereign fund investor RUSNANO.

www.neophotonics.com

IN BRIEF

Infinera's Q1 revenue up 19% year-on-year

For first-quarter 2013, Infinera Corp of Sunnyvale, CA, USA, a vertically integrated manufacturer of digital optical network systems incorporating its own indium phosphide-based photonic integrated circuits (PICs), has reported revenue of \$124.6m, down 2.7% on \$128.1m last quarter but up 19% on \$104.7m a year ago.

On a non-GAAP basis, gross margin was 36%, level with last quarter but down from 40% a year ago. Net loss was \$7.3m (\$0.06 per share), up from \$6m (\$0.05 per share) last quarter but cut from \$11.2m (\$0.10 per share) a year ago. During the quarter, cash and cash equivalents fell from \$104.7m to \$99m.

"Our first quarter performance demonstrated solid execution in a traditionally slow quarter for the industry," says president & CEO Tom Fallon. "The DTN-X platform continued to gain traction in the market. During the quarter, we received purchase commitments from six additional customers, including two new to Infinera, for a total of 27 DTN-X customer commitments to date. Customer deployments were strong and we shipped a record number of 100G ports," he adds.

"The economic value proposition offered by Infinera's photonic integration and long-haul 500G super-channels has generated significant interest among potential customers," says Fallon. "As a result, our new business pipeline is extremely active and we are pursuing global opportunities in a wide variety of markets," he notes. "We exited the first quarter with an increased backlog and a robust pipeline of potential new business, positioning us well for 2013."

www.infinera.com

u2t unveils fastest balanced photo-detector with 70GHz 3dB bandwidth

u²t Photonics AG of Berlin, Germany, which makes high-speed InP-based photodetectors and receivers as well as GaAs-based optical modulators, has unveiled what it claims is the fastest balanced photodetector offering a 3dB bandwidth of 70GHz. The device supports systems for next-generation networks using 400Gb/s or 1Tb/s coherent-detection-based optical transmission.

The BPDV3120R complements u²t's product portfolio of ultra-high-speed photodetectors and receivers. The optical front-end consisting of a monolithic balanced photodetector chip with on-chip biasing has been tested in a system environment and will be used in test and measurement (T&M) equipment, such as optical modulation analyzers, for the test of next-generation coherent network components and modules.

The coaxial single-ended output can detect up to 64GBaud polarization diversity x-QAM signals featuring highly reliable results for common mode rejection ratio, linearity and optical input power. The device can hence be used in next-generation long-haul transmission systems at data rates of 400Gb/s and beyond. The BPDV3120R is also suited to T&M applications as well as ongoing R&D activities at high baud rates.

"While 100G coherent systems are being widely deployed today, we can already see that 400Gbit/s or even 1Tbit/s systems will be required in a few years to support the continued exponential growth of data traffic in mobile and fixed networks," says CEO Andreas Umbach. "Our 70GHz balanced photodetector provides one of the key building blocks that will enable systems providers to build and deploy systems operating at 400G per wavelength or higher."

u²t Photonics began sampling the BPDV3120R in March and was due to start production in June.

www.u2t.de/en

Mellanox to acquire Kotura

High-performance interconnects plus silicon photonics target 100 Gigabit InfiniBand/Ethernet and beyond

Mellanox Technologies Ltd of Sunnyvale, CA, USA and Yokneam, Israel, a supplier of end-to-end InfiniBand and Ethernet interconnect solutions for servers and storage systems, has agreed to acquire privately held Kotura Inc of Monterey Park, CA, USA, which designs silicon photonics application-specific integrated circuits (ASICs) for the communications, computing, sensing and detection markets, for about \$82m. The transaction has been approved by both the Mellanox and Kotura boards of directors.

The transaction is projected to close in second-half 2013. Mellanox expects the transaction to be accretive to its full-year fiscal 2014 earnings by \$0.01–0.03 per share (on a non-GAAP basis). Mellanox expects the acquisition to expand its ability to deliver high-speed networks with next-generation optical connectivity, allowing data-center customers to meet the growing demands of high-performance Web 2.0, cloud, data-center, database, financial services and storage applications. Mellanox believes that the acquisition will enhance its ability to provide leading technologies for high-speed, scalable and efficient end-to-end interconnect solutions.

Silicon photonics is expected to play a significant role in the enablement of high-speed networks. With more than 120 granted or pending patents in CMOS photonics and packaging design, Kotura has integrated multiple high-speed active and passive optical functions onto a silicon chip. Mellanox reckons that the technology will enable its interconnect products to reach bandwidths of 100Gb/s and beyond, and have longer-reach optical connectivity at a lower cost, allowing users to further reduce their capital and operating expenses and offer new revenue-generating services.

Mellanox expects the proposed acquisition of Kotura to enhance its competitiveness and its position as a provider of high-performance, end-to-end interconnect solutions for servers and storage systems.

Mellanox expects to establish its first R&D center in the USA at Kotura's current location. It also intends to retain Kotura's existing product lines to ensure continuity for customers and partners.

"Operating networks at 100 Gigabit per second rates and higher requires careful integration between all parts of the network," says Mellanox's president, CEO & chairman Eyal Waldman. "We believe that silicon photonics is an important component in the development of 100 Gigabit InfiniBand and Ethernet solutions, and that owning and controlling the technology will allow us to develop the best, most reliable solution for our customers. We expect that the proposed acquisition of Kotura's technology and the additional development team will better position us to produce 100Gb/s and faster interconnect solutions with higher-density optical connectivity at a lower cost," he adds.

"This acquisition is important for both companies to enable interconnect innovation for data centers that require solutions that move data faster and more efficiently," says Kotura's president & CEO Jean-Louis Malinge. "Together, we can execute faster and deliver better solutions based on Kotura's silicon photonics platform that delivers the demands of 100Gb/s interconnects and beyond," he believes.

The proposed acquisition is subject to customary closing conditions, including the receipt of applicable regulatory approvals and the approval of Kotura's shareholders.

www.mellanox.com

www.kotura.com

HELIOS program develops supply chain for integrating photonics with CMOS

European Union's new framework program Horizon 2020 to industrialize silicon photonics

Grenoble-based CEA-Leti (the French government's Laboratory for Electronics & Information Technology) reckons that Europe is strongly positioned to design and manufacture volume silicon photonics devices because of the success of the recently completed program HELIOS (pHotonics ELEctronics functional Integration on CMOS).

Coordinated by Leti, the €8.5m European Commission project developed a complete design and fabrication supply chain for integrating a photonic layer with a CMOS circuit, using microelectronics fabrication processes.

HELIOS also demonstrated a complete design flow, integrating both silicon photonics device design and electronic/photonic system design in an EDA-compatible framework.

"It is strategically important for Europe to maintain photonic chip-design and chip-integrating functions to compete with other countries and to encourage innovation by European microelectronics companies," says Leti's CEO Laurent Malier. "HELIOS' success in creating the essential building blocks for integrating photonics with CMOS circuits and making the process available to a variety of users underscores the key role that broad European technological cooperation plays in a very competitive global business environment," he adds.

Thomas Skordas, head of the EC's photonics unit, says HELIOS has shown the great potential that silicon photonics has in many different applications, such as data communications.

"The technology roadmap of silicon photonics becomes clearer now," he adds. "Europe will have to move fast to become competitive in this new field," Skordas says.

"Strategies for the industrialization of silicon photonics are currently being discussed in the context of Horizon 2020, the EU's new framework program for research and innovation for 2014–2020."

Because of the cost advantages of integrating photonic and electronic functions on the same chip, silicon photonics is seen as being key to developing optical telecommunications or for optical interconnects in microelectronic circuits. CMOS photonics may lead to low-cost solutions for a range of applications such as optical communications, optical interconnections between semiconductor chips and circuit boards, optical signal processing, optical sensing, and biological applications.

Launched by the European Commission in 2008, HELIOS focused on developing essential building blocks like efficient optical sources (silicon-based and heterogeneous integration of III-V on silicon), integrated lasers, high-speed modulators and photo-detectors. The project, which had 20 members, also combined and packaged these building blocks to demonstrate complex functions that address a variety of industrial needs.

These include a 10Gb/s modulator integrated with an electronic BiCMOS driver, a 16x10Gb/s transceiver for WDM-PON applications, a photonic QAM-10Gb/s wireless transmission system and a

mixed analog-and-digital transceiver module for multi-function antennas.

The building blocks also led to results exceeding the original specifications:

- high-performance passive devices were obtained and introduced in the demonstrators (rib/strip waveguides transitions with less than 0.2dB losses, grating couplers with 1.6dB losses, inverted taper couplers with 1dB losses, AWG and micro-ring based de-multiplexers);
- the wafer-level integration of laser by III-V/Si bonding led to the demonstration of single-mode operation with 3dBm output power, 30dB SMSR, $I_{th} < 35mA$ in continuous-wave (CW) mode;
- 40G carrier depletion silicon modulators were demonstrated in Mach-Zehnder interferometer (MZI), ring, slow wave, interdigitated modulators configuration.
- an integrated tunable laser-Mach-Zehnder modulator working at 10Gb/s.

The work of the HELIOS consortium led to more than 170 publications and communications in peer-review journals and international conferences.

Project partners included CNRS, Alcatel Thales III-V lab, Thales, University of Paris-Sud, 3S Photonics and Photline Technologies in France; IMEC in Belgium; Phoenix BV in The Netherlands; IHP and the University of Berlin in Germany; ams AG and the University of Vienna in Austria; IMM and the University of Trento in Italy; the University of Valencia, the University of Barcelona and DAS Photonics in Spain; and the University of Southampton and the University of Surrey in the UK.

www.helios-project.eu
www.leti.fr

It is strategically important for Europe to maintain photonic chip-design and chip-integrating functions to compete with other countries and to encourage innovation

GigOptix's optical component revenue grows 25% in Q1

Gross margin rises to record 65%, driving return to non-GAAP profit

For first-quarter 2013, GigOptix Inc of San Jose, CA, USA (a fabless supplier of analog semiconductor and optical communications components) has reported revenue of \$6.9m, down 25% on \$9.2m a year ago and 12.6% on \$7.9m last quarter (although that included \$0.9m of previously unrecognized government contract revenue; excluding this, product revenue was roughly level quarter-on-quarter).

On a non-GAAP basis, gross margin has risen from 56% a year ago and 60% last quarter to a record 65%. Excluding \$1.1m in stock-based compensation, \$1m of restructuring related expenses, \$0.4m in special litigation-related expenses, and \$0.3m in amortization of intangible assets, net income was \$0.2m. This compares with net loss of \$0.4m a year ago and \$0.1m last quarter (or \$1m, excluding the \$0.9m in one-time deferred government contract revenue). Adjusted EBITDA was \$0.7m, up on \$0.5m a year ago and level with \$0.7m last quarter (or a loss of \$0.2m, excluding \$0.9m government contract revenue).

During Q1, cash and cash equivalents fell from \$10.1m to \$9.5m. "We made our last payment for the 2012 acquisition of the E-band licenses from IBM in the March quarter, and we do not expect to use significant cash for operations or working capital in Q2," says senior VP & chief financial officer Curt Sacks. "Therefore, we anticipate we will maintain cash and cash equivalents at similar levels to the first quarter."

"We are pleased to have returned the company to non-GAAP profitability and significantly increased the adjusted EBITDA profitability in the first quarter, which is generally a seasonally weak quarter for our business and industry, with this year being weaker than in previous years," says chairman & CEO Dr Avi Katz.

"Dominating factors supporting our enhanced profitability were the substantial improvement to our gross margin, which reached a record 65%,

and the significant revenue growth of our optical components business, which increased 25% over the prior quarter, following on the 60% growth from this product line in fiscal 2012 over fiscal 2011," Katz notes.

"These gains have been driven mainly by our increased shipments of production devices for the fastest-growing deployments of the telecom and datacom optical industries, with remarkable production shipments of the related devices," Katz says.

"This includes the 4 and 12 parallel channels of 10–14Gbps drivers and amplifiers for datacom QSFP active optical cables (AOCs) where, based on industry data, our volume production device shipments command approximately 30%, or a dominant percentage, of the total QSFP short-reach and long-reach active optical cable devices," he adds. "On the telecom side, based on industry data, we believe that with our volume production device shipments we have an approximately 50% market share in the fast growing 100Gbps coherent line-card driver market."

"In addition, we have been expanding on our leading datacom technology by launching activities to deploy our devices into the consumer electronics industry, mainly for enhanced connectivity, and advanced 3D recognition and gesture tracking engines, which we expect will start to generate new revenue opportunities for us later this year and into 2014," Katz says.

"We completed the end-of-life process of the low-margin products that we inherited with our acquisitions of ChipX and Endwave," notes Katz. "By removing all those parts from our active portfolio we have stabilized revenue from these product lines and believe the March quarter revenue will be the low point, with revenue growth from these non-optical-related products starting in the June quarter at a similar gross margin to the current quarter."

"To solidify our lead position as transceiver devices supplier into

the next generation of systems, we have expanded the number of joint development programs (JDP) that we have with major tier-1 OEMs, with customers funding contracts that totaled approximately \$1m in the first quarter," says Katz. "These JDP contracts are important to us as they support rapid development of customized reference design platforms for next-generation telecom integration of small-form-factor optical system modules such as CFP2 and CFP4. Those platforms are based on our Telcordia-proofed thin-film-polymer-on-silicon (TFPS) modulator chips bundled with our drivers and TIAs, and using our advanced packaging architecture, which we expect should materialize to production revenue with those customers in fiscal year 2014," he adds.

"Through all of these activities alongside our financial streamlining and enhancements, we have built significant leverage into our business model that should translate into continuous accelerating profitability, and better shareholder value, as we are ready and looking forward to the eventual improvement in the telecoms carrier spending environment," Katz concludes.

"We have yet to see a tangible improvement in the markets we serve, particularly in the 100Gbps telecom market where lead times remain historically short. This continues to make forecasting our financial performance difficult," says Sacks. "While we expect our datacom-related revenue to increase, given this lack of clarity in the telecom environment, and the continuous average sales price erosion, we currently believe Q2 revenue will be about flat with the \$6.9m we recorded in Q1," he adds. "Longer-term, we continue to track the telecom carriers announcements of releasing the 100Gbps infrastructure spending, as we are clearly prepared and ready with production-worthy devices to support these systems."

www.gigoptix.com

GigOptix leverages parallel component products to expand into high-speed consumer electronics optical links market

GigOptix says it is leveraging its position as a key merchant component supplier in datacom markets serving the Cloud to introduce devices that enable a wide range of high-speed optical links for consumer systems and applications.

GigOptix's parallel optical devices are now shipping in production volumes for use in embedded active optical cables (AOCs), plug-gables and optical backplanes targeting high-speed optical data links for consumer electronics connectivity and applications, such as:

- tablets, ultrabooks, and smartphones using the highest video and display resolution;
- 4K/8K high-resolution video capture and multi-link transfer for video recording and consumer TVs in the living room and in studios;
- high-definition video broadcast links for end-points with reaches of greater than 100m; and
- high-speed applications used in 2D and 3D security and safety systems, gesture recognition and motion tracking.

Recently, GigOptix's parallel chipsets were used by a global electronics OEM to enable full production of 4K high-definition video capture and transfer in several of its consumer products. The firm's 4-channel parallel devices were used in 40Gbps active cable transfer rates to support increased video

frame rates and HD 3D imaging. GigOptix claims that its chipsets simplify consumer system designs by being fully programmable and providing advanced signal conditioning for superior optical performance with low power consumption.

GigOptix highlights interest in its vertical-cavity surface-emitting laser (VCSEL) parallel arrays of drivers and TIAs (transimpedance amplifiers) from an expanding number of companies designing consumer electronics applications. "GigOptix optical driver and receiver technology is moving towards high-volume applications with the integration of our chipsets in applications such as 4K video systems. System designers are migrating to our parallel chipsets for consumer applications as they face increased data-rate and signal integrity challenges with copper interconnects and copper ribbon cables," says Dr Raluca Dinu, general manager & VP of the Optics Product Line at GigOptix. "The growing gesture recognition and motion tracking markets in consumer electronics which gauge distance and detect object motion and boundaries, may also be addressed with GigOptix TIA technology, and is a natural progression to our current datacom TIAs," he adds, highlighting the firm's opportunities to employ its extensive chipset portfolio and expertise to capitalize on near-term

growth in markets such as short-reach, embedded very-short-reach (VSR), and 3D home entertainment.

For short-reach connectivity applications, GigOptix's broad optical interconnect portfolio of 1–12 channel VCSEL driver and TIA arrays fulfill high-speed link requirements with performance of 1–28Gbps per channel. GigOptix says that its chipsets have been designed specifically to address low-power-consumption AOC, pluggable and backplane optical connectivity applications that avoid electrical crosstalk seen in conventional systems, enabling what is claimed to be excellent transport sensitivity at high speeds.

Based on the March 2012 'Active Optical Cable Forecast' report from Light Counting, which provides initial data for only a small set of consumer electronic applications such as HDTVs, video equipment, notebook computers, tablets and smartphones, GigOptix estimates that the total available market (TAM) associated with embedded parallel devices for those optical links alone will grow at least 20-fold, from about \$2.5m in 2013 to about \$50m by 2016. Many new consumer electronics optical link applications are emerging, and these will provide additional component TAM opportunities in the next few years, the firm concludes.

GigOptix appoints director of sales, China, to expand sales reach

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 appointed Lake Qin as director of sales, China. Based in Shenzhen, Qin will be responsible for increasing sales revenue in China for all

GigOptix product lines.

"Lake brings nearly 15 years of communications experience to GigOptix," says Dr Raluca Dinu, general manager & VP of the Optics and RF Product Line at GigOptix. "Lake is responsible for driving revenue growth in China and will strengthen customer relationships in the region," he adds.

"Lake is supported by our regional applications team and distributors."

Prior to joining GigOptix, Qin held a sales account manager role at Semtech Corp in Shenzhen. He joined Semtech through the Gennum Corp acquisition, where he addressed sales in China. He also previously held a sales manager role at Lestina International.

IN BRIEF

ProPhotonix to distribute Osram's green & blue lasers

ProPhotonix Ltd of Salem, NH, USA, a designer and manufacturer of LED illumination systems and laser diode modules, has been appointed distributor for Osram Opto Semiconductors' range of green and blue laser diodes.

The product range includes single-mode green laser diodes PL520 with 50mW optical output at 515–530nm and PL 515 with 30mW output at 510–530nm. The PL450B is a single-mode blue laser diode with 80mW output at 440–460nm.

All three lasers are packaged in 3.8mm-diameter TO cans and feature low beam divergence, long lifetime and stability across a broad temperature range. Where the human eye perceives green light more readily than red light, the new green diodes will augment application solutions in alignment and targeting for medical, industrial & defense markets, and are suited to pico-projector and display applications. The blue diode lasers are suited to medical and analytical applications.

Higher-power, multi-mode laser diodes like the PL TB450, with 1.4W output in the blue 440–460nm range, share the beam quality and lifetime advantages of their single-mode equivalents.

"We expect to open up significant new markets which, until now, have been difficult to develop using established technologies," says ProPhotonix's chairman & CEO Mark W. Blodgett.

"ProPhotonix has an established reputation in the medical, industrial, security & defense markets and has recently expanded its technical sales team," says Stephan Kreusel, director Distribution Management Europe and Emerging Markets at Osram Opto. www.prophotonix.com

IQE and Chalmers report first 40Gb/s VCSELs operating at up to 85°C for data-centers

Date rate claimed to be record for VCSEL-based optical link without equalization

Epiwafer foundry and substrate maker IQE plc says that vertical-cavity surface-emitting laser (VCSEL) devices using wafers produced at its Cardiff, UK facility have broken the 40Gb/s barrier at high temperatures, which is reckoned to be a key milestone in the adoption of photonic technologies for a wide range of data communications applications.

Optical communications provide the only reliable means of transferring the large volumes of data at the ultra-high speeds needed in data-centers, says IQE. The computing environments in which the data is transferred generally operate at elevated temperatures, making reliable operation at high temperature an essential element for the deployment of optical components.

A joint paper 'High-Speed Oxide Confined 850-nm VCSELs Operating Error-Free at 40Gb/s up to 85°C' by Chalmers University of Technology and IQE published on 15 April in IEEE Photonics Technology Letters (vol. 25, no. 8, p768, 2013) reports the development of VCSEL devices operating at data rates of up to 47Gb/s at 25°C and 40Gb/s at 85°C.

VCSELs provide the primary light source for short-reach optical communication and currently provide the enabling technology for high-capacity optical interconnect cables in storage area networks such as data-centers and server farms. VCSEL-enabled multimode fibre-optic interconnects optimized for transmission speed at a wavelength of 850nm are also used in high-performance computing systems such as computer clusters and supercomputers.

Current high-speed optical interconnects use VCSEL technology to operate at serial data rates of 10–14Gb/s, with devices expected to perform at 25–28Gb/s under development. Next-generation optical interconnect standards are expected to require data rates in excess of 40Gb/s. Such devices will be required to operate at the high ambient temperatures expected inside datacoms equipment.

The results were achieved at a modulation bandwidth of 27GHz at 25°C and 21GHz at 85°C, which is the highest for any VCSEL, and the data rate is the highest of any VCSEL-based optical link without equalization, it is reckoned. This is also the first 40Gb/s VCSEL operating at elevated temperatures, which is of key importance for practical applications, says IQE.

The firm says that the results also generated commercial interest when they were presented at the Optical Fiber Communication conference (OFC) in late March.

40Gb/s devices will be required to operate at the high ambient temperatures expected inside datacoms equipment

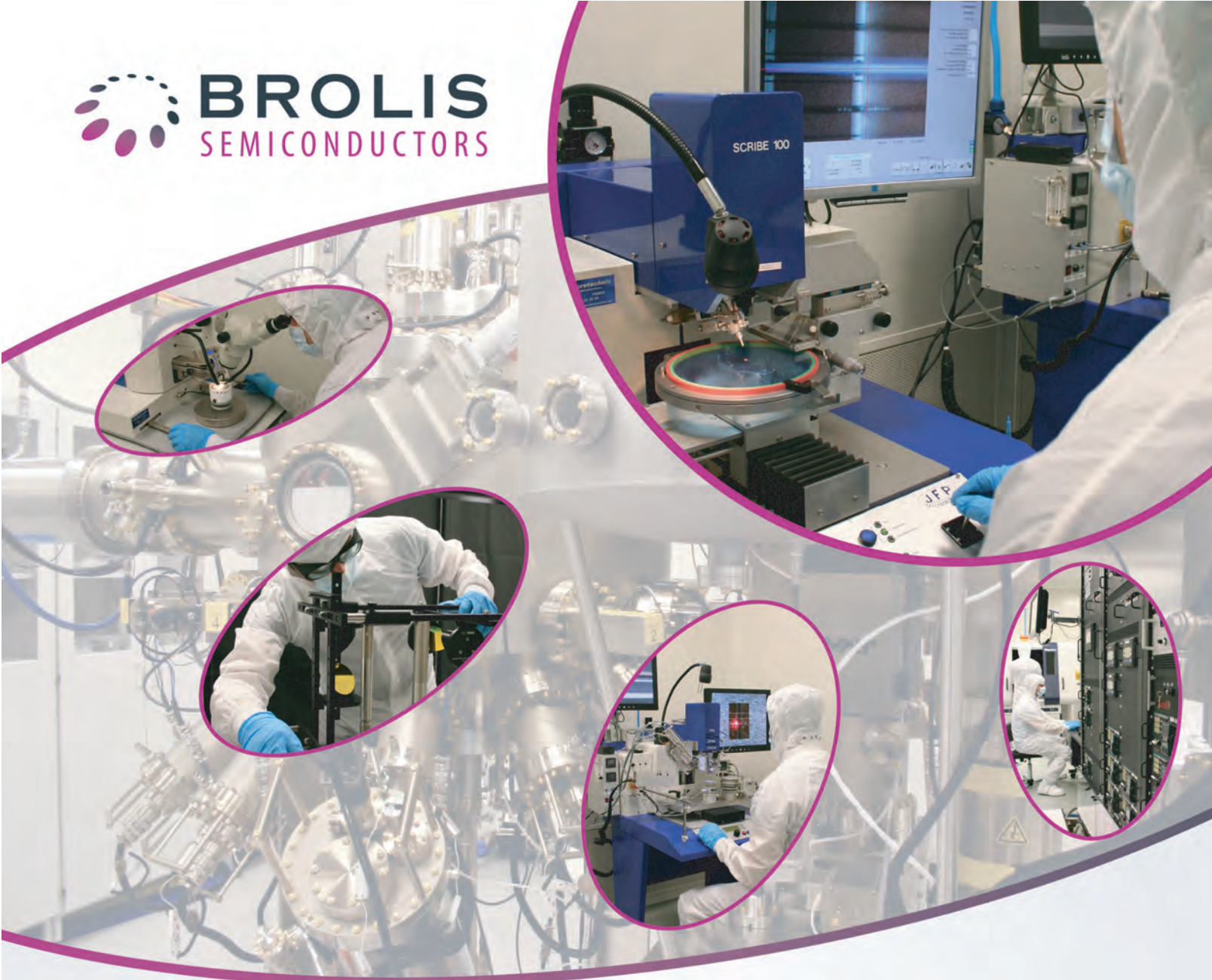
"Photonics applications are emerging as a key enabling technology and the deployment of devices such as VCSELs is expected to rapidly increase over the coming years as global data

usage grows exponentially," says IQE's CEO Dr Drew Nelson.

www.iqep.com

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**BEYOND STATE-OF-THE-ART TECHNOLOGY
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JDSU's quarterly revenue hit by delayed carrier spending ...but CCOP division margin rises; June quarter revenue to grow 7–11%

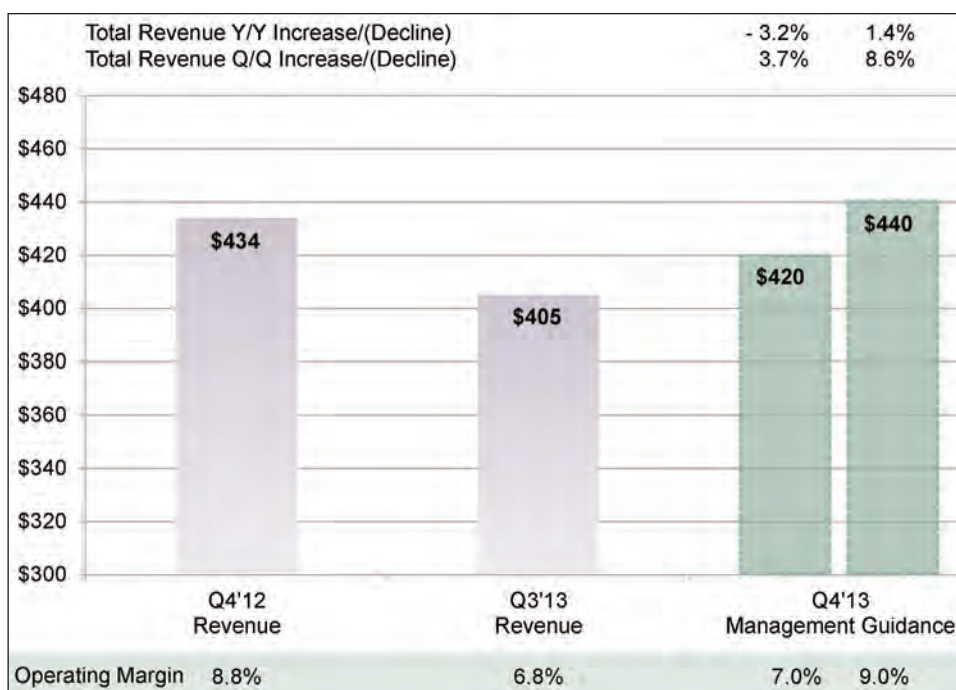
Including \$0.4m from the March acquisition of Arieso, JDSU of Milpitas, CA, USA has reported net revenue of \$405.3m for its fiscal third-quarter 2013 (to end-March), down 5.6% on \$429.4m last quarter but up 0.5% on \$403.3m a year ago (excluding results from the discontinued holographic security business, sold last October). This was at the low-end of the \$405–\$425m guidance due to seasonality and budget delays.

Of total revenue, 47.9% (\$194.1m) came from the Americas, 23.5% (\$95.1m) came from EMEA (Europe, Middle-East and Africa), and 28.6% (\$116.1m) came from Asia-Pacific. This compares with 49.9%, 23.8% and 26.3% respectively last quarter, "reflecting a slight positive shift towards the Asia-Pacific region for the quarter," noted executive VP & chief financial officer Rex Jackson.

By sector, 44.2% of revenue came from Communications & Commercial Optical Products (CCOP), 43% from Communications Test & Measurement (CommTest) and 12.8% from Optical Security & Performance (OSP).

"The March 2013 quarter experienced delayed carrier capital expenditure budget releases [well into March, later than the February norm], which resulted in lower revenue than expected in our Communications Test & Measurement and Optical Communications businesses," commented president & CEO Tom Waechter.

CCOP revenue of \$179.2m, up 3.5% on \$173.1m a year ago but down 3.6% on last quarter's \$185.8m, and just below the low end of the guidance range (of flat plus or minus 3%). Within CCOP, Optical Communications revenue was \$152.9m, down 1.7% on \$155.6m last quarter but up 6.8% on \$143.2m a year ago; Lasers revenue was \$26.3m, down 12.6% on \$30.2m last quarter due to fiber-laser revenue almost halving from \$7m to \$3.8m after a customer



JDSU's fiscal Q4/2013 guidance for revenue and operating margin.

inventory correction.

"But despite the revenue challenges, we delivered solid results in most areas of the business," Waechter adds. Both the CCOP and OSP divisions increased gross margin sequentially and exceeded their operating margin guidance ranges. On a non-GAAP basis, CCOP gross margin improved sequentially from 30.9% to 31.8% (including Optical Communications improving from 28.3% to 29%, despite lower revenue, due mainly to product mix and cost improvements; Lasers gross margin rose from 44.4% to 48%). Despite this, overall gross margin was just 45.9% (or 46%, excluding Arieso), down on 48% last quarter (due primarily to lower CommTest segment mix and gross margin) but up on 45.6% a year ago.

Operating expenses were \$158.4m, up \$1.2m on \$157.2m last quarter due mostly to the beginning of calendar-year payroll expenses. Operating margin was hence 6.8%, down on 11.4% last quarter and 7.2% a year ago (although fiscal Q3/2013 would also have been 7.2%, excluding Arieso). This

included CCOP operating margin of 10.7%, down on 11.4% last quarter but exceeding the guidance range due to initiatives in supply chain optimization, multi-sourcing and design cost reductions.

Net income was \$24.1m, down from \$42.3m last quarter and \$24.6m a year ago (although fiscal Q3/2013 would have been up, at \$25.2m, without Arieso).

To focus on higher-growth, higher-margin sectors, during the quarter JDSU approved a strategic plan to exit a number of legacy low-speed wireline product lines in CommTest, incurring charges of \$2.2m for accelerated amortization of related intangibles plus \$11.3m for the write-off of inventory (both excluded from non-GAAP operating results). These discontinued low-margin products contributed about \$1m of revenue in fiscal Q3.

"Our innovation engine and product portfolio align well with customers' strategic priorities, enabled by healthy cash generation and our strong balance sheet," says Waechter. JDSU generated \$28.2m of cash from operations, more than

► halving from \$59.4m last quarter but up on \$13.2m a year ago. Capital expenditure (CapEx) totaled \$13.4m. During the quarter, total cash and investments fell from \$740.2m to \$638.8m.

For fiscal Q4/2013 (to 29 June), JDSU expects revenue to rise to \$420–440m, including 7–11% sequential growth in both CCOP and CommTest (including \$1–2m from Arieso). Operating expenses should rise \$6–11m sequentially, reflecting a full quarter of Arieso of \$4–5m, continuing investments in R&D, and higher variable compensation. Operating margin should be 9.5–11.5% for CommTest, 10–12% for CCOP, and 31–33% for OSP, and 7–9% overall (including more

than a point of incremental operating loss from Arieso).

"Our outlook is based upon several factors," Waechter commented.

"First, we see major spending by some large carrier customers as they work to align their incremental CapEx and their top strategic priorities. Second, we see a healthy level of carrier network design, bidding and award activity but again the timing of actual deployment is unclear." An example is 100G network deployment announced for one of the larger carriers in China.

"The timing of actual deployment is not yet known," noted Waechter.

"Finally, we are seeing a faster shift from legacy wireline to high-speed broadband and wireless technolo-

gies than we previously expected," he added.

"We indicated previously that we expected to see positive impact of increased network investments in our June quarter," said Waechter. "We believe public commentary by key customers and others continue to support that view, but continuing delays by certain significant customers lead us to be cautious," he added. "Looking forward in CommTest, we expect higher revenue and recovery in gross and operating margin. In CCOP, we also expect better revenue, including higher Lasers revenue and new gesture recognition revenue."

www.jdsu.com

Matthew Peach, Contributing Editor

Commercial lasers for manufacturing and life science markets

At Laser World of Photonics 2013 in Munich, Germany (13–16 May), JDSU bolstered its commercial laser diode portfolio by introducing two lasers — the ST Series and the FCD561 — for the manufacturing and life sciences markets.

The ST Series fiber-laser pump has what is claimed to be the brightest fiber-coupled diode laser performance available. Output power is 140W within a 106.5µm core, targeted at speeding adoption of fiber lasers by machine-tool makers and speed metal cutting and shaping manufacturing.

A continuous need for finished metal goods and the displacement of competing cutting technologies have resulted in rapid growth of the fiber-laser market, creating a demand for diode laser pump sources producing the necessary high power and brightness. The highly integrated ST Series cuts the number of components needed to produce a kilowatt-class fiber laser, resulting in simpler, lower-cost and more robust design alternatives, claims JDSU.

"The adoption of fiber lasers has been increasing due to their smaller packages versus other lasers on the market while maintaining compara-

ble power output," comments Allen Noguee, senior analyst, Lasers & LED Lighting, at Strategies Unlimited.

"They have proven to be reliable, especially in rugged environments, since they require minimal maintenance and recalibration," he adds.

"The fiber-laser market will grow an average of 14% each year over the next 5 years and will exceed \$800m in revenue in 2013. This growth also impacts the diode laser pump market, which we had forecast at \$143m in 2012."

The ST Series builds on JDSU's previous-generation pump lasers' reputation for reliability, and has been tested for endurance and power stability to withstand prolonged use, enabling manufacturers to spend more time producing metal products, says JDSU.

"The ST Series enables a simple fiber-laser architecture that brings the power of fiber lasers to a wider range of customers," says Tomoko Ohtsuki, Industrial Diode product line manager. "Combined with optical and mechanical design innovations to achieve ultra-low optical loss and thermal management, JDSU establishes a new foundation for high-brightness laser pumps," he claims.

The FCD561 Series adds to JDSU's frequency-converted diode (FCD) family of continuous-wave lasers for the life sciences. Used in the health services industry to identify health disorders in both clinical and research environments, flow cytometer instruments use laser light sources of specific wavelengths to identify characteristics of cells, proteins and other particles.

The FCD561 allows targeted fluorescent pumping of specific fluorophores at their ideal absorption band, minimizing the required incident laser power and reducing pumping of adjacent fluorophores in a sample. This increases the overall flow cytometer sensitivity, resulting in statistically improved results and the ability to observe population data that may not have been resolvable previously. Using an efficient 561nm solution, the FCD561 brings the reliability and efficiency needed to allow bioinstrumentation to pump yellow-green fluorophores currently not covered by more common direct-diode laser systems or alternative laser technologies, says JDSU.

The new solution also features 30mW free-space and fiber-delivered packages.

Emcore reports below-guidance quarterly revenue of \$42.3m, but breaks even

June-quarter revenue to fall to \$35–39m, but CATV business to recover in second-half 2013

For fiscal second-quarter 2013 (to end-March), Emcore Corp of Albuquerque, NM, USA, which manufactures compound semiconductor-based components and subsystems for the fiber-optic and solar power markets, has reported revenue of \$42.3m, up 11.9% on \$37.8m a year ago but down 14.3% on \$49.3m last quarter (and below the guidance of \$45–49m).

"The decrease was primarily due to lower fiber-optics revenue as our broadband fiber shipments fell," explained chief financial officer Mark B. Weinswig. Fiber Optics revenue was \$23.1m (55% of total revenue), up 5.4% on \$21.9m a year ago but down 22.1% on \$29.7m last quarter. "The revenue decline is related primarily to the softness of our cable TV broadband business, which showed a sequential drop of \$6.5m or about 30% in revenues," added CEO Hong Hou.

The revenue contribution from new products — tunable XFPs (TXFPs) and micro-ITLAs — was about \$1m.

Photovoltaics revenue was \$19.1m (45% of total revenue), up 20.9% on \$15.8m a year ago but down 2.5% on \$19.6m last quarter.

Photovoltaics' gross margin has grown from 20.9% a year ago and 30.5% last quarter to 32.5%, due to "the early CapEx investments to improve the production yields and also due to the more efficient loading of the manufacturing OpEx," said Hou. "We were able to reach gross margins of greater than 30% this quarter, which is our target," added Weinswig. In contrast, Fiber optics' gross margin was 7.0%, down from 9.4% a year ago and 16.7% last quarter. However, excluding a warranty charge of \$1.4m on previously divested product lines, gross margin from continued operations in Fiber Optics would have been 13.5%. Overall

gross margin was 18.5%, up from 14.2% a year ago but down on 22.2% last quarter (although it would have been 22% without the warranty charge).

"Margins have been impacted primarily due to lower revenue levels and our \$1m negative impact from the TXFP product line through the ramp-up stage," said Weinswig. "We expect our gross margins in the Fiber Optics segment to improve in future quarters as we complete the ramp-up of our new product line at our contract manufacturer and as our fiber-optic revenues increase," he concluded.

Operating income was \$12.2m, a \$21.1m improvement over the \$8.9m loss a year ago and a \$9.3m improvement on last quarter's income of \$2.8m, due primarily to higher insurance proceeds related to the flooding in Thailand at primary contract manufacturer Fabrinet Co Ltd in October 2011.

"We recovered \$14.8m from flood-damage insurance claims during the quarter [up from \$4.2m last quarter] and do not expect any further amounts in future quarters," noted Weinswig. In particular, operating income for the Photovoltaics segment improved to more than \$4m, which is "among the best results that this business has been able to achieve over the last several years," said Hou.

"Despite the lower revenues and partly due to the receiving the final payment from the insurance claim related to the Thailand flooding in the fall of 2011, we showed a significant net profit [of \$11.7m on a GAAP basis]," said Hou.

Even on a non-GAAP basis (excluding the insurance proceeds), Emcore reported net income of \$36,000, an improvement on a loss of \$5.2m a year ago although down slightly on net income of \$107,000 last quarter. "We were able to achieve a slightly positive operating income, which continues to be the positive outcome of the restructuring that the company has been focused on over the last year," said Hou.

Cash, cash equivalents and restricted cash balance has more than halved from \$12.8m to \$6.2m. However, this does not include \$8.2m in cash received on 2 April from insurance recoveries. "As a result of our final insurance recoveries, we have significantly improved our net working capital balance to be at the highest level in the last eight quarters," noted Weinswig.

At the end of March, order backlog for the Photovoltaics segment was \$36.5m (included \$9.2m of terrestrial solar cell orders from Emcore's Suncore joint venture). This is up 3% on \$35.3m at the end of December (which included \$3.4m from Suncore).

Regarding the Fiber Optics business segment: "Booking activities for the cable TV business has been very slow, starting in December 2012," said Hou. "We saw in the beginning it was an easy seasonality because the March quarter is usually weaker. However, the softness continued throughout the March quarter due to the overall decline in capital spending from the CATV service providers," he added.

We have implemented certain cost-reduction activities in our Fiber Optics business to reduce overhead expenses. We have moved some non-essential functions to our operators in China

► “In early May, two major cable service operators reported their CapEx during the March quarter and their budgets for the whole of 2013. Compared to the December 2012 quarter, their March 2013 quarter CapEx spending decreased over 20% in the infrastructure upgrades category, which related to our products,” Hou said.

“On a positive note, they reported a generally higher total annual CapEx spending for 2013 versus 2012,” he added. “For instance, one MSO [multi-system operator] reported a 16% increase in their annual CapEx budget for operating spending, and in their March quarter spending ratcheted only about 18% of their annual 2013 total

budget. This suggests a much higher spending rate toward the second half of the year. So we are hopeful that the CapEx will be more back-end loaded for their 2013.”

For fiscal Q3/2013 (to end-June), Emcore expects revenue to fall to \$35–39m (including revenue from the joint venture Suncore). Revenue from optical components should remain roughly flat. However, for the space photovoltaics business, Emcore expects a \$4–5m decline. “This is mainly due to some delays we are experiencing with the start of a few new programs,” Hou noted. “In addition, we are seeing a mix shift towards more international-based business, which is lower margin traditionally,” he added.

“We have implemented certain cost-reduction activities in our Fiber Optics business to reduce overhead expenses,” Hou said. “We have restructured several departments and have moved some non-essential functions to our operators in China. Although we are seeing revenue pressure, we have worked hard to establish a profit-focused culture, and we’re seeing the benefit of that hard work now. Our forecasted revenue for [full year] 2013 is expected to be near record levels, and our profit margins are currently projected to show marked improvement over the last year’s results,” Hou concluded.

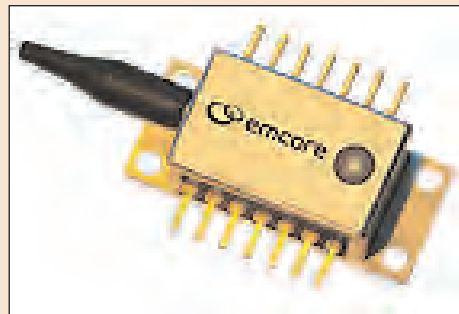
www.emcore.com

Matthew Peach, Contributing Editor

Emcore launches 1550nm C-band DWDM and 1310nm DFB laser modules for wireless and distributed antenna systems

Emcore Corp of Albuquerque, NM, USA, which makes components, subsystems and systems for the fiber-optic and solar power markets, has launched two new distributed feedback (DFB) laser modules designed for analog wireless and distributed antenna system (DAS) applications. The new 1764 1550nm C-band DWDM and 1615 1310nm DFB laser modules were previewed by Emcore and EO Photonics at the ANGA-COM 2013 broadband trade fair in Cologne, Germany (4–6 June).

The increasing demands on wireless networks from social media, texting, email, and the uploading and downloading of applications, music, videos and photos, is creating greater need for the deployment of cost-effective, integrated wireless DAS systems, says Emcore. Both the new 1764 and 1615 Series laser modules are designed, tested and optimized specifically to support highly linearized wireless applications. The lasers are matched to 50Ω systems typical of wireless networks and have a wide operating temperature range of –40°C to +85°C for reliable performance in harsh



Emcore's new 1764 1550nm C-band DWDM laser module.

node environments and narrow transmitter designs. Both models have a bandwidth up to 2.7GHz.

The 1764 1550nm C-band DWDM laser module has low adiabatic chirp to maximize signal quality over both short and long fiber lengths. The laser's linearity minimizes degradation of the broadcast signals caused by distortions and non-linear effects. The 1764 is available in all C-band ITU grid wavelengths. The 1615 1310nm DFB laser module also delivers superior linearity and supports fiber lengths up to 10km without dispersion issues, says Emcore.

“We are seeing a growing market opportunity for adaptation of our highly linear DFB laser technology

for specialized wireless and DAS applications,” says Jaime Reloj, VP of business development. “Wireless systems providers are building systems in subway tunnels, massive stadiums, high-speed trains and cruise ships,” he adds. “Our new DFB lasers for wireless applications integrate extremely well into these systems, enhancing bandwidth to help enable the delivery of consistent, reliable WiFi signals in areas where interference is high, or signals are normally weak.”

Emcore says that all its lasers use the highly linear, directly modulated DFB technology that has become synonymous with the highest-quality, high-speed photonics that drove the wide-scale deployment of fiber optics in CATV networks, satellite earth stations and mobile phone antenna sites. The firm adds that the new 1764 and 1615 DFB lasers extend that heritage of performance and reliability to today's demanding DAS applications and are compatible with the 4G LTE (long-term evolution) standard for wireless high-speed data communications over mobile devices.

IN BRIEF

Emcore awarded PV contract by ATK for Green Propellant Infusion Mission

Emcore has been awarded a contract by aerospace, defense and commercial products firm ATK to design and manufacture solar panels for NASA's Green Propellant Infusion Mission (GPIM), planned for launch in 2015. Solar panels using Emcore's ZTJ triple-junction solar cells will power a satellite that will carry the GPIM payload. ATK will integrate Emcore's solar panels into its heritage-designed solar arrays for final flight configuration for the GPIM satellite, and provide the solar arrays to Ball Aerospace.

The GPIM project will demonstrate the practical capabilities of AF-M315E, a high-performance green alternative to hydrazine that has traditionally been used to fuel many spacecraft. The low-toxicity propellant is expected to improve overall vehicle performance. It has a higher density than hydrazine, so more can be stored in containers of the same volume, and it delivers a greater thrust per given quantity of fuel.

"Emcore has partnered with ATK on many successful missions, and we greatly value our long-standing business relationship," says Brad Clevenger Ph.D., general manager of Emcore's Photovoltaics Division.

With a beginning-of-life (BOL) conversion efficiency nearing 30% and the option for a patented, onboard monolithic bypass diode, Emcore's multi-junction solar cells provide amongst the highest available power to interplanetary spacecraft and earth orbiting satellites, says the firm.

www.emcore.com
www.atk.com

Fraunhofer ISE researchers receive SEMIKRON Innovation Award

At the PCIM Europe 2013 power electronics show in Nuremberg, Germany (14–16 May), the researchers Dr Olivier Stalter, Florian Reiners, Michael Eberlin and Sebastian Franz from Fraunhofer Institute for Solar Energy Systems ISE in Freiburg, Germany — together with Frank Seybold from KACO new energy GmbH of Neckarsulm, Germany — jointly received the annual SEMIKRON Innovation Award for their concept 'Innovative power Electronics for the next-generation village energy supply'.

The SEMIKRON Innovation Award is bestowed for innovation in projects, prototypes, services and novel concepts in power electronics in Europe. The foundation honors innovations that generate a high potential social benefit and improve energy efficiency, preservation of resources, sustainability and environmental protection. Laureates are elected in cooperation with the ECPE European Centre for Power Electronics e.V., research network. The main award is endowed with €10,000.

Of a total of 19 applicants this year, the jury selected the Fraunhofer ISE power electronics technology for facilitating a complete off-grid village power supply in developing and threshold countries. With this technology the entire electricity for remote towns can be centrally generated and supplied with renewable energy.

"About 1.6 billion people in the world do not have access to electricity," says project leader Dr Olivier Stalter. "Since most of these countries are located in the Earth's sun belt, solar electricity is an obvious solution that has become more attractive in the past years due to the decrease in the price of photovoltaic (PV) modules," he adds. "Up to now, such solar PV systems were limited to low powers of about 100W. Our system applies the newest technological developments of the industrial nations to meet the needs of



The SEMIKRON Innovation Award.

remote village communities and larger consumers such as hospitals or smaller firms."

The system components developed at Fraunhofer ISE consist mainly of a

standalone 125kW inverter and a 51kW charger for battery voltages up to 1000V. The basic idea was to design the system for high voltages and high internal switching frequencies using the latest semiconductor devices such as super-junction MOSFETs and silicon carbide (SiC) diodes. This allows low currents and low losses, reducing device dimensions, cooling demand, material use and costs. Meanwhile, losses can be reduced by 60% compared with conventional units, it is reckoned. The inverter and charger operate with efficiencies of up to 98% and 99%, respectively.

Especially for developing countries, it is important to keep the technology simple, says Fraunhofer ISE. Whereas before, units with extensive cables and switching had to be connected in parallel to achieve high capacities, now only one unit is needed. High-tech devices and continuous digital control allow maximum flexibility. PV systems from 350V up to 1200V and battery systems with a nominal voltage from 650V up to 1000V can hence be used. In most cases, diesel generators are installed already on site and therefore an energy management system controls the different generators, the battery charging and the electricity supply.

www.semikron-stiftung.com
www.ise.fraunhofer.de

UK's Salford University to design quantum dots for third-generation solar cells

Tokyo University to help fabricate CdSe, InAs and GaAs QD materials

The University of Salford is to conduct theoretical work on third-generation solar cells, which aim to use to semiconductor nanostructures to significantly increase the electricity produced by sunlight — from about 10% efficiency to 31% or more.

Professor Stanko Tomic and his team at the University of Salford's School of Computing, Science & Engineering will design the quantum dots, which have the ability to greatly reduce the energy losses present in conventional silicon solar cells.

The conversion of extra energy, which would otherwise be lost in the form of panel heat, into electricity is key to increasing solar cell efficiency and reducing cost, the researchers say. Conventional solar cells convert

10–20% of light into electricity — the new cells should increase this to as much as 31% or even higher.

Tomic and his team will use methods of computational physics (combining quantum mechanics and numerical algorithms), together with supercomputers, to describe the structure of the materials, in order to design new solar cell devices.

The quantum dots will be fabricated at the University of Manchester and the University of Tokyo using materials including cadmium selenide (CdSe), indium arsenide (InAs), and gallium arsenide (GaAs).

The research is funded by the UK's Engineering and Physical Sciences Research Council (EPSRC) and the Royal Society, London (among others).

Currently, though prices are falling, solar generation is more expensive than traditional fossil-fuel generation. The researchers say that, once this technology reaches efficiencies that can be mass-produced, the gap will diminish and possibly disappear, and more energy can be generated from fewer cells covering less space. This would suit densely populated urban areas, which currently receive electricity through inefficient long-distances power grids.

"Governments around the world are keen to pursue this technology, but in the UK we have one of the few teams able to create working cells," reckons Tomic.

www.salford.ac.uk

Soitec CPV pilot plant for Chilean mining operation

Soitec of Bernin, France says that Santiago-based Minera El Tesoro (MET), part of one of the largest mining groups in Chile, has built the first pilot plant in South America using its Soitec Solar technology. Four CX-S420 concentrating photovoltaic systems have been installed at a site in Chile's Sierra Gorda district to provide renewable energy for a remote copper-mining operation. As well as robust glass–glass technology (suited hot and arid environments), Soitec says its systems offer low degradation and do not need any water for cooling, suited installation in the Atacama (the world's driest desert).

The systems installed for MET use Soitec Solar's Concentrix CPV technology and two-axis tracking systems to generate a total installed capacity of 64kWp. In addition to providing electricity for the site's data center, the installation serves as a research and demonstration platform for MET using solar technologies that are designed to opti-

mize energy costs in hot, arid locations with high direct normal irradiation (DNI). On 22 May, MET and Soitec signed a memorandum of understanding to leverage the experience gained from this pilot plant to facilitate their respective plans to develop additional projects with CPV technology in Chile.

"This demonstration site is an important step in our commercial efforts in a region where we have high ambition," says Fabio Mondini, VP, geographical expansion with Soitec's Solar Division (Soitec has installed its CPV technology in 18 countries to date). "Chile's energy demand is growing and should lead to a doubling of the installed capacity in the next few years, particularly in the northern part of the country, which has the highest DNI and strong mining-sector electricity demand," he adds.

"Considering our location within the Atacama desert, one of the highest irradiation regions on earth, we are very pleased to be working with

one of the CPV leaders on this pilot installation and to have the opportunity to use Soitec's CPV technology in real-world conditions," says Martin Brown, environmental superintendent at Minera El Tesoro. "As the demo units feed energy to our mine's internal grid, we are testing Soitec's technology in the harshest conditions, and at the same time, assessing the possibility of incorporating renewable and clean energy on a larger scale in the future."

In 2012, Chile's renewable energy agency Centro de Energías Renovables (CER) published its National Energy Strategy ENE 2012–2030, announcing approval of over 3.1GW in solar-energy projects to address issues such as power shortages, price increases for fossil fuels, Chile's economic growth and increasing demand for electricity. Chile has the world's highest solar irradiation and is expected to be the site of some of the world's first large-scale solar projects.

www.soitec.com

Fraunhofer ISE and Soitec achieve 43.6% efficiency with four-junction CPV cell

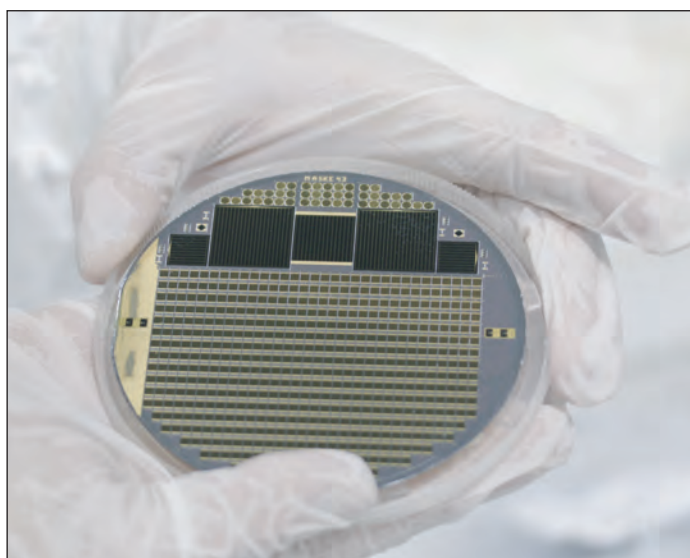
Soitec and CEA-Leti adapt wafer bonding technology for solar cells

In an industry project with concentrating photovoltaic (CPV) solar system maker Soitec of Bernin, France, Fraunhofer Institute for Solar Energy Systems (ISE) in Freiburg, Germany is developing a new generation of multi-junction solar cells (for use in CPV power plants) with potential efficiency as high as 50% under concentrated sunlight.

For this, the researchers are replacing the conventional triple-junction III-V solar cell by a new four-junction device. Two dual-junction sub-cell structures are first grown on different III-V compound semiconductor substrates, allowing optimal bandgap combinations tailored to capture a broader range of the solar spectrum (maximizing energy-generating efficiency). Then, using wafer bonding (where the two different semiconductor crystals are compressed together to form covalent bonds at the interface), the sub-cells are fused together so efficiently that the interface promotes current flow through the four-junction solar cell device.

At Fraunhofer ISE, more than 30 individual semiconductor layers had to be engineered and optimized for the new four-junction solar cell. Part of the cell structure was developed at the Helmholtz-Zentrum für Materialien und Energie in Berlin in the research group of professor Thomas Hannappel (now with Technical University Ilmenau) and transferred to Fraunhofer ISE, where it was integrated into the epitaxy process.

The result of the French–German collaboration is a four-junction solar cell device with efficiency of 43.6% at a concentration level of 319 suns, as confirmed by the Fraunhofer ISE Calibration Laboratory. The efficiency remains above 43% in a concentration range of 250–500 suns. It is the first time



Solar cell wafer with four-junction concentrator cells and test structures. ©Fraunhofer ISE.

that such a high efficiency has been obtained for a solar cell with four pn-junctions in series. The further development of this new four-junction solar cell offers the opportunity to improve conversion efficiencies even further to 50% in the future.

“For the first time, we can combine the best III-V compound materials in one solar cell device. This leads us into a new generation of multi-junction solar cells showing outstanding efficiency potential,” says Dr Frank Dimroth, department head of III-V Epitaxy and Solar Cells at Fraunhofer ISE. “Now we are able to combine lattice-mismatched crystals which, with conventional technology, cannot be grown on top of each other without deteriorating material quality,” he adds.

Wafer bonding is a key expertise of Soitec and development partner CEA-Leti in Grenoble, France, having been used for decades in manufacturing engineered substrates for the microelectronics industry. Soitec and CEA-Leti together have hence adapted Soitec’s proprietary SmartStacking semiconductor-bonding and SmartCut layer-transfer process

technologies to meet the specific requirements of solar cells, namely mechanical stability, optical transparency and electrical conductivity of the bond interface. The process not only enables the stacking of non-lattice-matched materials but also raises the prospect of re-using expensive materials.

The application for the high-efficiency

multi-junction solar cells is primarily in Soitec’s CPV modules. In 2009, the firm acquired Fraunhofer ISE spin-off Concentrix Solar GmbH. Since then, Fraunhofer ISE has continued to support Soitec in developing high-efficiency solar cells and point-focus CPV modules. The technology is used worldwide in solar power plants in regions with high solar irradiance.

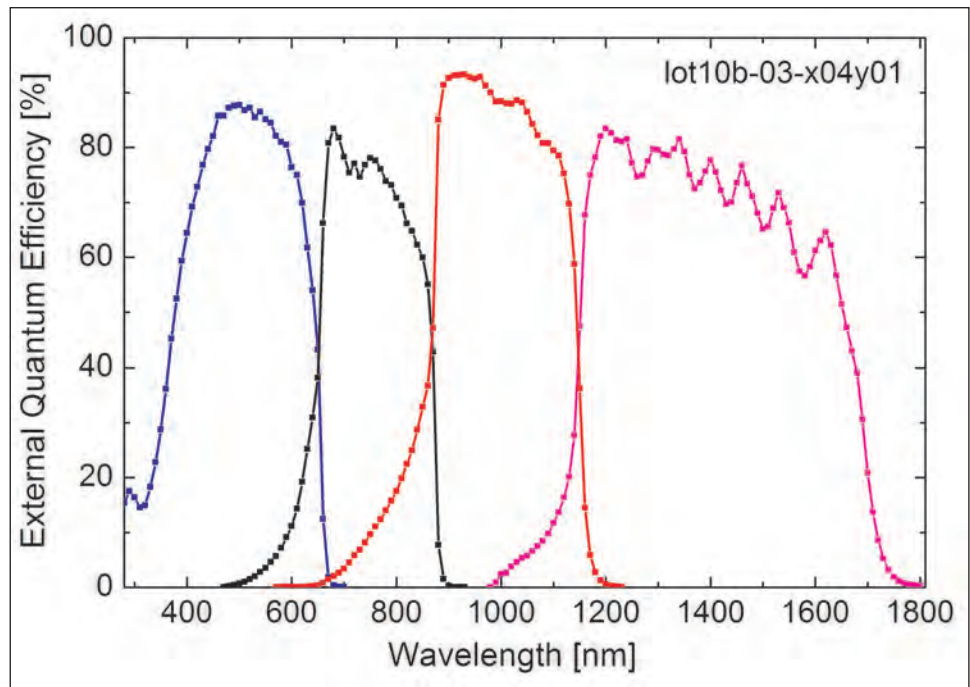
“Concentrator photovoltaics constantly improves in conversion efficiency and therefore lowers area-related costs,” says Fraunhofer ISE’s director professor Eicke Weber. “The new solar cells, with their new process technology and outstanding efficiency potential, will make an important contribution to the success of concentrator photovoltaics,” he reckons.

“Boosting efficiency levels is a key step in outperforming the economics of conventional PV,” says Soitec’s CEO André-Jacques Auberton-Hervé. “This great achievement brings strong value to our solar division and validates our strategy and business model in the solar market,” he adds. “This repre-

►sents a major proof-of-concept, on track to demonstrate a concentrated solar cell with 50% efficiency as soon as 2015."

The French-German cooperation between Fraunhofer ISE, CEA-Leti and Soitec started with the project 'SolarBond' between Fraunhofer ISE and France's Carnot-Institut, sponsored under the Programme Inter Carnot Fraunhofer (PICF) and funded by the French Agence Nationale de la Recherche (ANR) and Germany's Federal Ministry for Education and Research (BMBF) over 2009–2011. In this project, the partners demonstrated for the first time the transfer of ultra-thin solar cell layer structures and the application of re-usable engineered substrates (a key milestone on the way to commercializing the new four-junction solar cell). The achievements were honored by the Franco-German Business Award in 2011.

www.ise.fraunhofer.de



External quantum efficiency of four-junction solar cell, measured at the Fraunhofer ISE CalLab. ©Fraunhofer ISE.

www.soitec.com
www.leti.fr/en

www.programme.inter.carnot.fraunhofer.org

Soitec completes solar financing bond transaction in South Africa

Soitec of Bernin, France, which makes engineered substrates — including silicon-on-insulator (SOI) wafers and III-V epiwafers — as well as concentrating photovoltaic (CPV) solar systems, has finalised a ZAR1,000,000,000 (over \$100m) solar financing bond issued by CPV Power Plant No.1 Bond SPV (RF) Ltd, an affiliate of Soitec Solar GmbH.

The bonds will finance the construction of a 44MWp utility-scale concentrator photovoltaic (CPV) solar power plant in Touwsrivier, South Africa. This is the first publicly listed project bond ever issued to finance a solar power plant based on CPV technology, says the firm. In terms of financing solar energy projects, the bond is an inaugural transaction in South Africa and only the third such transaction worldwide.

A consortium consisting of Deloitte & Touche, The Standard Bank of South Africa, Trident Capital and Webber Wentzel Attorneys advised Soitec throughout the

transaction, with the bank acting as lead manager, book runner and debt sponsor for the offering. Credit rating agency Moody confirmed the supportive investment-grade rating of Baa2.za assigned to the Touwsrivier project.

"The bonds were placed with a diverse pool of South African institutional investors, pension funds and asset managers, all of whom welcomed the opportunity to participate in this inaugural offering," says Trident Capital's chief investment officer Kimon Boyiatjis. "The bond provides developers with a new and attractive capital market instrument to finance solar power plants," adds Rainer Nowak, director at Webber Wentzel.

"It opens an entirely new field of project funding to the solar industry in South Africa," says Ompi Aphane, deputy director General Energy Policy and Planning of the Department of Energy. "We hope that this will contribute to the creation of a new pool of financial

resources that can support the South African government's ambitious plans for renewable energy."

"Together with the selected equity investors for this project, we are well positioned to rapidly deploy the 44MWp Touwsrivier project," says Gaëtan Borgers executive VP of Soitec Solar Division. "Group Five, our EPC partner, has already started construction, and the first of more than 1500 high-efficiency Soitec CPV systems will soon be erected on the project site. Scheduled for completion by June 2014, Touwsrivier will be the largest CPV plant in the western world," he reckons.

"The market for utility-scale solar power plants is the fastest growing segment today," says Soitec's CEO & founder André-Jacques Auberton-Hervé. "We will continue to execute our pipeline of over 440MWp and to develop new opportunities in South Africa and other high irradiance countries."

www.soitec.com

First Solar set to begin construction of New Mexico's largest solar power plant

First Solar Inc of Tempe, AZ, USA, which manufactures thin-film photovoltaic (PV) modules based on cadmium telluride (CdTe) as well as providing engineering, procurement & construction (EPC) services, has been granted a power purchase agreement (PPA) from the New Mexico Public Regulatory Commission, clearing the way for it to begin construction on the state's largest solar power plant (to be located on State Trust Land in Luna County). The PPA will provide El Paso Electric Power with 50MW of solar energy for 25 years.

"This 50MW solar power project will provide about 300 jobs during the construction phase, which is a huge boost to New Mexico's ailing construction industry, and it will provide a constant stream of revenue for our public schools,

universities and hospitals," says State Land Commissioner Ray Powell.

"This project will provide clean, efficient solar power to El Paso Electric service territory customers, and the lease payments could generate as much as \$40m for state land trust beneficiaries over the 40-year term of the lease."

The solar array will realize significant water savings over gas-fired or coal-fired generating plants and will have zero air emissions. The proposed Macho Springs solar power plant will generate enough energy to power more than 18,000 average New Mexico homes (which use about 669 kilowatt hours of electricity per month) and displace more than 40,000 metric tons of CO₂ (equivalent to taking 7500 cars off the road) as well as more than 340,000 metric tons of annual

water consumption.

First Solar has submitted its final development plan, which provides a site plan and specific mitigation plans and strategies, and is obtaining various construction permits. Once approved, construction should begin in July.

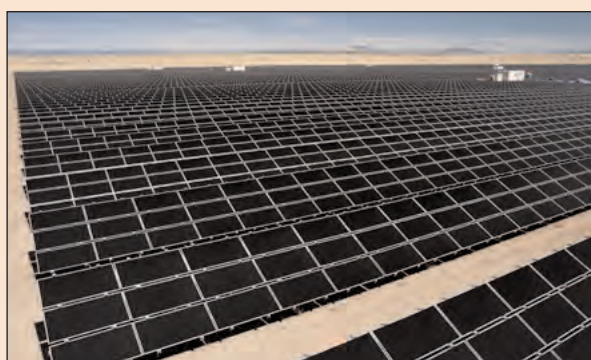
El Paso Electric Company will purchase the entire output power from the Macho Springs solar power project through a purchase power agreement with First Solar. The project was secured by El Paso Electric through an all-source competitive Request for Proposal process conducted in 2011. The project will operate on a commercial lease from the State Land Office on about 500 acres of land at Macho Springs, near Deming. First Solar also has an interconnection agreement with El Paso Electric.

First Solar sells 139MW Campo Verde solar project

First Solar has sold the 139MW_{AC} Campo Verde Solar Project to Southern Company subsidiary Southern Power and Turner Renewable Energy. First Solar will complete project construction (which began in December) and will operate and maintain the power plant for 10 years. Commercial operation is expected this fall.

The Campo Verde project is located on a 1443-acre site near El Centro in Imperial County, CA and is expected to generate enough electricity to power nearly 48,000 homes, displacing 80,000 metric tons of CO₂ per year (equivalent to taking 15,000 cars off the road). San Diego Gas & Electric Company (SDG&E) will purchase the project's output under a 20-year power purchase agreement (PPA).

According to an independent study conducted for Imperial County, the Campo Verde Solar Facility will have an economic impact to the Imperial County area



Cimarron I Solar Project, sold to Southern Power and Turner Renewable Energy in 2010.

totaling about \$239m over the next 30 years. It is expected to contribute \$17.5m in local tax revenue and employ an average of 250 workers during construction.

The Campo Verde project integrates First Solar's solar modules with its power plant controls and grid-integration technology.

"By leading the project from development through engineering, construction and operations, we are able to offer the highest per-

formance and greatest reliability," reckons James F. Cook, First Solar's director of project development.

Campo Verde is the second project that First Solar has designed and constructed for Southern Power and Turner Renewable Energy. In 2010, it sold the 30MW_{AC} Cimarron I Solar Project, adjacent to Ted Turner's Vermejo Park Ranch in northern

New Mexico, to the partnership.

"First Solar was the developer of our partnership's first venture — the Cimarron Solar Facility in New Mexico — and we're pleased to expand our joint efforts through our largest solar acquisition to date," says Southern Power's president & CEO Oscar Harper.

First Solar does not expect to recognize revenue prior to commercial operation of the plant.

www.firstsolar.com

First Solar's stock offering raises \$427.7m

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 closed its underwritten public offering of 9,747,000 shares of common stock (announced on 11 June) at a public offering price of \$46 per share. This comprises a public offering of 8,500,000 shares

(worth \$390m), plus 1,247,000 shares issued and sold as a result of the exercise of almost all of the underwriters' over-allotment option (of 1,275,000 shares, worth \$58.65m) on 17 June.

After underwriting discounts and estimated offering expenses, First Solar received about \$427.7m in net proceeds. The firm intends to use them for general corporate purposes, which may include

acquisitions of under development photovoltaic solar power system projects, investments in photovoltaic solar power system projects that will be jointly developed with strategic partners, and capital expenditures or strategic investments to develop certain business units and expand in new geographies.

www.firstsolar.com

www.sec.gov

First Solar reports first-quarter sales up 52% year-on-year to a more-than-expected \$755m

For first-quarter 2013, 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 \$755m (slightly above the guidance of \$650-750m). This is down 30% on \$1.07bn last quarter (due mainly to less revenue recognition from systems business projects related primarily to the Topaz project) but up 52% on \$497m a year ago (due mainly to higher sales volumes for third-party module sales and an increase in revenue from systems projects).

R&D expenses have fallen further, from \$36.1m a year ago and \$31.6m last quarter to \$29.9m. Selling, general and administrative (SG&A) expenses have risen from \$63.4m last quarter to \$74.5m, but that is still down on \$91.8m a year ago.

With module conversion efficiency having risen from 12.4% a year ago to 12.9%, the core module manufacturing cost per watt produced has fallen from \$0.70/W to \$0.64/W.

On a non-GAAP basis (excluding restructuring charges etc), net income was \$61.5m (\$0.69 per fully diluted share, slightly below the expected \$0.70-0.90). This is



Panels at one of First Solar's manufacturing plants.

down from \$180.4m (\$2.04 per fully diluted share) last quarter, but still much better than the net loss of \$6.7m (\$0.08 per fully diluted share) a year ago.

Operating cash flow was \$66.5m, down on \$327.6m last quarter but much better than \$16.1m cash burn a year ago. Capital expenditure has risen from \$40m last quarter to \$71.7m, but that is still less than the \$124.5m a year ago (and less than the expected \$80-100m). Free cash flow is hence \$19.7m, down from \$253.3m last quarter but a big improvement on -\$211.8m a year ago. Cash and marketable securities remained steady during the quarter at about \$1bn, but this is up \$262m on \$750m a year ago.

"We demonstrated progress on several fronts during the first quarter, including continued

strengthening of our balance sheet and additions to our pipeline," says CEO Jim Hughes. "We remain on track for the year and reaffirm our full-year 2013 financial guidance [as issued during the firm's 2013 Analyst Day event on 9 April] and are focused on achieving our goal of new bookings to shipments ratio of one-to-one," he adds (albeit with earnings more heavily weighted in second-half 2013 due to an expected push-out in revenue recognition for the Desert Sunlight project).

For full-year 2013, First Solar expects production of 1.5-1.7GW, shipments of 1.4GW(DC) in systems and 200-400MW(DC) in modules, average module efficiency of 13.1%, and core module manufacturing cost per watt of \$0.61/W (average over the year, but just \$0.58/W at the end of the year).

Hence, First Solar expects net sales of \$3.8-4.0bn, gross margin of 20-22%, operating expenses of \$380-400m, earnings per share of \$4.00-4.50, operating cash flow of \$0.8-1.0bn, and capital expenditure of \$350-400m.

TSMC Solar's commercial-sized CIGS modules raise efficiency record for monolithic thin-film PVs to 15.7% Record raised from 15.1% in just 4 months

TSMC Solar Ltd, which was founded in May 2009 as a subsidiary of the world's biggest silicon wafer foundry Taiwan Semiconductor Manufacturing Co Inc (TSMC), says TUV SUD has confirmed that its latest commercial-sized (1.09m²) CIGS (copper indium gallium diselenide) champion module has achieved 15.7% module total area efficiency.

The new champion module improves on TSMC Solar's previous 15.1% world record for monolithic thin-film module efficiency, set in January. The module was produced using the current manufacturing equipment and materials at the firm's manufacturing facility in Taichung, Taiwan.



TSMC Solar's S-Fab production line.

"Our new champion module not only pushed our efficiency record up by 0.6% points in just 4 months, but also achieved a record temperature coefficient of $-0.26\%/^{\circ}\text{C}$, showing our continued ability to improve our process technology," says TSMC Solar's president Ying-Chen Chao.

TSMC Solar has also announced the introduction of its new TS-CIGS Series Model C1 module, with nameplate power spanning 140–155W. The UL- and TUV SUD-certified module has an improved temperature coefficient of $-0.31\%/^{\circ}\text{C}$ and has passed both the Blowing Sand Test based on IEC 60068-2-68 and the Salt Mist Ed.2 test.

"Our Model C1 modules deliver improved energy yield and reliability in high-temperature and desert environments and prove our ability to bring record-setting process improvements to market," comments Stephen McKenery, TSMC Solar's worldwide sales head.

www.tsmc-solar.com

CIGS firm XsunX appoints DayStar co-founder John Tuttle to advisory board

XsunX Inc of Aliso Viejo, CA, USA, which is developing hybrid copper indium gallium (di)selenide thin-film (CIGS) photovoltaic (TFPV) cell technologies and 'CIGSolar' manufacturing processes, has appointed Dr John R. Tuttle to its advisory board as a senior scientific and business advisor.

"John's extensive entrepreneurial background and comprehensive knowledge of the cleantech industry is the perfect addition to XsunX at just the right time," believes XsunX's CEO Tom Djokovich.

Recently, XsunX began its transition from focusing on its CIGSolar baseline system design and build-out to marketing its CIGSolar technology, which the firm says required the addition of an industry veteran to further develop its relationships with customers and investors.

"There's been a paradigm shift occurring at virtually every level of the solar industry including, and

most significantly, how business, the capital markets, and project finance assess the value of the solar industry as a whole and, more specifically, the value of any particular technology," says Djokovich. "Our current requirement was to find someone with world-class CIGS experience and someone who could also 'think outside of the box' — or, in the CIGS business, outside of the vacuum chamber — to commercialize technology," he adds. "Tuttle's years of noteworthy experience at NREL elevating the science and capabilities of CIGS, and his experience transitioning innovation into operational results, provides XsunX with the hands-on capabilities that we were looking for."

Tuttle has 30 years of experience in the semiconductor and photovoltaic industries, and for the last several years he has focused on assisting with operational and capital management of early-stage

companies in the cleantech sector. Previously, he was the co-founder, chief executive & chairman of DayStar Technologies Inc, where he took the firm from three employees to an operational organization with world-class development and pilot production facilities, achieving an over 900% value creation for its IPO shareholders.

From 1986–1997, Tuttle was a senior scientist at NREL, where his research guided the fabrication of thin-film CIGS PV devices with multiple world-record efficiencies.

Tuttle has authored or co-authored over 70 publications and 14 patents/patent applications, and conducted over 100 presentations about technology & business development. He holds a Ph.D. in electrical engineering from the University of Colorado, an M.S. from the Colorado School of Mines, and a B.S. in Applied and Engineering Physics from Cornell University.

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Head Office and Manufacturing Plant

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www.wafertech.co.uk sales@wafertech.co.uk



ISO9001:2000, Certificate No.: FM 26963
ISO14001:2004, Certificate No.: EMS 502245

Report analyses how best to make progress with HCPV

How can III-V cells compete with cheap crystalline silicon PV?

New insight into the state of and prospects for the high-concentrating photovoltaic (HCPV) sector is available in the latest report published by technology market analyst firm Yole Développement.

The report presents what the company identifies as “the key factors to improve the bankability of HCPV installation projects” — with new analysis to guide strategic business decisions related to this technology. Yole

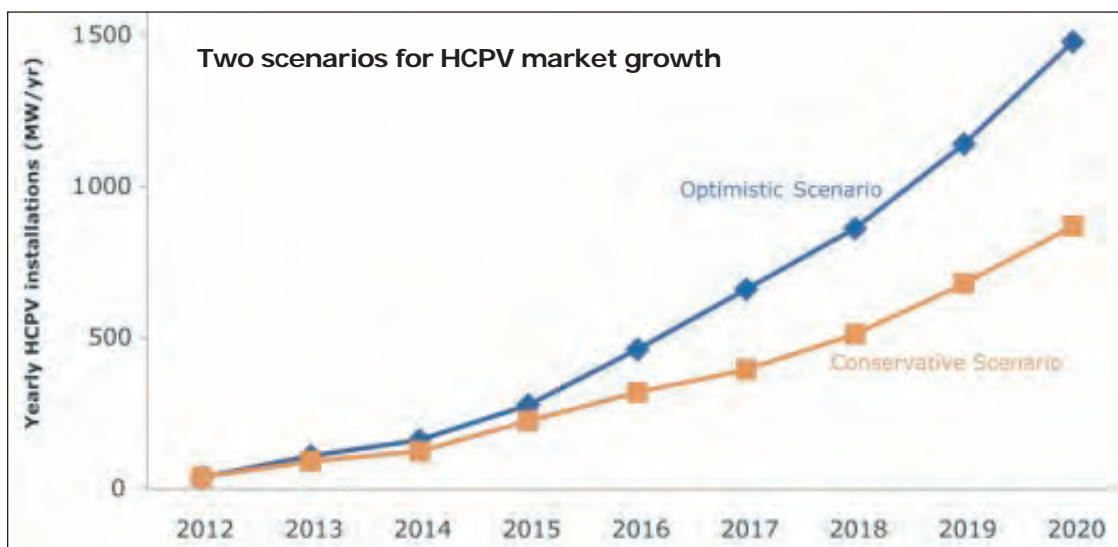
has also updated its 2011 analysis of market data for wafers, epiwafers and installation as well as the costs of HCPV modules and systems.

Yole assess that, as of March, about 120 HCPV installations have been installed throughout the world, accounting for a total capacity of 130MW. This is only about 1/1000 of the total current installations of flat-plate PV, represented mainly by crystalline silicon.

The main advantage of HCPV over flat-plate PV is its greater efficiency; HCPV can surpass 40% at cell level, reaching about 30% at module level, which is not achievable by conventional PV technologies. Yole says that the high efficiency of HCPV systems will be the key driver for this technology in the future.

The report states, “In order to increase the differentiation between HCPV and its strong competitor, conventional flat-plate PV, HCPV cell efficiency needs to be significantly increased — but without significantly increasing manufacturing costs — and overall system costs must be reduced.” The report adds, “HCPV’s high system efficiency, together with its high electricity production (kWh/kW installed), makes HCPV levelized cost of electricity (LCOE) competitive with that generated by fossil-fueled power plants in certain sunny locations.”

Most technology challenges identified early, at the beginning of HCPV development, have already been resolved, Yole continues. However, today’s relatively weak HCPV market development is related not only to the technology issues, but also to the lack of financing and low interest among potential customers.



To speed up market growth, Yole assess that the bankability of HCPV projects must be improved at all levels, including technology development and testing, and minimizing the uncertainty about the solar resources at the future installation site, among other things. The report considers the factors that can improve the bankability of HCPV installation projects and help the HCPV market to grow. Based on future technological achievements and improved bankability, two possible scenarios — conservative and optimistic — are proposed for the likely patterns in HCPV market evolution during 2013–2020.

Vertical integration or subcontracting

Yole assess that the HCPV market is today very restricted and there is “no place for less-competitive players”. Several companies have recently stopped or reduced their HCPV activities due to either strong competition or after losing interest in a relatively small and low-margin market — “such as HCPV is today”.

Market leaders are not yet established, and new companies with innovative technology or business models may take a lead in the future. As shown in the report, with rising market volume, there will be an increasing trend for vertical integration in the near future.

Although more vertical integration is associated with a higher business risk, it enables better control of the system performance and total system costs.

“Their at least partial vertical integration, together with 100MW+ in-house production capacities, may enable companies such as Suncore or Soitec to gain a significant advantage compared to their competitors,” comments

Milan Rosina,
Market & Technol-
ogy Analyst, Pho-
tovoltaics, at Yole.

"An alternative approach is to subcontract most of the business and thus lower a company's capital needs while at the same time transfer most of the business risk to subcontractors," he adds.

"This approach is advantageous for small companies with limited sources of financing...We have analyzed both approaches."

Arizona State University demos room-temperature electrically powered nanolasers

Operating temperature has been raised by adjusting the SiN insulating layer thickness in sub-wavelength metallic-cavity laser.

Researchers at Arizona State University (ASU) have succeeded in developing electrically powered nano-scale lasers that operate effectively at room temperature – a step that could pave the way for their use in a variety of practical applications.

This is the latest development in the R&D group's long history of trying to make such a breakthrough. Previously, electrically powered nano-scale lasers could only be made to work at relatively low temperatures. Researchers in this field have been striving to enable them to perform reliably at room temperature.

Details of how the ASU researchers, led by Cun-Zheng Ning, made the room-temperature advance were published recently in the research journal *Optics Express*, vol. 21, issue 4, p4728 (2013).

Ning works as an electrical engineering professor in the university's School of Electrical, Computer and Energy Engineering, one of ASU's several Schools of Engineering, based in Phoenix. He has been among many groups of engineers and scientists worldwide trying to fabricate a workable nanolaser with a volume smaller than its wavelength cubed – which would be an intermediate step toward further miniaturization of lasers.

Miniaturizing lasers is crucial to making electronics smaller and better, and enabling them to operate faster. Being able to integrate more lasers onto a small microchip could hence make next-generation computers faster and smaller. The researchers say that wavelength scale is the next milestone to achieve in their overall effort to enable greater miniaturization.

Ning says that while other groups have developed extremely small and thin lasers, they always needed to be optically driven by a larger laser. Furthermore, existing electrically driven nanolasers can operate only at low temperatures and/or emit light only in short bursts or pulses.

To enable them to be useful in practical applications – particularly for improvements of electronic and photonic technologies – such lasers must possess three particular features: operate at room temperature

without a refrigeration system; be powered by a simple battery instead of by another laser; and emit light continuously.

Ning commented, "This combination has long been the ultimate goal in the nanolaser research community." His team started looking for solutions in 2006, before he joined ASU, with his then postdoctoral assistant, Alex Maslov, who is currently a scientist working with Canon USA Inc.

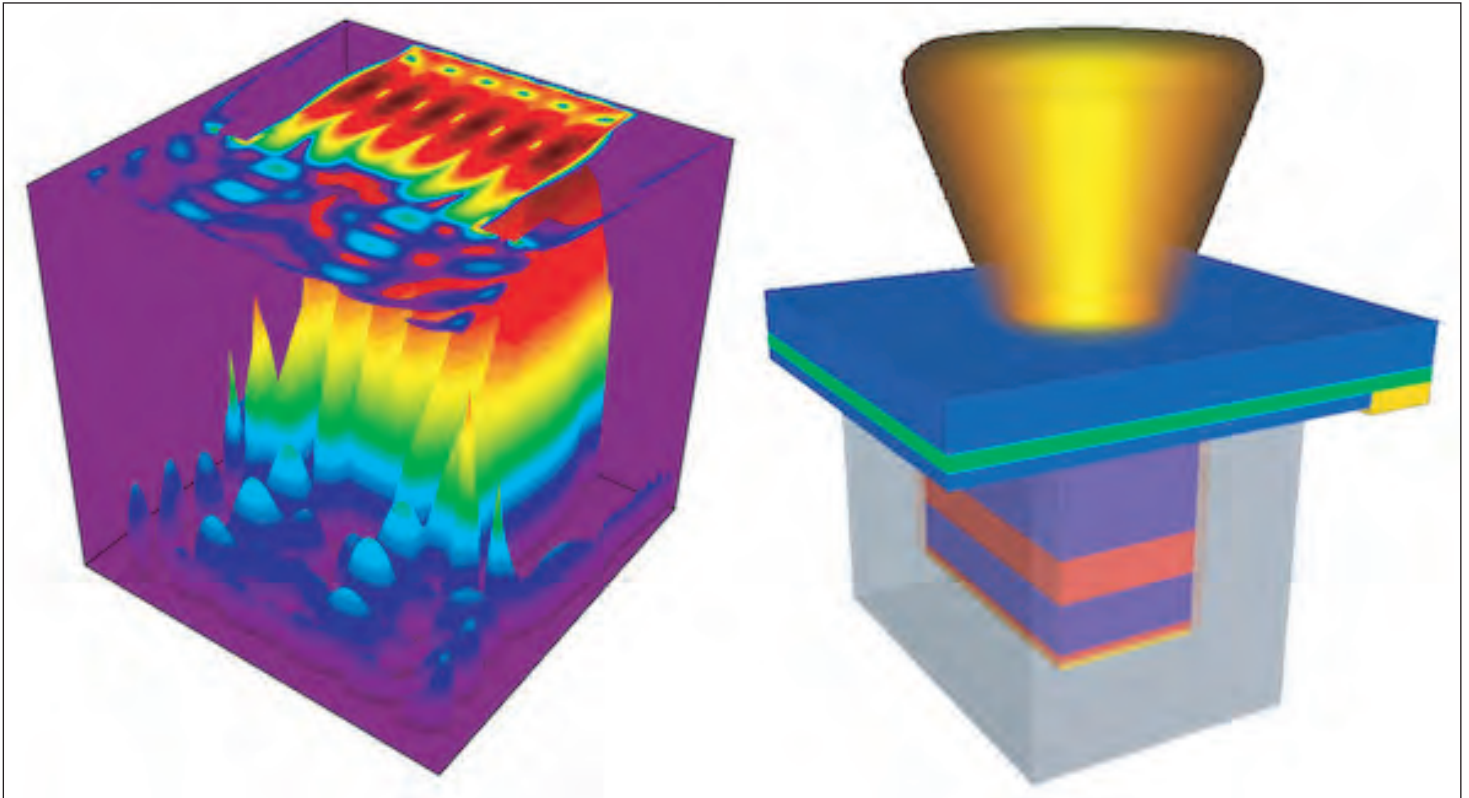
While working for the US National Aeronautics and Space Administration's Ames Research Center, they proposed a semiconductor wire coated with a silver shell and showed that such a core-shell structure was able to shrink the nanolaser to an incredibly small scale.

In 2011, working with Martin Hill, a former professor at Eindhoven University of Technology in the Netherlands, Ning's team then developed the thinnest nanolaser capable of operating at low temperatures. In 2011, with the aid of Ning's student, Kang Ding, they were able to raise the operating temperature to 260K (–13.2°C / –8.3 °F).

More recently, using an indium phosphide/indium gallium arsenide/indium phosphide (InP/InGaAs/InP) rectangular core and silicon nitride (SiN) insulating layer (encapsulated in a silver shell), the team demonstrated a nano-laser that could operate at room temperature, as reported in the journal *Physical Review B*, vol. 85, p041301(R) (2012). However, the overheating led to imperfect device operation and a conclusive demonstration of lasing remained elusive.

However, the latest results — obtained by using the same sub-wavelength metallic-cavity laser device structure but adjusting the thickness of the SiN layer and refining the fabrication process — have demonstrated an eight-fold improvement over previous results from a year ago. This finally provides an unambiguous demonstration of continuous electrically driven operation of a laser at room temperature, Ning says.

To explain the significance of such an advance, Ning says, "Imagine if computers had to be cooled down to



Left: variations in light intensity within a nanolaser. Right: nanolaser with a metallic cavity, where the center red region confines electrons and the grey enclosure is a silver cavity. The blue layer on top is the growth substrate. The orange-yellow color indicates the light emission.

–200°C (73.2K /–350°F) for our current information technology to work. If that were the case, we would not have the widespread usage of computers and social media.”

Nanolasers that can operate at room temperature and be powered by a simple battery can be used to make computers operate faster, significantly broaden Internet bandwidth, and provide light sources for many computer-chip-based sensing and detection technologies.

Show-stopping advance

But the benefits of achieving continuous room-temperature operation go beyond the practical aspects. Ning commented, “In terms of fundamental science, it shows for the first time that metal heating loss is not an insurmountable barrier for room-temperature operation of a metallic cavity nanolaser under electrical injection. For a long time, many doubted if such operation is even possible.”

“Unlike nanolasers driven by another laser, for which the driving laser can be chosen so that the heat generation is minimized, electrical injection by a battery produces more heat. In addition, typical metals can be heated quickly by the operation of the nanolasers. Thus, such elevated heat generation has been perceived as a show-stopper for such nanolasers.”

He added, “More importantly, similar metal semi-

conductor structures used for nanolasers are also currently being explored for many other applications, such as being a building block for the formation of artificial materials that have remarkable properties. This demonstration is thus also important to the researchers working in those areas of materials science and engineering.”

Ning says many challenges remain in efforts to integrate nanolasers into a photonic system on-chip platform, as well as to prolong the lifetime of laser operation, and to further develop the capabilities of such devices. In addition, the physical mechanisms involved in the interaction of photons with metallic structures on small scale are not yet fully understood, so there is still much research to be done in this area.

Ning concluded, “But thanks to the realization of room-temperature operation of nanolasers, all these goals can start to be more effectively explored.”

Constructive collaboration

The breakthrough by Ning’s team required nanofabrication and measurements, credited to several of his students, primarily Kang Ding, Leijun Yin, and Zhicheng Liu. Yin is pursuing his doctorate in physics. Ding and Liu are pursuing doctoral degrees in electrical engineering. ■

[www.opticsinfobase.org/oe/abstract.cfm?](http://www.opticsinfobase.org/oe/abstract.cfm?URI=oe-21-4-4728)

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By Matthew Peach, Contributing Editor

Fraunhofer demos AlGaN-based sensors for continuous monitoring of UV exposure

The next stage is to optimize crystal growth and obtain more sharply defined wavelength limits.

Ultraviolet (UV) lamps are used to cure coatings and adhesives in many industrial manufacturing processes, and special sensors are used to measure the intensity of the UV light applied to these surfaces. But because these sensors age too quickly, they can only be used to record intermittent measurements. Now, researchers at Germany's Fraunhofer Institute have developed a new generation of sensors based on aluminium gallium nitride (AlGaN) that are capable of continuously monitoring UV intensity.

The devices were presented for the first time at the Sensor + Test trade show in Nuremberg (14–16 May).

UV light can be beneficial, or indeed essential, since the human body needs it to produce vitamin D. Also, industry makes use of UV light, for example to cure adhesives or the coatings applied to food packaging, and to disinfect water. On the other hand, surfaces can be damaged if they are exposed to too much UV light, and poorly regulated UV lamps also waste energy and generate excessive amounts of ozone. UV sensors are therefore used to optimize light intensity.

Usually these sensors are made of silicon or silicon carbide (SiC). The problem with silicon sensors is that they only deliver useful results if external filters are used to exclude visible light from the measurement. Unfortunately, the filters are very expensive and not particularly resistant to UV light. So, to reduce ageing, measurements can only be taken intermittently, as snapshots. Silicon carbide sensors have the advantage of being able to withstand longer exposure to UV light, but they only operate in a narrow spectral band. In most industrial curing processes, it is the longer wavelengths that are of interest — precisely the area in which these sensors are least accurate.

Researchers at the Fraunhofer Institute for Applied Solid State Physics (IAF) in Freiburg have now developed a new UV sensor in collaboration with colleagues at the Fraunhofer Institutes for Manufacturing Technology and Advanced Materials (IFAM), for Optronics, System Technologies and Image Exploitation (IOSB), for Silicon Technology (ISIT) and for Physical Measurement Techniques (IPM). "Our sensor is based on

aluminium gallium nitride (AlGaN) technology and can withstand continuous exposure to UV light without damage," says IAF project manager Dr Susanne Kopta. "This enables it to be used not only for intermittent snapshots but also for permanent inline monitoring," she adds. A sapphire wafer serves as the substrate for epitaxial growth of the material in the active layers of the sensors.

Sensor for high UV intensities

The sensor is particularly suited to applications involving very high UV intensities, and for tasks that require the monitoring of specific spectral ranges. This is due to the fact that the detectors can be set to operate in two different ways. The first option is to define a maximum wavelength threshold. In this case the sensor detects all UV light emitted at wavelengths below the set limit. The alternative is to define two wavelength thresholds, thus cutting out certain parts of the spectrum. "The narrowest range we have been able to achieve is a separation of 20nm," reports Kopta. This makes it possible to manufacture one sensor for UV-A, another for UV-B, and a third for UV-C wavelengths. The researchers set the wavelengths to be detected by the sensor by varying the ratio of gallium to aluminium in one of the AlGaN layers. Defining this ratio is one of the challenges that the researchers are working on at present.

Another challenge is growing the AlGaN crystal so that it is free of structural defects and impurities. Failure to do so would result in unreliable measurements, because different areas of the sensor would absorb light at different wavelengths. "The hardest part is dealing with the wide range of parameters that affect the manufacture of thin crystal films, which demands a great deal of experience," says Kopta.

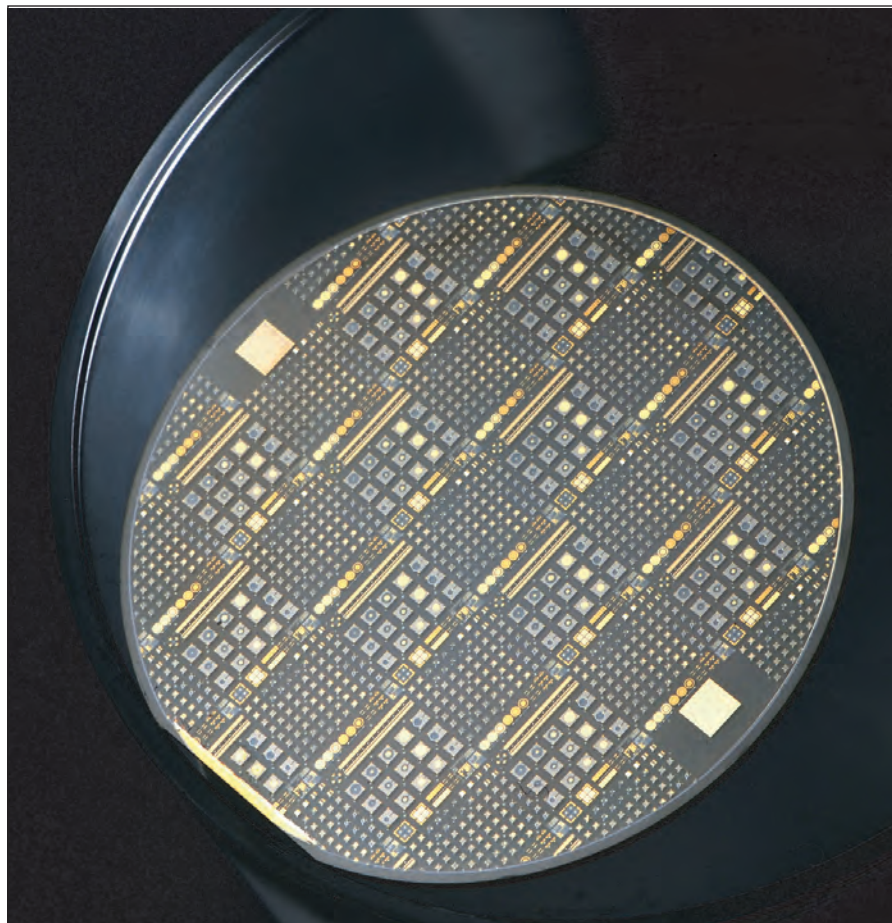
A few demonstration models have already been produced. In the next stage of the project, the researchers aim to optimize crystal growth and obtain more sharply defined wavelength limits. They are also investigating the component durability, with results so far said to be very encouraging. "Initial tests have

confirmed that the sensors are capable of operating for 1000 hours under high UV exposure without suffering any damage," reports Kopta.

UV cameras as a spectrometer or plasma deposition monitor

By placing more than 100 detectors side by side in a strip, a UV camera can be obtained. This device can be used to monitor plasma deposition processes, such as those employed to coat solar cells with an antireflective film. The sensor strip can also serve as a spectrometer. In this case, the UV light is first passed through a diffraction grating, splitting the light into its various spectral components. Each individual sensor detects a specific wavelength and provides information on the intensity of light at that wavelength. The Fraunhofer reckons that this would be a good way of conducting ageing tests on the mercury lamps commonly used for water disinfection or UV curing, e.g. checking if the lamp still emits light of the desired intensity throughout the entire spectrum, or if certain wavelengths are weaker than they should be. ■

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Processed AlGaIn-based UV sensors on a sapphire wafer.
Credit: Fraunhofer IAF.

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Thermal anneal for improving adhesion of gold-doped graphene to nitride LEDs

Light output power from a near-UV LED has been increased by 34% over a device with bare multi-layer graphene.

Researchers in South Korea have developed a new gold-doping process for graphene transparent conducting layers (TCLs) that improves its adhesion and electrical contact with near-ultraviolet light-emitting diodes (NUV-LEDs) [Chu-Young Cho et al, *J. Appl. Phys.*, vol113, 113102, p2013].

TCLs are used to improve current spreading and efficiency of NUV-LEDs. A common TCL material for visible light is indium tin oxide (ITO), which unfortunately becomes opaque in the UV range. The optical transmittance of graphene extends further into the UV than ITO.

The team consisted of researchers from Gwangju Institute of Science and Technology, Seoul National University, and Samsung Electronics Co Ltd. Some of the same researchers were involved in research at Gwangju Institute of Science and Technology, Korea Basic Science Institute Jeonju Center, and Seoul National University that previously developed a solution-based

gold-doping process to improve the conductivity of graphene TCLs [www.semiconductor-today.com/news_items/2012/AUG/GIST_020812.html]. This latter technique was found to suffer from poor adhesion to the underlying gallium nitride (GaN) semiconductor p-contact layer.

The new technique began by producing multi-layer graphene (MLG) through chemical vapor deposition (CVD) on a 300nm layer of nickel on a silicon dioxide/silicon substrate. The carbon source was methane in hydrogen and argon. The growth tempera-

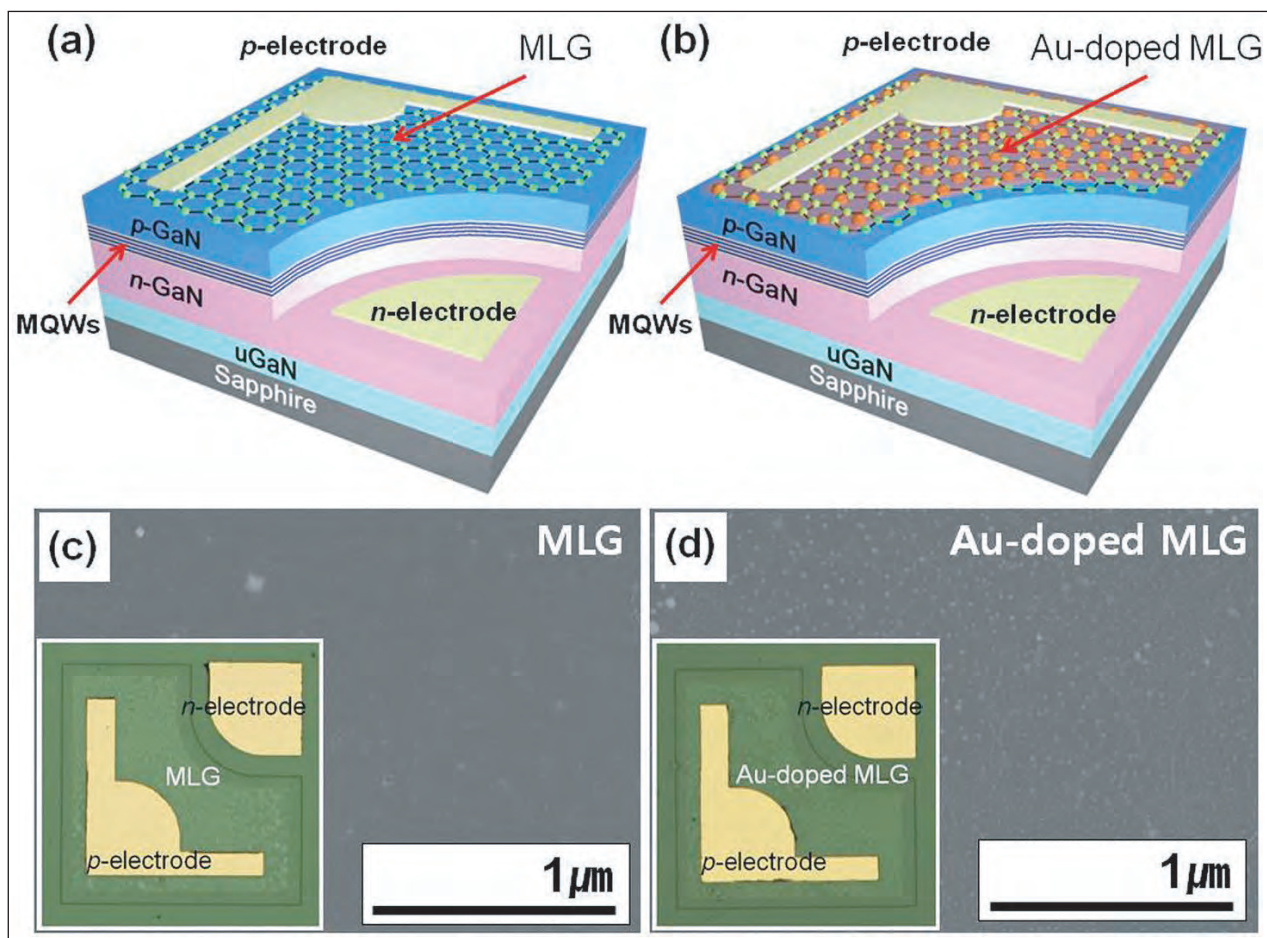


Figure 1. Schematic diagrams of NUV-LEDs with (a) MLG and (b) Au-doped MLG TCLs. (c) and (d) SEM images of MLG and Au-doped MLG. Inset: optical microscopy images of NUV-LEDs with MLG and Au-doped MLG TCLs.

ture was 900°C. After rapid cooling to avoid excessive carbon precipitation, the multi-layer graphene was released by etching in iron chloride aqueous solution.

The floating graphene films were directly transferred to NUV LED structures produced by metal-organic chemical vapor deposition (MOCVD) — see Figure 1. The emission wavelength of the 5-period indium gallium nitride (InGaN) multi-quantum well (MQW) structure with GaN barriers was 415nm. The LED structure was etched by inductively coupled plasma to expose an n-contact area.

After the MLG transfer, p-electrode and n-electrode regions were selectively cleared of MLG material through photolithography and reactive-ion etching.

Gold-doping of the MLG was achieved by depositing 0.2nm of the metal onto the surface using electron-beam evaporation, followed by annealing at 700°C for 5 minutes in nitrogen. It was found that this method improved the adhesion between the MLG and GaN.

Previously, the researchers had found that MLG only weakly adhered to GaN, resulting in easy detachment of the MLG in lift-off processes and in a poor electrical contact between the materials that degraded LED performance.

The researchers think that the adhesion is improved by the formation of gold (Au) nanoparticles and diffusion of gold into the p-GaN material. They also believe that the thermal anneal step could remove oxidized p-GaN and residual chemicals, further improving MLG/LED adhesion.

The n- and p-pad electrode metals were both chromium/gold.

Atomic force microscope (AFM) study of the surface showed that thermal annealing transforms the gold layer into ~50nm-diameter and ~8nm-high nanoparticles. Optical transmittance study of the layer gives a value of 88% for 415nm light, about the same as for bare MLG. This compares with 80% for 200nm indium tin oxide. MLG with unannealed gold has somewhat depressed transmittance. Further into the UV, annealed gold-nanoparticle MLG has improved transmittance compared with bare MLG.

At 20mA injection current, the forward voltage of the LED with annealed gold-doped MLG TCL is 6.8V, reduced from 7.8V for the bare-MLG device. This indicates reduced resistance for the gold-doped layer. The sheet resistance of the annealed gold MLG was 18Ω/square, compared with 1000Ω/square for the previously developed MLG treated with gold chloride solution.

The researchers comment that “the improved I-V characteristics of the NUV-LEDs with an Au-doped MLG layer can be attributed to the reduced sheet resistance of the Au-doped MLG films and the decreased contact resistance between Au-doped MLG and p-GaN layer.”

Electroluminescence was also much increased with annealed gold-doped MLG TCL (Figure 2). More effective

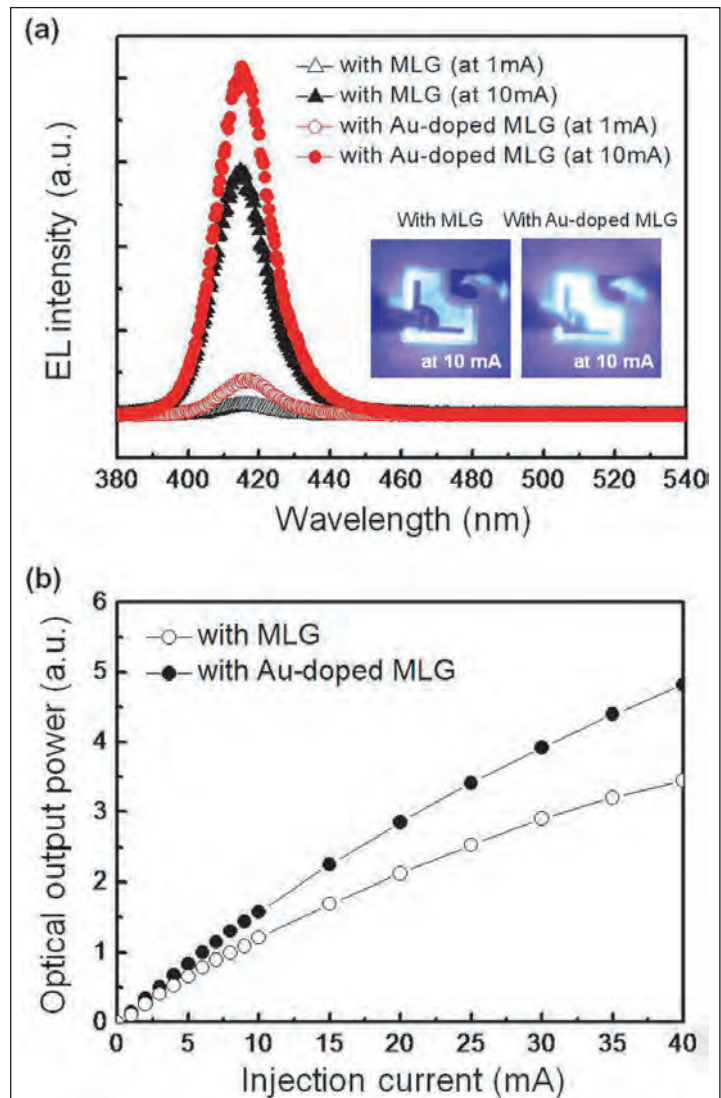


Figure 2. (a) Room-temperature electroluminescence spectra of NUV-LEDs with MLG and Au-doped MLG TCLs, measured at 1mA and 10mA. Inset: photos of NUV-LEDs with MLG and Au-doped MLG TCLs at 10mA. (b) Optical output power of NUV-LEDs with MLG and Au-doped MLG TCLs.

current injection and spreading also lead to more uniform and stronger emissions.

Spectral analysis indicates a slight blue shift to 413nm in moving from 1mA to 10mA current. This is attributed to screening of “polarization-induced electric field by carriers and a band-filling effect of localized energy states formed by potential fluctuation in MQWs”.

At 20mA, the optical power output of the gold-doped MLG LED is increased by 34% over a device with bare MLG TCL. “This improvement of the optical output power of NUV-LEDs is attributed to the increased current injection efficiency, current spreading, and transmittance of Au-doped MLG TCL,” the researchers write. ■

<http://link.aip.org/link/doi/10.1063/1.4795502>

The author Mike Cooke is a freelance technology journalist who has worked in the semiconductor and advanced technology sectors since 1997.

MIT & Brookhaven show that In-rich clustering does not drive efficiency in InGaN LEDs

Aberration-corrected STEM plus EELS enables non-destructive analysis of LED function.

A contentious controversy surrounds the high intensity of indium gallium nitride (InGaN) LEDs, with experts split on whether or not indium-rich clusters within the material provide their remarkable efficiency. Now, researchers from the Massachusetts Institute of Technology (MIT) and the US Department of Energy (DOE)'s Brookhaven National Laboratory claim to have demonstrated that clustering is not the source ('Revisiting the "In-clustering" question in InGaN through the use of aberration-corrected electron microscopy below the knock-on threshold' by Baloch et al, Applied Physics Letters 102, 191910 (2013)).

"This discovery helps solve a significant mystery in the field of LED research and demonstrates breakthrough experimental techniques that can advance other sensitive and cutting-edge electronics," says coauthor Silvija Gradecak, MIT associate professor of Materials Science and Engineering.

Higher-efficiency bulbs

Incandescent lights convert only about 5% of electricity into visible light, with the rest lost as heat. Fluorescent lights push that efficiency up to about 20%, but still waste 80% of the electricity. In both of these cases, light is only the byproduct of heat-generating reactions rather than the principal effect. "Solid-state lights convert electric current directly into photons," notes co-author Eric Stach, leader of the Electron Microscopy Group at Brookhaven Lab's Center for Functional Nanomaterials (CFN). The efficiency of the electroluminescence light-generating process in LED bulbs could, in theory, be nearly perfect, but experimental realization has not reached those levels. "That disconnect helped motivate this study," adds Stach.

InGaN alloys contain dislocations in the crystal lattice, which can inhibit electricity flow and light production, but despite this the alloy performs exceptionally well. Understanding the light-emitting mechanism requires an understanding of what is happening on the atomic scale.

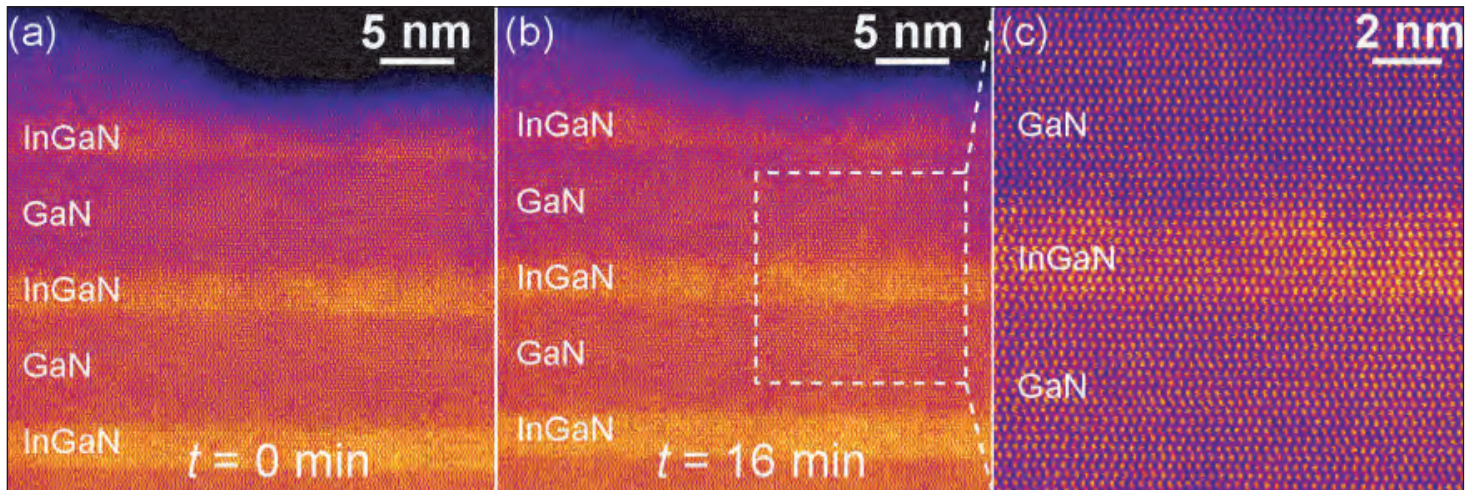


CFN's Kim Kisslinger, here with a focused-ion beam instrument, thinned the InGaN samples to 20nm for electron microscopy.

Controversial clusters

"Years ago, a team of researchers used electron microscopes to examine InGaN samples, and they identified a surprising phenomenon — the material appeared to be spontaneously decomposing and forming these isolated indium-rich clusters," Stach says. "This behavior could explain the efficient light emission, as the clusters might help electrons avoid the structural problems in the InGaN," he adds. "But then things became really interesting when another group proposed that the electron microscope itself caused that clustering decomposition. We had a real divide in the semiconductor field."

Rather than using light to examine materials, electron microscopes bombard samples with finely tuned beams of electrons and detect their interactions when they pass through a sample to reveal atomic structures. To achieve high enough resolution to examine the InGaN alloys, the electron microscopes used in the older experiments needed high-voltage beams. The controversy revolved around whether or not the experiment itself produced the clusters, rather than discovering the mechanism behind efficient light emission.



Images of InGaN samples produced by CFN's low-voltage STEM reveal a lack of structural changes over time. After 16 minutes of scanning, no damage or decomposition is visible. Higher magnification (c) exhibits none of the clustering previously theorized to be central to LED efficiency.

Improved imaging

"The state-of-the-art instruments available at Brookhaven Lab's CFN changed the way we could test these promising materials," Gradecak says. "The CFN's aberration-corrected scanning transmission electron



Non-destructive STEM imaging of specific InGaN samples demonstrates that indium-rich clustering does not drive the efficient light emission.

microscope (STEM) opened a new and non-destructive window into the LED samples. For the first time, we could get Ångstrom-level details without the risk of the device affecting the sample."

The researchers combined the STEM techniques with high-resolution electron energy-loss spectroscopy (EELS), which measures the energy lost by electrons as they passed through the sample. MIT post-doctoral researchers Kamal Baloch (lead author of the study) and Aaron Johnston-Peck of CFN applied these imaging techniques to the same samples that first launched the controversy over clustering, with the aim of helping to settle the issue.

"We found that the indium-rich clusters do not actually exist in these samples, even though they remain efficient light emitters," Baloch says. "While clustering may still occur in other samples, which may be prepared in different ways, the important point is that we've established a foolproof method for investigating InGaN materials. We can use these non-destructive imaging techniques to explore the fundamental relationship between cluster formation and light emission."

Beyond the advanced imaging instruments, researchers used the expertise of Brookhaven Lab physicist Kim Kisslinger, who specializes in nanoscale sample preparation. The InGaN samples were thinned to just 20nm (essential for priming the materials for STEM and EELS). The samples were also cleaned and polished to eliminate artifacts that might impact image resolution.

The work was supported by the Center for Excitonics, an Energy Frontier Research Center funded by the DOE's Office of Science. The work at CFN was also supported by the Office of Science, with additional work performed at the MIT Center for Materials Science Engineering. ■

www.bnl.gov/cfn

www.rle.mit.edu/excitonics

http://apl.aip.org/resource/1/applab/v102/i19/p191910_s1

Strain engineering improves light output from green LEDs

Research in China shows how a shallow quantum well step boosts optical output power in green LEDs by 28.9% at a current of 150mA.

Researchers in China have used strain engineering to improve the light output power of 530nm green light-emitting diodes (LEDs) by 28.9% at 150mA current injection [Hongjian Li et al, Appl. Phys. Express, vol6, p052102, 2013]. The research was carried out by Chinese Academy of Sciences' Institute of Semiconductors, Beijing, and University of Hong Kong.

Green-emitting nitride semiconductor LED structures tend to suffer from low light output due to the difficulty in producing the high-indium-content indium gallium nitride (InGaN) needed for longer-wavelength light emission. Apart from the material quality challenge, strain induced by the lattice mismatch with pure GaN leads to large piezoelectric effects, giving electric fields that tend to pull electrons and holes apart, reducing rates of recombination into photons (i.e. the quantum-confined Stark effect, or QCSE).

The Chinese team tackled the problem by inserting a layer of lower-indium-content InGaN before the high-In-content light-emitting layer. Simulations were carried out first, suggesting that such a layer could reduce the strain-dependent electric fields in the active light-emitting multiple quantum well (MQW) structure.

Epitaxial material with a low-In-content InGaN shallow quantum well (SQW) step was realized using metal-organic chemical vapor deposition (MOCVD) on c-plane (0001) sapphire (Figure 1). Conventional device structures were also produced. The conventional multi-quantum well (MQW) active region consisted of

Contact	p-GaN	200nm
Electron blocker	p-AlGaIn	20nm
Active	MQW	
Contact	n-GaN	2μm
Buffer	Undoped GaN	2μm
Nucleation	Low-temperature GaN	30nm
Substrate	Sapphire (0001) plane	

Figure 1. Schematic of epitaxial material for conventional and shallow quantum well (SQW) LEDs.

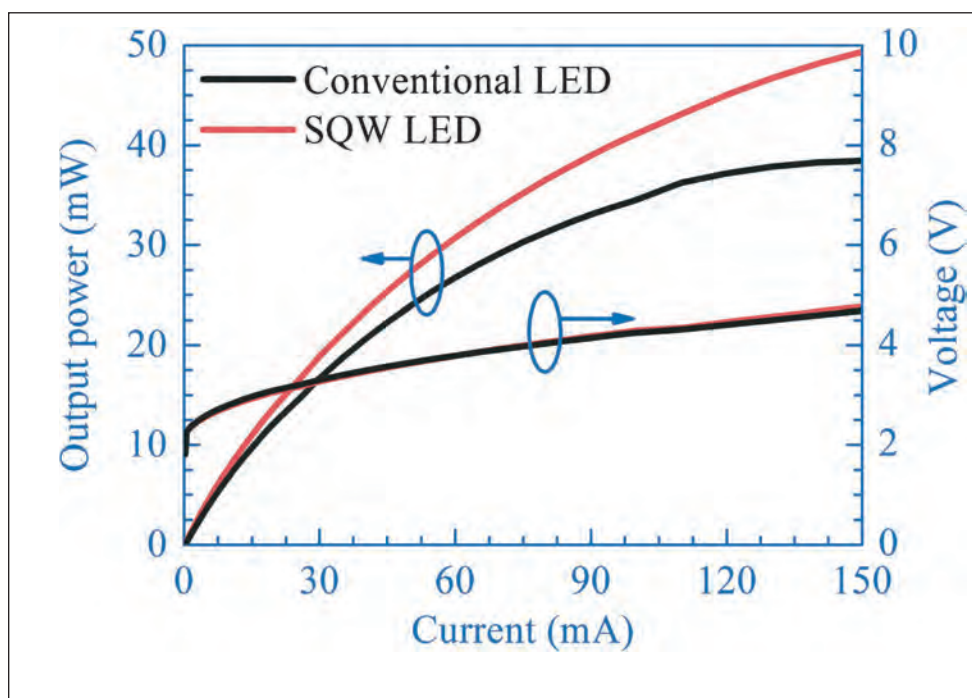


Figure 2. Light output power-current-voltage (L-I-V) characteristics of conventional LED and SQW LED.

12 periods of 3nm $\text{In}_{0.3}\text{Ga}_{0.7}\text{N}$ wells between 12nm GaN barriers. The SQW structure consisted of 12 periods of a 2nm $\text{In}_{0.1}\text{Ga}_{0.9}\text{N}$ shallow well and a 3nm $\text{In}_{0.3}\text{Ga}_{0.7}\text{N}$ deeper well between 12nm GaN barriers. These materials were then fabricated into $256\mu\text{m} \times 300\mu\text{m}$ mesa-structure LED chips.

A 325nm helium-cadmium laser was used to excite the photoluminescence spectra of the materials at low temperature (85K) and room temperature (298K). One effect of the SQW was to reduce the width of the spectral peak full-width at half maximum (FWHM) at 85K from 16.7nm for the conventional LED material to 13.1nm for the SQW material. The 298K measurement reduced the conventional FWHM of 20.1nm to 15.7nm.

The peak intensity was also higher with the SQW structure. These results are taken as indicating improved crystal quality for the SQW material. In particular, the narrow FWHM suggests "more uniform indium distribution and less carrier localization within the active region" due to lower stress in the active region.

The peak height for the SQW material at 298K was 55.1% that at 85K. The corresponding ratio for the conventional structure was 24.1%. The higher ratio for the SQW material indicates a higher rate of radiative recombination and higher internal quantum efficiency (IQE) due to a smaller QCSE.

The electroluminescence was measured in an integrating sphere, giving light output power–current–voltage (L–I–V) results (Figure 2). The voltage performance is similar in the SQW and conventional devices. However, the light output at 150mA is 28.9% greater in the SQW

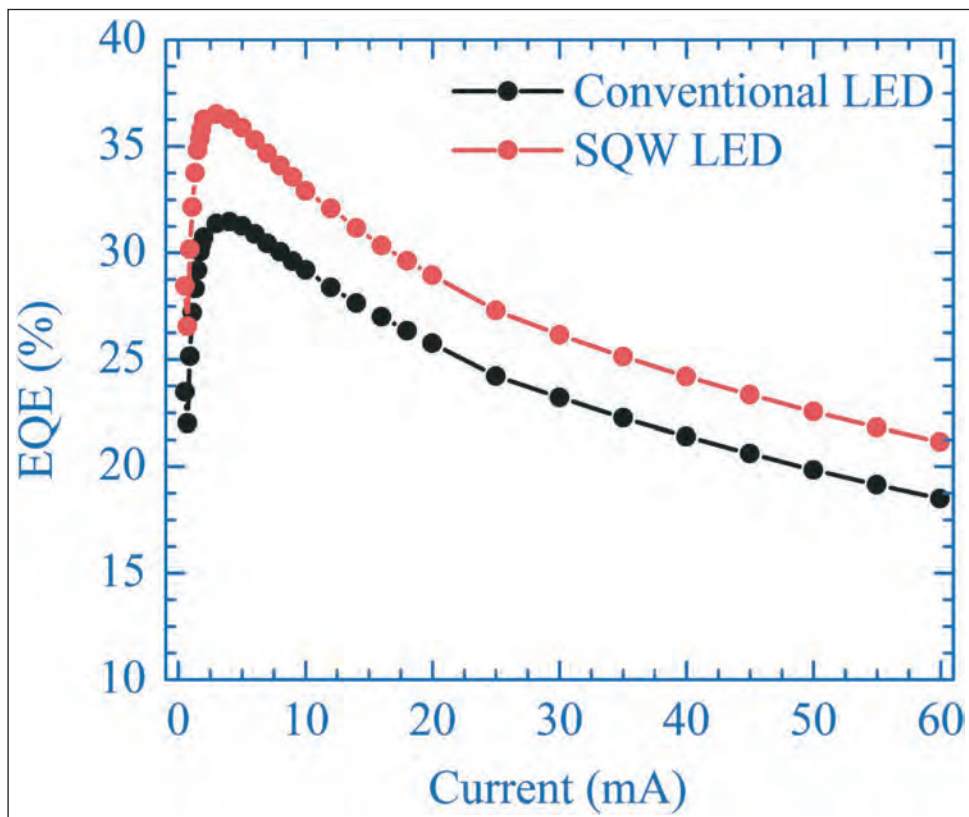


Figure 3. EQE versus current characteristics of conventional LED and SQW LED.

LED (49.3mW) over the conventional device (38.4mW).

The researchers attribute the enhanced results for the SQW LED to improved overlap of the electron and hole wavefunctions in the device, leading to improved recombination into photons. The performance is not enhanced to the same extent as for photoluminescence because the biasing in electroluminescence increases the polarization fields.

The external quantum efficiency (EQE) is increased 10.2–13.3% over the conventional LED performance (Figure 3). ■

<http://apex.jsap.jp/link?APEX/6/052102>

Author: Mike Cooke

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Putting coats on ZnO nanorods for improved light extraction from GaN LEDs

The graded-refractive-index effect has been improved by coating zinc oxide nanorods with silicon dioxide.

Gwangju Institute of Science and Technology and Samsung Electronics Co Ltd of South Korea have developed a zinc oxide (ZnO) nanorod (NR) process for improving light extraction from gallium nitride (GaN) light-emitting diodes (LEDs) by up to 21% [Chu-Young Cho et al, Appl. Phys. Express, vol6, p042102, 2013].

Light extraction is a problem for GaN-based LEDs because the refractive index of GaN is 2.5, creating a large contrast with that of air (1). The large difference means that light striking a GaN-air interface will be 'Fresnel reflected' unless its angle with the normal is less than $\sim 24^\circ$.

The Gwangju/Samsung team has developed a process that grows ZnO NRs on indium tin oxide (ITO), a material commonly used as a transparent conductive layer (TCL) for the p-electrode of GaN LEDs.

The blue LED structure (Figure 1) was designed to emit at a wavelength of 470nm. The epitaxial material was grown on patterned c-plane sapphire using metal-organic chemical vapor deposition (MOCVD). The patterning consisted of periodic lenses with $3\mu\text{m}$ diameter and $4\mu\text{m}$ spacing and $1.5\mu\text{m}$ height. Patterning of sapphire can improve the crystal structure

of epitaxial nitride semiconductor material.

The nitride layer sequence consisted of 25nm GaN nucleation (550°C), $2\mu\text{m}$ n-GaN buffer/contact (1010°C), 5-period 750°C InGaN (3nm) multi-quantum well (MQW) with GaN barriers (12nm), and a 200nm p-GaN contact (980°C).

The $300\mu\text{m} \times 300\mu\text{m}$ LEDs were constructed using inductively coupled plasma (ICP) mesa etch to expose the n-contact layer, deposition of 150nm of indium tin oxide (ITO) as transparent conductive electrode, and deposition of chromium/gold as n-electrode and p-electrode metals.

The ZnO nanorods were seeded by radio-frequency magnetron sputtering a few nanometers of ZnO as a seed layer onto selectively exposed areas of the ITO. The main nanorod growth was carried out by dipping in zinc nitrate hexahydrate ($\text{ZnO}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$) and hexamethylenetetramine ($\text{C}_6\text{H}_{12}\text{N}_4$) in aqueous solution. The 40nm silicon dioxide (SiO_2) coating of the nanorods was achieved through plasma-enhanced chemical vapor deposition (PECVD).

Electron microscopy gave the diameter and height of the nanorods without SiO_2 as being $\sim 50\text{nm}$ and $\sim 150\text{nm}$, respectively. With SiO_2 coating, these values

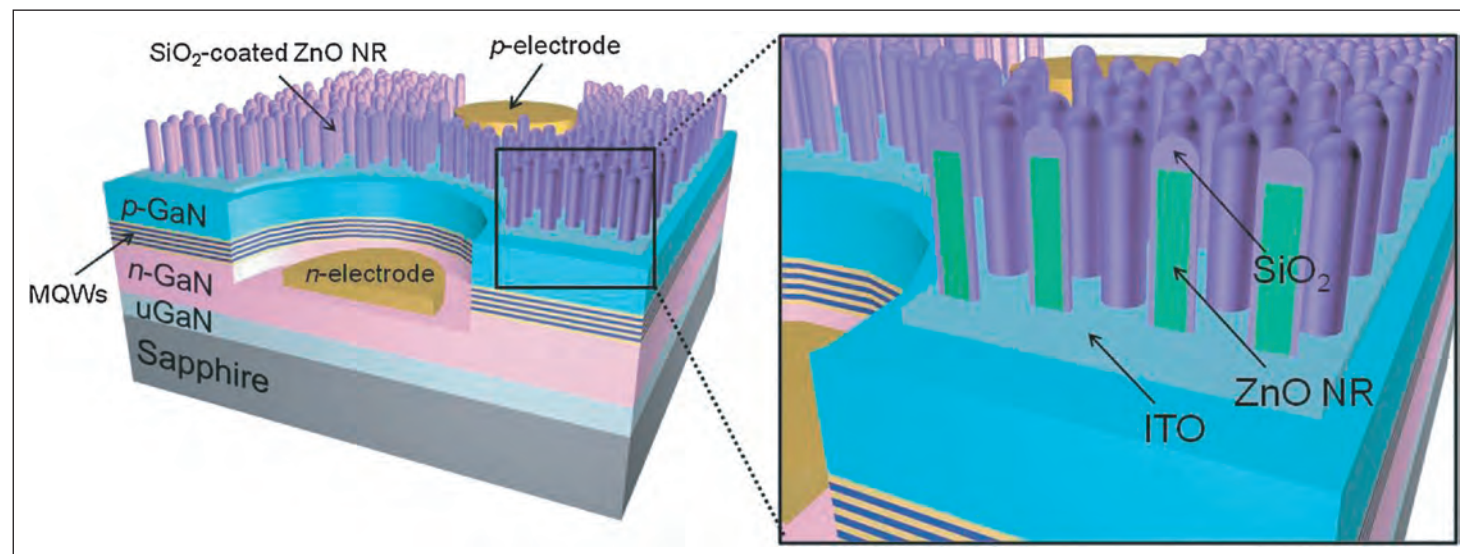


Figure 1. Schematic diagram of blue LEDs with SiO_2 -coated ZnO NRs on ITO TCL.

increased to ~70nm and ~185nm, respectively. The diameters varied about 20nm each way, and the heights around 10nm.

The ZnO nanorods have a refractive index of 2.08; that of the SiO₂ coating is 1.55. The index of ITO is around 2.

Transmittance tests were carried out with ITO/ZnO nanorod structures on glass. At 470nm wavelength, the transmittance without nanorods was 85%. Adding bare nanorods increased this to 90%, and with a SiO₂ coating 93% of the light was transmitted.

The current-voltage behaviors of LEDs with and without nanorods/coating were very similar. The electroluminescence peak blue-shifts from 472nm to 469nm between 20mA and 100mA current injection

(Figure 2). The peak shift is attributed to the "screening effect of the polarization-induced electric field by carriers and to the band-filling effect of the localized energy states formed by the potential fluctuations in MQWs".

At 20mA, the effect of ZnO nanorods on optical output power was measured as a 15% increase over that of an LED with bare ITO TCL. For the SiO₂-coated ZnO nanorods, the improvement was 21% over bare ITO. The percentage increase for SiO₂-coated nanorods over bare nanorods was 5% (1.21/1.15-1).

The researchers explain the increased output power with ZnO nanorods as being due to the sub-wavelength surface roughness providing an effective graded refractive index between the ITO layer and air. The SiO₂ coating provides a further reduction of the Fresnel reflection effect. ■

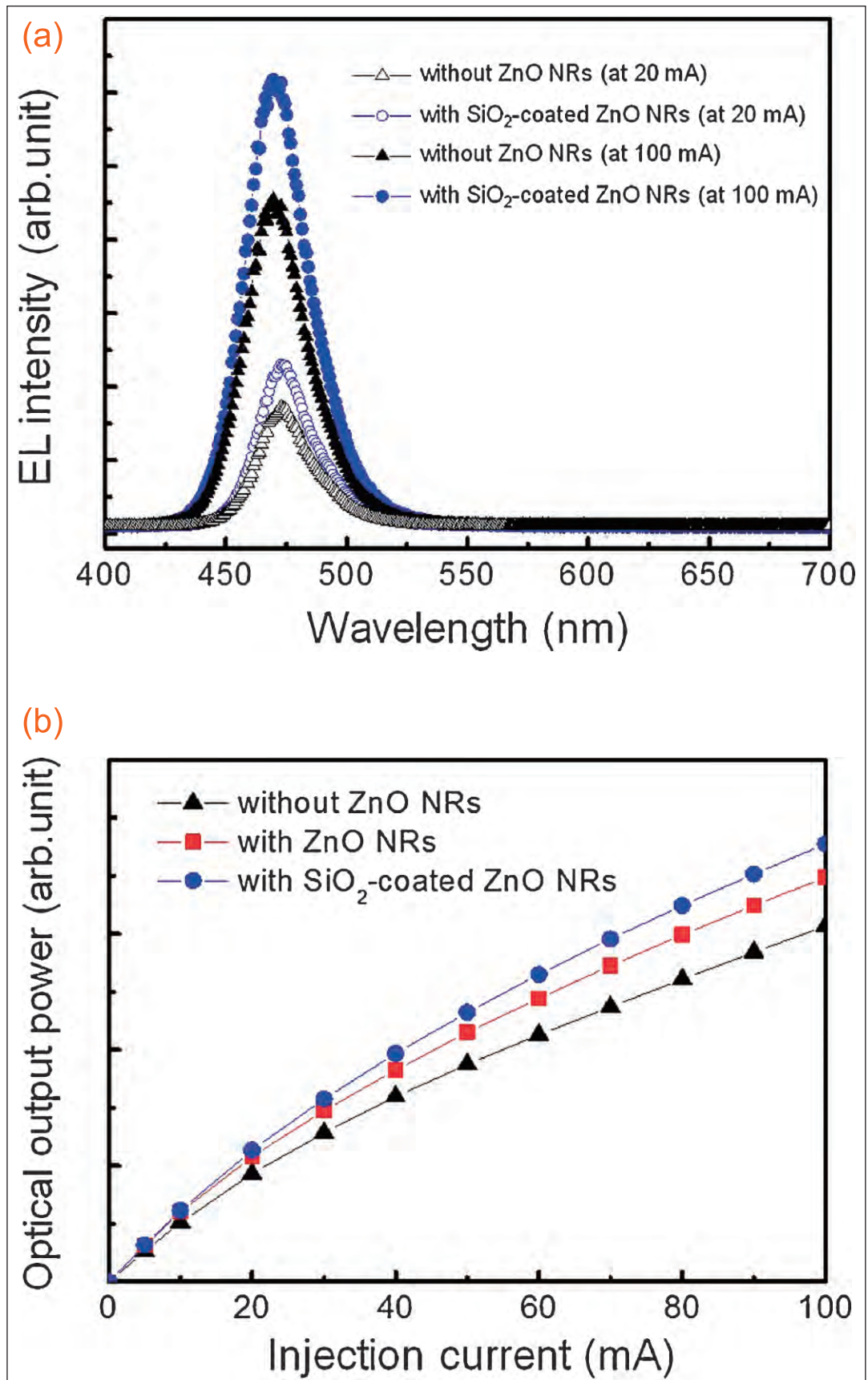


Figure 2. (a) Room-temperature electroluminescence spectra of blue LEDs with and without SiO₂-coated ZnO NRs on ITO TCL at injection currents of 20mA and 100mA. **(b)** Optical output power of LEDs as a function of injection current.

<http://apex.jsap.jp/link?APEX/6/042102>

Author: Mike Cooke

Lowering tunneling resistance in GaN/InGaN/GaN structures

Polarization engineering has yielded the lowest ever reported specific resistivity of $1.2 \times 10^{-4} \Omega\text{-cm}^2$.

Ohio State University (OSU) has used polarization engineering to create low-resistance tunnel junctions in gallium nitride (GaN)-based structures [Sriram Krishnamoorthy et al, Appl. Phys. Lett., vol102, p113503, 2013]. Such junctions could be used to improve hole injection into light-emitting structures.

Normally, nitride semiconductor hole injection is achieved by creating p-type regions with magnesium-doping (Mg). Unfortunately, the Mg acceptor level is in the range 140–210 meV above the valence band, meaning that the dopant concentration has to be high to achieve reasonable hole concentrations at room temperature (300K ~ 26 meV).

By contrast, the silicon donor level for n-type doping is in the range 12–20 meV below the conduction band. This makes low-resistance n-type conducting GaN relatively easy to achieve. In addition, even without doping, GaN has n-type characteristics due, it is thought, to electrons associated with nitrogen vacancies.

Tunnel junctions can be used to convert electrons from n-type regions into holes in thin p-type regions, improving injection into undoped active light-emitting

regions. Without such structures, using a thick (200 nm) p-GaN region as a hole source creates a relatively high-resistance volume of material and this tends to impede current spreading from metal electrodes.

Non-uniform current injection into light-emitting regions tends to reduce the power efficiency of electron-hole recombination into photons. On the other hand, increasing the metal electrode area to spread the current more evenly blocks light from emerging from the devices, lowering light extraction efficiency.

With tunnel junctions, the current could be spread more evenly in relatively low-resistance n-type regions and then converted to holes before injection into light-emitting structures.

Another possible application is producing devices where the p-injection region is under the n-type region. Presently, the p-region is grown last because of the difficulties in manufacture. It is thought that reversed-polarization quantum well LEDs could benefit from improved carrier injection and confinement. Also, multi-junction solar cells generally use tunnel junctions to connect different subcells in series.

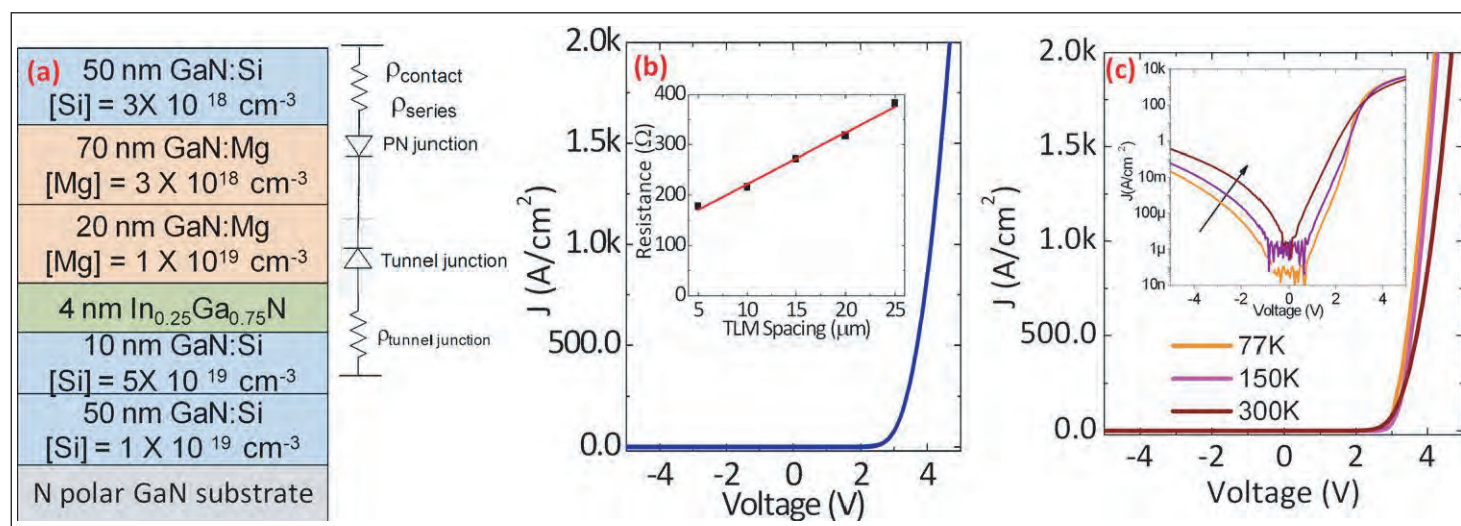


Figure 1. (a) Epitaxial stack of GaN p-n junction with GaN/InGaN/GaN tunneling contact layer to p-GaN. Circuit model shows two back-to-back diodes and various resistance components. (b) Characteristics of p-contactless p-n junction device showing negligible additional voltage drop across tunnel junction. Inset: resistance across transmission-line method pads with different spacing, used to extract specific top contact resistivity. (c) Temperature-dependent current-voltage (I-V) characteristics of device, showing efficient hole tunnel injection even at low temperatures. Inset: temperature-dependent I-V characteristics of device on logarithmic scale.

Of course, this all depends on achieving tunnel junctions with relatively low resistance. The large bandgap of indium aluminium gallium nitride (InAlGaN) semiconductor materials would suggest low tunneling probabilities and high resistivity. However, these materials also have large spontaneous and strain-dependent (piezoelectric) electric polarizations that can lead to high electric fields in heterostructures.

OSU believes that these fields can be used to align the conduction and valence bands on opposite sides of a tunnel junction. The researchers carried out a number of theoretical investigations to provide guidelines for constructing junctions with high tunneling probability and low resistance.

A polarization-induced tunnel junction was then produced using nitrogen-plasma-assisted molecular beam epitaxy (PA-MBE) on nitrogen-face freestanding GaN templates (Figure 1a). The structure consisted of a pn junction with a tunnel junction feeding holes into the p-side. The $50\mu\text{m} \times 50\mu\text{m}$ test device was created with titanium/gold ohmic metallization on the top n-contact, mesa isolation, and finally evaporation of metal on the bottom n-contact.

The structure demonstrated rectifying behavior (Figure 1b). The linear region of the forward bias region gives a series specific resistivity fit of $4.7 \times 10^{-4} \Omega\text{-cm}^2$. The researchers estimate that the contribution of the top n-contact resistance was $3.5 \times 10^{-4} \Omega\text{-cm}^2$, providing an upper limit on the specific resistivity of the tunnel junction of $1.2 \times 10^{-4} \Omega\text{-cm}^2$. This is claimed as “the lowest observed resistance for a III-nitride tunnel junction”.

For a $100\text{mA}/\text{cm}^2$ current injection, the voltage drop across the pn junction is estimated at 3.05V and across the tunnel junction 12mV.

Temperature-dependent measurements show reduced current leakage under reverse bias at low temperature (Figure 1c). In addition, the forward current is maintained at the lower temperature of 77K. For a traditional nitride semiconductor pn junction one would expect the resistivity under forward bias to increase as the holes in the p-type region are frozen out of the system.

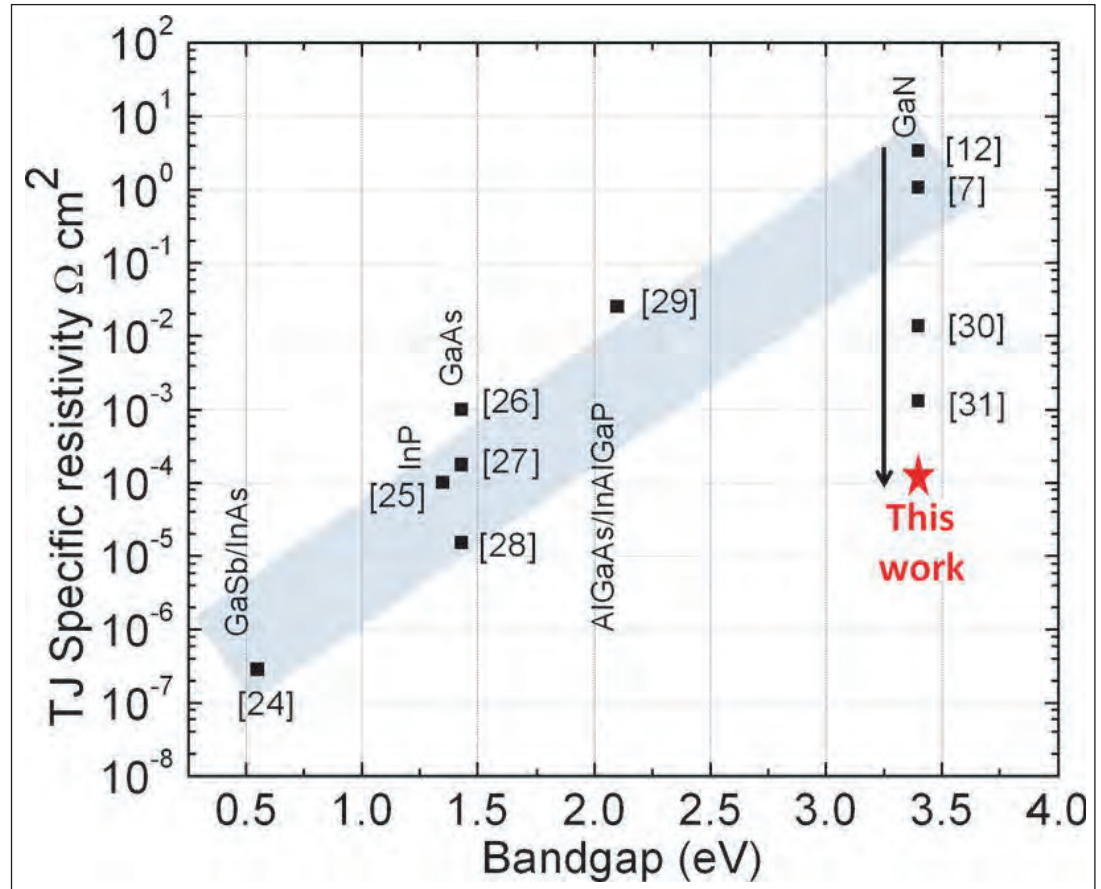


Figure 2. Tunnel junction resistivity in different material systems. OSU's structure demonstrates the lowest tunneling resistivity so far for GaN-based structure.

The researchers compared their results with a number of others in nitride and non-nitride material systems (Figure 2). They comment: “Although this device demonstration was performed on N-face orientation with the p-type layer down structure, similar characteristics would be obtained from a Ga-face n-GaN/InGaP tunnel junction on a +c-plane-oriented p-up p-n junction or LED structure. This implies that the low-resistance tunnel junctions demonstrated in this work can be directly extended to commercial c-plane LEDs.”

However, there remain some challenges such as activation of the buried p-type layer, particularly for devices grown using commercial metal-organic chemical vapor deposition (MOCVD). The researchers suggest activation through etched mesa sidewalls as a possible approach. Photon absorption losses in narrower-bandgap InGaP layers are also a concern for the demonstrated structure.

The researchers also believe that the polarization engineering of tunnel junctions could be applied to magnesium/zinc oxide devices, where p-type doping has been even more difficult to achieve than in nitride semiconductors.

The researchers received funding from US Office of Naval Research (ONR) under the DATE MURI program and the US National Science Foundation (NSF). ■

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Author: Mike Cooke

EU-supported €11.8m NEWLED project to 'revolutionize' LED lighting

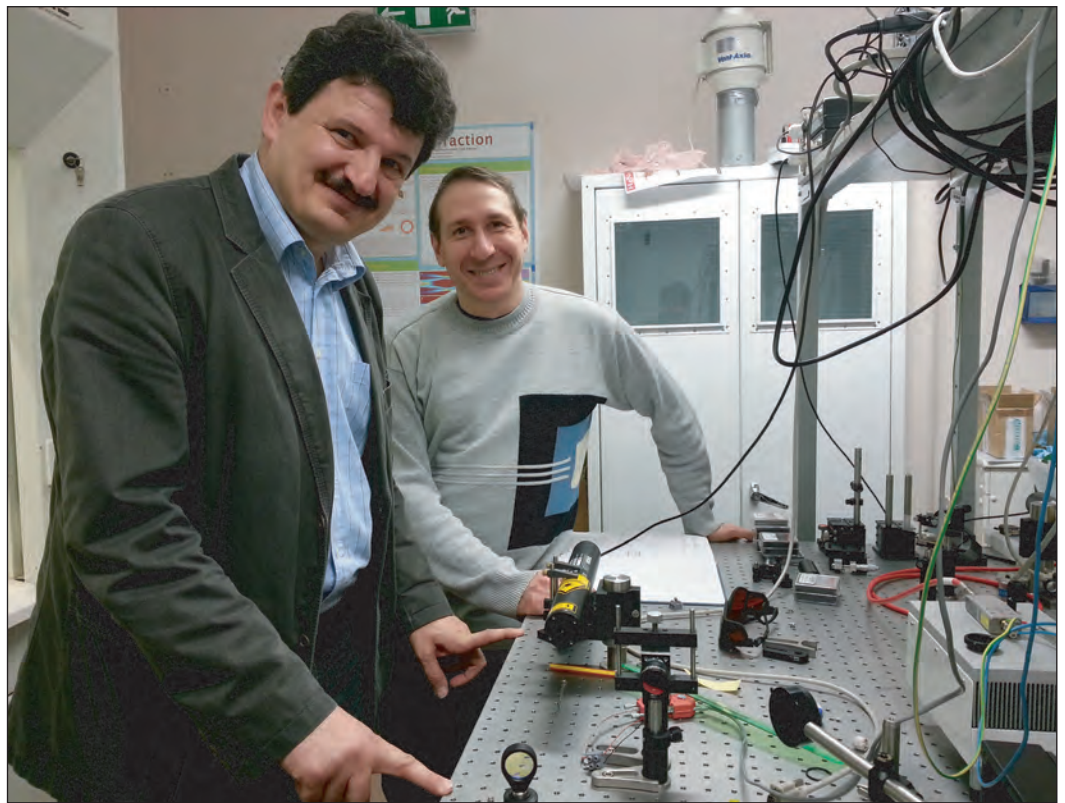
European R&D is to boost the efficiency of yellow InGaAlP/AlGaAs LEDs for monolithic and hybrid white lighting by using bandgap-engineered superlattices.

The €11.8m pan-European project NEWLED ('Nanostructured Efficient White LEDs based on short-period superlattices and quantum dots') is aiming to develop a new generation of 50–60% energy-efficient white light-emitting LED lights, which would be more than twice as efficient as existing LED-based bulbs. The project leaders, based at the University of Dundee in Scotland, say that the higher-efficiency white-light LEDs, if widely implemented, could have a significant effect on reducing global energy consumption and CO2 emissions.

The European-wide research project is focused on achieving high-efficiency and high-brightness monolithic and hybrid all-semiconductor white light-emitting gallium nitride (GaN)-based diodes. The NEWLED project brings together a wide range of academic and industrial partners and is funded through the European Union's FP7 program (see partners below).

"Common light bulbs have a pretty low efficiency rating and even the best current white LEDs in use only have an overall efficiency of around 25%," commented NEWLED project leader professor Edik Rafailov, who is based in the School of Engineering, Physics & Mathematics at Dundee.

"What we are aiming to develop is a significantly more efficient white LED, which would be around 50–60% efficient. If we can achieve that and they subsequently become widely adopted, then the effects



Professor Edik Rafailov, leader of the Newled project.

on overall energy consumption would be enormous. Such LEDs would also enable lighting over which much more control could be exercised in brightness and tone."

Power losses due to phosphor conversion and the problem of different ageing rates of the GaN LED pump will be eliminated by the development of phosphor-free structures with increased brightness (power emitted per surface per angle). NEWLED aims to enhance the efficiency of yellow InGaAlP/AlGaAs LEDs by using a bandgap-engineered superlattice design.

Novel light extraction approaches will target advanced directionality and colour adjustment. Values of 50–60% overall efficiency with a conversion of greater than 200lm/W in the exploited warm white LEDs are targeted as well as the realization of a colour rendering

index (CRI) of greater than 95.

Advanced packaging will enable effective heat dissipation and light management. The devices can have immediate applications in automotive, industrial lighting and displays industries. Widespread implementation could reduce global energy consumption by about 10% and reduce CO2 emissions by 3bn tones, with consequent economic and environmental benefits, it is reckoned.

The effort to produce highly efficient white LEDs will see the project examine each stage of the LED fabrication process, from developing new knowledge on the control of semiconductor properties on a near-atomistic level to light mixing and heat management.

By examining the entire process, NEWLED aims to ensure that the LEDs will be well adjusted to avoid compromising the achievements of the overall process and to ensure significant system and operating cost reduction.

Project details

The NEWLEDs project started in November and runs for four years until end-October 2016. The budget is €11.8m, with funding of €8.4m already committed from the EU's FP7 Seventh Framework Programme.

Besides Dundee, the 13 other participants are: Universita Degli Studi Di Roma Tor Vergata in Rome, Italy; Technische Universität Berlin and VI Systems of Berlin, Germany; Top-Gan of Warsaw, Poland; CNRS in Paris, France; M-Squared Lasers Ltd and Compound Semiconductor Technologies Global Ltd in Glasgow, UK; Osram Opto Semiconductors of Regensburg, Germany; Vilnius University in Lithuania; IOFFE Physico-Technical Institute of the Russian Academy of Sciences in St Petersburg; Lux-TSI Ltd in Pencoe Technology Park, UK; and the Optoelectronics Research Centre of Tampere, Finland.

www.dundee.ac.uk/elecengphysics/research/photronics/photonicnanoscience

By Matthew Peach, Contributing Editor

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Atomic-layer prospects for compound semi devices

Researchers are seeking to use ALD advantages such as uniformity to enable better performance. **Mike Cooke** reports.

Although the principles of atomic-layer deposition have been known for some time, it is only recently that the technology has started to gain traction in production environments. Atomic-layer deposition/epitaxy (ALD/ALE) consists of sequences of pulsed precursors to build up thin films a monolayer at a time. At present, the main applications in microelectronics are for dielectric deposition (gate insulation and DRAM capacitors), transition metal nitrides, and metal films in mainstream silicon semiconductor and hard drive production.

Although there are reports from time to time of ALD of semiconductor structures such as gallium nitride quantum wells in aluminium gallium nitride barriers, the most recent uses of ALD in compound semiconductor devices are mainly of dielectric deposition for various applications. This is due to the more extensive development of these processes having already been carried out for silicon semiconductor production.

The advantages of ALD include uniformity of the layers and the atomic-level control of the resulting material structure. However, these advantages are gained at the cost of relatively slow growth rates. The growth rate depends on how fast the system can cycle through the various pulsed process steps. As one would expect from these features of ALD, the best potential for applications comes where thin but precise layers of material are needed to achieve desired properties.

While most of the present work is being carried out in the universities, some companies are also involved. In addition, the US Navy issued a call for proposals for a Small Business Innovation Research (SBIR) on 'Atomic Layer Deposition Technology for Gallium Nitride Microwave Monolithic Integrated Circuits' in December 2011 (closed in January 2012).

The aim was to develop an ALD silicon nitride (SiN) process with requirements for the resulting thin-film to be conformal, uniform, void- and pinhole-free, dense, and with no embedded traps. Further the process temperature should not exceed 300°C. The desired process would also be cost and processing time competitive compared with present plasma-enhanced chemical vapor deposition (PECVD).

In May 2012, Sundew Technologies was awarded a Phase I contract for this work. It produces ALD systems, claiming record throughput and uptime for its equipment.

Nitride HEMT passivation

In fact, many researchers prefer to use ALD to apply aluminium oxide (Al_2O_3). For example, researchers in the USA from BAE Systems and Purdue University have developed Al_2O_3 ALD as passivation for nitride semiconductor high electron mobility transistors (HEMTs) [Dong Xu et al, Electron Device Letters, published online 22 April 2013].

Nitride HEMTs allow higher-power-density and higher-efficiency amplification at high frequency. However, current collapse with pulsed signals needs to be dealt with. One technique is to add field plates that can manipulate electric fields in nitride semiconductor transistors, reducing the effect of interface traps. However, these field plates add parasitic capacitance that negatively impacts frequency and gain performance.

Another approach is to tackle the dangling bonds that create interface traps through passivation layers.

The epitaxial structure for the BAE/Purdue HEMTs was realized using metal-organic chemical vapor deposition (MOCVD) on semi-insulating silicon carbide substrates. Aluminium nitride (AlN) was used as a nucleation layer. Part of the gallium nitride (GaN) buffer was iron doped to give a semi-insulating layer below the undoped GaN buffer. The structure was completed with undoped AlGaN barrier and 2nm GaN cap.

Before the transistor formation the wafers were cleaned in acetone, methanol and isopropanol to remove organic residues and in ammonia solution to strip surface oxide layers. The Al_2O_3 layer was applied in an ASM F-120 ALD system.

The process sequence included ramp-up to 300°C and oxide self-cleaning with trimethyl aluminium (TMA). The Al_2O_3 passivation layer was built up by alternating pulses of TMA and water (H_2O) precursors in nitrogen carrier gas. The growth rate was 0.86Å/cycle.

One aim of the cleaning steps was to unpin the Fermi level by removing oxides on the epitaxial structure that can form trap states at the interface with the gate. The researchers estimate the as-grown interface trap density for their Al_2O_3 /GaN cap at between $10^{11}/\text{cm}^2\text{-eV}$ and $10^{12}/\text{cm}^2\text{-eV}$. This can be reduced to less than $10^{11}/\text{cm}^2\text{-eV}$ by a post-deposition anneal.

Comparison wafers were also produced with a more conventional silicon nitride (SiN) passivation applied with PECVD (250°C) and ammonia plasma pre-treatment.

The passivated material was used to create 200nm-long T-gate HEMTs with mesa isolation achieved using inductively coupled plasma etch. The ohmic source-drain contacts consisted of annealed titanium/aluminium/gold.

One effect of the Al_2O_3 layer was to reduce parasitic resistance due to the improved interface between passivation and GaN cap. This increased the 10V-drain-bias maximum drain current and extrinsic peak transconductance by 10% and 8%, respectively, over the values for SiN passivation. In addition, the subthreshold drain current was reduced by an order of magnitude in the Al_2O_3 device.

The subthreshold current was attributed to gate leakage, which in the Al_2O_3 device was reduced due to the improved interface leading to better performance of the Schottky gate under reverse bias.

Performance under current pulses with 200ns width and 2ms separation was tested at different quiescent points (Figure 1). With the quiescent gate and drain bias at 0V, the maximum drain current was 10% better in the Al_2O_3 device. A 'deep' quiescent point of -5V gate and 30V drain gave an even better maximum drain current performance boost of 20% to the Al_2O_3 -passivated HEMT. The pulsed performance is also more uniform across the 3-inch wafers that contain the Al_2O_3 HEMTs: the maximum current standard deviation was 11mA/mm at the zero quiescent point and 20mA/mm for the deep quiescent point, compared with 49mA/mm and 54mA/mm, respectively, for the SiN-passivated HEMT.

The researchers comment: "The improved uniformity and consistency of pulsed-IV performance with the use of an ALD Al_2O_3 passivation layer would certainly contribute to higher yield of MMIC's based on these devices, making it a more manufacturing friendly technology."

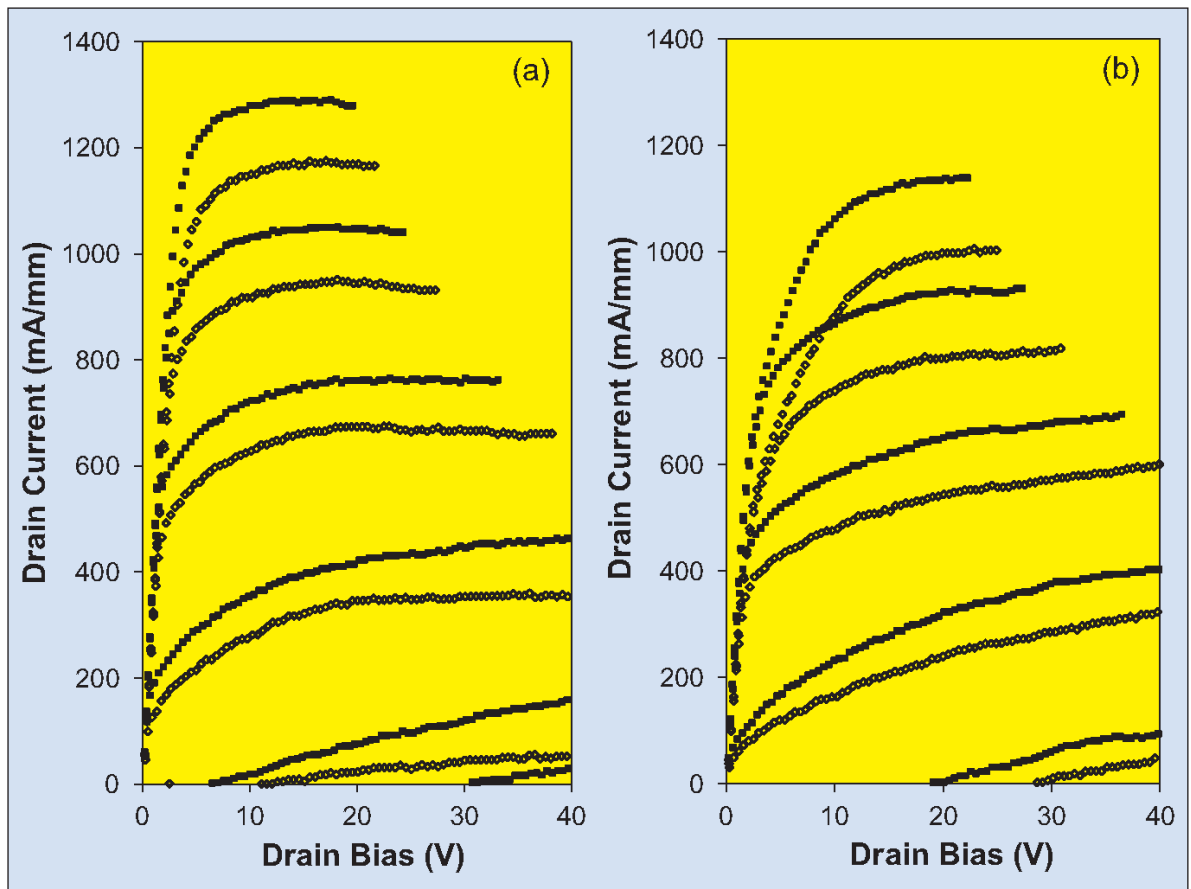


Figure 1. Pulsed current-voltage (IV) characteristics for 200nm long T-gate GaN HEMTs with PECVD SiN (open symbols) and ALD Al_2O_3 passivation (solid symbols). Devices were measured at quiescent points of (a) 0V gate and drain and (b) -5V gate and 30V drain. The gate for the top curves was 1V, and the others represent -1V steps.

The frequency performance of the two device types was similar, with a cut-off frequency (f_T) of 54–55GHz and maximum oscillation (f_{max}) of 117–120GHz at 20V drain. However, the 10GHz continuous wave (CW) power performance (Figure 2) at 20V drain of the Al_2O_3 device was 30% better in terms of maximum output (4.55W/mm vs. 3.5W/mm). Also, the power-added efficiency (PAE) was better by about 8%. Increasing the drain bias to 25V slightly reduced the enhancement to 27% for maximum power output and 5% for PAE.

Researchers from Purdue have also worked with Harvard university, using atomic layer epitaxy (ALE) to develop gallium arsenide (GaAs) enhancement-mode (E-mode) surface/n-channel metal-organic-semiconductor field-effect transistors (NMOSFETs) with a maximum drain current of 336mA/mm, claimed to be a record high for such devices [L. Dong et al, IEEE Electron Device Letters, published online 7 March 2013; reported by Mike Cooke, Semiconductor Today, April/May, p94, 2013]. ALE and annealing of the gate dielectric reduced the density of interface traps that again kill performance by collecting charge. The charge shields the gate, reducing its electrostatic effectiveness.

The ALE dielectric stack consisted of 7.5nm lanthanum yttrium oxide ($\text{La}_{1.8}\text{Y}_{0.2}\text{O}_3$) and 6.5nm aluminium oxide

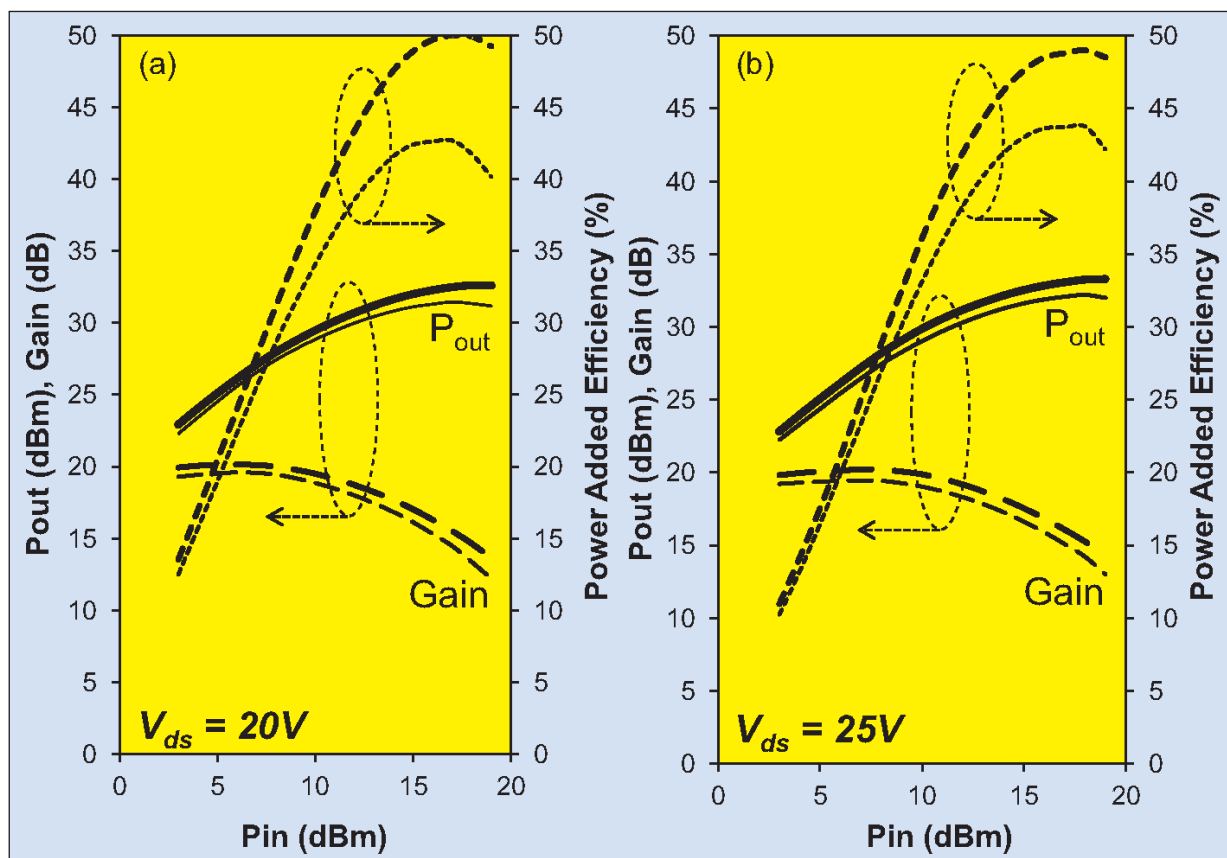


Figure 2. Output power, associated power gain, and power-added efficiency as a function of drive power for 200nm 4x100μm HEMTs passivated with PECVD SiN (thin lines) and ALD Al₂O₃ (thick lines) at 10GHz. Devices were biased at drain current of 200mA/mm and drain voltage of (a) 20V and (b) 25V.

(Al₂O₃). The Al₂O₃ was used to protect the lower dielectric layer from reacting with water molecules from the air and from the following process steps. The equivalent oxide thickness of the structure was around 4.5nm.

The researchers believe that the high quality of their novel La_{1.8}Y_{0.2}O₃ epitaxial interface passivates dangling bonds on the GaAs surface, reducing the number of interface traps.

Another collaboration using ALD to enhance arsenide transistor performance involved GLOBALFOUNDRIES, SEMATECH, and Massachusetts Institute of Technology (MIT) [Dae-Hyun Kim et al, IEEE Electron Device Letters, published online 4 January 2013; reported by Mike Cooke, Semiconductor Today March, p92, 2013].

In this case, ALD of 3nm Al₂O₃ gate insulator enabled indium arsenide quantum well metal-oxide-semiconductor field-effect transistor (InAs QW MOSFET) technology to achieve some of the highest and most balanced frequency performance values seen yet. Many of the improvements were attributed to the dramatically higher quality interface between dielectrics and III-V semiconductors enabled by ALD.

The gate leakage was suppressed by the Al₂O₃ insulation to less than 1nA/μm at all measured biases. This is a factor of 10⁵ better than the forward bias values typical of III-V high-electron-mobility transistors

(HEMTs) that depend on metal-semiconductor Schottky barriers to isolate the gate electrode.

ALD of Al₂O₃ gate insulation was also used by another team at MIT as part of an etch stop technique to improve performance of recessed-gate nitride semiconductor metal-insulator-semiconductor field-effect transistors (MISFETs) [Bin Lu et al, IEEE Electron

Device Letters, published online 24 January 2013; reported by Mike Cooke,

Semiconductor Today March, p90, 2013].

Gallium-doped zinc oxide

Taiwan National Tsing Hua University has reported improved modulation performance of high output power nitride semiconductor light-emitting diodes (LEDs) by using an ALD Ga-doped ZnO (GZO) transparent conducting layer [Chien-Lan Liao et al, IEEE Electron Device Letters, published online 28 March 2013].

Up to now, most research effort for visible LEDs based on indium gallium nitride (InGaN) alloys has focused on extracting higher power efficiency for white light illumination and shorter-wavelength applications.

In principle, shorter-wavelength light should enable broader bandwidths for visible light over the normal infrared of fiber optical communication. With InGaN LEDs, high power output has generally resulted in poor modulation performance.

The Tsing Hua research resulted in an InGaN LED with 225.4MHz 3dB-modulation bandwidth at 35mA injection current and 1.6mW output power. Previously high output power resulted in modulation bandwidths of tens of MHz, although at lower output powers some groups have achieved 200–330MHz.

The researchers see their device as incorporating two key technologies: the GZO current spreader and a

smaller RC constant. The GZO transparent conducting oxide (TCO) layer creates a low contact resistance while also creating a uniform near-vertical current flow through the active light-emitting layers (Figure 3). The smaller RC constant is the result of employing smaller bonding pads and rapid thermal annealing to repair damage from plasma etch processes used in fabricating the device.

The Tsing Hua LED wafer was grown using MOCVD on sapphire (Figure 4). The undoped GaN buffer was 800nm, the n^+ -GaN contact/confinement 3000nm (3 μ m), the p-type aluminium gallium nitride (p-AlGaIn) confinement 20nm, p-GaN cap 560nm, and the n^+ -InGaIn contact 1.4nm. The multi-quantum well (MQW) light-emitting active region consisted of 5x 3nm InGaIn wells separated by 4x 14.4nm GaN barriers.

The final 250nm GZO layer was applied using ALD with diethylzinc, triethylgallium, and water vapor precursors.

The LEDs were fabricated with ring electrodes to avoid excessive lateral current spreading. The current confined aperture was 75 μ m with 80 μ m-diameter bonding pad. The chip dimensions were 400 μ m x 400 μ m.

The sapphire substrate was lapped and polished from 430 μ m down to 130 μ m to improve its thermal conductance. Sapphire has a high thermal resistivity, which can cause problems with thermal management. Reducing the heat transport distance across sapphire was aimed at tackling this.

The peak wavelength of the device was ~441nm, although there was some blue-shift to shorter wavelengths at high current injection due to energy level shifts in the MQW as electric fields are applied (quantum-confined Stark effect). The capacitance of the device under reverse bias was low at ~2pF on average. The capacitance of the bonding pad was also reduced by using relatively low dielectric constant silicon dioxide as insulator. The series resistance of the device was estimated at 28 Ω . The forward voltage at 20mA was 4.9V.

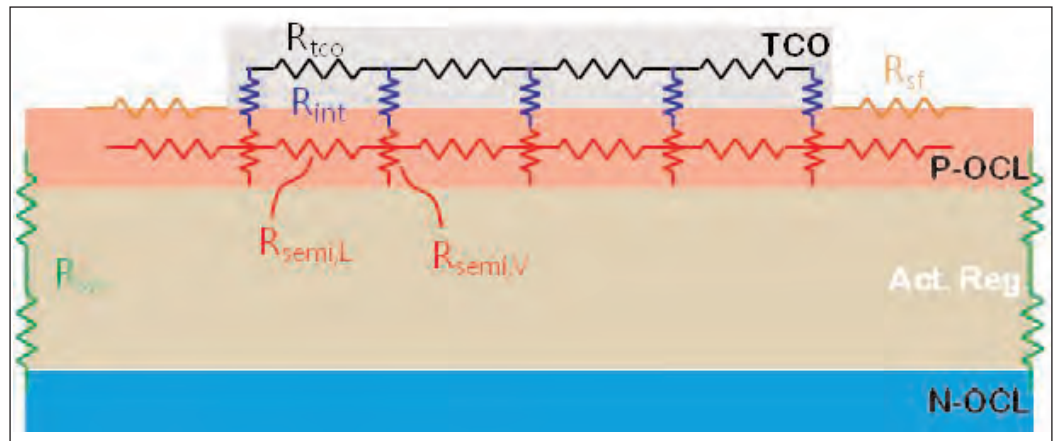


Figure 3. Resistivity optimization to create uniform near-vertical current flow through InGaIn LED. This is achieved by minimizing the resistance of the TCO (R_{tco}), interface with (R_{int}) and the vertical component in the cap ($R_{semi,V}$) of the ohmic contact layer (OCL), while maximizing the resistance of the surface (R_{sf}), MQW (R_{sw}) and lateral-component for the cap ($R_{semi,L}$).

The researchers performed light output power and modulation bandwidth measurements (Figure 5). At 35mA, the power reached 1.6mW. The modulation bandwidth was measured as a 3dB reduction in output power (f_{3dB}) compared with the DC performance (Figure 5 inset). The bandwidth increases with injection current level. At 35mA, a bandwidth of 225.4MHz was achieved.

The researchers believe that further optimization of the confined region would increase current density and hence the bandwidth. However there are trade-offs, since increased currents tend to heat devices reducing efficiency and there are also efficiency droop effects independent of self-heating (tested using pulsed operation).

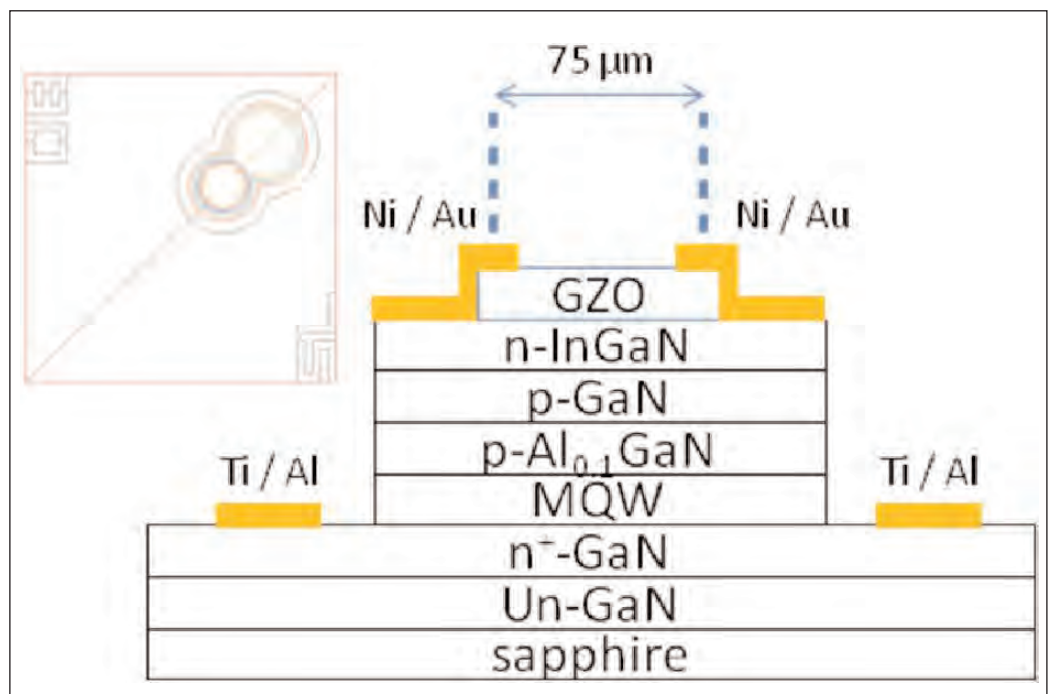


Figure 4. Epitaxial structure for blue high-speed LED. Inset: designed mask after overlapping with five steps.

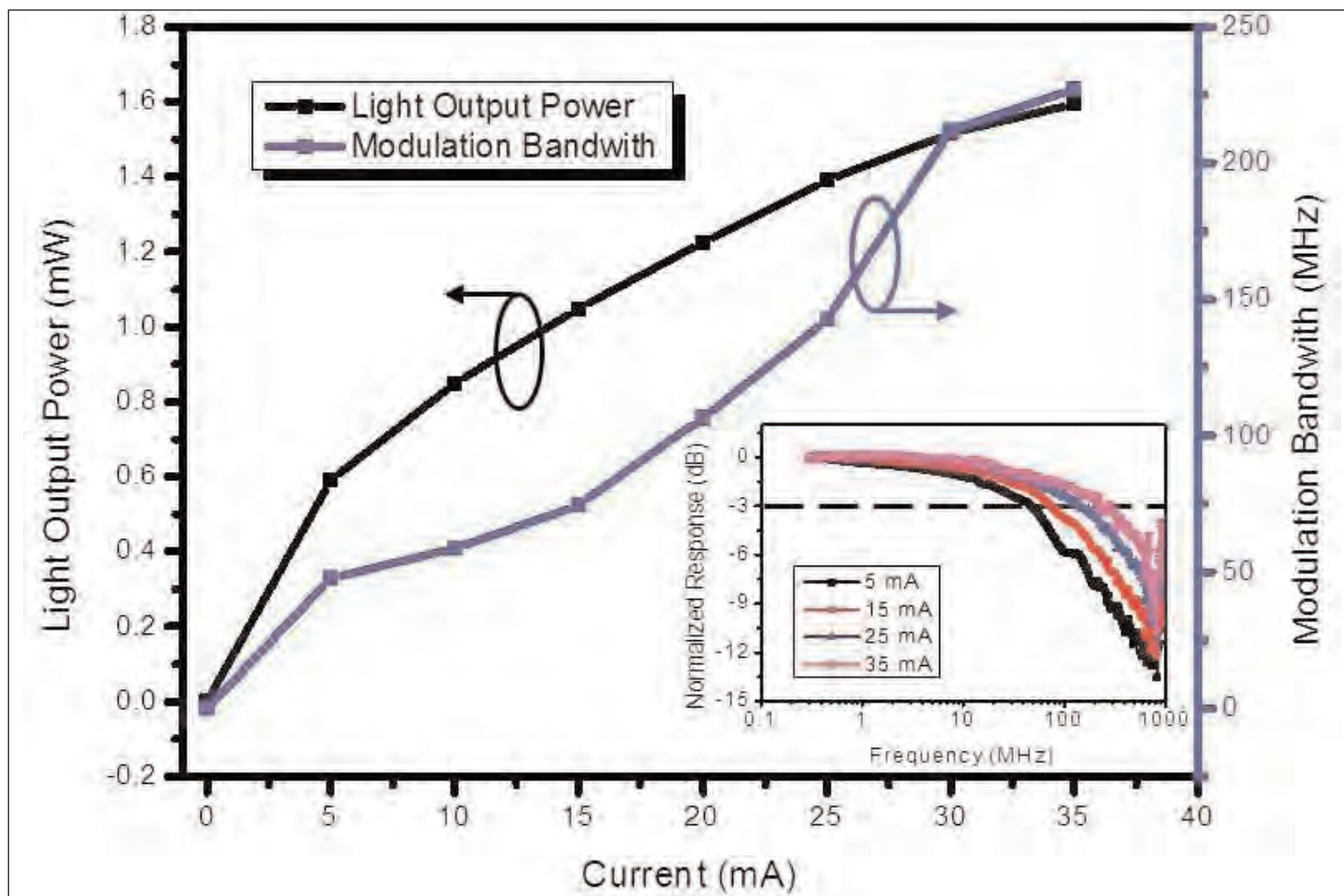


Figure 5. Light output power and 3dB frequency bandwidth (f_{3dB}) as function of forward current measured at 300K for 441nm high-speed LED. Inset: spectra of 3dB frequency bandwidth at various currents.

Efficiency droop has been ascribed to various causes such as Auger-type non-radiative recombination that kicks in at high current, polarization effects from the more ionic nature of the nitride semiconductor bond, and carriers overshooting the MQW light-emitting regions.

Finally, researchers in China have used ALD to create distributed Bragg reflectors (DBR) for increasing nitride semiconductor LED output power by up to 43% [Hongjun Chen et al, Appl. Phys. Express, vol6, p022101, 2013; reported Mike Cooke, Semiconductor Today March, p78, 2013].

Although some groups have developed DBRs for such purposes before, this is claimed as the first proposal and demonstration of DBRs grown using atomic layer deposition (ALD) rather than electron-beam (EB) evaporation. The advantages of ALD over EB evaporation include better thickness uniformity over large-diameter substrates and thickness control at the atomic level.

To develop an ALD process, the researchers from Institute of Microelectronics of Chinese Academy of Sciences and Southeast University changed the composition of the DBR from the usual titanium dioxide (TiO_2) and silicon dioxide (SiO_2) pairs to a TiO_2 and Al_2O_3 recipe. The use of Al_2O_3 also allows better adhesion of Al metal so that Al-mirror/DBR combinations can

also be developed. With $\text{TiO}_2/\text{SiO}_2$ DBRs, an extra layer of Al_2O_3 is often applied to enable adhesion of Al-metal.

The LED wafer was back-side thinned to 100 μm before the DBR and Al mirror were applied. The atomic layer deposition was preceded by soft polishing for 30 minutes to minimize the roughness of the surface. The $\text{TiO}_2/\text{Al}_2\text{O}_3$ DBR was designed to maximize reflectivity between 420nm and 500nm. This was achieved with 67nm Al_2O_3 and 49nm TiO_2 .

The ALD used trimethyl-aluminium and water precursors for the Al_2O_3 , and titanium tetrachloride and water for the TiO_2 . The carrier gas was nitrogen. The growth temperature for both materials was 250 $^\circ\text{C}$. This enabled a reduced fabrication time and high-quality thin films. The different material depositions were separated by nitrogen purging to avoid mixing of the respective precursors.

The DBR was capped with 150nm aluminium deposited using electron-beam evaporation. Devices with $\text{TiO}_2/\text{SiO}_2$ (48.5nm/78.5nm) DBRs deposited using electron-beam evaporation were also produced. These were finished with a 15nm Al_2O_3 adhesive layer and 150nm Al metal.

The improvement over the traditional reflector structure was attributed to the better uniformity and thickness control of ALD compared with EB evaporation. ■

NCSU develops new technique for atomic-layer thin-film growth

Self-limiting growth of wafer-scale monolayer MoS₂ promises large-scale application to FETs, LEDs.

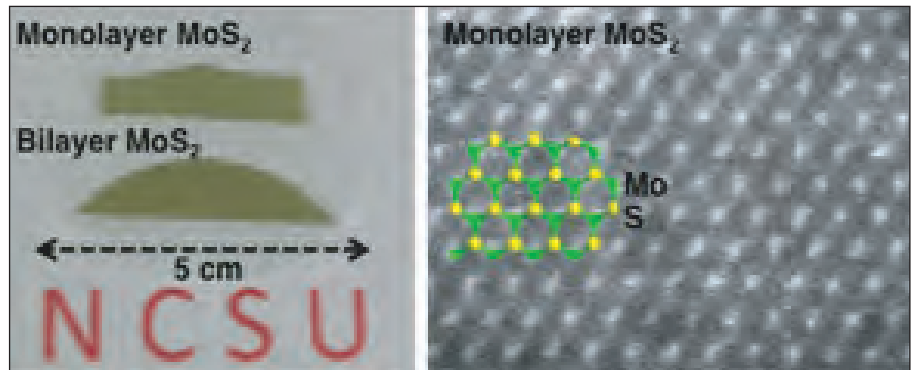
Funded by the US Army Research Office, researchers at North Carolina State University (NCSU) have developed a new technique for creating high-quality semiconductor thin films at the atomic scale (just one atom thick). The technique can be used to create the thin films on a large scale, sufficient to coat wafers that are 2-inches wide, or larger.

"This could be used to scale current semiconductor technologies down to the atomic scale — lasers, light-emitting diodes (LEDs), computer chips, anything," says Dr Linyou Cao, an assistant professor of materials science and engineering at NC State and senior author of the paper 'Controlled Scalable Synthesis of Uniform, High-Quality Monolayer and Few-layer MoS₂ Films' published online in *Scientific Reports* (a journal of the Nature Publishing Group). "People have been talking about this concept for a long time, but it wasn't possible. With this discovery, I think it's possible," he adds.

The researchers worked with molybdenum sulfide (MoS₂), an inexpensive semiconductor material with electronic and optical properties similar to materials already used in the semiconductor industry. However, MoS₂ can be grown in layers just one atom thick without compromising its properties.

In the new technique, researchers place sulfur and molybdenum chloride powders in a furnace and gradually raise the temperature to 850°C, which vaporizes the powder. The two substances react at high temperatures to form MoS₂. While still at high temperature, the vapor is then deposited in a thin layer onto the substrate.

"The key to our success is the development of a new growth mechanism, a self-limiting growth," Cao says. The researchers can precisely control the thickness of the MoS₂ layer by controlling both the partial pressure (the tendency of atoms or molecules suspended in air to condense into a solid and settle onto the substrate) and the vapor pressure (the tendency of solid atoms or



As-grown MoS₂ monolayer (1L) and bilayer (2L) films (left); high-angle annular dark-field (HAADF) scanning transmission electron microscopy (STEM) image of MoS₂ monolayer film (right).

molecules on the substrate to vaporize and rise into the air) in the furnace.

To create a single layer of MoS₂ on the substrate, the partial pressure must be higher than the vapor pressure. The higher the partial pressure, the more layers of MoS₂ will settle to the bottom. If the partial pressure is higher than the vapor pressure of a single layer of atoms on the substrate, but not higher than the vapor pressure of two layers, then the balance between the partial pressure and the vapor pressure can ensure that thin-film growth automatically stops once the monolayer is formed. Cao calls this 'self-limiting' growth.

Partial pressure is controlled by adjusting the amount of molybdenum chloride in the furnace — the more molybdenum is in the furnace, the higher the partial pressure. "Using this technique, we can create wafer-scale MoS₂ monolayer thin films, one atom thick, every time," Cao says. "We can also produce layers that are two, three or four atoms thick."

Cao's team is now trying to find ways to create similar thin films in which each atomic layer is made of a different material. Cao is also working to create field-effect transistors (FETs) and LEDs using the technique. He has filed a patent on the new technique. ■

www.nature.com/srep/2013/130521/srep01866/full/srep01866.html

www.mse.ncsu.edu/research/linyou

High power-gain cut-off frequency with high breakdown in GaN-on-Si HEMT

France's IEMN has reported a GaN-on-Si HEMT with performance "well beyond any previously reported data for GaN-on-Si devices".

The Institute of Electronic, Microelectronic and Nanotechnology (IEMN) in France has developed a gallium nitride on silicon (GaN-on-Si) high-electron-mobility transistor (HEMT) with a power gain cut-off frequency of 220GHz and a three-terminal breakdown voltage above 100V [Farid Medjdoub et al, Appl. Phys. Express, vol6, p044001, 2013].

"For high-power applications, one of the most important figures of merit is the combination of the power gain with the three-terminal breakdown voltage (V_{BK}) together with low dispersion," according to the IEMN team. They add that their results give a record $f_{max}V_{BK}$ product of 20.6THzV, "which is well beyond any previously reported data for GaN-on-Si devices and is comparable to the best GaN-on-SiC $f_{max}V_{BK}$ product." (Figure 1)

Up to now, silicon carbide (SiC) has been the preferred substrate for high-current-density, high-speed GaN transistors capable of operating at high voltages and temperatures, due to the high thermal conductivity and the small lattice mismatch of SiC with GaN. However, SiC is very expensive, and much less costly silicon has been gaining favor with improving performance and maturity. In addition, the prospect is raised of combining GaN power devices monolithically with silicon CMOS logic.

The epitaxial material used for the IEMN transistors consisted of a double aluminium gallium nitride (AlGaIn) heterostructure of AlN/GaN/AlGaIn, produced on 4-inch-diameter highly resistive (111) silicon at metal-organic chemical vapor deposition (MOCVD) firm EpiGaN (Figure 2). The delivered material included an in-situ silicon nitride (SiN) layer that both passivates

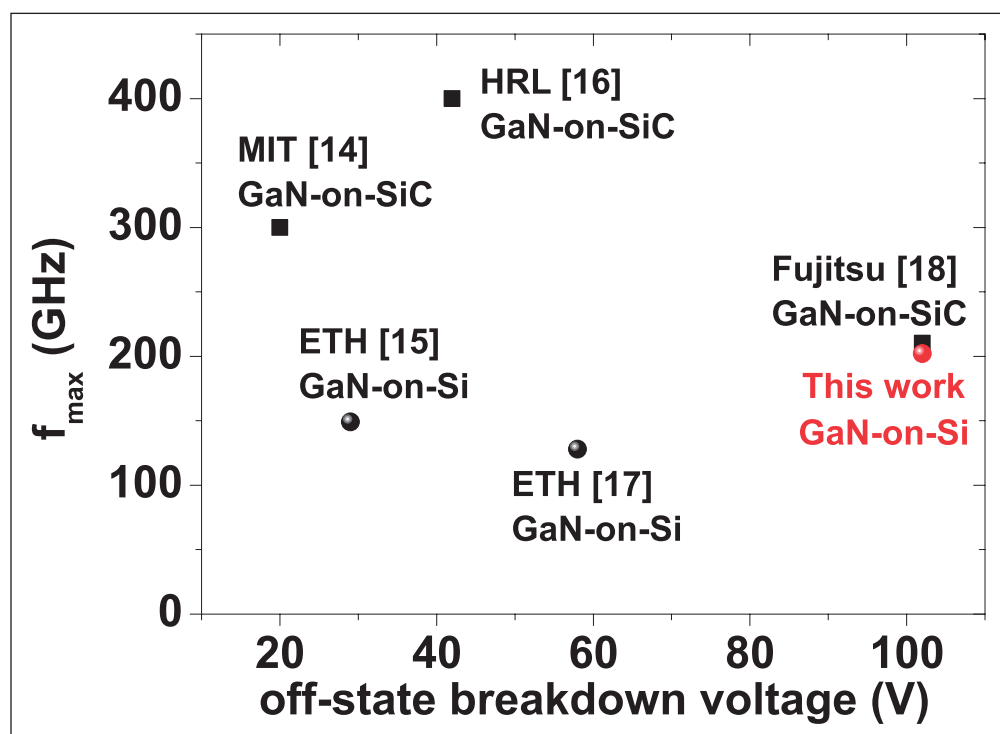


Figure 1. Benchmark of power-gain cut-off frequency versus the off-state three-terminal breakdown voltage of GaN-on-SiC and GaN-on-Si devices.

the structure and prevents the relaxation of strain.

The strain is used to create high carrier densities in the two-dimensional electron gas (2DEG) channel through the generation of polarization fields. Hall measurements give a carrier density of $2 \times 10^{13}/\text{cm}^2$ with a mobility of $1400 \text{ cm}^2/\text{V-s}$, resulting in a uniform sheet resistance of $\sim 240 \Omega/\text{square}$ ($\pm 2.3\%$).

The ohmic source-drain contacts of titanium/aluminium/nickel/gold were formed directly on etched regions exposing the AlN layer. These contacts were rapidly annealed at 875°C . Device isolation was achieved with nitrogen implantation.

A further 50nm of SiN was applied using plasma-enhanced chemical vapor deposition (PECVD). A 120nm gate-length was defined using electron-beam lithography followed by sulfur hexafluoride (SF_6) plasma etch down to the AlN. The etch process was designed to avoid plasma damage under the gate. The

nickel/gold gate (with optimized field plate) was formed with additional electron-beam lithography and deposition.

Other dimensions of the device were 0.2 μm gate–source and 0.3 μm gate–drain spacing, and 50 μm gate width.

The maximum current density with a +2V gate and 6V drain bias was 1.5A/mm (Figure 2a). The peak extrinsic transconductance was more than 550mS/mm. The off-state leakage was less than 2 $\mu\text{A}/\text{mm}$.

The three-terminal breakdown voltage was over 100V (Figure 2b). Below 100V drain bias, the drain leakage remained less than 30 $\mu\text{A}/\text{mm}$.

Measurements with pulsed biasing of 500ns showed no threshold voltage shifts up to 30V drain bias. The researchers attribute this to “enhancement of the electron confinement in the 2DEG resulting from the use of the AlGaN back barrier”.

High-frequency testing was carried out up to 110GHz, giving a current gain cut-off (f_T) of 75GHz and a power gain cut-off (f_{max}) of 220GHz at gate bias of -1.6V and drain bias of 20V. The researchers comment: “The high transconductance associated with the reduction of the

short-channel effect by introducing a back barrier explains the outstanding power gain above 200GHz.”

The drain bias dependence of the cut-offs are that f_{max} increases to saturation at 20V, while f_T decreases due to the impact of self-heating on transconductance.

The researchers believe that further performance improvement could be obtained from reduction of contact resistances and residual RF losses. In particular, the access resistances were relatively high and the

residual RF loss appears to emanate from the interface between buffer and silicon substrate, which have a high lattice mismatch.

The researchers conclude: “These results show that GaN-on-Si devices have excellent potential for millimeter-wave applications, and will enable low-cost and next-generation highly integrated circuits.” ■

<http://apex.jsap.jp/link?APEX/6/044001>

Author: Mike Cooke

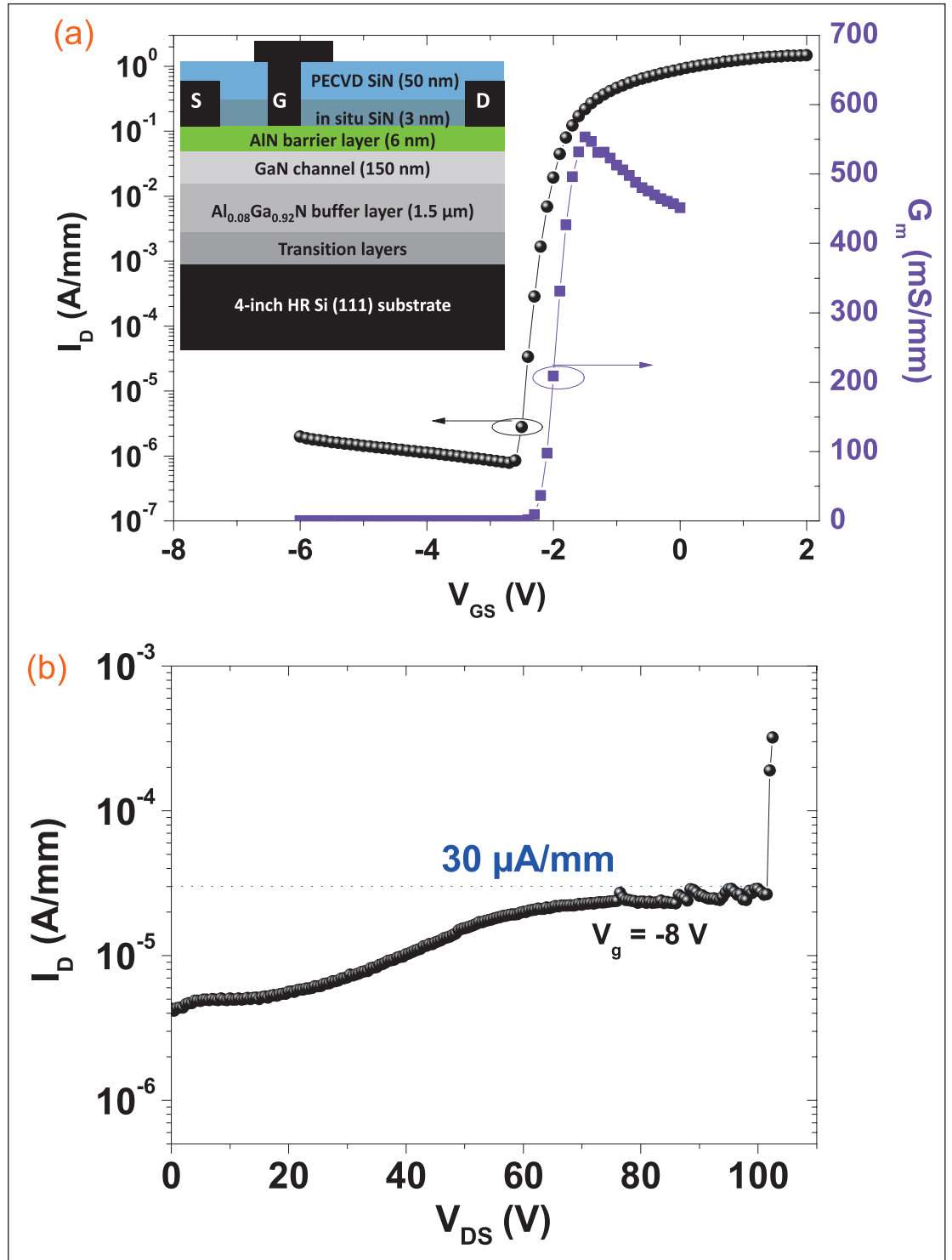


Figure 2. (a) Transfer characteristics of 0.12 μm x 50 μm AlN/GaN-on-Si DHFET at drain bias $V_{\text{DS}} = 6\text{V}$. Inset: cross section of the fabricated device. (b) Off-state three-terminal breakdown voltage of 0.12 μm x 50 μm AlN/GaN-on-Si DHFET.

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Shanghai, China

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8–11 July 2013

Intersolar North America 2013

Moscone Center, San Francisco, CA, USA

E-mail: koch@intersolar.us

www.intersolar.us

9–11 July 2013

SEMICON West 2013

San Francisco, CA, USA

E-mail: semiconwest@xpressreg.net

<http://semiconwest.org>

21–26 July 2013

ICDS-2013 (27th International Conference on Defects in Semiconductors)

Bologna, Italy

E-mail: info@icds2013.eu

www.icds2013.eu

22–23 July 2013

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www.greenworldconferences.com

1–3 August 2013

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KTPO Exhibition Complex, Bangalore, India

E-mail: semiindia@semi.org

www.solarconindia.org

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PRICM-8 (8th Pacific Rim International Conference on Advanced Materials and Processing)

Hilton Waikoloa Village, Waikoloa, Hawaii, USA

E-mail: mtgserv@tms.org

www.tms.org/meetings/specialty/pricm8

4–10 August 2013

15th Summer School on Crystal Growth (ISSCG-15)

Gdansk, Poland

E-mail: isscg15@mif.pg.gda.pl

<http://science24.com/event/isscg15>

5–6 August 2013

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11–16 August 2013

17th International Conference on Crystal Growth and Epitaxy (ICCGE-17)

Warsaw, Poland

E-mail: iccge17sec@mail.unipress.waw.pl

<http://science24.com/event/iccge17>

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>

25–30 August 2013

10th International Conference on Nitride Semiconductors (ICNS 2013)

Gaylord National Hotel and Convention Center,

Washington DC Metropolitan Area, USA

E-mail: info@mrs.org

www.icns10.org www.mrs.org/icns-10

28–30 August 2013

IEEE Photonics Society's 10th International Conference on Group IV Photonics (GFP 2013)

Grand Hilton Seoul, Korea

E-mail: m.figueroa@ieee.org

www.gfp-ieee.org

4–6 September 2013

SEMICON Taiwan 2013 and LED Taiwan 2013

TWTC Nangang Exhibition Hall, Taipei, Taiwan

E-mail: ali@semi.org

www.semicontaiwan.org/en

8–12 September 2013

IEEE Photonics Society's annual Photonics Conference (IPC-2013, formerly the IEEE LEOS Annual Meeting)

Hyatt Regency Bellevue Hotel, Seattle, WA, USA

E-mail: m.hendrickx@ieee.org

www.ipc-ieee.org

18–20 September 2013

Intersolar South America 2013

Expo Center Norte, São Paulo, Brazil

E-mail: boesl@solarpromotion.com

www.intersolar.net.br

22–26 September 2013

39th European Conference on Optical Communications (ECOC 2013)

ExCeL London Exhibition Centre, London, UK

E-mail: carina.meakins@nexusmediaevents.com

www.ecoc2013.org

23–24 September 2013

CPV USA 2013 (5th Concentrated Photovoltaic Summit USA)

San Jose, CA, USA

E-mail: matt@pv-insider.com

www.pv-insider.com/cpv

23–26 September 2013

SPIE Remote Sensing 2013, co-located with SPIE Security+Defence 2013

Internationales Congress Centre Dresden, Germany

E-mail: info@spieeurope.org

<http://spie.org/remote-sensing-europe.xml>

<http://spie.org/security-defence-europe.xml>

23–26 September 2013

5th International Conference on One dimensional Nanomaterials (ICON 2013)

Annecy, France

E-mail: icon2013@grenoble.cnrs.fr

www.icon2013.fr

24–26 September 2013

3rd International LED professional Symposium + Expo (LpS 2013)

Bregenz, Austria

E-mail: symposium@led-professional.com

www.led-professional-symposium.com

29 September– 4 October 2013

International Conference on Silicon Carbide and Related Materials (ICSCRM 2013)

Phoenix Seagaia Resort, Miyazaki, Japan

E-mail: secretary@icscrm2013.org

<http://icscrm2013.org>

30 September – 4 October 2013

28th European Photovoltaic Solar Energy Conference and Exhibition (EU PVSEC 2013)

Parc des Expositions Paris Nord Villepinte, Paris, France

E-mail: press@wip-munich.de

www.photovoltaic-conference.com

1–2 October 2013

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Mexico City, Mexico

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